KAUNAS UNIVERSITY OF TECHNOLOGY PANEVEZYS INSTITUTE
PANEVEZYS TECHNOLOGY AND SCIENCE PARK
INTELLIGENT TRANSPORT SYSTEMS, POLAND
TALLINN UNIVERSITY OF TECHNOLOGY
RIGA TECHNICAL UNIVERSITY

INTELLIGENT TECHNOLOGIES IN LOGISTICS AND MECHATRONICS SYSTEMS

ITELMS'2011

PROCEEDINGS OF THE 6TH INTERNATIONAL CONFERENCE

EDITED BY Z. BAZARAS AND V. KLEIZA

May 05-06, 2011
Panevėžys, Lithuania

TECHNOLOGIJA
KAUNAS·2011

CONFERENCE IS ORGANIZED BY

Kaunas University of Technology Panevezys Institute
Panevezys Technology and Science Park
Intelligent Transport Systems, Poland
Tallinn University of Technology
Riga Technical University

CONFERENCE IS SUPPORTED BY

State Fund of Science and Study of Lithuania

The proceedings of the 6th International Conference INTELLIGENT TECHNOLOGIES IN LOGISTICS AND MECHATRONICS SYSTEMS contain selected papers.

All papers were reviewed.

The style and language of authors were not corrected. Only minor editorial corrections have been carried out by the Publisher.

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Klaipedos str. 1, Panevezys LT-35209, Lithuania
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PREFACE

The first (2006) and second International Workshops "Intelligent Technologies in Logistics and Mechatronics Systems ITELMS" were held at Riga Technical University. The 3rd international workshop ITELMS'2008 was held at Kaunas University of Technology Panevezys Institute on 22 – 23 May, 2008. The international conferences ITELMS'2009, ITELMS'2010 and ITELMS'2011 continues three year tradition and takes place at Kaunas University of Technology Panevezys Institute.

The aims of the Conference are to share the latest topical information on the issues of intelligent technologies in logistics and mechatronics Systems. The papers in the Proceedings presented the following areas:

- Intelligent Logistics Systems
- Multi Criteria Decision Making
- Composites in Infrastructures
- Automotive Transport
- Intelligent applications of solid state physics
- Intelligent Mechatronics Systems
- Mechanisms of Transport Means and their Diagnostics
- Railway Transport
- Transport Technologies
- Modern Building Technologies

In the invitations to Conference, sent year before the Conference starts, the instructions how to prepare reports and manuscripts provided as well as the deadlines for the reports are indicated.

A primary goal of Conference is to present the highest quality research results. A key element in attiring goal is the evolution and selection procedure developed by the Conference Scientific Committee.

All papers presented in Conference and published in Proceedings undergo this procedure. Instruction for submitting proposals, including requirements and deadlines, are published in Call for Papers in the http://www.ktu.lt/lt/apie_renginius/konferencijos/2011/meniu.asp. Paper proposals must contain sufficient information for a trough review. All submissions to determine topic areas are directed to appropriate Topic Coordinators. The Topic Coordinators review the submissions much them to the expertise according to the interests and forward them to selected reviewers. At least two reviewers examine each submission in details.

Selection of papers for the Conference is highly competitive, so authors should assure their submissions to meet all Conference Scientific Committee's requirements and to be of the highest possible quality.

All Conference participants prepare manuscripts according to the requirements that make our Proceedings to be valuable recourse of new information which allows evaluating investigations of the scientists from different countries.

Prof. Z. Bazaras
Prof. V. Kleiza

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Tribologic Methods Used for an Engine Diagnostics

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Abstract

Tribological diagnostics is a non-destructive and non-disassembling diagnostic method. It uses lubricating oil as a source of information about processes and changes in mechanical systems. Corrective maintenance costs often exceed investments into preventive maintenance which includes also the methods of tribological diagnostics. For that purpose a whole range of tribodiagnostic methods was developed. The procedures of the tribodiagnostic methods can range from simple ones to complex which require special instrumentation. In this paper there are described methods of engine oil guality assessment, engine condition evaluation and methods of wearing process estimation in the engine.
KEY WORDS: tribodiagnostics, tribology, wear, particle analysis, laser particle counters, engine oil.

1. Introduction

Tribological diagnostics is a non-destructive and non-disassembling diagnostic method that uses lubricating oil as a source of information about processes and changes in mechanical systems, to which it is applied.

Tribological diagnostics used for engine diagnostics deals with two basic ranges of issues:

- Determining condition, extending usable life and forecasting degradation of engine oils.
- Determining mode, point and trend of combustion engine wear by way of evaluating foreign matters occurrence in the oil in terms of quantitative and qualitative points of view.

Traditional reputable methods and special tribodiagnostic methods are used for monitoring the operating degradation of oils.

Determining wear of engines lubricated by oil is based on knowledge, that engine oil shows a certain percentage of foreign matter after some operating time. Especially metallic abrasive wear (wear particles), that are dispersed in oil and that after the quantification by some suitable method allows indirect monitoring of mechanical changes in the engine that uses the oil. It is then possible to draw specific conclusions based on the determined amount of metallic abrasive wear, growth rate, shape, morphology, size and material composition. If the growth and other parameters are in accordance with nominal values stated for the given engine, it is possible to legitimately deduce normal wear progress without an increased risk of engine failure. An abnormal or sudden growth of metallic particles, or their size, indicates an exceptional process. From the size, shape, velocity of growth and other parameters it is possible to deduce the failure severity and necessity to take remedial measures. Knowing the material of all system parts lubricated and rinsed with oil, and then according to the metallic abrasive wear type, it is possible to determine and localize the frictional pair with the rapid increase of degrading wear. If it is not possible to localize the position of the increased abrasive wear by this method, then some other technical diagnostics suitable for failure localization should be applied.

Tribological diagnostic methods are generally considered to be very significant for engines for these reasons. Wearing processes crucially affect engines lifetime, their failure-free operation time, maintenance costs, repairs etc. Tribological diagnostics positively affects the friction process and engines wear. Changing oil and lubricants in determinated periods based only on experiences and projected average engine oils lifetime is not optimal in terms of economical use of these substances. Monitoring the operating degradation of engine oils by the tribological methods allows significantly more intensive use of these engine oils until the end of their lifetime without any risk of failures from the aforementioned reasons.

Despite the considerable equipment purchase costs, the rational use of tribological diagnostics results in possible effective oil management. Therefore, it can prevent unnecessary change of engine oil that could still remain operational and whose replacement is consequently disadvantageous not only from an economic, but also an environmental point of view. On the contrary if the changing periods are adhered to very strictly, there is a risk of using excessively worn-out oil that does not correspond to the requirements and whose further use might lead to engine damage. Subsequent repair costs often exceed investments in preventive care including regular engine condition monitoring using the tribological diagnostic methods.

Monitoring of chemical and physical changes that occur during operation provides a relatively accurate overview of the up-to-date engine oil state and its potential for further use. The basis for the evaluation of the dynamics of individual parameter changes are their values for new engine oil. There exist a number of methods used for that purpose including infrared spectrometry or electrochemical methods. Wear progress and size of engine components that are lubricated by the relevant lubricant can be monitored also by a group of other methods suitable for morphology description and particle separation formed by metallic abrasive wear.

2. Engine oil diagnostics

Quality and condition evaluation of the engine oil used is based on measuring a range of physicochemical parameters of the engine oil properties. For that purpose a whole range of methods was developed, from the simplest ones up to complicated and machine-demanding. Standardized methods with scientifically determined conditions and testing procedures are used for quality evaluation and measurement of engine oils. Monitoring of chemical and physical changes that occur during operation provide a relatively accurate overview of the up-to-date engine oil state and its potential for further use. The basis for evaluating the dynamics of individual parameter changes are their values for the new engine oil.

Examples of some typical engine oil quality evaluation tests

Viscosity: The basic characteristic feature of the engine oil is viscosity. It is a result of the internal friction of the oil during its flow. It is basically the internal friction resistance by which the oil works against forces that try to mutually move its smallest particles. It causes shear stress on the contact area of two oil layers that are moving at different velocities. Shear stress is directly proportional to the velocity gradient and the proportionality constant is called dynamic viscosity η [Pa·s]. The ratio of dynamic viscosity η to density is called kinematic viscosity [$mm^2 \cdot s^{-1}$]. The inverse value of viscosity is called fluidity. The kinetic viscosity is primarily measured in different types of viscometers. The best-known one is Ubbelohde capillary viscometer.

Water contents: Water is an adverse substance in the engine oil that gets into the oil frequently through leaks in cooling systems or from the environment. Its presence causes oil emulsification and damage of the lubricating film. The water content also affects other oil additives, causes corrosion etc. It is possible to use the oil with some small amount of water (for example combustion engine – 0.2%), but on an overrun it is necessary to separate the water element or change the oil. Water content [ppm] is determined by distillation test or by Coulometric titration for better results.

Total Base Number (TBN): This method is used to determine the total amount of alkaline elements including organic and inorganic bases, amino compounds, weak acid salts and heavy metal salts, that can affect the total alkalinity of the oil. This indicator is used for engine oils and its amount relates to alkaline-like contents – mostly additives of the detergent-dispersant type. Potentiometric titration by perchloric acid is used for determination and the measurement unit is [mg $KOH \cdot g^{-1}$]. TBN indicates the alkaline reserve that the engine oil can use for neutralization of acidic products of thermooxidation reactions and acidic products of fuel combustion and oil additives.

Total Acid Number (TAN) defines the amount of acidic proportions in the oil, i.e. weakly acid-reacting proportions contained partly already in the new engine oil and partly resulted from the combustion process and oil oxidation. TAN is defined as the KOH amount (in mg) used for neutralization of all acidic elements included in 1 gram of the analyzed oil. Potentiometric titration is used for determination and the measurement unit is [mg $KOH \cdot g^{-1}$].

Special tests of engine oil condition:

Conradson Carbon Residue (CCR) is determined by thermal degradation of the tested oil in an air-free environment followed with annealing treatment. Its size is determined by the tendency to create carbon residues on the hot parts of the machine. The ageing of oil in operation causes the creation of substances that increase the value of the carbon residue. CCR is expressed in % of unburnt hydrocarbons.

Ignition point is an indicator related to the amount of volatile matter in the oil. It is primarily used for measurements of engine oils, where its value indirectly determines the fuel contents in the oil. Open-cup or close-cup method are used to determine the ignition point. The ignition point is expressed in degrees centigrade.

Soot belongs to mechanical impurities that are produced in the combustion space during fuel combustion. Infrared spectroscopy is the most common method used for soot content measurement. Since soot and other mechanical impurities are dark and do not transmit light, they cause, during measurement of the infra-red spectrum, the elevation of the so called base line, which is measured at 2000 cm^{-1}. The higher content of soot and other impurities, the higher the base line elevation.

Determining the contents of additives: defines contents of elements contained in almost all currently used engine oils, usually in the form of admixtures that improve certain attributes. The amount of additives decreases during operation and once the given minimum limit is exceeded, the lubricant starts losing its capabilities. Some elements (Ca, Zn, Mg, Ba etc.) contained in additives are determined by Emission spectrometry with inductively coupled plasma (ICP-OES) or Atomic absorption spectrometry (AAS). X-ray fluorescence analysis (XRF) is most commonly used for S and P elements content determination. Fourier transform infrared spectroscopy (FTIR) is very often used for additives contents determination.

3. Engine diagnostics

Metallic particles and other elements can get into the engine oil during the wearing process. Regular monitoring of a specific group of metals and elements allows the prediction of incipient failures. Different methods of instrumental analysis are used for determining the contents of metals and other elements in engine oils. The most commonly used methods are spectroscopy and polarography. Wear progress and size of components that are lubricated by the relevant lubricant can be monitored also by a group of other methods suitable for morphology description and particle separation formed by the metallic abrasive wear, by filter material fibres, environment contaminants and others. Particularly ferrography followed by image analysis. The objective of these diagnostic methods is to determine the type of material that issued the particles contained in the engine oil. Following with determination of a subgroup or respectively the frictional pair with the increased wear. For that it is necessary to be familiar with materials and construction of the engine that is being diagnosed and the composition of the engine oil used.

Engine oil analysis methods:

Atomic absorption spectrometry (AAS) is a method based on specific absorption of monochromatic radiation by free atoms of the monitored element in the ground electronic state. This method is commonly used to determine the existence and content of some metals, especially Fe, Pb, Cu, Al, Zn, and others.

Atomic emission spectrometry (AES) is a method that uses arc or spark sources to get the oil sample into the gaseous state and atomize it. As a result of atomic collisions or energy quantum absorption, the electrons of individual atoms are transiting from the ground state to the excited state. During the transition back to the ground state, atoms emit energy that equals the proportion of the energy levels in question in the form of luminous energy. The wavelength of light value is specific for each element.

Fourier transform infrared spectroscopy (FTIR) is an analytical method designed primarily for identification and structural characterization of particularly organic compounds. Infrared spectrometry measures the absorption of infrared radiation of different wavelength by the analyzed material. The analytical output is the infrared-spectrum that is the graphic representation of energy dependence functions on wavelength of the incident radiation. During the Fourier transform infrared spectroscopy the interferometrically acquired signal is transformed by the Fourier transformation to the infra-red spectrum.

X-ray fluorescence analysis (XRF) is a highly sensitive method that can detect concentrations up to 0.0001 % of Cu or 0.001 % of Fe, Pb, Si, Ti, Mn, Mo, Sn and others. This method is based on measuring energy of the fluorescent x-ray radiation. Each element has its typical fluorescent radiation energy, which is used for quantitative analysis. The principle of the quantitative analysis is measuring the intensity of outcoming secondary x-rays (their quantity).

Emission spectrometry with inductively coupled plasma (ICP-OES) is an analytical method used to determine the contents of individual elements in the analyzed sample. It allows the analysis of almost all elements of the Periodic table.

Polarography is a very sensitive electrochemical method studying effects originating on polarized electrodes placed in the measured solution. The system of electrodes consists of usually absolutely polarized measuring dropping mercury electrode (detector) and also an absolute reference non-polarizable electrode. Controlled electric voltage is then placed between the electrodes and the dependency of the originating electric current on the inserted voltage is being monitored. Pulse polarography is used in the first place because its current dependency on the inserted voltage has a pure shape of the base with sharply salient amplitudes of which location characterizes the type of substances contained in the solution. These methods can be used for determining a number of inorganic and organic substances in various matrixes. For example metal concentrations are determined by this method within the engine oil analytics.

Methods of morphology assessment and distribution of abrasive particles

Experience shows that the determination of metal abrasive wear concentration is not always sufficient to evaluate the wear mode. For that reason methods were developed allowing the evaluation of the quantity, shape, size, coloring and morphology of the abrasive wear particles surface originating in the engine.

Ferrography is a method based on separation of foreign substances contained in the oil filling of machines lubricating systems from the oil itself. It uses particles sedimentation on a special slide during oil sample flow in a strong inhomogeneous magnetic field. It describes the trapped particles circulating along with the oil and classifies them to the individual wear mechanisms. As a non-disassembling diagnostic method it allows us to objectively determine the wear mode of the oiled machine. Then on the basis of morphology analysis and quantity of abrasive wear particles it is possible to discover the approaching engine failure. In some cases it is also possible to determine the point of origin of the abrasive wear particles, which has an outstanding importance for machinery wear evaluation. Both Direct-reading ferrography and Analytic ferrography are used in practice these days. The bichromatic microscope can be used to examine; shape, color, surface character and other morphologic characteristics of the sedimentation particles that contain very important information about prevalent abrasion type and oil wear of the engine. Analytic ferrography shows the real technical condition of the lubricating system and lubricated parts as well as the wear nature of the individual frictional pairs. For these purposes it is beneficial to combine Analytic ferrography with Image analysis or also with Scanning electron microscopy.

Image Analysis allows the gathering of quantitative information about different geometric and statistic parameters of particles (for example quantity, area and other quantitative parameters of individual particles), about their total area proportion on a ferrogram and others. This data can be used directly for the evaluation of isolated particles or as a basis for further Stereological analysis. Quantitative evaluation of the characteristic particle parameters is an important part of examination of the relationship between operating conditions and the method, intensity, or regularity of abrasive surfaces wear. Using computer technology and suitable software makes the work with digital image easier and allows a whole number of other operations. For example change contrast, brightness, do gamma-correction or other picture parameters, eliminate image objects smaller then a predefined limit, suppress displaying artefacts, group objects into classes according to chosen attributes etc. Good-quality, precise and correct results during visual data processing can be gathered only on condition that the microscopic visual display is accurate, the picture is sufficiently sharp and objects are easily identifiable.

Particle Counter and Particle Shapes Classifier is used for oils samples analysis from different types of machines and is unique for its multifunctionality. After sample preparation (homogenization and bubbles removal) the engine oil is sucked and circulated in a measurement cell. At the same time impulse laser rays are passing through the same cell and incident on a background scanned by a CCD digital camera that can catch an image contour of the oil sample particles flowing through the cell. During sample processing, the photos (pictures of the flow cell) are analyzed at 30 frames per second. The highly sensitive machine is able to register all particles up to 100 µm size. Numbers of particles are converted to codes of purity according to international and national standards. Furthermore it is possible to read off contents of free water and soot. All particles bigger than 20 µm are sorted according to their typical shape into categories: (depending on the origin of their wear type) abrasive, sliding, fatigue, non-metallic and then are statistically evaluated. For individual particle types are stated quantities per 1 ml, average size, standard deviation and maximal diameter. The result is not only analysis of the quantity and size of the particles contained in the oil, but also analysis of abnormal abrasive wear particles and an overview of previous results related to the same engine. This allows the gathering of data about engine oil condition, but above all also about wear mode and technical condition of the engine, from which the oil sample was taken.

4. Example of Practical Application

Engine oil Ursa Super (20W/50) from UTD-20 engine was chosen as an example of measurement results. The engine was subjected to a demanding performance test in a testing room on an engine brake. This test was compounded of 48 stress cycles consisting of 10 operating hours each. [1 operating cycles = 10 operating hours]. Such test time and stress magnitude equals to double of normal given operating time for this type of engine. Standard maintenance was carried out in this test time – such maintenance scheme includes also oil addition, total oil changes according to rules and schedule giveny by engine producer. Oil samples were taken and analyzed during the whole test period (481 OpHrs) regularly in relatively short intervals. 62 engine oil samples were analyzed in total. The samples were analyzed by the infrared spectrometer FTIR, by atomic emission spectrometer AES and by an automatic computer and particles classificator LNF-C. For this analysis was chosen the contents of soot in the engine oil measured by the FTIR and LNF-C methods, concentration of abrasive wear metals (Fe, Cu, Pb) in the engine oil using the atomic emission spectrometry AES and the quantity of monitored particles was analyzed with LNF-C. Measurements of soot contents in a combustion-ignition engine oil during its operation measured by the FTIR method, automatic laser computer and particles classificator LNF-C (Fig. 1), showed a substantial oscilation affected mainly by the oil refilling and notably its changing. The soot contents during the operation did not exceed 0.4%. Monitoring of metals and particles quantities contents (Fig. 2 and 3) demonstrated increase of all monitored values within the period of 432 OpHrs, especially from the operation beginning to the first 22 OpHrs due to a running up, when a cooling liquid spread into the oil – due to a cylinder rupture and the elevated wear started. Water intrusion into the oil was acknowledged also by the FTIR method measurements (Fig. 4). Testing of the engine continued after the engine head was repaired and oil added. However, the particles contents had been increasing even when following oil change was performed – this due to increased oild

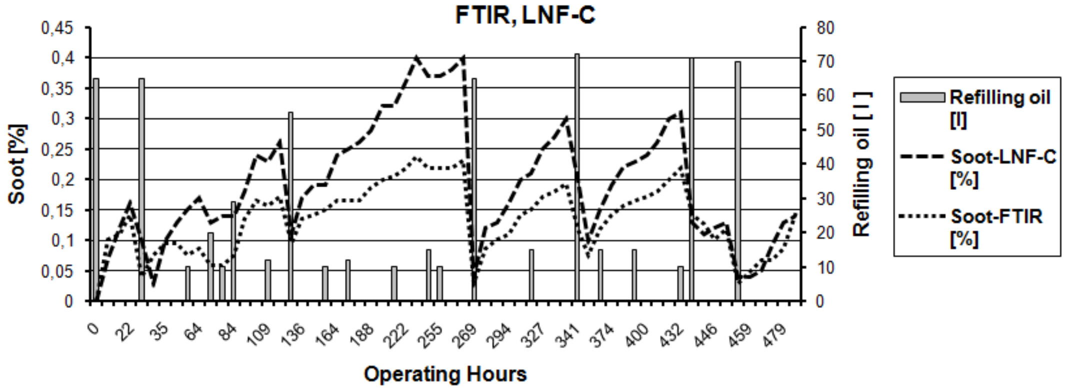

Fig. 1. Dependency of the soot contents on engine operating hours and oil refilling

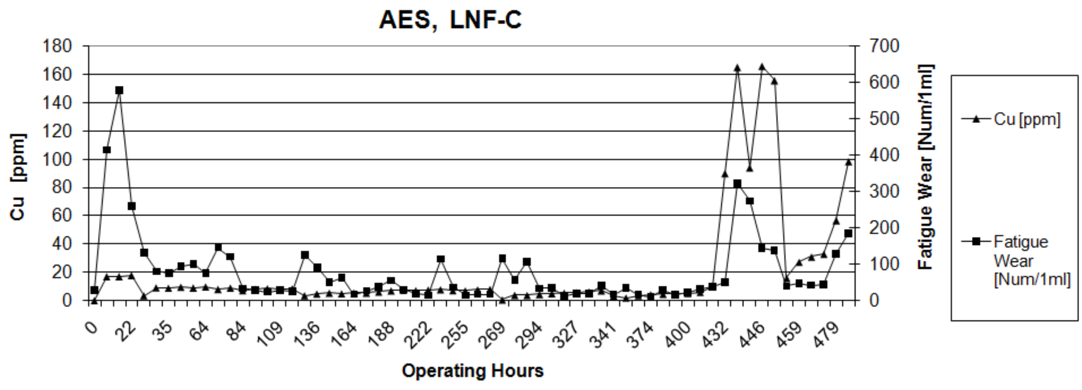

Fig. 2. Dependency of Cu concentration and fatigue particles on operating hours

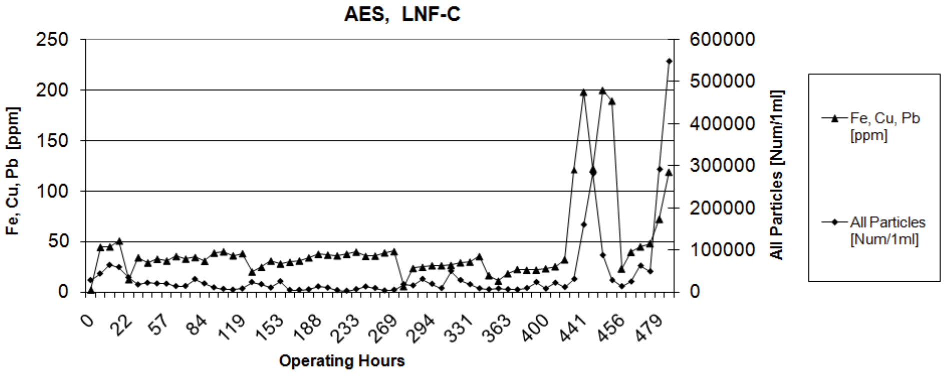

Fig. 3. Dependency of metals concentration (Cu, Fe, Pb) and all particles on operating hours

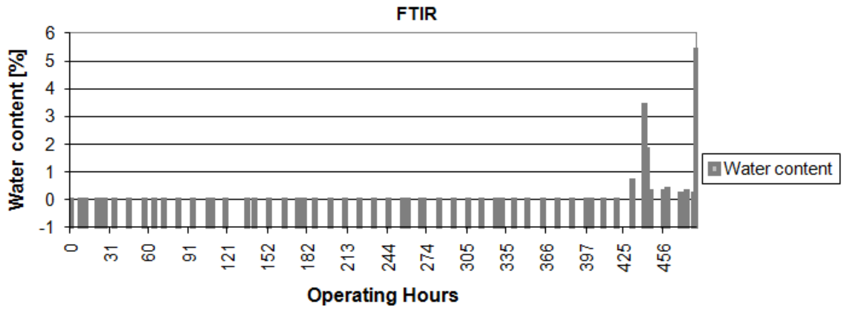

Fig. 4. Dependency of water contents on operating hours

consumption and small contamination of the oil by cooling water. The total test time was 480 operating hours when test was finished due to a massive incursion of water into the oil see figure 4. Increased wearing was observed during constant particles and metal pieces contents investigation especially in the running up period. Next significant increase of the particles and metal pieces came when wearing increased therefore the clearance of friction places increased too. This whole situation was perhaps also caused by the previous oil contamination by cooling water which affected the engine parts condition.

5. Conclusions

Monitoring engine condition by means of engine oils is nowadays a very important part of technical diagnostics, especially because the oil analysis results of the monitored engine is sufficiently reliable and also the return of investments in analysis is very good. If the analysis is carried out regularly, the engine oil changing intervals can be in most cases prolonged and therefore it is possible to get approximately 20 % of the total savings just on engine oil costs. The engine oil analysis costs are usually compared just with this amount but the biggest savings are provably in minimization of the monitored equipment downtimes, costs of repair or replacement parts and last but not least in increased general reliability of the monitored engine. For monitoring individual engine types it is convenient to use groups of tests according to engine type in which the engine oil is used. The tests are chosen in a way to keep the basic preconditions for a successful tribological diagnostics, i.e. speed, comprehensive analysis evaluation and a fairly good price. In the future is possible to expect more and more use of instrumental analysis and computer technology to allow carrying out the analysis as well as evaluation of individual analysis types completely automatically. The next step to speedup the tribological diagnostics response will most probably be diagnostic elements and systems operating directly on engine and their connection to the whole operation diagnostics of the monitored engine with real-time results.

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Proceedings of 6th International Conference ITELMS'2011

On Liquid Physical Properties Influence for Laminar Film Thickness

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Abstract

The purpose of the present research is to obtain knowledge for the heat transfer developments in gravitational liquid film flow. Analytical study of stabilized heat transfer for laminar liquid film was performed. The numerical calculations for water, compressor oil and fuel oil films at various values of relative cross curvature of the films and ratios of heat fluxes densities were carried out. A function allowing estimating non-isothermality effect on film thickness was established. It has been determined that film thickness variation depends on liquid physical properties variability. Theoretical analysis of film cross curvature and external heat exchange influence on liquid film thickness variation was performed as well.
KEY WORDS: *heat transfer, laminar film, cross curvature, film thickness, physical properties.*

1. Introduction

Thin liquid films frequently appear in processes for the fuel/air mixing in spark ignition engines of transport means [1-5]. The deposition of liquid fuel as film on the walls of intake ports, valves and liner of internal combustion engines, its transport and the subsequent evaporation of the fuel may significantly influence the engine warm-up behavior, the generation of emissions and the oil distribution along the cylinder sleeve surface. Particularly in the inlet manifold of gasoline engines, but also in direct injection engines, a significant amount of fuel can be deposited on the walls as a thin liquid film due to incomplete evaporation and collisions of injected droplets with the walls. Due to the much greater viscosity of the liquid phase, the film's velocity is just 1-3 % compared to the mean air stream's velocity. This leads to an undesired storage effect of liquid fuel on the walls.

At the valve and the valve-seat, the film breaks up into relatively large droplets which subsequently move into the combustion chamber or are driven back into the manifold during early intake valve opening. On the other hand, excess film stored on the walls, which can amount to several cubic centimeters, evaporates at a decrease of manifold pressure, as caused by closing the throttle.

All these effects negatively influence mixture formation especially at cold start and at unsteady engine load. This in turn leads to a reduction of potential engine performance and an increase in emissions. If wall film is generated along the cylinder liner it destroys the oil film there and is increasing the friction between liner and piston rings. Therefore, it is very important for engine engineers to know the amount and location of the film as well as its dynamics.

The paper [6] dealt with the basic research on the fuel mixture preparation process, and reported the experimental and numerical investigations on characteristics of the wall-wetted fuel film. The film thickness on the wall was measured by using laser induced fluorescence technique. The results show that, in the radial direction, the film thickness increases to a peak around the impingement center and then decreases eventually reaching zero at the external edge. Enlarging the injection duration could expand the film area and make the fuel film thicker. Diminishing the impingement angle could expand the area of the thick part of the fuel film and meanwhile make the maximum film thickness smaller.

The coupling influence of airflow and temperature on the two-dimensional distribution of the film resulted from fuel spray impinging on a horizontal flat wall was studied experimentally in paper [7]. The results showed that, as air velocity increased, the film shape turned from a circle to an oblong. Film thickness decreased as wall temperature or air velocity increased. It was found that the boiling point of the fuel is an important temperature to affect the film area and the film thickness.

The paper [8] presents a numerical study of the interaction of a premixed flame with a cold wall covered with a film of liquid fuel. Simulations showed that the presence of the film leads to a very rich zone at the wall in which the flame cannot propagate. As a result, the flame wall distance remains larger with liquid fuel than it is for a dry wall, and maximum heat fluxes are smaller.

Liquid film thickness inside two swirl injectors for direct injection gasoline engines was measured at different injection pressure conditions in study [9]. Based on the evaluation, a new equation for the liquid film thickness inside the swirl injectors was introduced. The results showed that the liquid film thickness remains constant at the injection pressures for direct injection gasoline engines while the ratio of nozzle length to nozzle diameter shows significant effect on the liquid film thickness. The research [10] is aimed at examining fuel film behavior in general, the particular emphasis being on the application of fundamental experiments in an especially designed rig and numerical simulation to obtain a better understanding of film formation. The numerical results correspond reasonably well with the assessment from the rig.

2. Analysis of liquid film thickness variation

Let us consider the stabilized heat transfer for laminar liquid film flow. In this case the thicknesses of hydrodynamic and thermal boundary layers are both equal to the film thickness and the conduction may be as a mode of heat transfer only.

In the case of heat exchange between flowing film and tube surface, liquid density ρ and kinematic viscosity ν becomes of variables values and in order to determine them, the film temperature field to be known. Then, heat transfer problem must be solved together with momentum transfer one.

Heat flux across the elementary volume dx of laminar film can be expressed as follows:

$$\mathrm{d}Q = -2\lambda\pi r \frac{\mathrm{d}T}{\mathrm{d}r}\mathrm{d}x \tag{1}$$

Heat flux density falling to the unit of tube surface can be written as:

$$q = \frac{\mathrm{d}Q}{2\pi R\,\mathrm{d}x} = -\lambda \frac{r}{R}\cdot\frac{\mathrm{d}T}{\mathrm{d}r} \tag{2}$$

where R is cross curvature of wetted surface (tube external radius), m; λ is thermal conductivity, W/(m·K); r is variable radius in the film, m.

For the momentum transfer analysis, it is more reasonable variable r to express through the distance from wetted surface:

$$y = r - R \tag{3}$$

By using the dimensionless quantities $\varepsilon_R = \delta/R$ and $\varsigma = y/\delta$, we obtain that:

$$\mathrm{d}T = -\frac{q\,\delta}{\lambda}(1+\varepsilon_R\,\varsigma)^{-1}\,\mathrm{d}\varsigma \tag{4}$$

where $\varepsilon_R = \delta/R$ is relative cross curvature of the film; δ is liquid film thickness, m; $\varsigma = y/\delta$ is dimensionless distance from the wetted surface; y is distance from wetted surface, m.

By solving Eq. (4) with the following boundary conditions:

$$T = T_w \quad \text{for} \quad \varsigma = 0\,, \tag{5}$$

we obtain the expression of temperature field in the film:

$$T = T_w \pm \frac{q_w\,\delta}{\lambda_f}\int_0^{\varsigma}\frac{q/q_w}{\left(\lambda/\lambda_f\right)\left(1+\varepsilon_R\,\varsigma\right)}\mathrm{d}\varsigma \tag{6}$$

where T and T_w represents liquid film and the wetted wall surface temperature, K, respectively; q is heat flux density across the film, W/m^2; q_w represents the wall heat flux density, W/m^2; λ_f is thermal conductivity referred to the film mean temperature, W/(m·K).

The negative sign is put in the case of film heating and positive sign, when the film is cooling.

Heat flux density in the film first of all is a function of ς. It can be determined by solving the following differential energy equation:

$$\left(1+\varepsilon_R\,\varsigma\right)c\,\rho\,w\delta\frac{\partial T}{\partial x} + \frac{\partial q}{\partial \varsigma} = 0 \tag{7}$$

where c is specific heat, J/(kg·K); w is local velocity of stabilized film, m/s.

By integrating Eq. (7) within the limits from 0 to ς and using the boundary condition $q = q_w$ for $\varsigma = 0$, we obtain that:

$$\frac{q}{q_w} = 1 - \frac{\delta}{q_w}\int_0^{\varsigma} c\,\rho\,w\left(1+\varepsilon_R\,\varsigma\right)\frac{\partial T}{\partial x}\mathrm{d}\varsigma \tag{8}$$

The longitudinal temperature gradient $\partial T/\partial x$ depends upon the boundary conditions on a surface of the tube. Usually it is expressed at the boundary condition $q_w = const$. Then, we have:

$$\frac{\partial T}{\partial x}=\frac{dT_f}{\mathrm{d}x} \tag{9}$$

The derivative $\mathrm{d}T_f/\mathrm{d}x$ one can determine from the heat balance equation written for the elementary volume of the film:

$$2\pi R\left(q_w-q_s\right)\mathrm{d}x=G\,c_m\,\mathrm{d}T_f \tag{10}$$

where q_s is heat flux density on the film surface, W/m^2; G is liquid mass flow rate, kg/s; c_m is the mean specific heat of the film, J/(kg·K).

The mean specific capacity can be defined as follows:

$$c_m=\frac{2\pi}{G}\int\limits_R^{R+\delta}c\,\rho\,w\,r\,\mathrm{d}r=\frac{2\pi\,\delta}{G}\int\limits_0^1 c\,\rho\,w\left(1+\varepsilon_R\,\varsigma\right)\mathrm{d}\varsigma \tag{11}$$

By taking into account Eq. (11), we obtain:

$$\frac{\mathrm{d}T_f}{\mathrm{d}x}=\frac{q_w-q_s}{\delta\int\limits_0^1 c\,\rho\,w\left(1+\varepsilon_R\,\varsigma\right)\mathrm{d}\varsigma} \tag{12}$$

Let us denote that:

$$\frac{w\nu_f}{g\,\delta^2}=u \tag{13}$$

where ν_f is kinematic viscosity referred to the film mean temperature, m^2/s; g is acceleration of gravity, m/s^2.

By substituting expression $\partial T/\partial x=\mathrm{d}T_f/\mathrm{d}x$ into Eq. (8) in accordance with Eq. (12), we obtain that:

$$\frac{q}{q_w}=1-\left(1-\frac{q_s}{q_w}\right)\frac{\int\limits_0^{\varsigma}\left(1+\varepsilon_R\,\varsigma\right)\frac{c\,\rho}{c_f\,\rho_f}u\,\mathrm{d}\varsigma}{\int\limits_0^1\left(1+\varepsilon_R\,\varsigma\right)\frac{\rho\,\nu}{\rho_f\,\nu_f}u\,\mathrm{d}\varsigma} \tag{14}$$

By rearranging Eq. (13) and substituting of variable r for variables y and ς, we obtain the following expression:

$$u=\int\limits_0^{\varsigma}\frac{\int\limits_{\varsigma}^1\frac{\rho-\rho_g}{\rho_f}\left(1+\varepsilon_R\,\varsigma\right)\mathrm{d}\varsigma}{\left(1+\varepsilon_R\,\varsigma\right)\frac{\rho\,\nu}{\rho_f\,\nu_f}}\mathrm{d}\varsigma \tag{15}$$

In the case of liquid density variation, mass flow rate of the film can be defined as:

$$G=2\pi\,R\int\limits_R^{R+\delta}\rho\,w\,r\,\mathrm{d}r=2\pi\,\delta\,R\int\limits_0^1\rho\,w\left(1+\varepsilon_R\,\varsigma\right)\mathrm{d}\varsigma \tag{16}$$

The wetting density can be expressed as follows:

$$\Gamma=\frac{G}{2\pi\,R}=\delta\int\limits_0^1\rho\,w\left(1+\varepsilon_R\,\varsigma\right)\mathrm{d}\varsigma \tag{17}$$

By taking into account Eq. (13), we can define the Reynolds number for film flow through the mean film temperature T_f by the following expression:

$$Re_f=\frac{4\Gamma}{\rho_f\,\nu_f}=4\,Ga_f\int\limits_0^1\frac{\rho}{\rho_f}\left(1+\varepsilon_R\,\varsigma\right)\mathrm{d}\varsigma \tag{18}$$

or

$$Ga_f = \frac{Re_f}{4\int\limits_0^1 \frac{\rho}{\rho_f}\left(1+\varepsilon_R\,\varsigma\right)\mathrm{d}\varsigma} \tag{19}$$

where $Re_f = 4\Gamma/\left(\rho_f\,\nu_f\right)$ is Reynolds number referred to the mean film temperature; Γ is wetting density, kg/(m·s); Ga_f is Galileo number referred to the mean film temperature, $g\,R^3/\nu_f^{\;2}$.

The mean temperature of the film can be expressed as follows:

$$T_f = \frac{\int\limits_0^1 \left(1+\varepsilon_R\,\varsigma\right)c\,\rho\,u\,T\,\mathrm{d}\varsigma}{\int\limits_0^1 \left(1+\varepsilon_R\,\varsigma\right)c\,\rho\,u\,\mathrm{d}\varsigma} \tag{20}$$

By denoting that:

$$\psi = \int\limits_0^{\varsigma} \frac{q/q_w}{\left(\lambda/\lambda_f\right)\left(1+\varepsilon_R\,\varsigma\right)}\,\mathrm{d}\varsigma \tag{21}$$

in accordance with Eqs. (6) and (20), we obtain that:

$$T_w = T_f \pm \frac{q_w\,\delta}{\lambda_f}\cdot\frac{\int\limits_0^1 \left(1+\varepsilon_R\,\varsigma\right)c\,\rho\,u\,\psi\,\mathrm{d}\varsigma}{\int\limits_0^1 \left(1+\varepsilon_R\,\varsigma\right)c\,\rho\,u\,\mathrm{d}\varsigma} \tag{22}$$

By employing Eqs. (6), (21) and (22), the liquid film temperature field can be defined by the following expression:

$$T = T_f \pm \frac{q_w\,\delta}{\lambda_f}\left[\frac{\int\limits_0^1 \psi\left(1+\varepsilon_R\,\varsigma\right)c\,\rho\,u\,\mathrm{d}\varsigma}{\int\limits_0^1 \left(1+\varepsilon_R\,\varsigma\right)c\,\rho\,u\,\mathrm{d}\varsigma} - \psi\right] \tag{23}$$

For the case of isothermal flow, by denoting the film thickness as δ_{is}, the temperature T_{is}, the Reynolds number as Re_{is} and the Galileo number as $Ga_{fis} = g\delta_{is}^3/\nu_f^2$ from Eqs. (15) and (18), we obtain that:

$$u_{is} = \int\limits_0^{\varsigma} \frac{\int\limits_{\varsigma}^1 \left(1-\rho_g/\rho_f\right)\left(1+\varepsilon_R\,\varsigma\right)\mathrm{d}\varsigma}{1+\varepsilon_R\,\varsigma}\,\mathrm{d}\varsigma \tag{24}$$

$$Re_{fis} = 4\,Ga_{fis}\int\limits_0^1 \left(1+\varepsilon_R\,\varsigma\right)u_{is}\,\mathrm{d}\varsigma \tag{25}$$

The liquid physical properties variation influence on film thickness can be evaluated using the ratio $\varepsilon_\delta = \delta/\delta_{is}$. For $Re_f = Re_{fis}$ and $T_f = T_{fis}$, this ratio in accordance with Eqs. (18) and (24) is as follows:

$$\varepsilon_\delta = \frac{\delta}{\delta_{is}} = \left(\frac{\int\limits_0^1 \left(1+\varepsilon_R\,\varsigma\right)u_{is}\,\mathrm{d}\varsigma}{\int\limits_0^1 \left(\rho/\rho_f\right)\left(1+\varepsilon_R\,\varsigma\right)u\,\mathrm{d}\varsigma}\right)^{1/3} \tag{26}$$

Liquid viscosity variation has a significant influence on the film thickness. However, viscosity variation depends on the film temperature field, which is determined by the liquid thermal properties as well. Therefore, the liquid physical properties variation influence on film thickness it is purposely to evaluate using the ratio Pr_f/Pr_w .The calculation results were obtained by evaluating a function $\varepsilon_\delta = f(Pr_f/Pr_w)$. This function is presented in Fig. (1). As can be seen from Fig. (1), despite the analyzed of very different liquid physical properties dependences on temperature, the calculation data unambiguously can be defined by the following expression:

$$\varepsilon_\delta = A\left(Pr_f/Pr_w\right)^{-n} \tag{27}$$

where Pr_f and Pr_w represent Prandtl numbers referred to the mean temperature film and wetted surface temperature, ν/a, respectively.

$$A = 1.2\ ,\ n = 0.088\text{, for } 0.01 \le \left(Pr_f/Pr_w\right) \le 0.1$$

$$A = 1,\ n = 0.17\text{, for } 0.1 \le \left(Pr_f/Pr_w\right) \le 1$$

$$A = 1,\ n = 0.22\text{, for } 1 \le \left(Pr_f/Pr_w\right) \le 10$$

$$A = 1.2,\ n = 0.3\text{, for } 10 \le \left(Pr_f/Pr_w\right) \le 100\,.$$

For the case of isothermal laminar film flow, the film thickness can be calculated by the following equations: when the film flows down a vertical plane surface:

$$\delta_{is} = \left(\frac{3}{4}\cdot\frac{\nu_f^2}{g}Re\right)^{1/3} \tag{28}$$

and when the film flows down an outside surface of vertical tube:

$$\delta_{is} = 1.67\left\{\left[1 + 1.09\left(\frac{Re_f}{Ga_{Rf}}\right)^{1/3}\right]^{1/2} - 1\right\} \tag{29}$$

In the case of flowing film heating or cooling, its thickness can be determined by the equation:

$$\delta = \varepsilon_\delta \delta_{is} \tag{30}$$

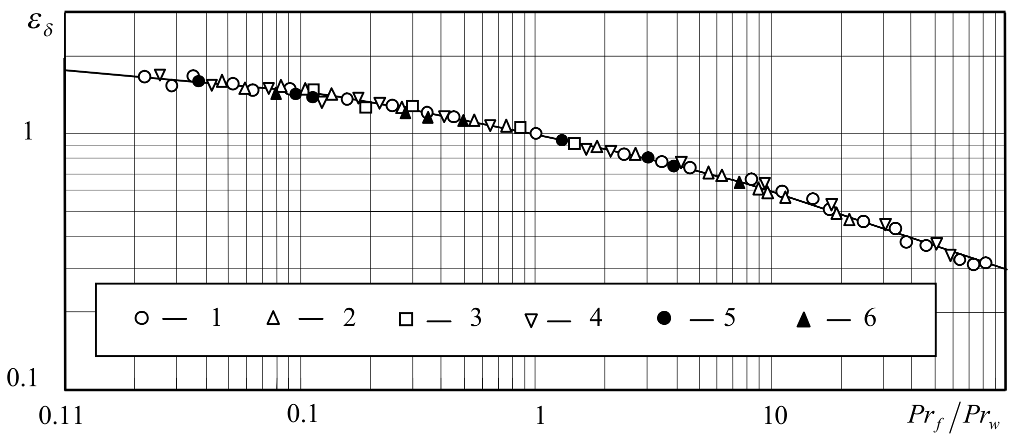

Fig. 1 Dependence of the film thickness alteration on the size of non-isothermality: 1, 2, 3 – fuel oil, compressor oil and water films respectively, when $\varepsilon_R = 0.5$; 4, 5, 6 – fuel oil, compressor oil and water films respectively, when $\varepsilon_R = 1$

3. Conclusions

For the most part, transformation of the film thickness is related to variation of liquid viscosity. However, viscosity variation depends on film temperature field, which is determined by liquid thermal properties. Therefore, the effect of liquid physical properties on film thickness was evaluated using the ratio Pr_f / Pr_w .

The calculation data analysis showed that film cross curvature and external heat exchange between the film surface and surrounding medium of gas or vapour influence on liquid film thickness variation practically is negligible.

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Proceedings of 6th International Conference ITELMS'2011

Safety Assessment of Military Systems

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Abstract

The article deals with the methodology to assess the safety aspects of special military systems. Risk, hazard and safety assessment, and reliability technology has not developed as a unified discipline, but has grown out of their integration of number activities which were previously the province of the engineer. The application of technology to risk and hazardous areas requires the formal application of this feedback principle in order to maximize the rate of reliability improvement.
KEY WORDS: *risk, hazard, safety, reliability, identify, assess, eliminate, failures, military system.*

1. Introduction

Risk and safety is generally considered as one of the primary objectives in the special programme and requires to be given equal priority with reliability, maintainability, performance, cost and timescale during all phases. A safety assessment is performed to identify, assess and eliminate (or reduce to an acceptable level) the effects of hazards. Safety concept has always been present in the designer's mind, but it was treated in a deterministic way, while now a probabilistic approach is considered. Risk and safety are generally considered as one of the primary objectives in the special programme and requires to be given equal priority with reliability, maintainability, performance, cost and timescale during all phases. A safety assessment is performed to identify, assess and eliminate (or reduce to an acceptable level) the effects of hazards. Results of this activity will represent a positive statement against System Qualification and Special Requirements.

2. Failure and hazard analysis of the system

A failure analysis starts from the system configuration and it identifies the involved items with their mutual relationship. It is finalized to discover all possible single failure modes and final effect at System level. A Functional Block Diagram shows the System functions, their relationships and the System input/output interfaces. Each function is then represented by means of blocks and for each block a list of the various associated components is provided. A component Part List and Primary Defect Rate prediction analysis identifies all the component parts that belong to the System. Further a Primary Defect Rate in the specified operational or environmental conditions is predicted for each component. The purpose of this activity is to verify, wherever possible, the quality of the selected components and their Reliability prediction. The quality of the components is verified through a predefined table where the design can be controlled in great detail. Through this table the following parameters are verified:

- Engineering safety factor defined as the ratio between allowable and applied limit stress for the material;
- Fatigue factor to take into account the fatigue analysis;
- Material treatment by considering the kind of component material, its protection, possible corrosion and/or contact with other materials.

Taking into account the environmental/operational conditions an adjustment factor is identified in order to adapt the base predicted defect rate at a realistic figure/condition. These adjustment factors take into account the different stress, environment, etc. of the involved System. The purpose of this activity is to identify all events, "Hazards" that can jeopardize the System/personnel Safety. The identification of the Hazard can be based on the "known hazards" from other similar programme and from "Analyses" such as Preliminary Hazard Analysis, Zone Hazard Analysis, Failure Mode Effect and Criticality Analysis. The first step in the identification of the Hazards is the experience accumulated from other similar programme. Accident, incidents and safety critical occurrences from other similar programme will be taken into consideration. These "known" Hazards will be analyzed jointly by System and Safety Engineers in the light of the actual design characteristics. The Safety analysis is a continuous process during System concept, development and production phases. A Safety analysis requires a clear definition of the System in form of understandable block diagrams for all the modes of operation. A Safety analysis will be based on the top down approach in order to discover Safety critical areas and to identify interface Hazards and it is performed for each function of the system. Three questions are considered for each function to identify relevant Functional Failure, these are:

- Loss of function;
- Function supplied not correctly (e.g. insufficient performance of the System function);
- Function supplied correctly when not required (e.g. false warning).

The effect of the Functional Failures on the System and/or personnel is given and the severity of the hazard categorized. Furthermore the Safety Analysis is used to extend the Hazard investigation into hazardous areas in more detail by qualitative and quantitative method.

Preliminary hazard analysis (PHA)

A Preliminary Hazard Analysis is the first one made by System and Safety Engineers the early system design. It must not be a cursory analysis because of the major influence it will have on the design philosophy, impact on design and on the production System Safety potential. This analysis is performed in order to identify Safety critical areas and to determine Safety design criteria to be used. The Preliminary Hazard Analysis is based on the best available data and past experience ("lesson learnt") to discover a preliminary list of Hazards, which may lead to a Safety critical occurrence. The steps of the analysis are:

- System Safety requirements definition;
- System historical data evaluation, accident and incident data together with their consequences from similar systems. Further their effect on the System will be postulated;
- Functional Failure analysis using a "Top Down" approach;
- Evaluation of System Safety impact relevant to physical location (Zone Hazard Analysis report);
- List of the identified Hazards and evaluation of Safety risk based on figures;
- Identification of Safety features to reduce Safety risk etc.

Failure mode effect and criticality analysis (FMECA)

The above paragraphs have identified the functions performed by the System and the related failure rates. The System has then been identified and now the failure modes are taken into consideration. With regard to this aim a FMECA is performed. The System and the Safety Engineers analyze in turn each functional block in order to highlight all the possible failure modes of its components. Once identified the failure modes, their effect on the System must be established. In order to follow a logical and self-explanatory sequence to assess the failure mode effects, the following steps are applicable: Identify the effect, at functional block level, of the failure induced by components belonging to that functional block. After applying the above procedure to all the Functional Blocks and relevant components of the System, a comprehensive analysis of the System failure modes/effects is performed. In order to assess the criticality of the failure effects, a criticality classification is established. The System and Safety Engineers decide jointly to highlight some failure effects whose occurrence could jeopardize the flight safety of the System/Vehicle. The categories are defined as follows:

- Operation Safety Critical. Indicates that a defect mode of the System can cause a Hazard. This is independent of the fact that internal redundancy may or may not prevent a hazardous single defect;
- Operation Safety Involved. Indicated that a defect mode of the System can only cause a Hazard in combination with additional defect mode(s)/event(s) external to that System.

All the remaining System failure effects not falling into one of the two above classes are assessed upon one of the following effects:

- Failures causing a mission loss/degradation;
- Failures causing an unscheduled maintenance.

All the above steps, performed during the FMECA activity, have identified all possible critical events caused by single failures. At this stage of the FMECA activity the failure modes and effects of the System have been identified; all the failure modes having an impact on the Safety and then identified through the categories shown above, will be considered as "Hazards".

Zone hazard analysis

Failure Analyses are usually performed using functional block diagrams, which do not take into account installation aspects. Then a Zone Hazard Analyses is required to enable the safety levels to be fully established. The Zone Hazard Analysis considers the physical location of the system components and the possible effects due to failures and disadvantageous operating conditions, maintenance and environment induced faults. One of the aims of this analysis is to verify if each functional redundancy is considered with regard to its physical location. The implementation of all corrective actions required as consequence of previous Zone Hazard Analyses on drawings, three-dimensional schemes and Mock-ups will be verified on prototypes and production system. Any possibly critical areas will be investigated. The Zone Hazard Analysis starts from the beginning of the installation design and continues during project development. At different steps of the project development different tools can be used, such as checklist, drawings, CAD systems, Mock-ups, prototype and production system. In order to prepare this list the System Engineer defines the installation requirements/criteria based on installation rules contained in standards and regulation and/or design requirements related to the programme, and/or design practices. The list of the requirements/criteria with relevant reference is included in a report using a dedicated table. After this, a checklist is prepared. This list consists of a series of questions, which allow the System Engineer to verify, from a safety point of view, that the design complies with the requirements. The checklist is prepared and updated during each stage of the design by the Safety Engineer together with the System/Design Engineers. At the end of this stage a report is prepared listing all the cases of not-compliance with recommendations for necessary corrective actions a dedicated table. All the above-identified corrective actions are verified during the assembly phase on the military system. The Safety Engineer performs this analysis by physical check inspections on the assembled system. An investigation, for further critical areas, will be done with a depth of analysis compatible to the current assembling phase. At the end of this phase a report is prepared describing the corrective actions introduced and listing all the new hazards identified. Finally during production phase the same approach is applicable.

Fault tree analysis

A Fault Tree Analysis is described as an analytical technique, whereby an undesired event is specified (Top Event), and then analyzed with a top down approach, in the context of its environment and operation to find all credible paths in which it can occur. The Fault Tree itself is a graphic model of the various parallel and sequential combinations (Boolean representation) of faults that result in the occurrence of the predefined undesired event. The faults are events that are associated with component hardware failures, human errors or any other pertinent events, which can lead to the undesired event. One of the main purposes of representing a Fault Tree in terms of Boolean equations is to determine the associated Fault Tree “minimal cut sets”. A minimal cut set is defined as the smallest combination of component failures that, if they occur, cause the Undesired Event to occur. The minimal cut sets define the “Failure Modes” of the Undesired Event and are usually obtained when a Fault Tree is evaluated. Once the minimal cut sets are obtained, the quantification of the Fault Tree is achieved through the minimal cut set unavailability summation. A minimal cut set thus identifies an Undesired Event. If one of the failures in the cut set does not occur, then the Undesired Event does not occur by this combination. Any Fault Tree consists of a finite number of minimal cut sets, which are unique for that Undesired Event. Once a Fault Tree is build up, it can be evaluated to obtain qualitative and/or quantitative results.

System failure

The quantitative results obtained from the evaluation includes: probability figures for Undesired Event and minimal cut sets, quantitative importance of components and of minimal cut sets, sensitivity and relative probability evaluations. The quantitative importance give the percentage of time that system failure is caused by a particular minimal cut sets on a particular component failure. The sensitivity and relative probability evaluations determine the effects of changing maintenance and checking times, implementing design modifications and changing components reliability. Also included in the sensitivity evaluations are error analyses to determine the effects of uncertainties in failure rate data. All the relevant reliability figures, for the component failures, are taken from the reliability analyses such a Primary Defect Rate prediction, Functional Block Diagram, Failure Mode Effect and Criticality Analysis.

3. Hazard risk assessment

In order to give priority to the treatment of Hazards and to thus ensure that the greatest effort in alleviating and resolving Hazards is aimed where the greatest risk exist, a method of risk assessment is implemented. For any Hazard the severity is firstly determined and when possible a probability of occurrence assigned. The combination of the above mentioned severity and probability define the Hazard Risk Index associated with Hazard. This is the factor in deciding the priority for treatment of Hazard. The Hazard severity expresses the qualitative results of the worst possible, but credible, effect of the Hazard. A Hazard severity category range is assigned by the Safety Engineer in accordance with Fig. 1. The assignment of the severity category is done jointly with the System Engineer. The qualitative risk assessment remains a fairly simple method in order not to introduce delay into the procedure to cover Hazards. The quantitative risk assessment for the Hazard, which expresses the likelihood that the Hazard occurs, is assigned as early as possible. For this purpose the Fig. 2 are used. Fault Tree technique is used to show the interdependence of events and contributing factors which lead to the Hazards and establish the probability of the Hazards. Probabilities of component failures are obtained from the Reliability analyses. Following assignment of severity and probability categories, the overall risk of the Hazard is determined by using the combination matrix in Fig. 3. The above analyses have identified all the possible Hazards to which the System may subject or contribute to. These Hazards are assessed from a qualitative and quantitative point of view in order to evaluate the risk induced by them.

Following this, four possible cases exist:

1. The risk level is acceptable without review;
2. The risk level is acceptable with review;
3. The risk level undesirable;
4. The risk level is unacceptable.
5. In the first case no further action are requested and the above theoretical analyses are sufficient to provide a compliance input to certification activity. In the second case a further discussion with the military customer is needed. The discussion defines if further analyses steps are necessary or if the confidence level can be increased and accepted. In the third case action is needed to eliminate the hazardous conditions or to reduce the risk by some of the following actions:
6. a) Incorporate Safety devices;
7. b) Incorporate warning devices;
8. c) Apply procedures or training.

Description	Category	Definition
Catastrophic	I	Death and/or system loss.
Critical	II	Severe injury, severe occupational illness, and/or major system damage.
Marginal (major)	III	Minor injury, minor occupational illness, and/or minor system damage.
Negligible (minor)	IV	Less than minor injury, occupational illness, and/or system damage.

Fig. 1. Hazard severity categories

Approximate Hazard Probability Ranking	Category	Specific Item	Probability	Fleet Frequency (1000 system)
Frequent	A	Likely to occur frequently	$>10^{-3}$	Likely to be continuously experienced during the system life
Probable	B	Will occur several times in life of an item	$<10^{-3}$ to $>10^{-5}$	Will occur frequently during the system life
Occasional	C	Likely to occur sometimes in life of an item	$<10^{-5}$ to $>10^{-7}$	Will occur several times during the system life
Extremely Remote	D	Unlikely but possible to occur in life of an item	$<10^{-7}$ to $>10^{-9}$	Unlikely but can reasonably be expected to occur during the system life
Improbable	E	So unlikely, that it can be assumed occurrence will not be experienced during the system life	below 10^{-9}	Unlikely to occur during the system life (but possible)

Fig. 2. Hazard probability categories

FREQUENCY OF OCCURRENCE	HAZARD CATEGORIES			
	I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A)Frequent	1	3	7	13
(B)Probable	2	5	9	16
(C)Occasional	4	6	11	18
(D)Extremely Remote	8	10	14	19
(E)Improbable	12	15	17	20
Hazard Risk Index		Suggested Criteria		
1 – 5		Unacceptable		
6 – 9		Undesirable (MS decision required)		
10 – 17		Acceptable with review by MS		
18 – 20		Acceptable without review		

Fig. 3. Hazard risk assessment

The above steps must be applied in order of preference with regard to their applicability. Once decided the corrective action, the Safety Engineers will monitor that it does not defect again the existing Safety level.

4. Software safety assessment

Scope of this activity is to analyze and assess the safety of the software configuration items of a system and ensures that software is given a risk classification appropriate to the severity of hazard which could be caused by a software error. The software safety assessment is performed by System Designers/Engineers, Software Developers and Safety Engineers and covers the System Design and Software Development Phases. It requires analysis of function from the highest level down to Line Replacement Item (LRI) processing specification followed by analysis throughout the software development phases from Preliminary Design to Code & Unit Testing. The software safety assessment is performed in parallel with the System Design and Software Development.

Software classification

Three software risk classifications are defined. Risk class 1 is the highest risk classification, risk class 2 is the intermediate classification and risk class 3 is the lowest classification. The general descriptions of the software risk classifications are:

- **Risk class 1** – Software for which the occurrence of any failure condition or design error would prevent the continued safe operation of the vehicle or lead to an inadvertent arming, release or non-release of stores.
- **Risk class 2** – Software for which the occurrence of any failure condition or design error would significantly reduce the capability of the vehicle or the ability of the crew to continue the assigned mission safely.
- **Risk class 3** – Software for which failures or design errors would not significantly degrade mission capability or crew ability.

In addition to these classifications an additional asterisk (*) attribute that applies to risk classes 2 and 3. The asterisk (*) is used to indicate that some “ancestor” of the function has a higher risk classification than the function itself. For functional failures which could be caused by software error, the software risk class (1, 2, 3) is established based upon the risk assessment. Three distinct cases are considered. Firstly the case where single software fault can lead to the identified functional failure mode. Secondly the case where a single software fault in combination with an independent event can lead to a failure mode, and thirdly the case where at least two different software faults must be present in order to lead to or contribute to the identified functional failure mode.

Single and double software fault

Independent events must occur or conditions exist in combination with the software malfunction in order to lead to the identified functional failure. The independent event or events may be of many kinds. The principle in all cases, however, is to establish that the events or conditions are truly independent from the software fault and could not be commonly caused by a single software fault. The probability of independent events or conditions will be assessed although this may necessarily be qualitative in the early project stages. When the failure frequency of the combined independent factors has been assessed, the software function classification can be determined from the Fig. 4. Just as there is a general requirement to consider coincident failures of independent hardware components as a part of the risk assessment process, it is necessary, when establishing software function classification, to consider the combined effects of independent software malfunctions. The malfunctions may be in different system/subsystem, on different processors in the same system/subsystem, or on the same processor. In any case the complete independence and diverse nature of the functions must be established if this section of the guidelines is to be applicable. If a complete independence and diversity argument cannot be made then both will be treated as a combined software function and the Single Software Faults guidelines applied. Use of similar algorithms, common routines, common operating systems, similar data structures, common memory areas, common I/O addressing, etc. during software development can easily invalidate arguments based on functional independence and diversity made at the system safety assessment stage. Such arguments, therefore, are particularly onerous to implement and to maintain throughout the life of a product and it is recommended not to invoke them, particularly for failure modes classed as "loss of function".

FREQUENCY OF INDEPENDENT EVENT		HAZARD SEVERITY			
QUALITATIVE	QUANTITATIVE	Catastrophic	Critical	Marginal	Negligible
Frequent	$> 10^{-3}$				
Probable	$10^{-3} – 10^{-5}$	CLASS 1			
Occasional	$10^{-5} – 10^{-7}$		CLASS 2		
Remote	$10^{-7} – 10^{-9}$			CLASS 3	
Improbable	$< 10^{-9}$				

Fig. 4 Risk classification of software fault

System design activities

The System Design comprises the System Requirement Analysis phase and the Software Requirement Analysis phase. In the System Requirement Analysis phase, which may itself be phased, the system/subsystem functional requirements are defined providing the functional baseline. In the software Requirement Analysis phase the software functional requirements are defined and assembled into individual LRI processing specification forming the allocated baseline. By the end of the System Requirement Analysis phase all the hazards that have been identified will be associated with identified functional failure modes or combined failure modes. The hazards will be categorized by severity and entered in the hazard log.

Provide a justification

A justification for the classification will be included in the Preliminary Hazard Analysis and referenced in the Hazard Log. Following the initial classifications the classifications in the subsequent phases of functional decomposition will be established and justified against the classifications assigned to their higher-level function(s). The following steps will be performed:

- Assign risk classification. At the subsequent functional classification stage a function shall inherit the classification of its parent function unless safety features have been incorporated which allow risk classification to be reduced. Once the asterisk has been established it must be inherited be all "descendants" of a function. The asterisk attribute is an indicator that safety requirements additional to those normally associated with the risk classification may exist. It is provided as a safeguard, particularly important in the maintenance phase of a product, which will ensure that safety related design decisions made early in the design process are not corrupted or invalidated by modifications to low level components.
- Analyze risk classification. The risk classifications of the functions will be analyzed to ensure the classifications have been correctly inherited. Where the risk classification has been reduced the functions will be analyzed to ensure they fulfil the higher-level safety requirements.
- Software Development Activities. The Aims of the software safety assessment during the Software Development phase are:
  - Substantiating the initial hazard analyses, assessment and software function classifications by detailed analysis;
  - Identifying new or additional hazards and hazardous failure modes of software.

  The software related hazard analysis activities are phased, in line with the software development process, through Preliminary Design and Detailed Design to Code and Unit Test and the results documented within each phase. At

each phase of the software development life cycle the relevant requirements from the previous hazard analyses will be incorporated in the design and test requirements the following steps will be performed:
- Assign Risk Classification;
- Analyze Risk Classification;
- Justify Risk Classification;
- Analyze for New Hazards Record the Analysis.

5. Conclusions

This methodology tries to assess the Safety aspects of Military Systems. The correlations between FMECA and Safety Assessment will be shown to identify all possible hazards caused by single failures. A tool using Fault Tree Analysis approach, to assess from a quantitative and qualitative point of view the discovered hazards, will identify the minimal cut sets and critical items in the System configuration. Failure Analyses are usually performed, using functional block diagrams, to identify the effect of the Functional Failures on the Military and/or personnel and categorise the hazard severity. This will have influence on the design philosophy, impact on design and on the production System Safety potential. Then a Zone Hazard Analysis is required to enable the Safety levels to be fully established. The Zone Hazard Analysis considers the physical location of the System components and the possible effects due to failures and disadvantageous operating conditions, maintenance and environment induced faults. One of the aims of this analysis is to verify if each functional redundancy is considered with regard to its physical location. The implementation of all corrective actions required as consequence of previous Zone Hazard Analyses on drawings, three-dimensional schemes and Electronic/Physical Mock-ups will be verified on prototypes and production system. Any potential critical areas will be investigated. The Zone Hazard Analyses starts from the beginning of the installation design and continues during project development. Particular risks are events or influences which are outside the system concerned but which may violate event independence claims. These particular risks may also influence several zones at the same time. Typical risks would include: Fire, High Energy Device (weapon, gun, tank, etc.), High Pressure/Temperature, Burst, and so on. Having identified the appropriate risks with respect to the design under consideration, each risk should be subject to a separate study. The objective of the relevant analysis is to ensure that any safety related effects are either designed out or shown to be acceptable. Software Safety Assessment is performed to analyze and assess the safety of the software configuration items of a System and ensures that a risk classification is allocated appropriate to the severity of hazard that could be caused by a software error. The software safety assessment is performed by System Designers/Engineers, Software Developers and Safety Engineers and covers the System Design and Software Development Phases. It requires analysis of function from the highest level down to Line Replacement Item (LRI) processing specification followed by analysis throughout the software development phases from Preliminary Design to Code & Unit Testing. The software safety assessment is performed in parallel with the System Design and Software Development. These results will lead to the definition of critical areas and the possible corrective actions to give a compliance statement to System Qualification and Military requirements.

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Proceedings of 6th International Conference ITELMS'2011

Selection of Steel Type for NPP Units Various Equipment

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Abstract

The paper presents the results of the selection of steel type for NPP units various equipment. The consideration of pressure vessel fractures has shown that metal fabrication defects or various surface imperfections in the most heavily stressed units constitute the main reason of this phenomenon. Taking into consideration this fact in the present paper it was attempted to look over the requirements imposed upon the material in connection with its local production or metallurgical imperfections.
KEY WORDS: *pressure vessels and piping, fatigue crack, stress concentration factor.*

1. Introduction

Analysis of damaged cases for pressure vessels and piping has been shown that the main factors to nucleation of fatigue cracks are: 1) service conditions (number of cycles during operation); 2) concentration of stresses in more loaded areas; 3) quality of base metal (crack, lamination, et. al.) and welds (crack. pore, slag inclusion, et. al.).

Low cycle fatigue strength of the structures is governed by the metal behavior in stress concentration regions. The stress level in these regions can considerably exceed the material yield strength. According to modern method of estimation structure endurance is identified using the fatigue crack initiation conditions on the basis of Coffin-Langer's equation, applicability of which has been experimentally supported by testing materials of different strength level. As it is shown in Ref. [1] for the approximate calculations the following equation may be used:

$$\frac{E}{4\sqrt{N}} \cdot \ln\frac{100}{100-\psi} + \frac{UTS}{2} = S_a , \tag{1}$$

where $S_a = e_a E$ – allowable amplitude of alternating stress intensity; e_a – total strain amplitude; E – modulus of elasticity; UTS – ultimate tensile strength; ψ – reduction of area.

S_a value in the most stressed region of the structure can be obtained if the strain concentration factors are known:

$$k_{\varepsilon\max} = \frac{S_a}{\sigma_{nom}} , \tag{2}$$

where σ_{nom} – calculated mean stress intensity.

These factor values characterize design quality of the most heavily stressed units in typical structures. The estimated and experimental data obtained by different investigators has shown that for pressure vessels the values of the strain concentration factor vary in the region 2.5 to 5 depending on the type of the structure.

2. Research

As the trend to use high strength materials for pressure vessels becomes increasingly pronounced, it is of particular interest to analyze structure endurance as a function of design quality and tensile properties of the materials used, starting from present standards (ASME Code, for example) and holding true the equation (1).

For this purpose on the basis of the equation (1) and taking into account the relationship (2) a diagram for fracture conditions of pressure vessels versus the material properties and $k_{\varepsilon\max}$ values was constructed. In this case the assumption was made that for vessels:

$$\sigma_{nom} = \frac{UTS}{2.6} \tag{3}$$

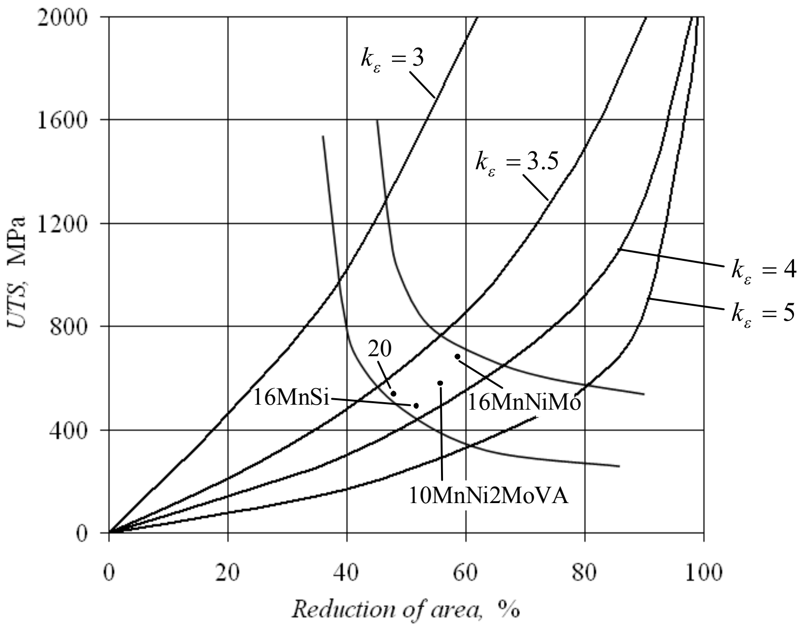
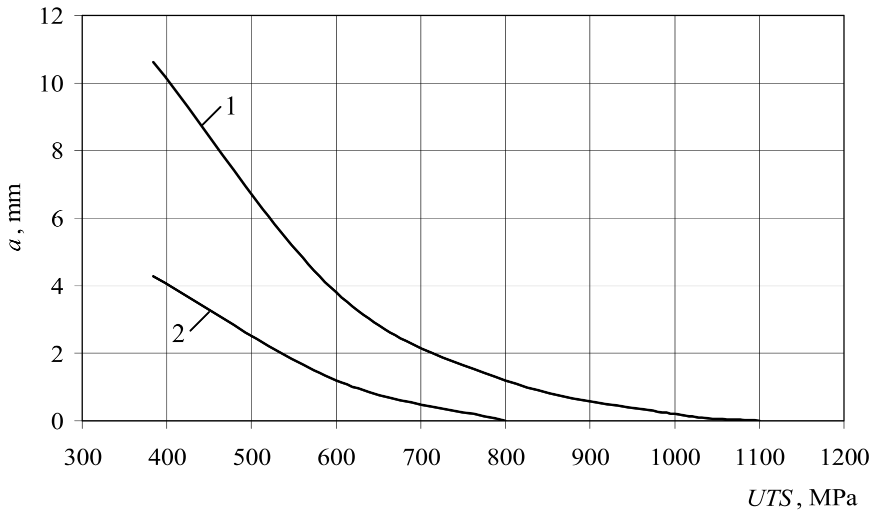
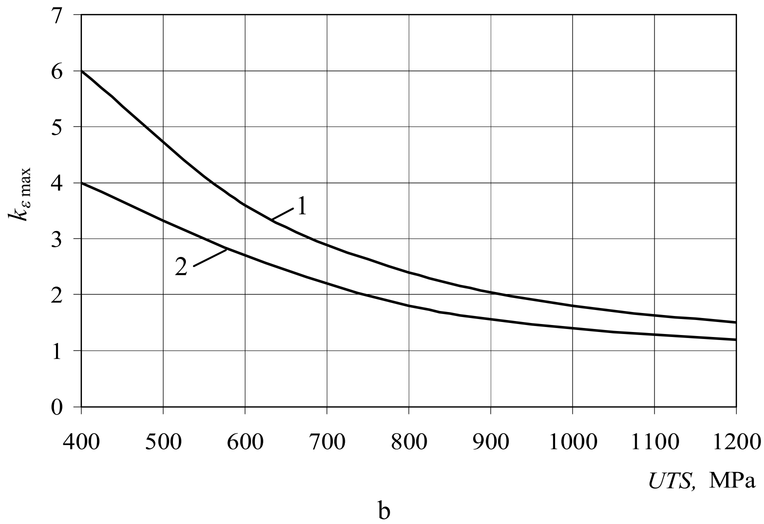


Fig. 1. Diagram of pressure vessel fracture condition



a



b

Fig. 2. Change of requirements to designed unit's arrangement on criterion of low cycle fatigue in dependence from strength material: a – at variation of fatigue crack size (1 – $a = 2$ mm; 2 – $a = 4$ mm); b – at variation of strain concentration factor (1 – $k_{\varepsilon\max} = 3$; 2 – $k_{\varepsilon\max} = 4.5$)

In this case equation (1) will be

$$\frac{E}{4\sqrt{N}} \cdot \ln\frac{100}{100-\psi} + \frac{UTS}{2} = \frac{UTS}{2\cdot 2.6} \cdot k_{\varepsilon\max} \quad (4)$$

The relationships for $N = 5\cdot 10^3$ cycles given in Fig. 1 were plotted taking into account safety factors 20 suggested by ASME Code, that is the most typical lifetime for power units.

Fig. 1 shows also a scatter band of mechanical properties for various structural steels for pipelines (20, 16MnSi, 16MnNiMo, 10MnNi2MoVA).

Separate points for these steel in the band corresponding to mechanical properties of certain best known materials are shown in this Fig.1. It is evident from Fig. 1 that to retain given structure endurance leaving invariable design quality of a vessel, it is important by increasing material strength to raise its ductility.

However, in reality material strength is accompanied as a rule by a certain drop of ductility. In this connection, in structures with $UTS = 400 - 500$ MPa the required endurance is provided in practice even for most unfavorable values of $k_{\varepsilon\max}$. When increasing the strength level of the material used with accompanying mean stress level raise, it is necessary to decrease $k_{\varepsilon\max}$ value to maintain structure endurance. So if the number of cycles $5\cdot 10^3$.

Then for production of the most heavily stressed structure units $k_{\varepsilon\max}$ should be 3.5 for materials having $UTS \leq 700$ MPa and 3 to 3.2 having $UTS = 900 - 1000$ MPa.

The considerations mentioned above are based on purely formal analysis. The drawback of the latter is that the assumed safety factor 20 includes all integrated factors which are effective in structure production and operation.

Some relations are given by Langer [2] who evaluated the correlation of structural material endurance and crack size for different strain concentration factors on the basis of Peterson's hypothesis. Such analysis is applied to fatigue when metal is in elastic region. It is known that the material in stress concentration zones is in elastic-plastic region, therefore the analysis given above needs refinement [3, 4].

Using the calculated method it is possible to estimate the requirements to designed arrangement of structure units on the criterion of fatigue crack nucleation from materials with different strength level [4]. The results of the calculation for endurance $5\cdot 10^3$ cycles are presented in Fig. 2.

As can you see to arrange this endurance it is not possible to use the materials with ultimate tensile strength more than 600 MPa. Thus with increasing strength level of materials it is necessary to decrease the maximum level of stress concentration factor $k_{\varepsilon\max}$.

3. Conclusion

1. Selection of steel type for NPP units various equipment on criterion of low cycle fatigue must be performed in dependence from strength material level and stress concentration factor. With increasing strength level of materials it is necessary to decrease the maximum level of stress concentration factor $k_{\varepsilon\max}$.

2. The most heavily stressed structure units $k_{\varepsilon\max}$ should be 3.5 for materials having $UTS \leq 700$ MPa for pressure vessels and piping.

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Proceedings of 6th International Conference ITELMS'2011

Providing of the Cold Resistance 09Mn2SiA-A Steel Welded Joints for the Containers With Spent Nuclear Fuel

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Abstract

The paper presents results of the providing of the cold resistance 09Mn2SiA-A steel welded joints for the containers with spent nuclear fuel. Forgings of this steel are subjected to special thermal processing, which contributes to grain refinement and obtain granular pearlite, which also makes it possible to increase the cold resistance of steel.
KEY WORDS: *welded joints, nuclear fuel, sheet, forging.*

1. Introduction

To ensure environmental cleanliness of the area, where nuclear power plants are located, spent fuel is usually collected in storage tanks or containers. After filling of the cask, it must be moved to a place of reprocessing spent nuclear fuel using a transportable container. Such containers for transportation and long storage spent fuel of the RBMK reactors have been developed in St. Petersburg at the end of the 90th of the last century by the engineering organization DOMM jointly with Central Research Institute of Structural Materials (CRISM) "Prometey" and several other organizations. They are designed to store spent fuel up to 50 years [1].

Based on the purpose and possible operating conditions, the basic requirement for the details and nodes of these containers is the exclusion of depressurization and release of radioactivity into the ambient at all stages of operation, including possible emergency situations in difficult climatic conditions, i.e. at air temperatures below zero brittle fracture should be excluded.

Consequently, materials for the containers and their welded joints must have high brittle fracture resistance including container must remain sealed if dropped from the 145 m on rocky ground at an ambient temperature 50 degrees below zero. Calculations of the brittle strength, according with [2], showed that the safe operation of the container with spent nuclear fuel is possible if the impact toughness of the base metal and welded joints 09Mn2SiA-A steel at the temperature -50ºC not less than 29.4 J/cm^2.

2. Research

The material should have a sufficiently high level of plastic properties, which primarily have stainless austenitic steels and some low-alloyed ferrite-perlitic steels [3].

However, the first does not provide a relatively low cost. At the same time, low-alloyed steel type 09Mn2Si widely applied for the various parts and elements of the metalworks, operating at the temperatures from -70ºC to +425°C. According to the Standard 19281-89, steel has the following chemical composition: ≤ 0.12% C, 0.5-0.8%Si, 1.3-1.7%Mn, ≤ 0.30%Cr; ≤ 0.30%Ni, ≤ 0.30%Cu, ≤ 0.035%P, ≤ 0,040%S and sheets of it, which thickness is from 4 mm to 160 mm, is used in nuclear power [4].

In accordance with the Appendix 1 of this document the guaranteed level of mechanical properties at the temperature +20°C is $UTS = 432$ MPa, $YS = 245$ MPa, $A = 21\%$, $Z = 45\%$, at the temperature +450°C is $UTS = 392$ MPa, $YS = 157$ MPa, $A = 16\%$, $Z = 44\%$. Toughness values for this steel grade, as shown in Fig. 1, are quite low. At the temperature -50ºC these values are no more than 50 J/cm^2.

09Mn2Si steel is smelted in Russia in converters and electric arc furnaces. After these smelting methods steel would be contaminated mainly with oxysulfides and large extented plastic silicates, that promotes the formation of check crack and sharply reduces the toughness.

To improve the visco-plastic characteristics of the silicon-manganese composition steel, which is the most cost-effective compared with other brands of steels ladle refining and vacuum degassing is used. It helps to reduce inclusions in the steel due to the induced ground slag deoxidation with carbon in vacuum and subsequent deoxidation in a constant electromagnetic stirring and purging liquid metal with the argon, which also allows to reduce the amount of hydrogen and nitrogen and provide a uniform temperature field in the entire volume of the melt.

Besides, forgings of this steel is subjected to special thermal processing, which contributes to grain refinement and obtain granular pearlite, which also makes it possible to increase the cold resistance of steel.

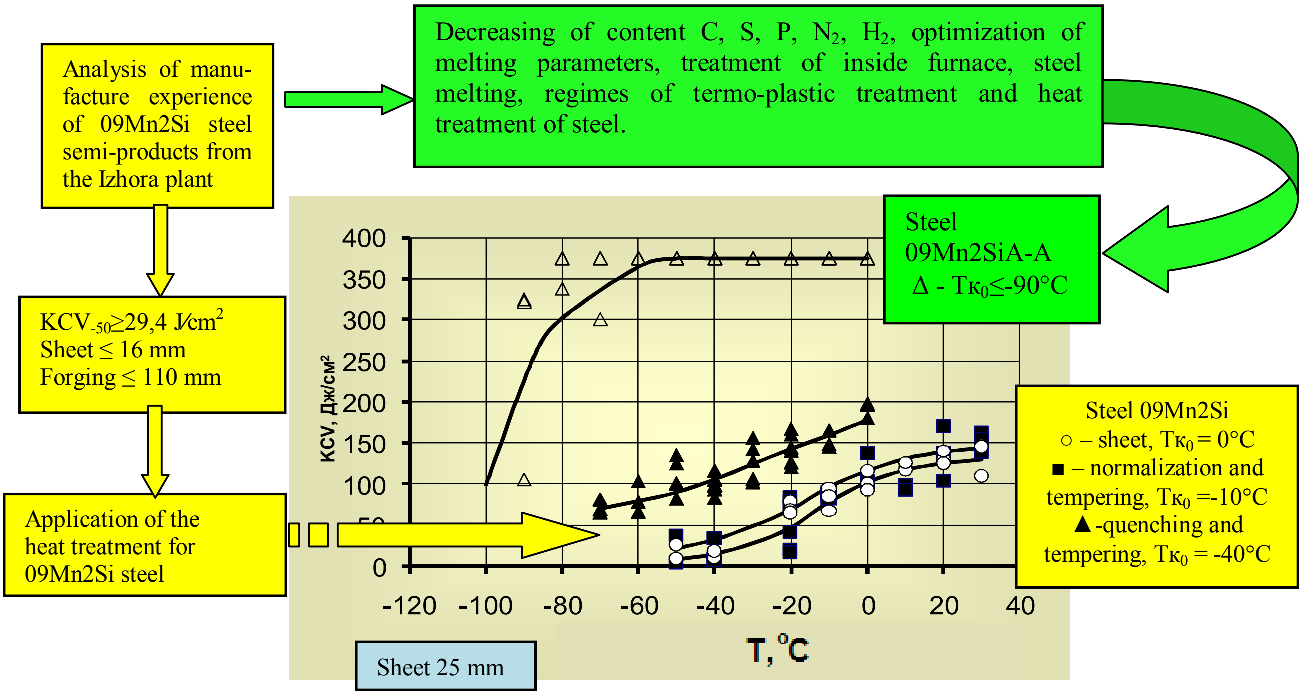

Fig. 1. Toughness values of the 09Mn2Si steel

Providing the required cold-resistance applies not only to the base metal, but also to the metal heat-affected zone (HAZ) of welded joints of containers made of semi-products (forgings and rolled products). Earlier in [5] was noted that in the HAZ of welded joints of silico-manganese steels may show a tendency to decrease the impact toughness at low temperatures. In this connection before using steel 09Mn2Si for parts and components in the manufacture of containers, it has been improved, in particular, reduced sulfur, phosphorus and other elements, as well as optimize the parameters of the smelting, ladle treatment and casting, and improved heat treatment.

In fact, in CRISM «Prometey» was developed a new steel grade 09Mn2SiA-A, which provides a high cold-resistance requirements for semi-finished steel in the form of plates thickness up to 160 mm and forging cross-section of 350 mm. This steel composition presented in Table 1. Research was carried out on the forging have 350 mm section, weighing 3.5 tonnes and sheet 25 mm thick.

To get sheets and forgings with high strength and plastic properties it is necessary to microalloying steel with vanadium and niobium. These elements contribute to the formation of stable carbides, which are allocated at the grain boundaries during solidification of liquid metal and prevent grain growth during heat treatment and welding.

The microstructure of large forgings of ferrite-pearlitic steel 09Mn2SiA-A, modified with vanadium and niobium, is shown in Fig. 2 (grain size in the forging is 7-8 [6]), and sheet metal - Fig. 3 (grain size 9-10). Steel was subjected to a deep cleaning of harmful impurities: sulfur, phosphorus, nitrogen, hydrogen and non-ferrous metals. Because of the deep cleaning of harmful impurities, carbon and nitrogen control, steel modification, as well as a special mode of heat treatment this steel has a high cold-resistance (Table 2, 3).

Table 1

Chemical composition of steel 09Mn2SiA-A

	Content of elements,%									
	C	Mn	Si	P	S	Cr	Ni	Al	Ti	N
forging	0,09	1,46	0,60	0,008	0,003	0,13	0,25	0,031	0,005	0,008
sheet	0,07	1,44	0,54	0,006	0,004	0,08	0,08	0,042	0,005	0,008

Table 2

Mechanical properties of the forgings

№	T°C	Toughness, KCV, J/cm^2		
A	+20	317,0	318,0	311,0
	-50	252,0	239,0	248,0
B	+20	372,0	330,0	348,0

	-50	240,0	249,0	251,0

Table 3

Mechanical properties of the sheets

№	T°C	Toughness, KCV, J/cm^2		
A	+20	355,0	≥375,0	372,0
	-50	374,0	≥375,0	354,0
B	+20	371,0	371,0	364,0
	-50	353,0	355,0	≥375,0

Note: ≥ 375 J/cm^2 - samples are not destroyed.

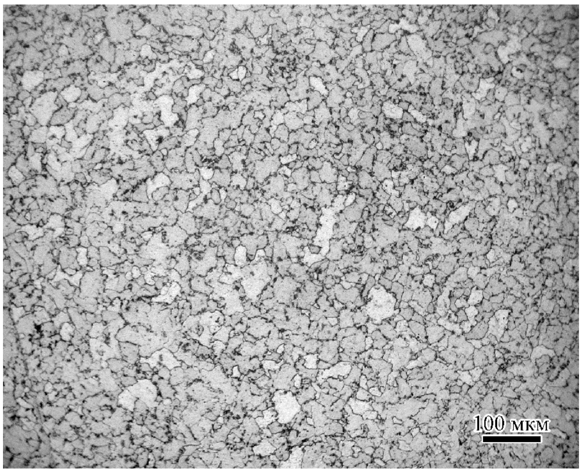

Fig. 2. Forging microstructure 09Mn2Si A-A steel (x100)

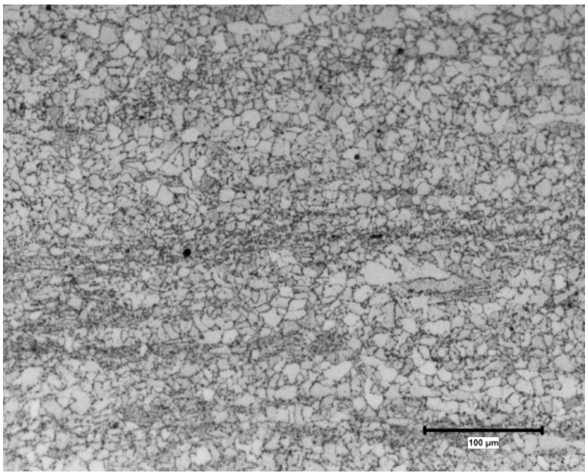

Fig. 3. Sheet microstructure 09Mn2SiA-A steel (x200)

Static testing of mechanical properties for specimens cut from forgings and sheets were carried out. Heat treatment of samples: A - after special regime of the heat treatment, B – A + simulated post weld heat treatment. Values of mechanical properties are shown in Tables 2 and 3.

According to the data, impact toughness of the material, tested at the temperature -50°C satisfies the requirements for forgings and sheets, which are used in the cold climatic conditions.

During the manufacture of the real structures was cases of the impact strength reduce below the required level of heat-affected zone steel 09Mn2Si A-A at a distance of 5-6 mm from the weld fusion line. This zone coincides with the wide area thermal-aging of the weld. Depending on the used welding method and mode (heat input), this area is exposed to the temperatures 275-420°C for a certain duration of time [5] – from about 40 s (when welding at higher modes) to 90-120 s (welding on the regime with an optimal heat input).

Increasing cold resistance of heat affected zone of welded joints is also achieved by heat treatment. Thermal treatment method [7] is the following:

- landing in the furnace at 300°C;
- heating from 300°C to 650°C at 30÷50°C/h;
- holding at the temperature 650±10°C for 8 hours followed by cooling in a temperature of 650°C to 300°C at 30÷50°C/h and then in the air.

3. Conclusions

In the research of weld forging-sheet products made of steel 09Mn2SiA-A with the use of automatic submerged arc welding was found that the toughness of the base metal of the sheet, tested at the temperature -50°C was satisfy the demand for cold resistance KCV^{-50} and was equal to 137, 174 and 184 J/cm^2, while the impact toughness of HAZ of the forgings was considerably lower (less than 29,4 J/cm^2).

This is due to the fact that the rapid heating of the heat treatment [7] could lead to the formation of hairline cracks due to hydrogen in the metal resulting from welding. Therefore slow heating in the temperature to 300°C was carried out, which allowed to obtain the values of impact toughness in the HAZ of the forgings 35÷130 J/cm^2.

Impact strength of the base metal HAZ of the sheet, in this case, had values of 268, 236 and 284 J/cm^2. Thus, provided the values of impact toughness at -50°C, far exceeding the requirements of normative and technical documentation.

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Proceedings of 6th International Conference ITELMS'2011

The Quality of Indoor Climate in Offices in Atrium-Type Buildings

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Abstract

In the present study the indoor climate quality assessment in atrium-type buildings' office rooms is given. The present investigation includes two atrium-type buildings (A built in 2003 and B – in 2009) where accordingly 120 (building A) and 360 (building B) scientific and administrative workers work. The workers' opinion on the existing work conditions was assessed. The atrium's (floor area 15×15 metres) roof of one of the buildings (A) is tightly covered with glass, the windows of the building towards the atrium are closed-type. So the office-workers, whose rooms' windows are towards the atrium, never feel fresh air. The other building (B) with atrium inside (15×30 metres) was built with opened windows closed to the atrium. The roof of this atrium is also built from glass but there is a 2 to 5-metre break between the walls and the roof. It gives the possibility for office-workers to open the windows and have the fresh air. The main results of the investigations: the indoor air is too dry in winter season (relative humidity10-20%); the air temperature in the workrooms depends on the rooms' location in the building and the relaxation time of the temperature is too high (the rooms are not heated or cooled with enough speed according to the sudden changes of the outdoor air temperature); if the room area is smaller than 10 m^2 per worker, then the concentration of CO_2 is over the limits (>800 ppm); noise is a problem when the ventilation is working in a very high capacity; the SBS syndromes include in moisture of the rooms (causing bad smell) and in the rooms where the windows cannot be opened.

KEY WORDS: *atrium-type buildings, indoor air, CO_2 concentration, lighting, sick building syndrome.*

Introduction

In the previous research (Saari et al., 2006; Skyberg et al., 2003; Nagar et al., 2006; Rashid et al., 2008) has been found that the indoor climate is related to the workers' wellbeing at workplace including job satisfaction, motivation and productivity. The European Standard EN 15251:2007 sets the new demands for previously Socialist-countries for indoor climate (IC) quality: for air temperature, humidity, velocity (ventilation), carbon dioxide concentration, noise and lighting in office and research-rooms.

During the 1970s energy crisis, buildings were designed to be airtight, conserving as much warm air during the winter and cooled air during the summer as was possible. Windows that could not be opened became a common part of building design. It is now clear that such airtight buildings create problems. Because of inadequate ventilation to the outside, the air pollutants inside the buildings have to be removed. The results can range from nose, eye and throat irritation and aggravation of asthma to an increased risk of lung cancer. Biological sources of indoor air pollution include mould, mildew, fungi and bacteria. Exposure to small amounts of indoor air pollutants can cause minor irritations, such as dry, scratchy eyes and throats, or headaches. However, in large concentrations pollutants can lead to dizziness, tiredness, and nausea, and rashes. Each year there are news reports of buildings being evacuated because of "sick building syndrome," a group of health symptoms listed above that stem from poor air quality inside a building and usually subside after leaving the building. Long-term exposure to some indoor air pollutants can lead to damage of the central nervous system, kidneys and liver. Although anyone can have problems because of indoor air pollution, most susceptible is the ageing workforce, people who have respiratory ailments such as bronchitis, asthma or emphysema. Nowadays, the airtight windows are used in the office-rooms in the atrium-type buildings around the atrium. The previous-mentioned problems arose again.

The physical environment of the workroom is important as it may induce stress on individuals and thereby reduce the results of their cognitive endeavours of scientific and office workers overall. EN 15251:2007 originates from different (I to IV) categories of comfort. The risk assessment levels for occupational hazards are given in BS8800; a flexible risk assessment (RA) method has been developed in Tallinn University of Technology (Reinhold et al. 2008, 2009a, b). Figure 1 gives the basis for risk assessment of indoor climate in office-rooms and gives the possibility to determine the level of comfort of the room (EN15251:2007) that has links with the previous methods (BS8800, the flexible RA method).

In the present study the indoor climate in atrium-type buildings' (Song, 2007; Mergi et al., 2007; Pan et al., 2009; Voeltzel et al., 2001) office rooms are given. The investigations on ventilation and indoor air quality show the problems and advantages of this construction style (Voetzel et al., 2008; Perino, 2009). The present investigation includes two atrium-type buildings where accordingly 120 (building A) and 360 (building B) scientific and administrative workers work. The workers' opinion on the existing work conditions was assessed. The atrium's roof of one of the buildings (A) is tightly covered with glass, the windows of the building towards the atrium are closed-type (they cannot be opened). The 6-storeyd building (A) for administrative and research needs was built in 2003 when the construction costs where very high and it was important to save money. Therefore the working conditions of office-workers were left in the background. So the office-workers, whose rooms' windows are towards the atrium never feel fresh air (Figure 2). The house is quadrangular, without any beetling construction parts. The floor area of the atrium A is 15×15 metres. It is a good place for students' relax during the breaks.

< 300	300	500	1000 - 1500[1]	Lighting, lx
< 4	< 4	> 7	> 10	Ventilation, l/s per person
< 20	> 20	> 25	> 30	Humidity, %
> 800	< 800	< 500	< 350	CO_2 ppm
more	19 - 27	20 - 26	21 - 23.5	Operative temperature, ºC
> 15	< 15	< 10	< 6	PPD[2]
< - 0.7; > + 0.7	-0.7< PMV< +0.7	-0.5< PMV< +0.5	-0.2< PMV <+0.2	PMV[3]

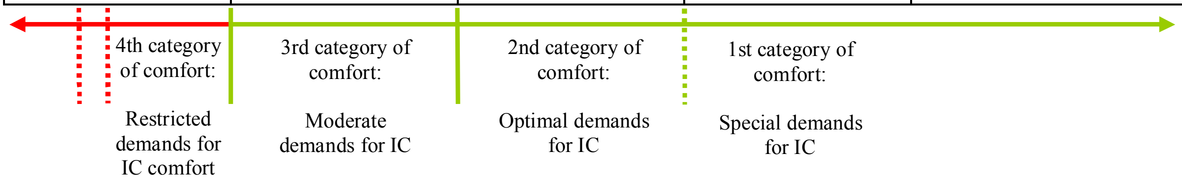

Fig 1. The categories of comfort for different hazardous factors in office rooms for administrative and research personnel. [1] Lighting 1500 lx is demanded for carrying out special jobs with higher demands for illumination (textile industry etc.). [2] predicts the mean value of the thermal votes of a large group of people exposed to the same environment. PPD is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people who feel too cool or too warm (ISO 7730:2005). [3] index that predicts the mean value of votes of a large number of persons on the 7-point thermal sensation scale (o-neutral; -1: slightly cool, -2: cool, -3: cold; +1: slightly warm, +2: warm, +3: hot), based on the heat balance of the human body (ISO 7730:2005)

Fig. 2. Atrium-type building (A) that is tightly covered with glass roof. Only the workrooms beginning the 4th floor are sun lighted

Fig. 3. Atrium-type building (B) with opened to the outdoor air cap between the floor and the walls

Fig. 4. As there is a slot between the roof and walls in the building (B), the snow is falling on the atrium floor in winter

Fig. 5. The office-rooms in the 2nd floor, directed to the south

The other building (B) with atrium inside (15×30 metres) was built in 2009 when the construction costs were low. It was possible for the university to install the office-rooms with opened windows closed to the atrium. The roof of this atrium is also built from glass but there is a 2 to 5-metre break between the walls and the roof (Fig 3). It gives the possibility for office-workers to open the windows and have the fresh air. The negative influence of that type of building occur in the changeable climate conditions (in the Nordic countries) when in winter snow is coming through the break and falling on the floor of the atrium where the rooms' windows of the first floor are very near to the floor (Fig 4). Some of the rooms are excessively humid (possible development of mycobacterium). The rooms are mostly meant for 2-3 persons. The new buildings also create the psychological problems (constricted workplaces, less good possibilities to carry out scientific work etc.) for workers. There are also some problems with indoor air temperature in the rooms outside the atrium, in the opposite side of the atrium offices, having two glass walls and empty space (design problems) under the floor (the air temperature in these office-rooms is very low in the winter season, Fig 5).

The aim of the study was to clear-up the shortages in the work environment in atrium buildings, to give recommendations for improvement of ventilation of rooms, for improving the heating system. The connections between the indoor climate quality and the satisfaction of workers with working conditions was cleared-up with the questionnaires given to the workers in the course of the risk assessment visits. The relationship between the air quality (sick building syndrome-SBS), ventilation, work area magnitude, lighting conditions, noise and stress phenomena was investigated.

Material and methods

The measurements were carried out in 137 office-rooms meant for 1-4 people.

The criteria for risk assessment at workplace were derived from regulative norms, standards, directives and scientific literature (Reinhold et al. 2008, 2009a, b):

1. To perform the measurements of occupational hazards, the following standard methods were used: ISO 7726:1998 "Thermal environments – Instruments and methods for measuring physical quantities"; EN 15251:2007 "Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics", EN 12464-1:2002 "Light and lighting- Lighting of work places- Part 1: Indoor work places", EVS 891:2008 "Measurement and evaluation of electrical lighting in working places", ISO 9612:1997: "Acoustics – Guidelines for the measurement and assessment of exposure to noise in a working environment", WCB method 1150:1998 "Particulates (total) in air"; EVS-EN 1231:1999 "Workplace atmospheres- Short term detector tube measurement systems- Requirements and test methods".

2. The parameters of indoor climate were measured with TESTO 435 (air temperature, relative humidity, air velocity) in 4 points of the workroom (8 if the surface area was over 100 m^2), at a level of 1.0 metres (sitting position) or 1.5 metres (standing position). Triplicate readings were recorded for each measurement and the average was presented. Before sampling, the doors between the rooms in the departments were closed for at least 1 hour and the doors to the corridors were close all the time. TESTO 435 enables also the measurements of CO_2. The measurements of room temperature were carried out in the cold season.

3. Measurements of lighting the workplaces and screen were performed using the light-metre TES 1332 (ranges from 1-1500 lx). The lighting was measured on the worktable, on the screen and on the keyboard. Lighting was measured at the local workplaces (normally at a height of 0.80 m above floor level), where a suitable measuring grid was applied. The arithmetic mean $\overline{E}$ was presented. A digital luxmeter TES 1332 was used. To exclude the stray light, the measurements were carried out either in the dark or where possible, the windows were covered with blinds.

4. Noise, measured as equivalent continuous A-weighted sound pressure level (L_{eq}(A)), was evaluated under normal operating conditions using a hand-held Type II Sound Level Meter (TES 1358).

The questionnaire consists of questions to clear-up the satisfaction with occupational health hazards.

Scientific basis

According to the EN 15251), the hazards determining the comfort class of the office-room are as follows: the performance of atrium type administrative buildings addressing indoor air quality, thermal environment, lighting and acoustics.

Office lighting and health: people prefer to have windows in many spaces. Boyce et al. (2003) found that workers in windowless offices spend a small but statistically significant greater amount of time talking to others, either directly or by telephone; and a small but statistically significant lesser amount of time working on their computer, relative to workers in windowed offices. An office desk situated near a window typically receives five times as much light from daylight as it would from electric lighting alone. The workers in windowless offices do not receive sufficient daylight to entrain their circadian system, and therefore seek additional daylight and social interactions. There are other health damages that could be happened (even cancer, Figueiro et al. (2006). The colour of the light is also very important (International.., 2009). The cool fluorescent light has negative effect on individuals' health. The luminous flicker of fluorescent lamps, which can be reduced or eliminated by replacing magnetic ballasts with digital ballasts, has shown to have affected visual performance, caused visual comfort and general stress (Veitch et al. 2006).

Office noise and health: unnecessary noise is perceived to be more harmful (Witterseh, T. et al. 2002). Sounds that are generated by others or unpredictable sounds (e.g. telephone rings) are considered uncontrollable, and more stressful. People talking in the background and telephones ringing have been cited most frequently as the primary sources of annoyance in offices. The noise hinders the performance of complex tasks more than it hinders of performance of simple tasks (Nagar et al. 2006). Most annoying sources of sounds in offices include people, telephones. Intrusive sounds, noise, make people tired and irritable. It has a negative effect on the performance, especially when working on tasks that depend on short-term memory. Those working in noisy office environments have also been found to be less cognitively motivated, and to have higher stress levels, according to a Cornell University study (Even., 2001). Noise pollution has been linked with health problems such as heart disease, high blood pressure, and stroke. It's also been linked with musculoskeletal problems, as a Cornell University study on office noise found that those working in noisy office environments can also be less likely to ergonomically adjust their workstations for comfort, which can contribute to physical problems.

Ambient temperature, air quality (SBS) and ventilation: ambient temperature is a predominant stressor in office buildings. Witterseh et al. (2002) reported that if the temperature in offices increased from 22^{0}C to 26^{0}C the participants in the study reported increased difficulty of thinking and concentrating. In the Northern European workplace studies, a linear relationship between the symptoms of sick building syndrome (SBS) and room temperatures above 22^{0}C has been a consistent finding (Reinikainen & Jaakkola, 2001). Air supply, odour, and pollutants determine the air quality within a building. Numerous workplace studies (Skyberg et al., 2003; Saari et al., 2006; Perino, M., 2009) have shown that air quality can cause stress among workers. The quality of indoor air could be improved with well-organized ventilation Seppanen et al. (2004) found that ventilation rates below 10 l/s per person in all building types were associated with significant worsening in one or more or perceived air quality outcomes, also with increased symptoms of SBS. The risk of SBS symptoms continued to decrease significantly with decreasing carbon dioxide concentrations below 800 ppm. There are some other not-exactly determinable pollutants (from carpets, carpet clues, wall-paints), which concentration is low and the determination of the exact volatile component is difficult and expensive. Chamber experiments show less dry throat and less difficulty thinking clearly with increased velocity of the air (>1 m/s) at workplace (Wargocki et al. 2000). Northern European studies show that temperatures above 23^{0}C increase SBS (Graves et al. 2006).

Airway infections seem also to be associated with dampness indoors (Schleibinger, H.et al. 2008).

Satisfaction with working conditions: the needs for ergonomic workplace design are nowadays very important as the workforce is ageing. Older people may be more affected by noise and lighting conditions than younger people. Some cognitive needs may be more pressing for highly educated (researchers) individuals. Time may be an additional factor determining the potency of environmental stressors. In some contexts, people may simply get used to a stressor if exposed to it for an extended period. Stress is primarily a psycho-physiological phenomenon that arises from an individual's perception of balance between environmental demands and response capabilities. From the job-demand perspective, stress results the joint effect as of the demands of work and the range of freedom (control) available to the worker facing those demands (Choi et al. 2009, Rashid, M. 2008).

Results of measurements and questionnaire

The work conditions in the building A: lighting norms in the office rooms located on 1st-2nd floor closed to the atrium is guaranteed with artificial sources only; the workrooms are airless; the mechanical ventilation does not guarantee the comfort of people; at the end of the workday, the CO_2 concentration is over the limits (>800 ppm).

The work conditions in building B (1st floor): in winter there is no daylight in the cabinets (located on very low level). The conditions of lighting are better in spring and autumn seasons. The workers in the 1st floor cabinets never see the sunlight. The workers in the 2nd-4th floor cabinets with windows directed north also never see the sunlight. During autumn, summer and spring the conditions are better depending on whether the direction of the

Table 1

Overall results of measurements of indoor climate in atrium-type buildings

Room type	Indoor air temperature, ºC, U = 0.6 ºC		Indoor air humidity, %, U = 2.0%		Air velocity, workplace, m/s, U = 0.01 m/s	Lighting, lx, U = 10.4%	Concentration of carbon dioxide CO_2, ppm U = 2ppm
	Cold season	Warm season	Cold season	Warm season			
Building A, towards the atrium	21.2..22.5	22.7..25.6	24.3..25.7	48.2..53.0	0.02…0.17	457..847	585..935
Building A, towards the outdoors	20.4…23.1	22.5..31.6	23.7..24.6	44.2..62.4	0.02…0.33	300..915	462..744
Building B, towards the atrium	21.0…22.8	24.3..26.5	24.0..32.5	35.1..47.6	0.02…0.19	433..1160	541..897
Building B, towards the outdoor	10.8…21.4	21.0...32.0	14.0..33.1	41.4...48.7	0.01…0.25	690…1209	478…1152
Atrium A	21.8..22.7	23.0..27.0	20.0..29.1	45.1..48.9	0.01..0.05	350….360	572…678

Where U is uncertainty of measurements.

cabinets windows of the rooms are sometimes sun lit. The rooms outside the atrium (Figure 5) are very cold in winter, but in summer the indoor air is too hot (over 30ºC). There are shortages in surveillance of the ventilation systems.

The questioning of workers about their work conditions gave varying results. The administrative workers who are working with computers during 8-hour workdays, complained about cold air blowing on their legs. They were also more sensitive to the temperature changes in the room (that are dependent on the sudden changes of the outdoor air temperature). So the heating system of the buildings has a long relaxation period. The biggest problem for 50% of people was too dry air in winter during the heating period. Some of the people have turned off the ventilation system as the air blows on them straight and causes health problems (sick throat, dryness in the nose, headache).

Conclusions

1. The investigation gave the conclusion that the workrooms in the two atrium-type building mostly belong to the 4th category of comfort (according to Fig 1). To get better working conditions for workers it is necessary to improve the surveillance of ventilation and heating system overall.
2. It is recommended to use supplementary heating sources (air-pumps), when the air temperature in the rooms is below 19^0C (in winter).
3. Use window blinds and efficient ventilation in summer.
4. Use modern equipment for raise the humidity of the air in the rooms.
5. To provide a good day lighting practice in offices where it is possible (it is not possible in the rooms close of the atrium).
6. The right ventilation and building care can prevent and fix IA quality problems. The concentration of a pollution component in the naturally or even artificially ventilated offices linked to glazed atria may be very low, but the odour might be strong. In such cases usually the cause is in the repair work where new, unknown clues were used. It takes some time for all volatile odours. If the odour does not disappear then the remove of the floor covering (carpet-type), clue and sometimes even a concrete layer from the floor will be necessary get smell-free indoor conditions.

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Proceedings of 6th International Conference ITELMS'2011

Interrelation between Parameters of Structural Degradation and Fracture Toughness of Heat-Resistant Steel

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Abstract

It was investigated the correlation between parameters of coercive force and fracture toughness of steel 15Kh2MFA (II) after preliminary thermo-mechanical loading (PTL). The influence of join effect of PTL and hydrogenation on the magnetic properties of heat-resistance steel is studied. It was define that the growth of the overloading level at PTL causes damage accumulation in the material. Increasing of the critical SIF and coercive force after PTL is shown.
KEY WORDS: *coercive force, fracture toughness, hydrogenation, fracture stress, grain boundaries.*

Introduction

Rising of the material brittle fracture resistance after preliminary thermal mechanical loading (PTL) is caused by the change of the stress-strain state, deformational strengthening of the material in the crack tip and its bluntness [1-4].

PTL is developed as one of the promising methods of increasing the operating time of the heavy units in nuclear power plants, which operate under high pressure, it is necessary to take into account the effect of multiple factors on this phenomena, absorbed hydrogen in particular [1, 5].

The sources of hydrogen effects on the reactor body material, which is the result of electro-chemical reactions, as well as the hydrogen of metallurgical and technological origin. Besides, hydrogen adsorption of the reactor body metal under decreasing of temperature of the transitional regimes during its stopping or starting, which is intensified by the neutron irradiations, is possible too.

Moreover, irradiation increases the negative effect of hydrogen on the reactor body material plasticity that is material becomes brittle more quickly.

Coercive force (H_c) was found to be used more often for nondestructive control of structure and mechanical properties. Coercive force is the outer magnetic field stress, under which magnetism in the preliminary magnetically saturated material equal zero [6]. The main factors, which affect the change of coercive force, are irreversible structural change, caused by the degradation of microstructure, dislocation substructure of the materials, as well as other non-uniformities and defects. Thus, coercive force is one of the most structural-sensible characteristics of ferromagnetic materials [3].

The purpose of this paper is to investigate the interrelation between the parameters of the coercive force and fracture toughness of 15Kh2MFA steel after PTL.

Experimental procedure

Crack resistance of the material in its original state and after PTL was found on the compact tension (CT) 15mm thickness specimens. The effect of the electrolytic hydrogen and the PTL on the brittle strength of the reactor body steel 15Kh2MFA after thermal treatment, which models the embitterment of the material in the middle of the operating time of VVER-440 type reactor, was investigated: hardening from 1000 ºC during 6.0 hours in oil, tempering during 6.0 hours at 600 ºC in the air.

Before that, fatigue cracks were grown on all specimens under the stress ratio of the loading cycle $R = K_{min} / K_{max} = 0$, and the loading frequency 40 Hz (here K_{min}, K_{max} – the smallest and the biggest stress intensity factor (SIF). Relative crack length was (0.45 … 0.55) b, (b – the specimen width). As the unloading value does not affect mostly the critical SIF of 15Kh2MFA steel, the PTL scheme with the total unloading was used in the experiments.

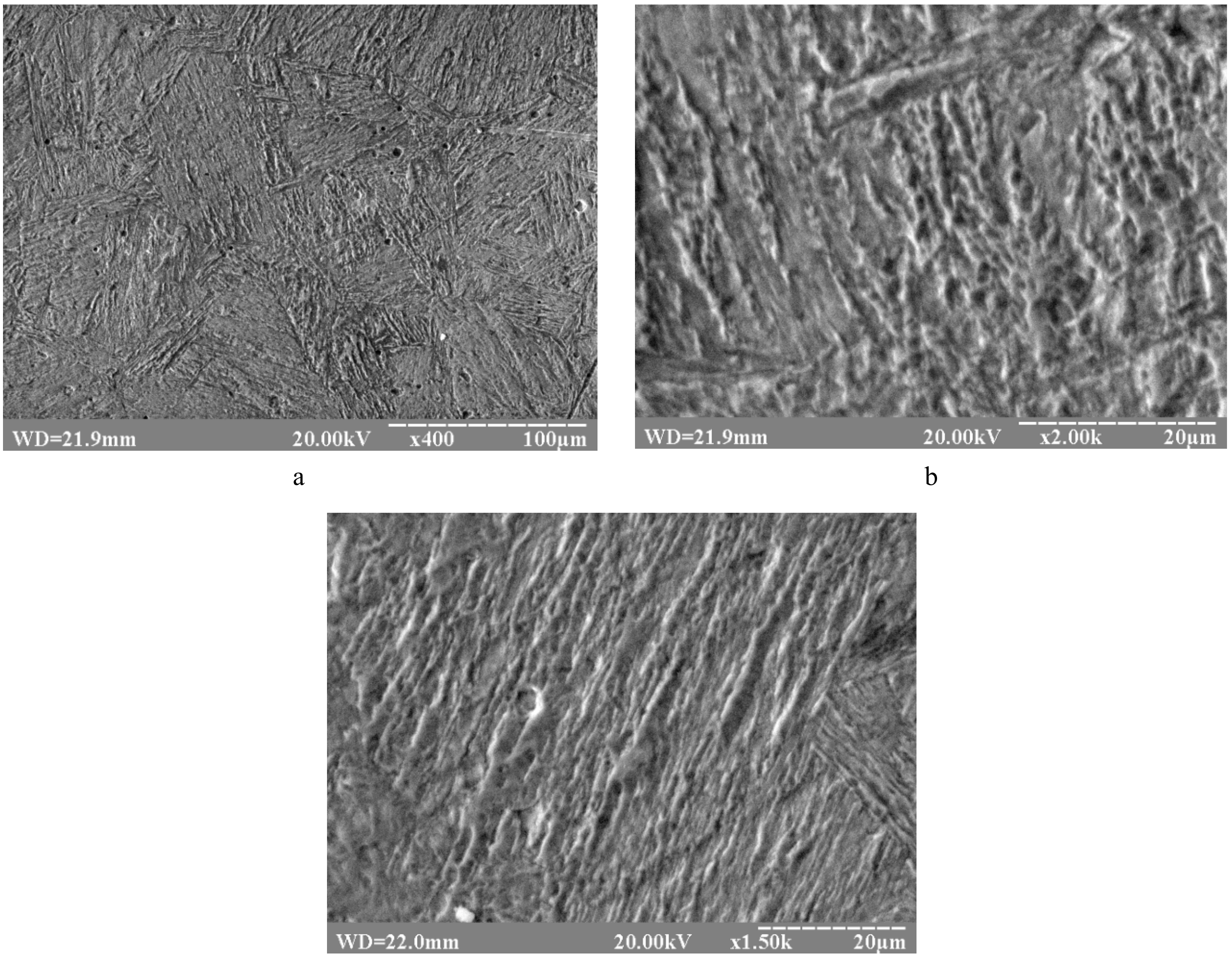
Preliminary thermal-mechanical loading of all specimens was carried out at the temperature T_1 = 350 ºC and $\overline{K}_1 = K_1 / K_Q^{5\%} = 0.85$, following procedure [7] (where K_1 – maximal SIF under thermo-mechanical loading; $K_Q^{5\%}$ – critical value of SIF, found with the help of 5% secant on the fracture diagram at the temperature 350 ºC). After that the specimen was unloaded and cooled to the room temperature. Than the specimens, before fracture toughness testing, was hydrogenation by the electrolytic method [5]. Before hydrogenation the specimens were oil-eliminated chemically at the temperature 80 ºC during 30 min in the water solutions and then were rinsed in hot and then in cold water.

Electrolytic hydrogenation was carried out in the solution of sulfuric acid (pH = 0) under current density 10 A/dm^2 and at the temperature 25 ºC during 2 hours. Then electro – chemical nickel-plating was done, which is the pad for the copper covering, during 30 min at the temperature 35 ºC and current density 5 A/dm^2. Copper covering was done to prevent the exposure of the absorbed hydrogen from the metal in the water solution during 30 min at the temperature 25 ºC and current density 5 A/dm^2.

The measurement of the coercive force was carried out using micro – processor impulse coercive force meter KIM-2, which is an electronic block with fitted transformer in the form of fitted magnet with the alternative electromagnets. The value of error of the coercive force measurements was about ± 7% of the measured value.

Structure of 15Kh2MFA steel

15Kh2MFA steel belong heat – resistant steel of the pearlite class. At the beginning of the VVER-440 nuclear reactor body operation the steel is of the ferrite – bainite structure [5]. During thermal treatment which models radiation embrittlement of the material in the middle of the nuclear reactor body operation, the 15Kh2MFA steel is of the bainite – martensite microstructure (Fig. 1,a). Martensite areas of the structure are of the low dislocation martensite. Parallel martensite laws form martensitic packets, Fig. 1 b.



a b

c

Fig. 1. Microstructure of 15Kh2MFA steel: a, b – bainite-martensite structure; b, c – martensite structure

The packets structure is characterised by the system of parallel laws of different size. Bainite structure of the steel is a complex system of parallel dislocation subboundaries [5]. Carbide needle – like depositions are located in the bainite in one direction at the angle of about 60º the dislocation subboundaries (Fig. 1, b). Availability of the carbide depositions at the angle 60º to the crystal axis crystallite possible identifies the structure as the bainite.

Results and discussion

Cracked specimens were deformed by tension (PTL) and tension with simultaneous imposition of the low – amplitude cyclic components (combined PTL), when $\Delta K = 20$ MPa $\sqrt{\text{m}}$ and frequency $f = 25$ Hz.

Increasing of the overloading under PTL (K_1) was found to cause the accumulation of damages in the materials. It results in the coercive force increase (H_c). This is by the creation of such dislocation substructures, which, under similar dislocation density in the small – angle boundaries from inside – grain substructure, which acts as the additional barriers, which are able to retard the microcrack [6].

Availability of hydrogen is another damaging factor. Embrittlement effect of hydrogen causes the decrease of stress, which is necessary to microcrack propagation through the boundaries of the structural elements, which decreases K_f of the hydrogenated materials, Fig. 2. It means, that it is PTL of the preliminary hydrogenated metal, which is the most dangerous because of its low brittle fracture resistance, and is caused, basing on the traditional ideas of the hydrogen embrittlement of the structural materials, by the development of microstructure degradation under PTL and the increased concentration of hydrogen in the created damages [5].

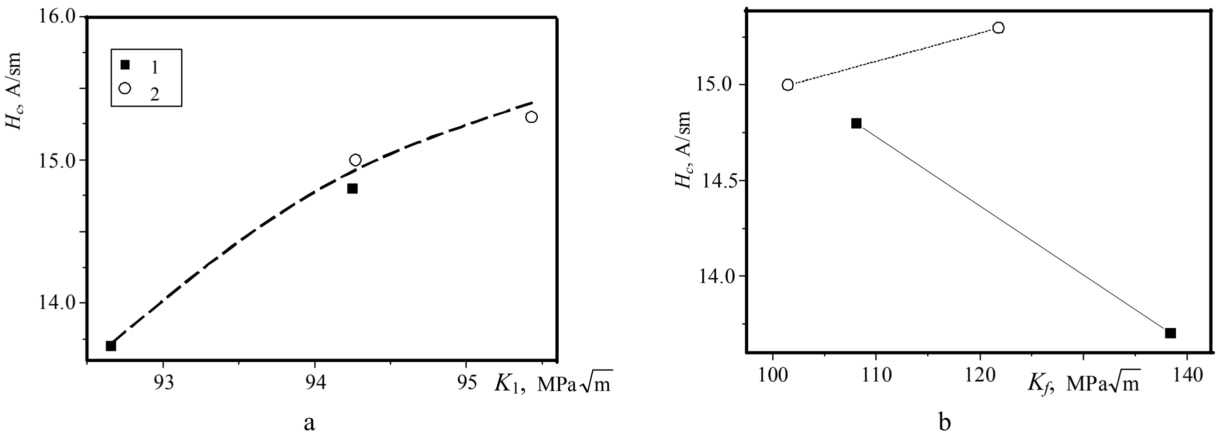


Fig. 2. Dependence of PTL parameters (K_I) (a) and static crack resistance of the material on the coercive force (H_c) (b)

In all cases, irrespective of the PTL regimes, advanced brittle fracture resistance of the investigated steel as compared with K_{IC}, was obtained. Universal dependence between PTL parameters and the coercive force for the hydrogenated and non-hydrogenated material was found, Fig. 1.

After PTL and further hydrogenation critical SIF K_f of 15Kh2MFA (II) steel increases in 20-30% as compared with K_{IC}, which is caused by the increase of the structure non-uniformity. It is demonstrated by the increase of the coercive force. Accumulation of the structure damage causes material plasticity exhausting, and limit state is obtained under smaller values of the stresses. Formation of the crack by its growth because of the structure damages is easier and it causes decrease of the critical SIF.

PTL causes similar effect on the critical SIF of the non-hydrogenated material in about 40% and 25% on the material, with has smaller structural degradation because of the hydrogen effect unavailability.

It is generally known, that the hydrogen embrittlement of the metals can be caused both by the diffusion-moved atomic hydrogen, with in the process of deformation moves to the local area of the volume-stressed state (pre-fracture area), where its concentration can be in the times higher than that of metal, and by the hydrogen, localised in the microcracks, because of the creation high pressure in defects [8].

It was investigated, that dislocation density increase in boundaries of subgrains, caused by the plastic deformation, irrespective of the PTL conditions (types of loading, temperature, elastic deformation) and increases K_f of 15Kh2MFA steel [7-9]. It is likely to be caused by the creation under PTL of such dislocation structures, with under equal dislocation density in the small-angle boundaries, form substructure, which are able to increase the material fracture toughness. These are the reasons which result in high values of coercive force in the material after PTL, as the value of the coercive force depends on the dislocation density, which changes the magnetic properties of 15Kh2MFA steel.

Conclusions

It was found, that when the level of overloading under PTL (K_I) increases, K_f of 15X2MFA steel increases too under thermal treatment, which models radiation embrittlement of the material in the middle of the operating time of the nuclear reactor body. Universal dependence between PTL parameters and the coercive force for material before and after hydrogenation was found.

After PTL and the further hydrogenation SIF K_f of 15Kh2MFA (II) steel increases in 20-35% as compared with K_{IC}, which is caused by the structural non-uniformity of the material and is demonstrated by the coercive force increase.

Accumulation of the increase of the material crack resistance, as the boundary state of the material is obtained under the higher values of the nominal stress, but, on the other hand, makes easier the microcracks creation of the material after hydrogenation by means of their growth under availability of the structure damages.

Acknowledgements

Financial support from the Ministry of Education, Science, Youth and Sport of Ukraine is gratefully acknowledged, project 0109U007705.

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Reuse-Oriented and Internet-Based Collaborative Framework for Transport Logistics Service Providers

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Abstract

This study describes the approach aimed at supporting industrial enterprises, especially small and medium enterprises in the business sector of transport logistics services. The approach is focused on defining the framework for organizations that are moving towards a systematic reuse program and Internet-based information technology (IT) solutions.
KEY WORDS: *transport and logistics, software reuse, e-business solutions.*

1. Introduction

The transport logistics segment is characterised by a very high competition and especially strong pressure from logistics giants. Logistics giants with their international networks have significant advantages over small and medium-sized transport logistics companies. For individual small and medium enterprises (SME) it is difficult to solve the problems alone; however, by co-operation and efficient utilization of knowledge and resources, they can keep relatively big segment of the world transport logistics market.

Looking at the transport domain, we face one of the biggest challenges of the next 10 years. As a response to these challenges, all SME actors have to cooperate and develop sustainable innovative solutions that will lead to advances in improving freight forwarding and logistics. At the same time in the current situation of financial crisis it is extremely important for applied technologies to provide some economic and organizational benefits by reducing development and operating costs, and by efficient utilization of development knowledge and corporate expertise. The need in systematic approach and effective software engineering methods, which allow reusing experience to address recurring problems successfully, is obvious and important in the transport domain. With more than 40-year history reuse is recognized as an important mechanism to improve software quality and development productivity [1]. Today, we are just at the start of this challenge but we believe that the synergy of Internet-based and reuse-oriented methods for software solutions may revolutionise the world of SME-based transport and logistics by creating a new platform of business opportunities.

The paper presents the review of the ongoing joint research activities related to the introduction of systematic software reuse and web-based collaboration in the enterprise paying special attention to the needs and the problems of transport logistics service providers (LSP). The following sections discuss current limitations and expected benefits of the research. It is followed by the review of proposed reuse-oriented and Internet-based collaborative frameworks. Finally, the conclusions are made in the last section.

1.1 Current bottlenecks and limitations

The following bottlenecks and limitations have been identified as the main drivers for our joint research activities:

- Logistics service providers often lack global visibility and are poorly integrated with suppliers and customers.
- Intermodal collaboration among logistics service providers usually isn't effectively organized.
- Most LSPs must undergo Internet-based technology transformation.
- The existing IT solutions mostly support separate stages of logistics processes and are not focused on "user demand driven" integrated Internet-Based solutions that provide an opportunity to manage business processes within logistics chains.
- Existing efforts to attain the main objective of software reuse in the transport domain rendered some successful stories, however, to benefit in more systematic and repeatable way, additional research is needed.
- Reuse requires up-front investments in infrastructure, methodology, training and tools without payoffs being realized immediately and cannot be widely achieved in LSP organizations without support of top-level management. However, reuse will only succeed, if it makes good business sense, and it will only be chosen, if a good case can be made that it is the best alternative choice for the use of capital [2].
- Reusing of large-scale system components is a problem too hard to be solved in general way. It is more effective when systematically applied in the context of families of related systems and thus is domain-dependent.

1.2 Expected advances and benefits

The expected advances and benefits of the research are the following:

- The reuse-oriented framework for organizations that are moving towards an effective reuse program composed of different aspects of software reuse and related practices. The final goal is to ingrain reuse into an organization's entire software production process [3]. A formalized process increases the chance that the project success can be repeated, facilitates adherence to the established best practices, standardization of practices across multiple, and helps less-expert developers to succeed via reliance on a standard process. Additionally, the framework expected to define effective measuring of economic benefits of the software reuse and development costs, where operational and strategic benefits are defined and quantified within the context of broader business strategy. However, each organization should analyze its own needs, define the key benefits it expects, identify and remove impediments, and manage risks [4].
- The methodology for Internet-based Collaborative Framework (ICF) development is based on transport and logistics CMM and Web technologies. ICF provides the adaptation mechanism to distinct between different target groups (technology supplier, technology receiver, technology transfer facilitator). ICF also provides easy adaptation of technology transfer process (Fig.1) and commercialization to the new conditions of target countries and SMEs requirements.

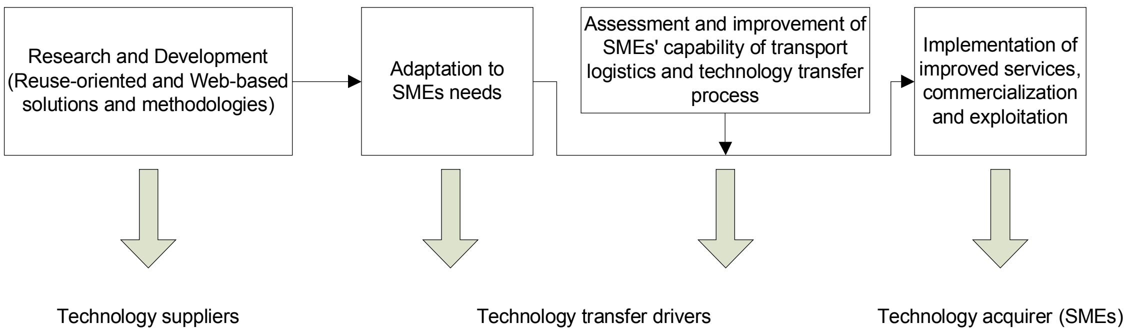

Fig. 1. General scheme of technology transfer process

2. Reuse-oriented framework for logistics service providers

Software reuse is the process of creating software systems from existing software rather than building them from scratch, whereby an organization defines a set of systematic operating procedures to specify, produce, classify, retrieve, and adapt software artefacts with the purpose of using them in its development activities [5], so that similarities in requirements and/or architecture between applications can be exploited to achieve substantial benefits [6]. Our retrospective analysis of the origins and main contributions in the research area performed in [1] outlines that software reuse is multidisciplinary and has deep and complex interactions with many areas of computer science. Table 1 consolidates the main benefits from [7] that can be achieved by the organizations with the maximization of the reuse level.

Directions and components for reuse-oriented framework comply with the following main conclusions that we have obtained through the survey [8] involving software organizations in Baltic regions, whose responses were analyzed and used to relate the characteristics of organizations with their reuse experience:

Table 1

Main benefits of reuse

Benefits of reuse	Description
Gains in quality	Quality of particular component could be improved because of error corrections accumulated from reuse
Gains in reliability	The use of a component in several systems increases the chance of errors to be detected and improves confidence in that component
Gains in productivity	Productivity could be achieved due to less design and code to be developed and less testing efforts
Gains in performance	Extensive reuse can be worth the effort invested in optimizations, that may yield better performance of a reused component
Reduction of maintenance costs	Fewer defects and reduction of maintenance costs can be expected when proven quality components have been used
Reduction of product time to market	By using reusable artefacts organizations could reduce the product time to market which influences the success or failure of a software product
Rapid prototyping support	Reusable components can provide an effective basis for quick building of a prototype of a software system

- 72% participants claimed to succeed in projects by the means of software reuse in their organization, and small and medium software organizations presented higher reuse success rates than organizations of a large size.
- Organizations should focus on the development of product families if applicable in the operating business area.
- Attention should be spent on the introduction of process-driven systematic reuse in the organization.
- Organizations should consider using repository for storing and retrieving reusable assets, and a configuration management process should guarantee proper evolution of these assets.

The overall structure of the proposed reuse-oriented framework is organized considering economic (A), organizational (B), and process (C) aspects of reuse as outlined on Figure 2.

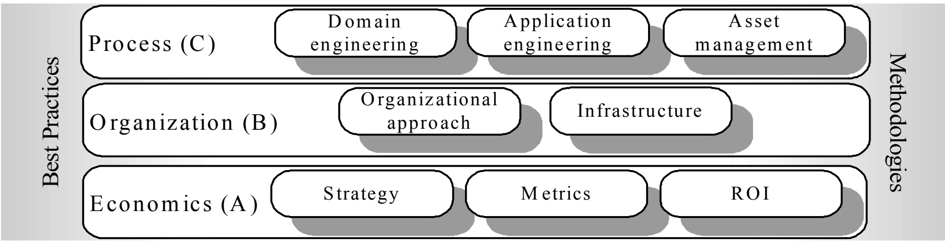

Fig. 2. The overall structure of reuse-oriented framework

(A) From the economic perspective implementing a reuse initiative in a corporate environment requires a decision about when and where capital investment for software reuse is to be made, and whether it will be proactive or reactive [2]. The measuring of economic benefits of the software reuse and development costs should be aligned with the following main principles from [9]:

- Economic value maximization drives reuse investment strategies for the business
- Strategy drives selection of reuse investments that are actively structured to maximize embedded strategic options.

Economic aspects of software reuse are divided into the following broad classes by [10]:

- metrics, which reflect attributes that increase the market value of an asset
- reuse cost estimation techniques and return-on-investment (ROI) models to quantify reuse related decisions.

(B) Several approaches exist for establishing a reuse program from the organizational perspective:

- Centralized, with an organizational unit dedicated to developing, distributing, maintaining, and providing training on reusable assets.
- Distributed asset development, where reuse is implemented collaboratively by projects in the same product line.

Reuse environment on the organizational level assumes development of

- managerial infrastructure in the form of a set of functions, responsibilities, reporting requirements, and reward, which are required to ensure operation of reuse processes
- technological infrastructure that includes a configuration management and quality assurance functions to support reuse operations, as well as enforcement of testing, verification and asset certification standards.

(C) Process-driven means that the software development is done in accordance with well defined processes that are enforced through management policies. A software process could be defined as a set of activities that lead to the production of a software product [13], and it is important in order to ensure efficiency, reproducibility, homogeneity, and predictable time and effort constraints. As it was noted already, a key concept of systematic reuse is the domain, which may be defined as an application area (e.g. transport domain) or, more formally, a set of systems that possess similar functionality and share design decisions (e.g. logistics information systems). By domain-specific reuse we assume, that the reusable assets, the development processes, and the supporting technologies are appropriate to the application domain for which the software is being developed.

It is common to identify three main stakeholders in the process of software reuse within an organization: corporate management, domain engineering and application engineering teams. By reviewing the tasks of each of these stakeholders, the following top-level reuse related activities can be identified:

- asset production – identification, development and classification of reusable artefacts
- asset usage – locating and evaluating assets, and achieving their actual reuse by integrating them into applications being developed
- asset management – asset storage, repository management, and asset dissemination
- maintenance and support – support for asset usage, methodological support, and corrective and evolutionary maintenance of assets
- reuse management – introducing and monitoring reuse within a company or department.

To support reuse, software processes have to consider two facets: developing for reuse and developing with reuse. As a result comparing to conventional “monolithic” set of tasks organizations are responsible for providing and maintaining software systems, software reuse introduces a differentiation between the tasks related to the production of reusable assets and the tasks related to the production of end-user applications [14]. Such two-life-cycle approach with generalized activities schematically displayed on Figure 3 is commonly referred as domain and application engineering, which address development for reuse and development with reuse respectively.

From the technical point of view the LSP development within the proposed framework should rely on best practices and appropriate supporting methodologies facilitating global visibility, integration and collaboration as previously noted in section 1.1. The Internet-based collaborative framework (ICF) as further discussed in the next section aimed to provide a facade for several advanced IT solutions in order to support networked logistics service providers.

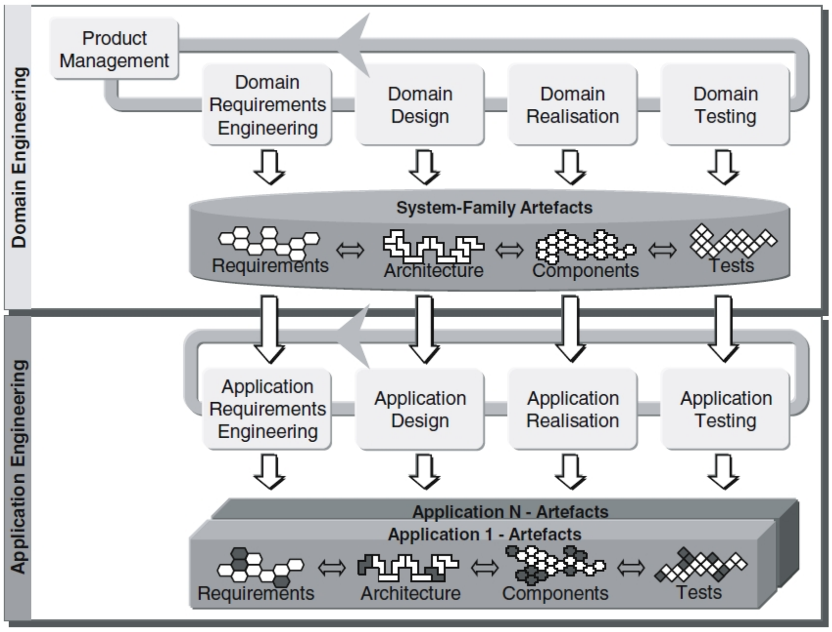

Fig. 3. The two-life-cycle model of domain and application engineering [15]

3. Internet-Based Support of Networked Logistics Processes

The number of stages of general logistics model "buy-move-make-sell" and, correspondingly, the individual structure of adapted to the specific needs of LSPs can be dynamically extended using Web-based coordinating mechanisms and semantic interoperable services. It is very important in a case when customers requirement are dynamically changed and they are willing to extend the number of provided services. The Internet enables and supports logistics collaboration among different LSPs, new dynamic relationships, new opportunities and markets.

Use of Internet-based Collaborative Framework incorporating several advanced IT solutions, makes it possible to support networked logistics service providers. The Internet enables LSPs to become the WYSIWYG (What You See Is What You Get) enterprises, where Web-based applications become as rich as their desktop equivalents.

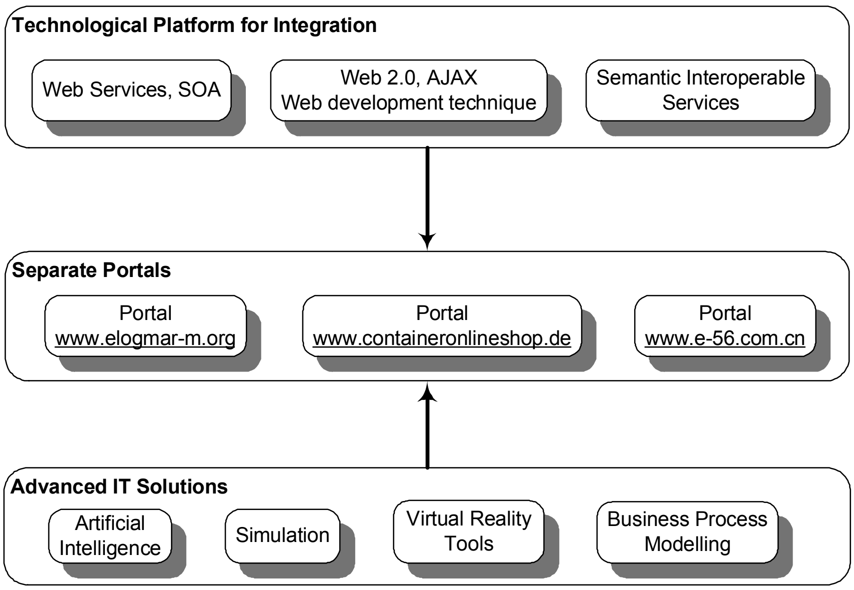

Fig. 4. Integration in ICF

SOA, Web services, Semantic Interoperable Services, XML, and AJAX Web development techniques are used as a technological platform for the integration. Using these technologies together with the existing enterprise web platforms and portal frameworks (Liferay, GateIn, WebSphere Portal, JetSpeed, etc), it is possible to design the integrated portals that will provide seamless integration of the various logistics-related services and data sources (Fig. 4). For instance, separate portals that support different logistics business processes along the selected freight route (www.elogmar-m.org, ww.containeronlineshop.de, www.e-56.com.cn) are united into one framework with a single entry point [11].

An enterprise portal, built with a robust portal product, provides an off-the-shelf framework for developing and deploying service-oriented applications. It can serve as a ready-made Web services consumer platform, and enables you to build composite applications, deploy syndicated content from other portals through remote portlets, replace/augment legacy interfacing applications, create common views of data, and facilitate access by mobile and wireless devices [12].

Most of the mentioned above portal frameworks also have personalization features. Personalization provides end-users with an opportunity to customize their version of a portal; thereby, greatly improving end-user performance and satisfaction. Using personalization mechanism, portal administrators can define specific groups which may represent portal users' real-life roles (operator, manager, CEO, etc). Depending on their roles, users will have access to the features and content designed for their group.

Conclusion

The need in systematic approach and effective software engineering methods, which facilitate global visibility and collaboration and allow reusing experience to address recurring problems successfully, is obvious and extremely important in the transport domain. The study presents the framework for organizations that are moving towards a reuse program that is organized considering economic, organizational and process aspects of software reuse. The concept of the development of the Internet-based collaborative framework for the transport logistics service providers, along with technology transfer model, is used to improve their business processes.

Acknowledgement

This work is partly financed by the European Union (European Regional Development Fund) within the Baltic Sea Region Programme 2007-2013 project BONITA (Baltic Organisation and Network of Innovation Transfer Associations). The present activity is partly funded by the ERDF project "Support of FP7 ICT STREP project "Simulation Highway"".

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Proceedings of 6th International Conference ITELMS'2011

Mathematical Model for the Prediction of Life Cycle Costs of Combat Vehicles

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Abstract

The given mathematical model may be used for preliminary determination of life cycle costs of a new vehicle type or also for comparison of several vehicles of the same category. This is applicable especially for tenders where life cycle costs present an important criterion for the selection of a supplier. The article also contains a graphic interpretation comparing life cycle costs of Land Rover Defender, the values of which were gained from its operation, and values calculated with the help of the model draft for the prediction of life cycle costs.
KEY WORDS: *predictive life cycle costs, predictive costs on vehicle purchase, predictive costs on operating state, predictive costs on preventive maintenance, predictive costs on corrective maintenance.*

1. Introduction

At present, ensuring desired vehicle safety and minimal life cycle costs is required. At the same time it is necessary for the vehicles to operate without an inappropriate impact on the environment and road traffic. The decision on the vehicle purchase is influenced by not only initial (purchase) costs, but also by expected operational costs and maintenance costs for the whole vehicle durability (possession costs) and disposal costs. According to the given model vehicle suppliers could optimise and evaluate various strategies of operation, maintenance and disposal.

The life cycle costs analysis is an economic analysis process for assessing the total costs of purchase, possessing, and disposal of an item. The analysis may be used within the whole life cycle of the item, or in some parts, or in combinations of various periods of the life cycle [1].

The primary guidance for vehicle life cycle cost evaluation is a standard [1]. According to this standard the vehicle life cycle cost can be divided into these five periods:

1. period of concept and requirements determination,
2. design and development period, } - purchase costs,
3. manufacture period,
4. operating state and maintenance period, - proprietary costs,
5. disposal period. - liquidation costs.

2. Calculation of Predictive Life Cycle Costs of Combat Vehicles

Generally, the total costs expended during the given periods may be divided to purchase costs, possession costs, and disposal costs [1]. For the draft model, division of the life cycle costs to the following five categories is recommended.

$$LCC = C_P + C_{OMC} + C_{OMP} + C_{OMO} + C_D \tag{1}$$

where LCC is predictive life cycle costs of combat vehicles; C_P is costs on vehicles purchase; C_{OMC} is predictive costs on corrective maintenance; C_{OMP} is predictive costs on preventive maintenance; C_{OMO} is predictive costs on operating state of vehicles; C_D is predictive costs on liquidation of combat vehicles.

2.1. Calculation of costs on vehicles purchase

The vehicle purchase cost can be expressed by the following equation [1]:

$$C_P = C_{CD} + C_{DD} + C_M\, C_S + C_G \tag{2}$$

where C_{CD} is costs on the period of concept and requirements determination; C_{DD} is costs on the design and development period; C_M is costs on the manufacture period; C_S is costs on the vehicle sale period; C_G is costs on ensuring repairs during a guarantee period.

2.2. Calculation of predictive costs on vehicles maintenance

The total vehicle maintenance costs comprise of preventive maintenance costs and corrective maintenance costs.

$$C_{OM} = C_{OMC} + C_{OMP} \tag{3}$$

where C_{OM} is maintenance costs; C_{OMC} is corrective maintenance costs; C_{OMP} is preventive maintenance costs.

The maintenance costs comprise of material costs, labour costs, and workshop equipment costs [1].

$$C_{OM} = (C_{OMCM} + C_{OMCL} + C_{OMCF}) + (C_{OMPM} + C_{OMPL} + C_{OMPF}) \tag{4}$$

where C_{OMCM} is costs of material used for corrective maintenance; C_{OMCL} is costs of labour force for corrective maintenance; C_{OMCF} is costs of workshop equipment used for corrective maintenance; C_{OMPM} is costs of material used for preventive maintenance; C_{OMPL} is costs of labour force for preventive maintenance; C_{OMPF} is costs of workshop equipment used for preventive maintenance.

1) Costs prediction on corrective maintenance. The total costs which are required for ensuring repairs during the vehicle operating time depend on the number of failures which occur in the vehicle during its operation, and on costs necessary for removing these failures. Corrective maintenance costs may be calculated as follows (6), (7) a (8):

$$C_{OMC_{(j)}} = \sum_{n=1}^{j} z_{(t)} \cdot i c_R \tag{5}$$

$$f_{C_{OMC}} = c_R \int_{t_0}^{t_n} \frac{t}{E_t} \mathrm{d}t \tag{6}$$

$$C_{OMC} = \frac{c_R}{\varphi} t \tag{7}$$

$$z(t) = \lim_{\Delta t \to 0+} \frac{E[N(t+\Delta t) - N(t)]}{\Delta t} \tag{8}$$

$$E(t) = \alpha\ K_\beta = \alpha\ \Gamma \left(1 + \frac{1}{\beta}\right) \tag{9}$$

where $C_{OMC_{(j)}}$ is prediction of costs on corrective maintenance during operating time; t is operating time in kilometres; i is determined value of the interval in kilometres; j is number of determined intervals i; $z_{(t)}$ is failure intensity in interval t; $E_{(t)}$ is mean time between failures depending on mileage, calculated with Weibull distribution; α and β are parameters of Weibull distribution; Γ is gamma function of Weibull distribution; $f_{C_{OMC}}$ is behaviour of the function expressing costs of corrective maintenance during operating time t; φ is mean time between failures; c_R is average cost on one failure repair, consisting of costs on material and costs on work.

The calculation of prediction of corrective maintenance costs shall be performed using at least one of the following methods, depending on information availability:

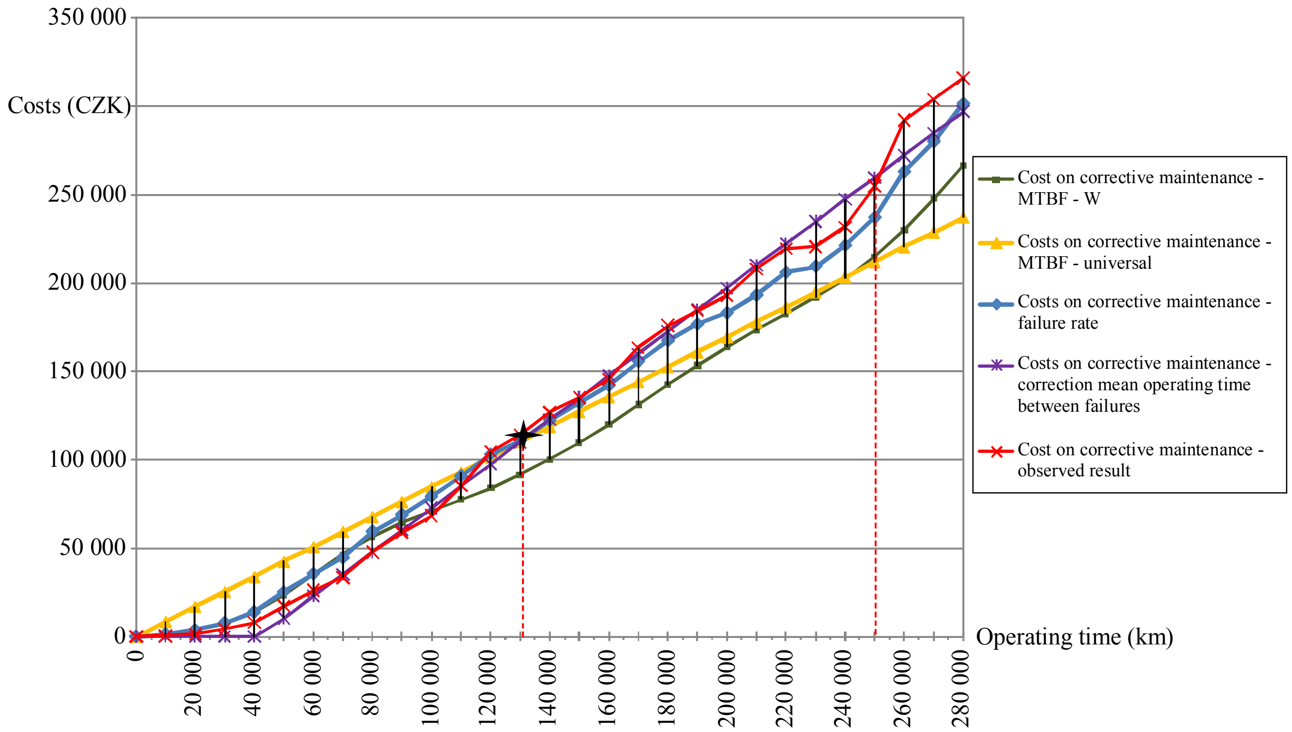

Fig. 1. Comparison of calculation costs on corrective maintenance of Land Rover Defender vehicles

a) from the calculation of failure intensity $z_{(t)}$,
b) from the calculation of the mean time between failures $E_{(t)}$ upon Weibull distribution and using Nelson's method [4, 5],
c) from the calculation of the mean time between failures c_R – so called common mean time which does not include the process of degradation.

Upon the given equations (6), (7) and (8), the corrective maintenance cumulative costs shall be calculated for the monitored predicted interval. Calculations of corrective maintenance costs, which are performed upon the failure intensity and mean time between failures upon Weibull distribution, include the process of aging and wear (degradation of the vehicle as a whole). On the contrary, calculation based on the mean time between failures, determined as an average distance between individual failures, does not include effects of degradation. Therefore, utilization of so called degradation coefficient is proposed, the aim of which is to implicate aging and wear of the vehicle. This calculation of the degradation coefficient is based on the calculation of corrective maintenance costs upon the mean time between failures – so called common meantime, and on actual monitoring of costs for one vehicle type of a given category [3].

2) Costs prediction on preventive maintenance. The costs given include costs of preventive maintenance which is performed in compliance with a specified schedule for maintenance of a given vehicle. The total amount of costs which shall be expended on ensuring the preventive maintenance during the vehicle operation depends on the number of preventive maintenance actions (maintenance interval) performed on the vehicle during its operation. The amount of these costs further depends on price relations of preventive maintenance actions, comprising of material price and labour costs. Thus, for costs of ensuring preventive maintenance it may be written [2]:

$$C_{OMP} = t\,\hat{c}_M \tag{10}$$

where C_{OMP} is predictive costs on ensuring preventive maintenance during operating time t; $\hat{c}_M$ is average cost on ensuring preventive maintenance, consisting of costs on material and costs on work relating to an operation time unit.

For the calculation of preventive maintenance costs prediction the following values are selected:
a) service maintenance interval (km),
b) frequency of service maintenance during the service maintenance period,
c) types of service maintenance during the service maintenance period,

From these values, the following indicators shall be calculated:
a) guarantee inspection costs (price),
b) costs of individual types of service maintenance, comprising of material price and labour costs (price),
c) costs of the service maintenance period (price),
d) average costs of service maintenance relating to a kilometre of operation (price/km),
e) cumulative costs of service maintenance during the operation time (price),
f) elaborated regression curve with the expression of the most suitable function. Upon theoretical and practical knowledge, this will be mostly linear regression.

2.3. Costs prediction on vehicles operation

The period of operation includes fuel costs C_F, costs of service fluids, oils and lubricants C_{OL}, which are refilled during the operation (not within service maintenance), tyre costs C_T, accumulator battery costs C_{AB}, costs of the vehicle insurance and road tax, and other possible costs resulting from the legislation C_{IRT}, motorway sticker costs C_{MT}, costs of technical condition control C_{TC}, exhaust-emission measurement costs C_E.

$$C_{OMO} = C_F + C_{OL} + C_T + C_{AB} + C_{IRT} + C_{MT} + C_{TC} + C_E \tag{11}$$

$$C_F = \frac{c_{aF}}{100}\,p_F\,t_0 \tag{12}$$

$$C_{OL} = \frac{c_{aOL}}{100}\,p_{OL}\,t_0 \tag{13}$$

$$C_T = \frac{t_0}{d_{aT}}\,n_T\,p_T \tag{14}$$

$$C_{AB} = \frac{t_0}{d_{AB}}\,n_{AB}\,p_{AB} \tag{15}$$

$$C_{IRT} = C_I + C_{RT} \tag{16}$$

where C_{OMO} is predictive costs on operation; c_{aF} is average fuel consumption (l/100 km); p_F is price per a litre of fuel (price/l); t_0 is operation time (km); c_{aOL} is average consumption of oil and lubricant (l/100 km); p_{OL} is oil and lubricant price (price/l); d_{aT} is average tyre durability (km); n_T is number of tyres on the vehicle (pcs); p_T is tyre price (price);

d_{aAB} is average accumulator battery durability (km); n_{AB} is number of accumulator batteries in the vehicle (pcs); p_{AB} is accumulator battery price (price); C_I is vehicle insurance price (price); C_{RT} is road tax price (price).

For the prediction of operational costs the following data must be available:

a) price per a litre of fuel (price),
b) average consumption of the vehicle in litres (l/100 km),
c) accumulator battery price (price),
d) accumulator battery durability in kilometres (years),
e) tyre price (price),
f) tyre durability (km),
g) price of annual liability insurance (price),
h) price of annual accident insurance (price),
i) price of annual motorway sticker (price),
j) costs of technical inspection and exhaust-emission measurement per year (price).

Upon specified data and with using equations (11–16), the total cumulative operation costs shall be calculated [3].

2.4. Costs prediction on disposal vehicles

This category includes costs of putting out of operation and disposal of vehicles with terminated durability.

$$C_D = C_{DD} + C_{DR} \tag{17}$$

where C_{DD} is costs of dismounting and removing engineering parts; C_{DR} is costs of recycling or safe disposal.

These disposal costs may present as a plus or minus value, depending on the disposal method. The plus value may be achieved if the vehicle is exploited and individual raw materials handed over to refuse collection. The minus values will be achieved if the vehicle is ecologically disposed of by another company.

A law including a vehicle disposal method as a duty of the manufacturer is being considered. This price would be included in the vehicle price, as it is for example in electrical appliances.

Table 1

Calculation of life cycle costs of Land Rover Defender vehicles

Item name	Unit	Input values	Calculated values
Basic values			
Purchase costs	(CZK)	830 000	-
Durability time	(km)	250 000	-
Durability time	(years)	25	-
Year average operating time	(km)	10 000	-
Preventive maintenance (CM)			
Service maintenance interval	(km)	10 000	-
Period of total service maintenance interval	(km)	40 000	-
Number of service maintenance during period	(-)	4	-
Costs of guarantee inspection	(CZK)	1 313	-
Costs of SM-I	(CZK)	2 311	-
Costs of SM-II	(CZK)	6 208	-
Costs of SM-III	(CZK)	7 317	-
Costs of total period SM	(CZK)	-	18 146
Average costs of PM of 1 km	**(CZK/km)**	**-**	**0.454**
Corrective maintenance (CM)			
Costs of 1 failure	(CZK)	4 300	-
Average mean time between failures	(km)	5 100	-
Average costs of 1 km	(CZK)	-	0.85
Failure intensity	-	-	Fig.1
Costs of CM depending on failure intensity	(CZK/km)	-	Fig.1
Costs of CM depending on mean tiume between failures - Weibull distribution	(CZK)	-	Fig.1
Costs of CM with correction MTBF - general	(CZK)	-	Fig.1

Item name	Unit	Input values	Calculated values
Costs of vehicle operation			
Average fuel consuption	(l/100 km)	10	-
Price per a litre of fuel	(CZK)	30	-
Operation time	(km)	250 000	-
Average consumption of oil and lubricant	(l/100 km)	0.1	-
Oil and lubricant price	(CZK)	100	-
Average tyre durability	(km)	40 000	-
Number of tyres on the vehicle	(piece)	4	-
Tyre price	(CZK)	3 600	-
Average accumulator battery durability	(yers)	4	-
Number of accumulator batteries in the vehicle	(piece)	1	-
Accumulator battery price	(CZK)	1 700	-
Vehicle insurance price	(CZK)	8 300	-
Road tax price	(CZK)	0	-
Pprice of annual motorway sticker	(CZK)	900	-
Costs of technical inspection per year	(CZK)	350	-
Costs of exhaust-emission measurement per year	(CZK)	300	-
Total operation costs of 1 km	**(CZK/km)**	**-**	**4.7**
Liquidation costs	(CZK)	0	-

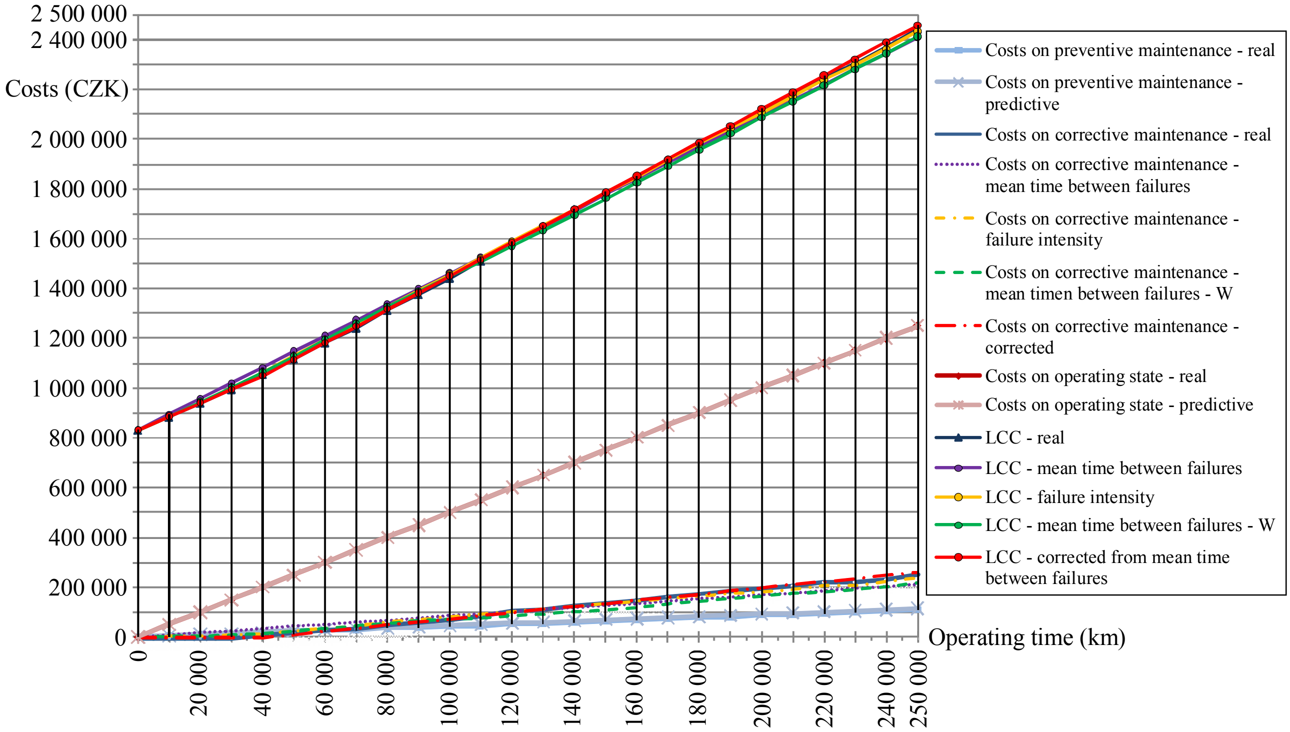

Fig. 2. Comparison of calculation predictive and real life cycle costs of Land Rover Defender vehicles

3. Conclusion

The article describes a model for the prediction of vehicle life cycle costs. It contains formulas, procedures, and necessary data for the calculation of individual costs of the vehicle life cycle. The method described may be applied to the preliminary determination of life cycle costs of a new vehicle and to a comparison of several vehicles of the same category. This comparison may be applied as a criterion in tenders for the supply of new technical equipment.

Acknowledgement

The work presented in this paper has been supported by the Ministry of Defence of the Czech Republic (research project No. MO0FVT0000401).

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Proceedings of 6th International Conference ITELMS'2011

Behaviour of Structural Steels Used in Nuclear Industry for Lwr Designed in Russia at Long Influence of Operational Temperatures

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Abstract

The generalized data on influence of operational temperatures 250-350°C on mechanical properties of the materials used for manufacturing of the main equipment (RPV, SG) and pipelines of the Russian NPP with LWR (WWER and RBMK reactors) for a prolonged operation time (100000 hours) are submitted. Degradation of mechanical properties of structural steels from this factor during designed service life is appreciated, and also the forecast of an opportunity of use of these materials at prolongation of service life.
KEY WORDS: *thermal ageing, degradation of materials, temperatures, mechanical properties.*

1. Introduction

One of the basic requirements to structural materials of the equipment operating in conditions of elevated temperatures is maintenance of stability of mechanical properties under influence of operational factors. Long influence of operational factors (pressure, temperature, cyclic loads, radiation and environment) can lead to the following consequences: embrittlement of materials as a result of thermal ageing and radiation, to nucleation of fatigue and corrosion damages. Naturally such consequences are necessary for taking into account at an assessment of designed service life of components [1], and also in case of its prolongation. For various components of the equipment neutron fluence, cyclic loadings, temperature are the basic contributing factors for damage (irradiation embrittlement, fatigue cracks, thermal embrittlement, etc.). The dominating mechanisms of material damages for various components of the NPP equipment and pipelines are submitted in Table 1.

Table 1

Dominating mechanisms of material damages for NPP equipment

Equipment component	Damages							
	Radiation	Fatigue				Corrosion	Thermal ageing	Wear
		Thermal fatigue	Mechanic fatigue	Crack growth	Vibration			
RPV case	+		+	+		+	+	
SG case		+	+	+	+	+	+	+
Internals	+		+		+	+		+
MCC		+	+	+	+	+	+	
Pump, valve		+	+	+	+	+	+	
Equalizer		+	+	+		+	+	
Pipe-lines		+	+	+	+	+	+	

Note: RPV – reactor pressure vessel, SG – steam generator, MCC – main circulation circuit

Power installations in the nuclear and thermal industry during full service life are exposed to influence of the elevated temperatures. Design service life of the Russian NPPs of the first generation with reactors such as WWER-440 and RBMK-1000 is 30 years. As their operation started from the beginning of 70-th years of the last century for the majority of objects this term either has ended, or comes to an end in the nearest future. In this connection it is necessary to solve questions on an opportunity of their further operation for what it is required to estimate, first of all, a technical condition of components after a design service life which is determined:

- change of mechanical properties of materials during full life cycle,
- defects in components of the equipment at EOL.

Various materials (steel and welded joints) are used for the NPP equipment and pipelines with the mentioned above types of reactors [1]. Besides operation conditions of this equipment also are various and naturally they differently can be reflected in mechanical properties of materials. The used materials and conditions of operation of the equipment and pipelines are submitted in Table 2.

Table 2

Main sizes, operational conditions and materials for NPP equipment

Type of NPP	Equipment	Primary circuit			Parameters	
		Sizes, mm	Base Metal	Weld	p, MPa	T, °C
WWER-440	Reactor pressure vessel (RPV)	∅3840×140	15Cr2MoVA	Sv10CrMoVTi	12.2	265-295
	Steam generator (SG)	∅3260×120	22K	Sv-08A	5.7	273
	Main circulating circuit (MCC)	∅560×32	08Cr18Ni10Ti	Sv-08A	12.2	265-295
WWER-1000	Reactor pressure vessel (RPV)	∅4535×190	15Cr2NiMoVA	Sv08CrMnNiMoTi	15.7	290-320
	Steam generator (SG)	∅4290×145	10MnNi2MoVA	Sv10MnNiMoA	6.3	279
	Main circulating circuit (MCC)	∅960×55	10MnNi2MoVA	Electrodes PT-30	15.7	290-320
	Steam line	∅630×25	16MnSi	УОНИ-13/55	6.4	287
	Pipeline of a feed water	∅159×6	08Cr18Ni10Ti	ЭА-400/10У	5.7	180
RBMK-1000	Separator	∅2300×105	22K+ЭИ-898	Sv-08A	7.6	260-275
	Pressure head collector	∅1040×70	22K+ЭИ-898	Sv-08A	8.5	260-275
	Soaking up collector	∅1020×70	22K+ЭИ-898	Sv-08A	7.6	260-275
	Pipeline Du-800	∅828×38	22K+ЭИ-898	УОНИ-13/55	8.5	
	Down comers Du-300	∅325×16	08Cr18Ni10Ti	ЭА-400/10У	7.6	270-290
	Pipeline of a feed water	∅426×24	20	УОНИ-13/45	5.7	177-190

Taking into account that these materials long time are under influence of constants and variable loadings at the elevated temperatures, and also corrosion and radiating influence, at an estimation of the service life it is necessary to define degradation of mechanical properties. In Russia these studies for materials of the equipment and pipelines of the primary loop are carried out within 10-15 years [2-6]. Their results for the first time are generalized for the following groups of materials:

- heat resistant steels of Cr-Mo-V and Cr-Ni-Mo-V compositions used for cases of nuclear reactors types WWER-440 and WWER-1000;
- carbon steels as 22K, used for steam generators PGV-440, a main forced circulating circuit of installations RBMK, and the steel 20 used for pipelines of different assignment and diameter;
- high alloyed austenite stainless steels such as 08Cr18Ni10Ti and 12Cr18Ni12Ti, used for a various kind of the equipment (pumps, valve) and pipelines of various purpose.

The most important operational factors rendering essential influence on degradation of properties of a material of NPP RPV cases, the operational temperature and neutron fluence are. For other equipment and pipelines, apparently from Table 1, dominating factors are other mechanisms of damages of a material. However long influence of the elevated temperatures of operation (180-350°C) takes place practically for all components. It is natural to assume, that under influence for a long time the elevated temperatures and the corrosion environment, and also static and cyclic loadings the mechanical properties degradation of a material is possible. According to [1] these factors should be taken into account at carrying out of calculations. The values of mechanical properties of materials during design service life should correspond to the certain requirements which are submitted in Ref. [6].

The embrittlement degree is defined by a material composition and from values of operational temperature and time of its influence. Corrosion and fatigue damages, and also irradiation embrittlement of materials for NPP components in present review are not examined. At the same time to value of the time factor of influence of operational temperature in connection with necessity of the decision of questions on prolongation of service life of active power installations pays the greater attention. Thus as operational temperature the maximal value 350°C though operating temperatures for the majority of elements of the equipment on 50°C are lower is accepted.

2. Requirements on stability of properties at operation

In accordance of item 7.6.3 of normative document PNAE G-7-008-89 [7] the inspection of material mechanical properties is carried out using destructive and non-destructive procedures after 10^5 hrs operation time. This procedure estimates the actual properties of the material during the operation provided the regulations of the NPP to ensure safety. This provides data on the actual change in material properties under the influence of operating conditions and based on this information we can conclude the change of values of safety margins taken at the design stage according to the initial mechanical properties of materials. Actual material properties can be defined in different ways: on witness samples, with clippings from the inner surface of a thin (less than 7 mm) layer of material (reactor vessel, steam generators and other large vessels) or a section of the pipeline [8, 9]. For RPV, as a rule, the mechanical properties determined using surveillance specimens (6 packages to estimate radiation effect and 2 packages to assess thermal effect). These packages are tested during RPV design life.

For other equipment and NPP according PNAE G-7-008-89 [7] safe operation is ensured by carrying out periodic monitoring of the mechanical properties of materials based on the results of tests of samples cut from sections of the pipeline. On this basis, it is possible to determine the actual state of the pipelines and the mechanical properties of base metal and welded joints under the influence of operating conditions (elevated temperature, pressure, corrosive environment) in all modes It is natural to assume that under the influence of long-term high temperature and coolant, as well as static and cyclic loads is possible degradation of the mechanical properties of the material. In accordance with Ref. [10], these factors should be considered in the calculations. Values of mechanical properties of materials during the design life must meet certain requirements, which are presented in Table 3.

Table 3

Requirements to mechanical properties of NPP materials

Base metal	Weld	At 20°C				At 350°C				*DBTT*, °C
		UTS, MPa	*YS*, MPa	*EL*, %	*RA*, %	*UTS*, MPa	*YS*, MPa	*EL*, %	*RA*, %	
15Cr2MoVA	-	540	432	14	50	491	395	14	50	0
	SAW	539	392	14	50	490	373	12	45	+40
15Cr2NiMoVA	-	549	441	15	55	491	395	12	45	-12
	SAW	539	422	15	55	490	392	14	50	0
10MnNi2MoVA	-	540	343	16	55	491	294	15	55	+15
	SAW	539	343	16	55	490	294	14	50	+10
	MAW	539	343	16	55	490	294	14	50	0
16MnSi	-	451	245	21	42	373	177	15	42	0
22K	-	430	215	18	40	392	177	18	40	+40
	SAW	353	196	20	55	314	176	13	50	0
	MAW									
	YONII-13/45	353	216	20	55	314	176	20	55	+20
	YONII-13/55	431	255	20	50	372	216	18	50	+30
08Cr18Ni10T	-	510	216	35	55	412	177	26	51	-
	MAW	539	343	18	30	431	294	-	-	-

At present, there is a wealth of experience to determine the aging process in operation NPP, which shows that the mechanical properties of the metal pipe is small and is within the measurement accuracy. Such a result could be expected for the conditions of pipelines easily water reactors under pressure due to:

- equilibrium nature of the structure of structural steel pipes, which should ensure the relative stability of the structure and properties of steels during the entire time of operation;
- low membrane stresses (safety factors $n_{0,2}$ = 1,5 and n_B = 2,6), which provides the basic operation of the metal mass in the elastic region;
- considered are mainly cyclically stable, which makes the process of cyclic hardening or softening almost insignificant.

The aim of this review is:

- generalization of experimental results and their analysis;
- determine the possibility of reducing the volume control of mechanical properties in nuclear power plants until it is full or partial cancellation, reduction or elimination of metal from cuttings of field pipelines, taking into account the fact that the cutting of samples from full-scale pipelines not contributed to improving the quality and reliability of pipelines as well as repairs to conducting increase of defects of welds of pipelines that run in field conditions in the presence of radiation exposure, which naturally does not contribute to the quality of welding.

For carrying out strength calculations based on the operating conditions the equipment necessary to consider changes in the properties due to effects of major damaging factors during the design life. These include:

- structural changes and degradation of mechanical properties due to the prolonged (10^5 hours and more) influence of elevated temperatures;
- crack nucleation from the joint action of static and cyclic mechanical loads, including thermal cycles of loading;
- embrittlement of the material and welds from the effects of static and cyclic loads;
- corrosion damage due to prolonged exposure to the material carrier.

In present review the experimental data on thermal ageing on the base up to 100000 for all steels used in nuclear industry are presented at first time. Earlier such results on thermal ageing will be presented as a rule on the limited time (10-20 thousand hours) in according with certification reports of material or some research works.

3. Experimental rezults

In present review experimental results are presented only for main structural steels which widely are used in nuclear industry in Russia for various NPP equipment with WWER-440, WWER-1000 and RBMK-1000 including cases of reactors, steam generators and different pipe-lines (main circulating circuit, steam line, feed water, down comers, etc.). We presented in this review only variation of standard mechanical properties steel at room and elevated temperatures in dependence from time of duration of thermal ageing at operational temperature though it was already registered earlier in Refs [11, 12], that the most sensitive characteristic to long thermal influence is the critical temperature T_K and impact strength. The data of impact strength of steels are presented partly.

3.1. Heat resistant steels for RPV

In the present the part of review experimental data only on influence of thermal ageing on properties are generalized and submitted only for RPV materials, namely, there were steel of types 15Cr2MoVA and its welded joints with reference to light water reactors (LWR) WWER-440 and 15Cr2NiMoVA and its welds with reference to serial light water reactors WWER-1000. From welded joints the circumferential welds of the mentioned above reactors, performed by submerged arc welding (SAW) under the cover flux and found application in maintained reactors have been submitted only. Results of researches of the Russian experts have been submitted earlier in detail enough in Ref. [2-6] and foreign - in Ref. [13-16].

Steel type 15Cr2MoVA. Influence of thermal ageing at operational temperatures on longer time base has been appreciated by results of tests of surveillance specimens from steel of type 15Cr2MoVA and its welds on two RPV thermal complete sets of the 3rd unit of the Kola NPP. These tests [17] have shown that thermal ageing leads to some increase strength characteristics (*UTS* and *YS*). At the same time characteristics of plasticity of a material (EL and RA) at thermal ageing practically have not changed.

At the same time from the submitted data it is visible, that the most sensitive characteristic to long thermal influence is the critical temperature T_K. Thermal ageing leads to some growth of this characteristic for weld metal and, practically, does not change value of critical temperature T_K for the base metal. During too time it is necessary to note, that because of available variability of data on value of impact strength the error at definition T_K is in limits ±10°, i.e. is comparable to size DBTT due to thermal ageing the basic metal accepted earlier in [10]. Experimental data of different researchers show, that in relation to normative value $T_K = 0$°C actual values of the characteristic, as a rule, less than this value ($T_K = -5$ C …–30°C).

It agrees to the data of above mentioned Refs steel 15Cr2MoVA it is not subject to thermal ageing at temperature 350°C on time bases till 10^5 hours. Shift ΔT_T practically does not differ from admissions on accuracy of definition T_K. The reason of high stability of steel 15Cr2MoVA against embrittlement as a result of thermal ageing, in opinion of authors, is complex alloying heat resistant steel molybdenum and vanadium without introduction of nickel. As to circumferential welds of WWER-440 RPV from Cr-Mo-V steel, performed by SAW using the wire

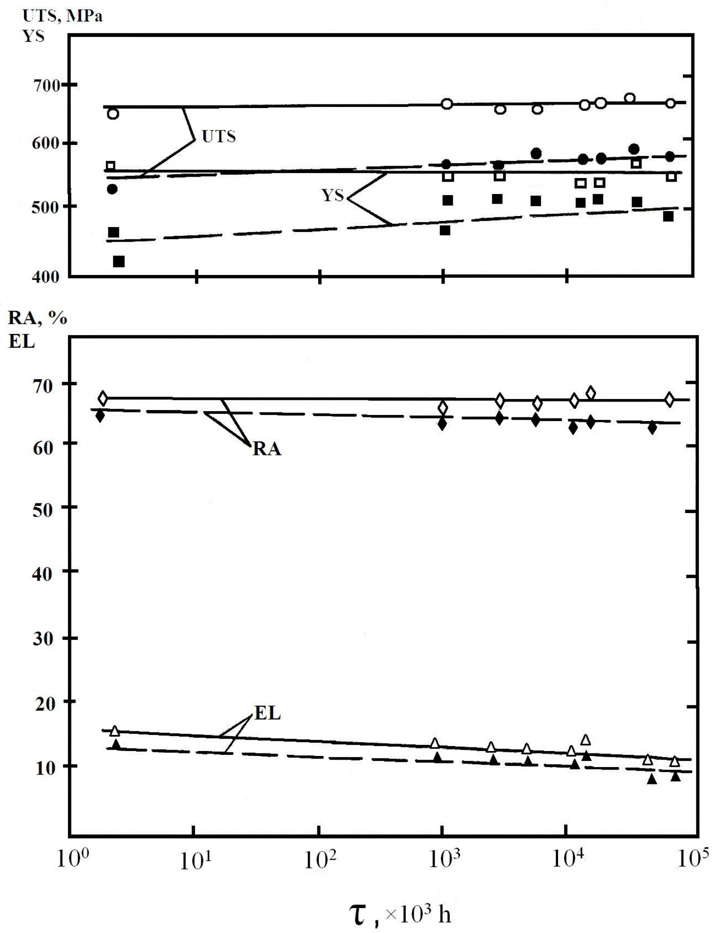

Fig. 1. Changed of mechanical properties of 15Cr2MoVA steel at 20°C (——) and 350°C (- - -) in dependence from time of duration of thermal ageing at operational temperature

Sv-10CrMoVTi under AN-42 flux, how shift ΔT_T follows due to thermal ageing though can reach 20°-30°, however value T_K does not exceed for all investigated variants of value +40°C, accepted for this weld in an initial condition according to the normative documentation [10].

Steel type 15Cr2NiMoVA. A little bit other problem is marked for reactor steel 15Cr2NiMoVA, containing the nickel which has been entered for increase of adaptability to manufacture and a level of strength for the base metal of more powerful reactors WWER-1000 in widely used earlier for cases of reactors steel Cr-Mo-V composition. Having provided a required level of these characteristics, at new type of steel higher propensity to thermal and radiation embrittlement has been marked. For this reason the content of nickel in the base metal it has been limited 1.3% though by development of materials for welding this steel applied the wire with the contents of nickel in weld metal from 1,5 (Sv-08CrMnNiMoTi) up to 2.0% (Sv-12Cr2Ni2MoA). It is necessary to note, that the information on change of mechanical properties of steel 15Cr2NiMoVA and its weld metal at long influence of operational temperatures appreciably has less than its welded joints, than for Cr-Mo-V steel. This information is based on the certification report and reports of the maintaining organizations. In the first case the data are received at temperature 350°C on the limited time base (10^4 hours) for several heats of steel (or welded test probes), and in the second - on the limited amount of steel heats (one, two) in rather narrow interval of temperatures (290-305°C).

Influence of thermal ageing at temperature 350°C (duration till 20 thousand hours) on 15Cr2NiMoVA steel has been appreciated by test results of six steel heats became various semi-product (forgings, plates) thickness from 240 up to 650 mm, going on manufacturing of WWER-1000 RPV [17]. For a weld metal effect of long endurance at the elevated temperature defined only for one welding test probe performed by SAW using the Sv-08CrMnNiMoTi wire under NF-18 flux. Apparently from the resulted data, degradation of mechanical properties of steel 15Cr2NiMoVA and its welds at duration of ageing till 20000 hrs does not occur. It can you see in Fig. 2, where the variation of mechanical properties is presented at room and elevated temperatures in dependence from time of duration of thermal ageing at operational temperature.

Influence of thermal ageing at temperature 350°C till 20 thousand hours on 15Cr2NiMoVA steel has been appreciated by test results of six steel heats became various semi-product (forgings, plates) thickness from 240 up to 650 mm, going on manufacturing of WWER-1000 RPV [18]. For a weld metal effect of long endurance at the elevated

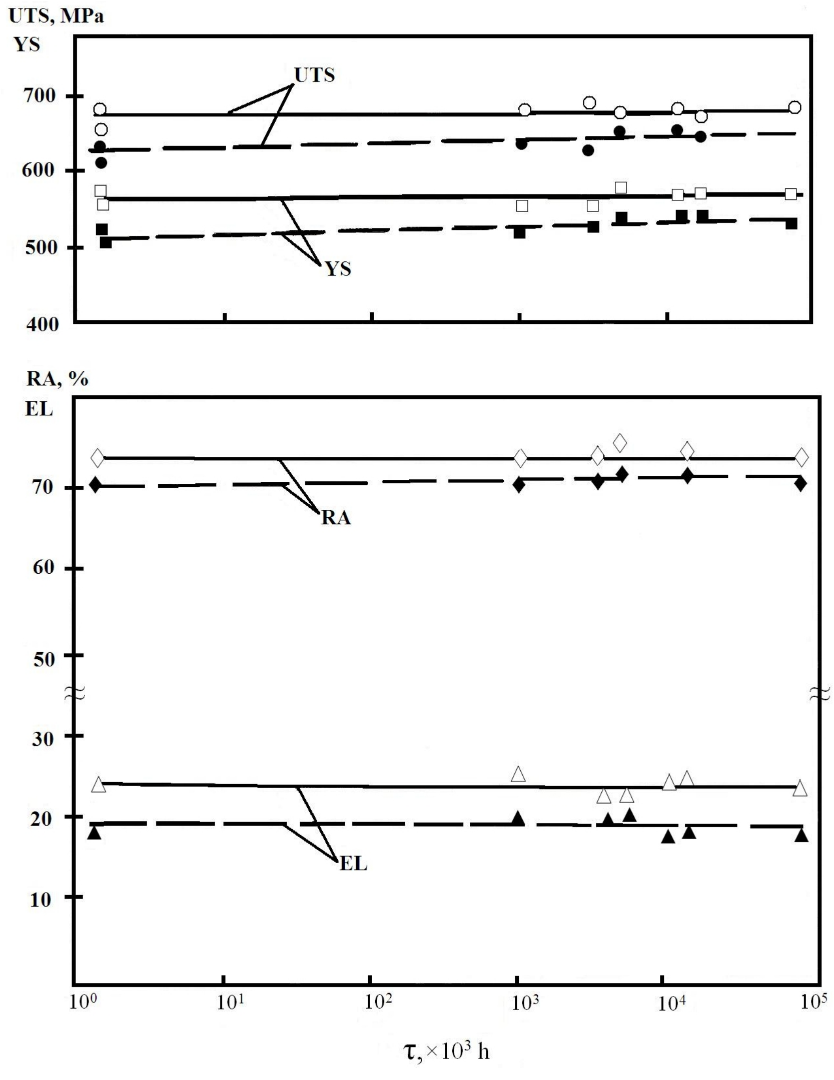

Fig. 2. Changed of mechanical properties of 15Cr2NiMoVA steel at 20°C (——) and 350°C (- - -) in dependence from time of duration of thermal ageing at operational temperature

temperature defined only for one welding test probe performed by SAW using the Sv-08CrMnNiMoTi wire under NF-18 flux. Apparently from the resulted data, degradation of mechanical properties of steel 15Cr2NiMoVA and its welds at duration of ageing till 100000 hrs does not occur.

Practically similar effect is observed and at impact strength tests. So, on the data submitted in certification reports shift of critical temperature ΔT_T owing to temperature ageing by duration till 10^4 hrs for the basic metal is equal to zero that is fixed in the normative documentation [10]. However in Ref. [18] this fact with reference to steel 15Cr2NiMoVA is challenged. In [18] on the basis of the analysis of the received experimental data it is shown, that for RPV steel, containing in the structure nickel, two forms of display thermal embrittlement are possible. The first is caused by allocation and coagulation cemented type and shown at ΔT_{Tmax} = 30°C and endurance only till 3000 hrs at temperature 300-350°C with the subsequent decrease up to ΔT_T = 0°C after 10000 hour, the second – segregation impurity experimental data it is shown, that for RPV steel, containing in the structure nickel, two forms of display thermal embrittlement are possible. The first is caused by type and shown at ΔT_{Tmax} = 30°C and endurance only till 3000 hrs at temperature 300-350°C with the subsequent decrease up to ΔT_T = 0°C after 10000 hour, the second - segregation impurity on borders of grains which at long endurances can take place even at temperature of operation of cases of water-cooled and water-moderated reactors.

Below in Fig. 3 and 4 showed the effect of the experimental thermal aging on the shift of the critical brittleness temperature for 9 batches with Cr-Ni-Mo-V composition. Investigations [17] were carried out at industrial metal shells of different ways of smelting (an acid open-hearth, basic open-hearth and basic electric) and purity. The bulk of the data obtained for the aging temperature of 350°C.

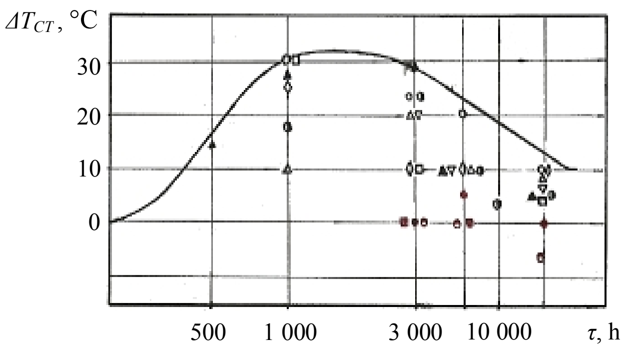

Fig. 3. Effect of thermal ageing at 350°C on shift ΔT_{CT} for 15Cr2NiMoVA steel on the basis experimental results (●○▲Δ■□◊) Russian and Czech researchers

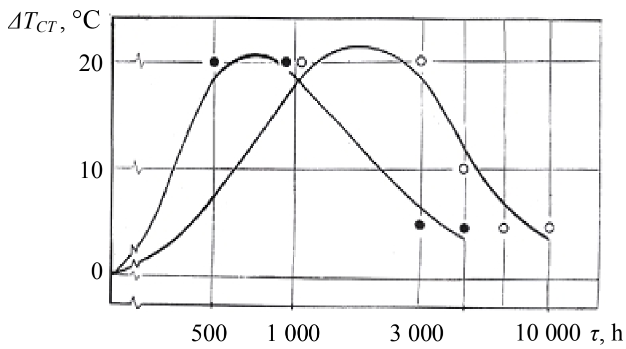

Fig. 4. Effect of stress level at thermal ageing of 15XCr2NiMoVA-A on shift ΔT_{CT}: ○ – σ = 0; ● – σ = 300 MPa

Shown in Fig. 3 data indicate no monotonic ΔT_{CT} with longer ageing. The envelope curve is constructed based on the results of all tests shows that the maximum shift ΔT_{CT} for this grade of steel is marked after the 1000-3000 hour exposure, with greater aging time shift is practically absent. The nature and magnitude of embrittlement during thermal aging are almost independent of the method of smelting, chemical composition and content of harmful impurities in the steel grade. Due to the fact that under normal operating conditions the reactor vessel is constantly under internal pressure and elevated temperatures actually estimate the combined effect of these factors on the thermal embrittlement of steel. This experiment was performed in [18] on a single melting steel 15Cr2NiMoVA at age 350°C at 300 MPa stress and exposure to 5000 hours. Fig.4 shows the effect of stress on the change of shift ΔT_{CT}. According to the authors [19] constant stress accelerates the aging process by 2-3 times, but the magnitude ΔT_{CT} virtually unchanged.

More detailed analysis of influence of thermal endurances on critical temperature of this type steel has been submitted in [20]. In this work of research carried out on metal shell thickness of 270 mm. A chemical compound of the investigated metal though corresponded to steel Cr-Ni-Mo-V of a composition, but the contents of nickel made 0,75 % and was a little bit lower, than in steel 15Cr2NiMoVA (1,0-1,5 % Ni) on TU108-765-78. Preparations of samples subjected to thermal ageing at temperature from 350°C up to 30000 hrs and at 400, 450, 500°C duration up to 7000 hrs. Thermal endurances at temperature 350°C in till 10000 hrs do not lead to decrease in a level of the top shelf of impact strength; however displace serial curves in area of higher temperatures. Thermal endurances from 10000 till 30000 hrs lower a level of the top shelf and displace transitive area of temperature dependence of impact strength aside higher temperatures. Thus the temperature interval of transitive area that testifies to increase of a degree of structural heterogeneity considerably extends. The similar effect is observed on dependences of a share of a fiber in a break of steel from duration of endurance. At carrying out of thermal endurances at temperatures 400 - 450°C downturn of a level of the top shelf is observed after endurances during 5000 - 7000 hrs. Transitive the area of temperature dependence of impact strength also is displaced aside higher temperatures. At endurances at temperature 500 - 550°C the given effect amplifies also downturn of a level of the top shelf of impact strength is observed already after endurances by duration 1000 - 3000 hrs.

The analysis of the received results shows, that at rise in temperature of endurances there is an intensification of processes of ageing. For this reason decreased in a level of the top shelf, displacement of transitive area of temperature dependence of impact strength aside higher temperatures occurs at shorter endurances. On the basis of the received data dependence of shift of critical temperature after thermal endurances is constructed at working temperature (350°C) duration till 30000 hrs. It is established, that the maximal shift of critical temperature after thermal endurances at 350°C in till 30000 hrs is equal 30°C. At carrying out of thermal endurances by duration 3000 - 7000 hours are observed a maximum of shift of critical temperature of fragility. Similar dependence has been marked earlier and for steel 15Cr2NiMoVA. The analysis of change strength properties from of temperature of endurances at duration of 5000 hours shows, that at rise in temperature of endurance up to 500°C strength characteristics practically do not change, and at temperature 550°C is observed decreased strength of steel that is connected to an intensification of processes of coagulation carbide phases.

3.2. Low-alloyed steels for SG and pipe-lines

Steel type 10MnNi2MoVA. Studies of this steel on the tendency to thermal aging were performed on flat rolled open hearth method of smelting in relation to the shells of steam generator PGV-1000. Earlier in [21, 22] was presented the behavior of this grade of steel and its welds, performed manual arc welding, under the influence of operating temperatures of different duration on the standard mechanical properties, including impact strength values *KCV*. It was noted no effect of temperature 300-350°C for up to 10 thousand hours on the strength and plastic properties of these materials, including the value of impact energy by Charpy impact test specimens. The results of similar tests based on 10^5 hours of confirmed previous findings. These results are shown in Fig. 5.

Analyzing the results, we can note a slight decrease in the relative values of the transverse narrowing at both room and elevated temperatures. However, the strength characteristics (*UTS* and *YS*) remain virtually unchanged over the entire range of time.

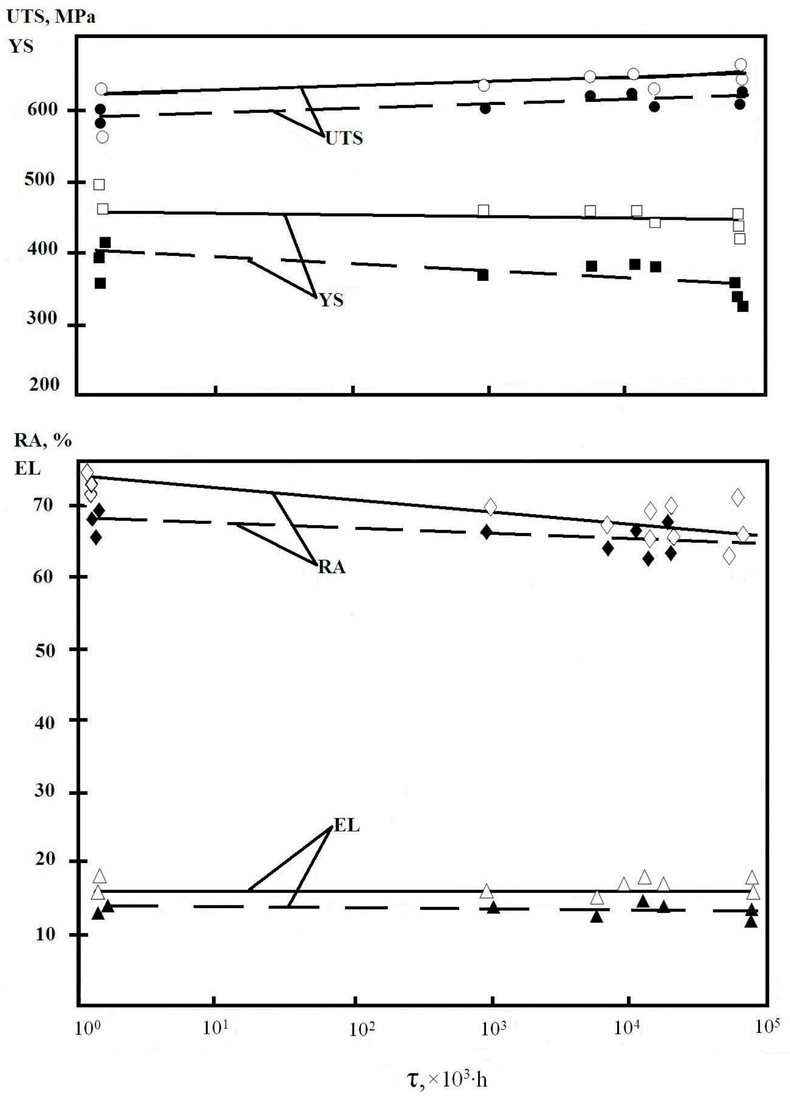

Fig. 5. Changed of mechanical properties of 10Mn Ni2MoVA steel at 20°C (——) and 350°C (- - -) in dependence from time of duration of thermal ageing at operational temperature

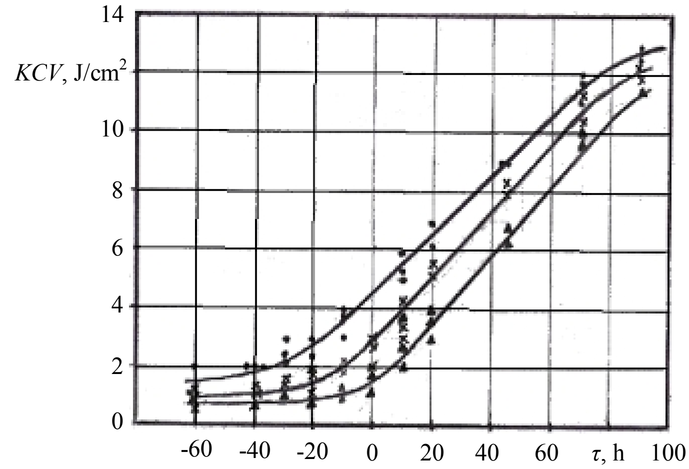

Fig. 6. Temperature dependence of 10MnNi2MoVA steel impact strength as produced condition (●) and after thermal ageing at 350°C after 5000 hrs (×) and 10000 hrs (▲)

As to test results on impact strength for this type of steel (Fig. 6), effect thermal ageing was be observed in shift of temperature dependences impact strength on 20-30°C in comparison with dependence of this steel as produced condition (BOL).

Steel type 16MnSi. Assessment of long-term operational impact on the mechanical properties of the steels were carried out for one heat (T1473) with the following composition: 0,14%C, 1,02%Mn, 0,67%Si, 0,45%Ni, 0,30%Cr, 0,020%S, 0,019%P, 0,11%Cu. The samples were cut from the pipe (heat treatment: hardening 930°C, cooling in water, tempering at 580°C, air cooling), outer diameter 630 mm and wall thickness of 25 mm. Thermal aging was performed at 300°C for varying duration [23]. The standard mechanical properties of steel at room and elevated temperatures were determined after aging. The experimental results are shown in Fig.7.

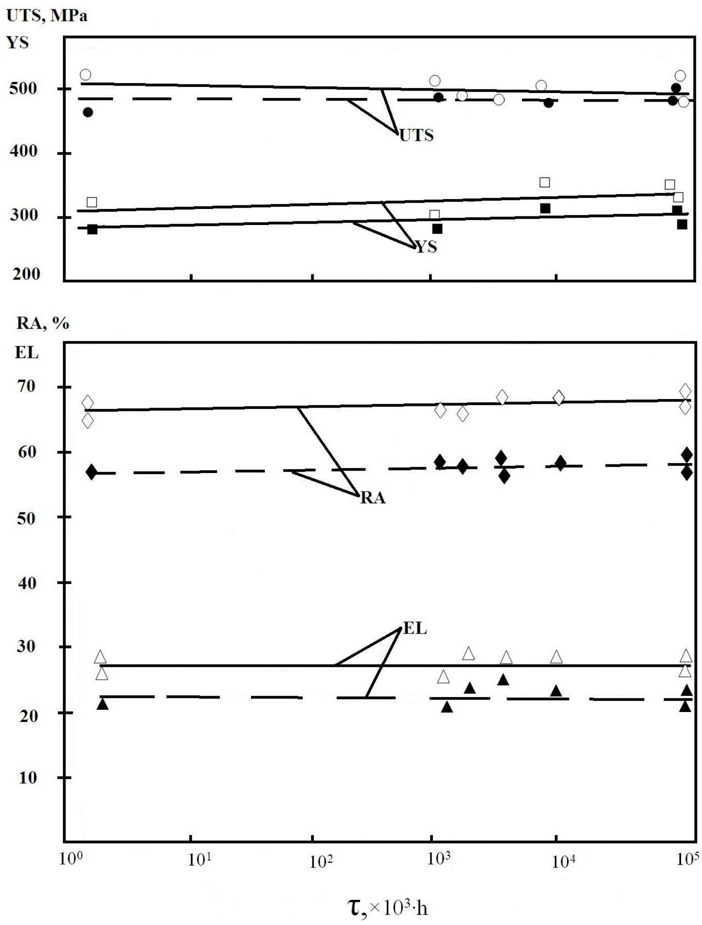

Fig. 7. Changed of mechanical properties of 16MnSi steel at 20°C (——) and 350°C (- - -) in dependence from time of duration of thermal ageing at operational temperature

3.3. Carbon Steels for SG and Pipe-Lines

Steel type 22K. The first results on influence of thermal ageing on the limited time base (till 20000 hrs) for pipelines from carbon steel of types 22K and 20 on mechanical properties have been submitted in Refs [2, 24, 25] on the basis of Certification Reports. It has be shown, the properties as such time on influence of the increased operational temperatures (250-450°C) practically do not change.

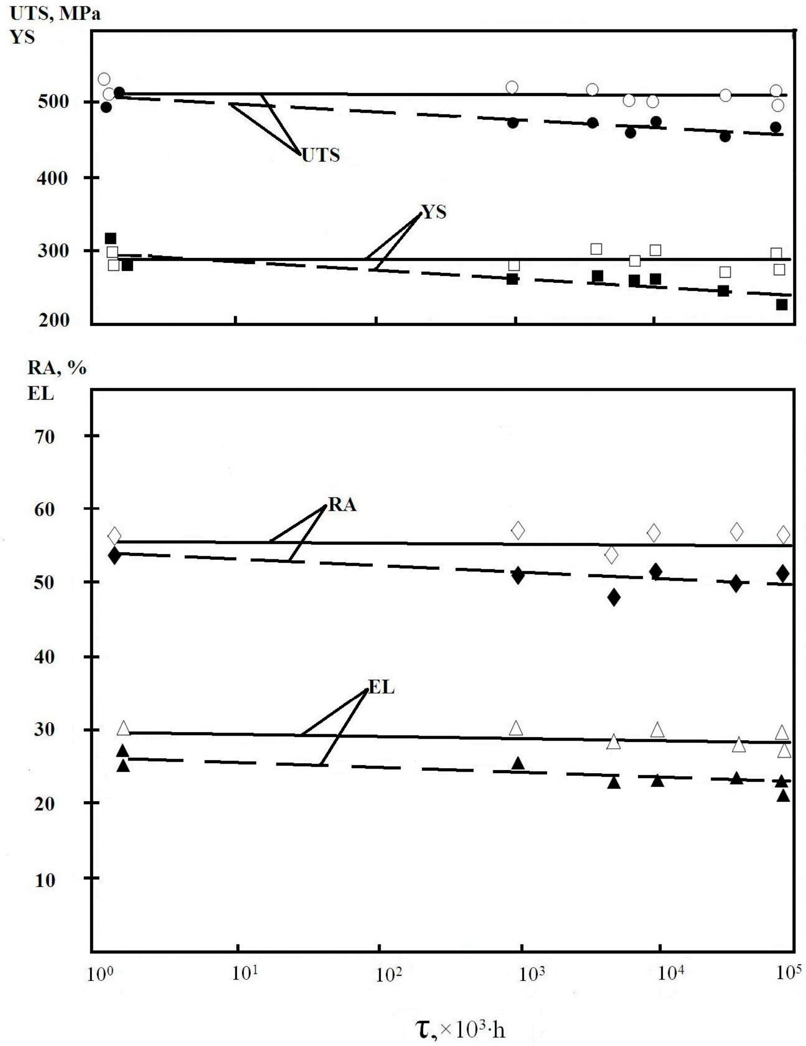

Fig. 8. Changed of mechanical properties of low carbon steel type 22K at 20°C (——) and 350°C (- - -) in dependence from time of duration of thermal ageing at operational temperature

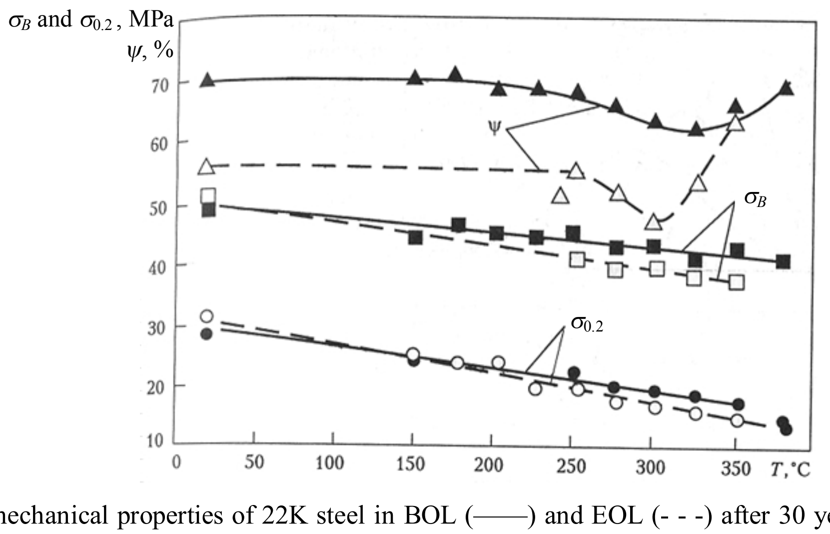

Fig. 9. Changes of mechanical properties of 22K steel in BOL (——) and EOL (- - -) after 30 years operational time for piping Du-800

However it was required to confirm this fact on longer time base. For this purpose we shall take advantage of the results of the periodic inspection of NPP pipelines with reactors WWER and RBMK which according with item 7.6.3 of PNAE G-7-008-89 [7] with the safety aim are carried out on a regular basis in each 100000 hour of operation. The fullest information is present for pipelines Du-800 from steel 22K and pipelines Du-400 from steel 20 of multi forced circulation circuit of NPP with reactor RBMK-1000. These data are submitted on Fig. 8.

Apparently from the submitted results of mechanical properties for both (base metal and weld) materials are enough stability [26, 27] and the safety factors accepted on a design stage are provided during all life cycle of components from carbon steels.

Steel type 20. Data on the effect of thermal aging on the properties of the steels were obtained in laboratory conditions on a limited basis, and in control at the plant after 100 thousand hours. Previously, they were presented in [2] for aging temperatures of 250, 300 and 350°C based on 10,000 hours at operating temperature after 100 thousand hours. Summing up these data using the dependence Holomona, Figure 10 shows the variation of strength and plastic properties at room and elevated temperature tests.

As seen from the results of any changes in the properties of steel in the process of operation does not occur.

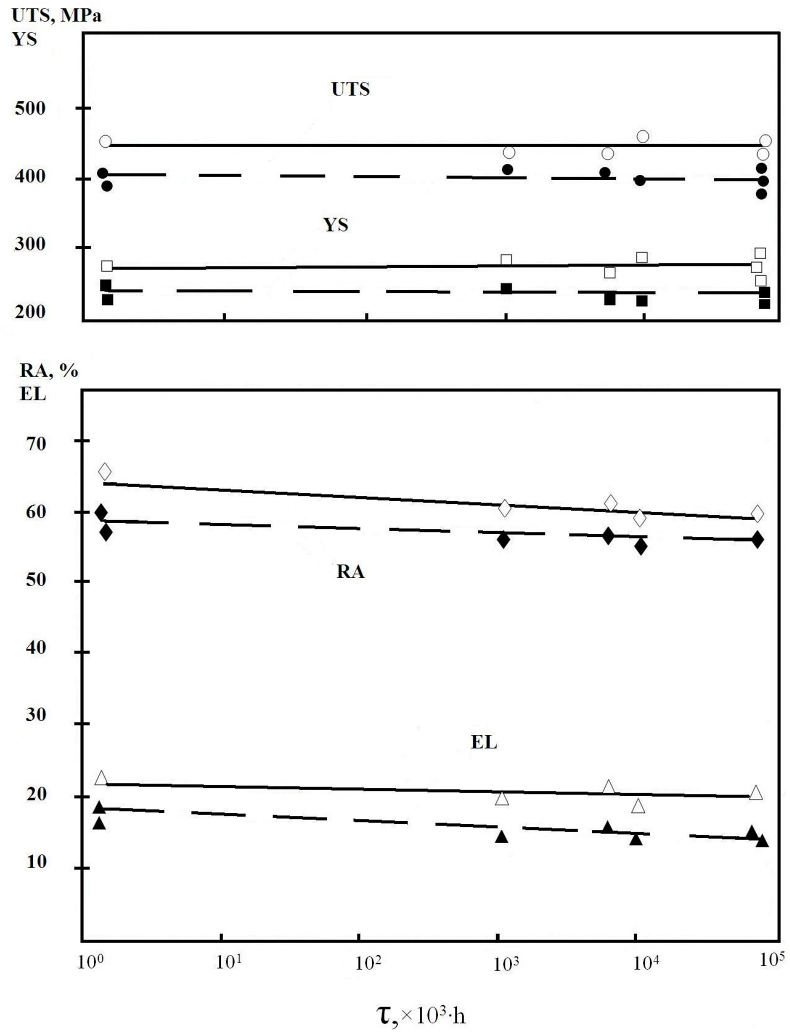

Fig. 10. Changed of mechanical properties of low carbon steel type 20 at 20°C (——) and 350°C (- - -) in dependence from time of duration of thermal ageing at operational temperature

3.4. High alloyed stainless austenite steels for pipe-lines

Steel type 08Cr18 Ni10Ti. As to austenite stainless steel which are widely used in the nuclear industry at manufacturing pipelines, internals and cases of pumps and valves they at so low temperatures characteristic for conditions of operation LWR (250-350^{o}C) also are rather stable and also their properties do not change at service life during 30-40 years.

The first results were received for base and weld metal of pipelines Du-500 in Novo-Voronezh NPP [28]. Stability of properties is well shown by results submitted on Fig.11.

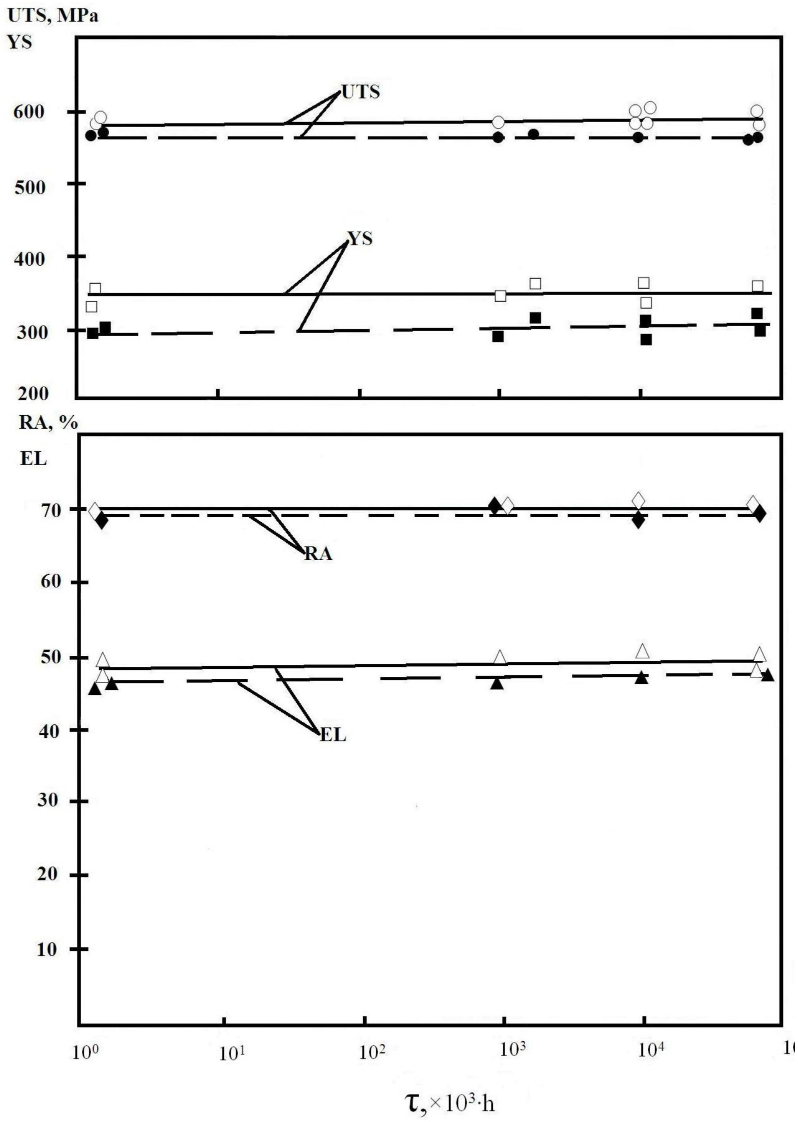

Fig. 11. Changed of mechanical properties of high alloyed stainless austenite steel type 08Cr18Ni10Ti at 20°C (——) and 350°C (- - -) in dependence from time of duration of thermal ageing at operational temperature

The submitted data have shown, that degradation of mechanical properties of pipelines does not occur. It is necessary to note, that stainless steel is applied to different NPP components not only as pipes and sheet but also as cast which have austenite and ferrite microstructure. The common content of ferrite in not stabilized cast stainless is usual less than 20% and for stabilized – it is less than 10% [29].

It is known, that ferrite is the elevated temperatures and should be taken into account it at the estimation of structural integrity of structures. A plenty of Refs [30-32] is devoted to this problem. Because of restrictions this question is here is not considered.

4. Conclusion

Practically for all structural materials used in the nuclear industry, degradation standard mechanical during design service life (30-40 years), does not occur, that allows to use these materials at prolongation of a resource for 10-15 years without decrease in safety and reliability of designs. The most sensitive characteristic to long thermal influence appeared critical temperature of embrittlement T_{KO} which for different groups of materials is shown on miscellaneous.

For RPV steels, it is especial for steel containing nickel, two forms of display thermal embrittlement are possible: the first is caused by allocation and coagulation carbides the cemented type, the second (at duration of influence more than 30000 hour) - segregation impurity on borders of grains.

Austenite stainless steels are not subject to thermal ageing. However cast preparations from these materials with austenite and ferrite microstructure have temperature dependence of impact strength and they are not recommended to be applied in the designs working at elevated temperatures, because of appreciable embrittlement a ferrite phase. As to welded seams with similar structure for them the amount ferrite phases, as a rule, is limited according to PNAE G7-009-89.

On the basis of analysis of mechanical properties of both RPV materials (base and weld metal) it was shown that their strength and plasticity at least do not decrease after prolonged operation time. Taking into account this fact it was suggested to use the certificate values during all life cycle equal 50-60 years.

The absence of noticeable change of mechanical properties structural steels of NPP components in operation within 100000 hours, that was confirmed by outcomes of researches of properties by destroying and not destroying methods of the inspection on NPP and on piece of elements of pipe-lines with welded joints will be agreed theoretical submissions about ageing these materials, have an equilibrium structure, which is provided by annealing or tempering.

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Proceedings of 6th International Conference ITELMS'2011

Control of Robot with Hand Gestures

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Abstract

This paper presents method and equipment for recognition of hand gestures used to control robot. Simple collection of hand gestures was created and tested. This collection of gestures can be used for control industrial or mobile robot arms. Results received during tests and experiments were used to control real ABB type industrial robot.
KEY WORDS: *Gesture recognition, industrial robot, mobile robot, image processing, control.*

1. Introduction

The largest part of information in communication is transferred to people in nonverbal way – mime, gestures or posture. Transport, aviation, marine or soldiership has its own constant language of hand gestures to transfer different information among people. All this should be understood by technology controlled by people or the one which services people, however almost all equipment is controlled by computer or control desk. It is necessary to have particular skills to control with control desk and in real outdoor conditions it is often impossible to use it therefore idea of control of technology and equipment by control gestures is spreading widely. There is an opportunity to use the same gestures to implement control activities.

2. Research

Universities, laboratories and different companies work in field of gesture control and huge amounts of money are given to implement the task. Meantime only first steps are taken in process of designing of manual interface. Company *GestureTek* designed technology intended to control electronic devices with integral WEB camera by simple hand movements without use of any control desks or pressing any buttons. The system tracks movements and gestures of all the body in three-dimensional space, recognizes them and gives appropriate commands. Factor limiting such televisions without remote control is price of cameras used, which is 10-20 times bigger than Internet cameras but they can do what Internet ones cannot, for example, eliminate moving background, camera eliminates views in particular distance behind the observed object and in front of the object [1]. Engineer of Tokyo University *Horo Tsuyoshi* designed a system for robotized chair control. It allows operator to control the robot by hand gestures. Considering the movements the system creates spatial model of human or object measurements in real time. Spatial view is analyzed, meaning of gesture is identified and it is transferred to the robot as a command. This way of interface of command transfer and robot control needs high quality video equipment. The disadvantage of the system is that the object must always be in the field of camera operation, otherwise robot control system will not be able to create spatial model [2]. Scientists of Brown University developed robot which understands people's gestures and verbal commands. *PackBot* platform was chosen which is used to construct robots intended for military industry (robots which neutralizes mines). It has additionally integrated *CSEM Swiss Ranger* camera which is able to define distance to the object. The whole system is controlled by laptop computer with specially installed software. Main advantages of this research are: 1) robot is taught to recognize the object from its silhouette; 2) special camera mounted in which uses infrared light to find object and to define distance to it; 3) operator does not have to track occurrence of robot (it can choose the right way and go around small obstruction) [3].

3. Gestures

Gestures are a natural system of information exchange which can be evaluated as perfect means for equipment control. There are a lot of fields (transport, soldiership, diving, finance market, construction, marine, deaf-and-dumb gesture language and so on) where gestures are used and at the same time a lot of collections of different purpose hand gestures but there is no confirmed popular and widely used gesture system to control equipment. Gestures used to control equipment can be divided into groups: 1) initial gestures – gestures describing reference point of information transfer; 2) control gestures – gestures used for direct control (control gestures are divided into specifying direction, identifying speed and additional gestures); 3) ending gestures – gestures used to finish work, to terminate transfer signal or work sequence in case of danger or problem.

4. Structure of recognition system of hand gestures

Recognition system of hand gestures (Fig. 1) consists of 4 main parts: image library, equipment of image receiving and transfer to computer, initial processing of received image and recognition-decision making parts.

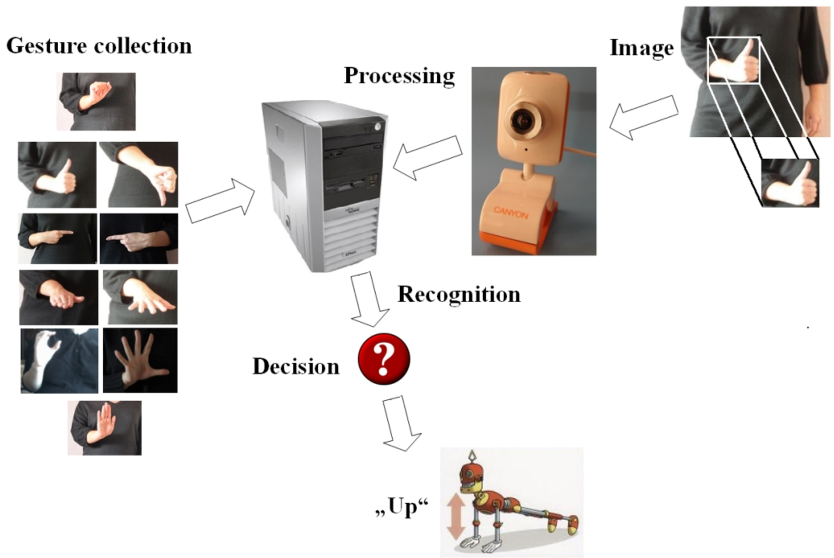


Fig. 1. Structure of recognition system of hand gestures

Image library consists of ten gestures: initial, control (up, down, right, left, forward, back, press, release) and ending. Images used for experiment are of different sizes, i.e. different resolution and received in several ways: from Internet web camera CANYON CNR-WCAM513G and from digital camera Olympus SP-590UZ. Initial processing of images was implemented with *MATLAB Image Processing Toolbox* (*IPT*) tools (Fig. 2) [4]. The image is ready for the process of recognition.

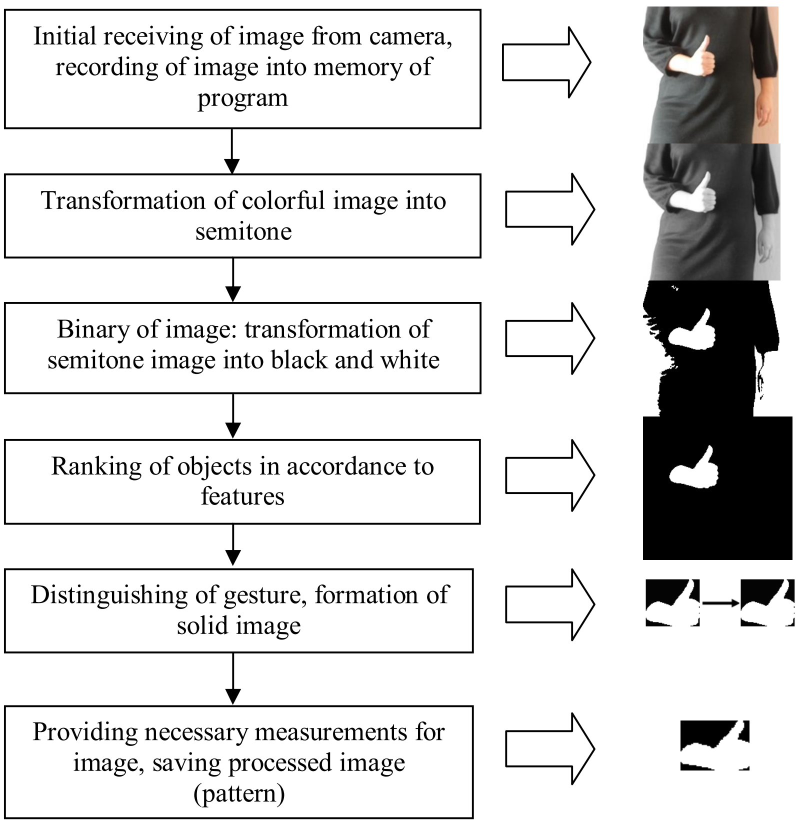


Fig. 2. Initial processing of image

Final stage is recognition of image. For process of recognition correlation method is used proper in realization of simple and not demanding a lot of financial, time and technical recourses system (Fig. 3).

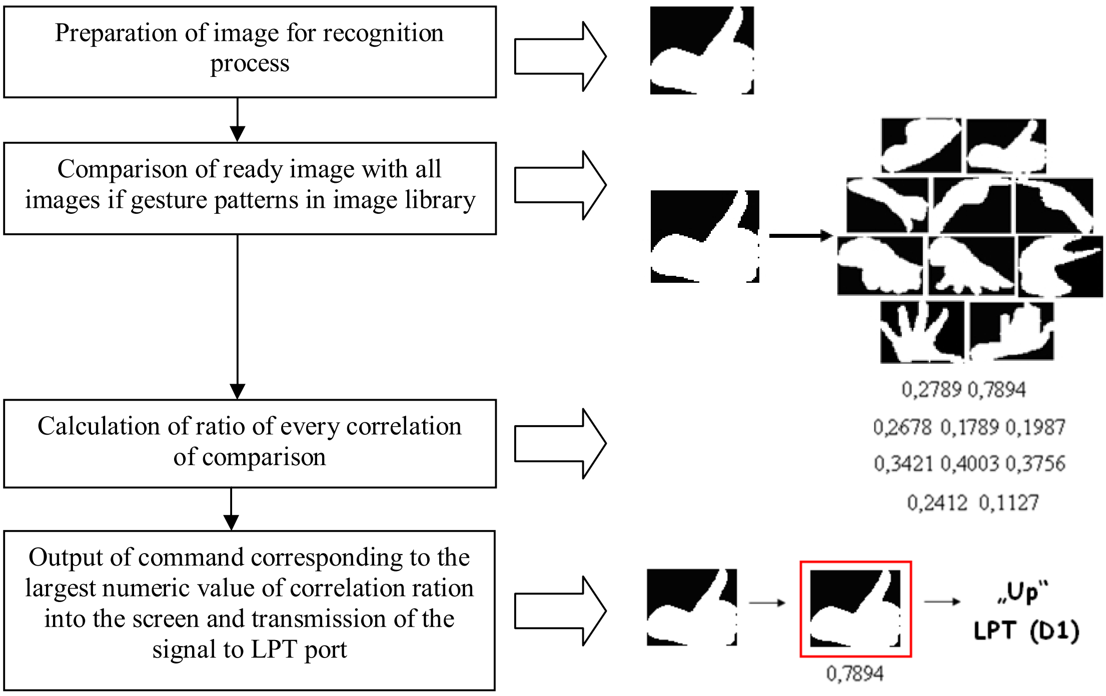


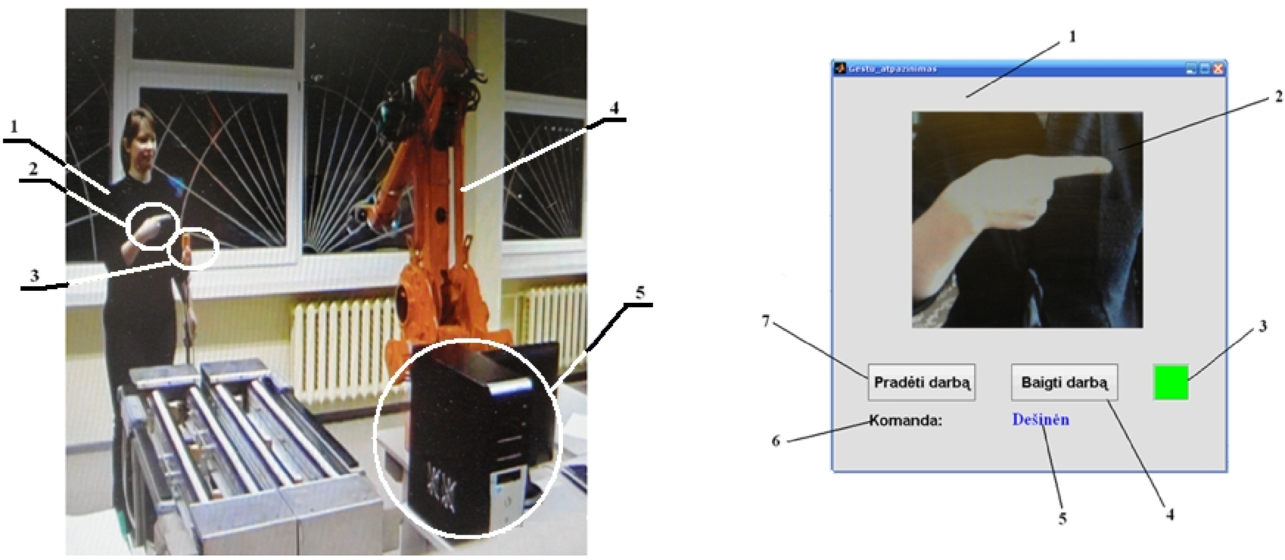
Fig. 3. Process of recognition

5. Research of recognition system of hand gestures

Efficiency of recognition of hand gestures reaches up to 100% when distance from operator to video camera is 0.4 m, natural light of working place reaches 200-400 lx, and artificial – 100-200 lx, operator is in no more than 10 degrees angle in respect of video camera and resolution of received images is 640×480 as then average time of gesture recognition is only 158 ms.

6. Practical application of the results of research of hand gesture recognition system

Operation of designed and examined hand gesture recognition system is tested controlling hand of industrial robot (Fig. 4).



a b

Fig. 4. Control of industrial robot with gestures (real system) (a) and review window seen on the screen (b)

Real system (Fig. 4, a) consists of such parts: operator (1), particular gesture (2); video camera (3), ABB IRB 14 industrial robot (4) and image library with gesture patterns and a part of image processing-recognition (5).

Structure of visualization window is shown in Fig. 4, b. In the desktop of review window (1) window of camera output can be seen (2), also two buttons are designed: „*Pradėti darbą*“ („*Start work*“*)* (7) and „*Baigti darbą*“ („*Finish work*“) (4). Warning light (3) has three-color indications: red, yellow and green. In the field of recognized line of commands (6) title of command corresponding to the gesture is shown (5).

7. Transfer of controlling signals to the robot

Module was designed to control with gestures industrial ABB IRB 1400 robot with control system S4, which harmonizes levels of TTL signals of LTP port of computer with levels of signals of installed DSQC 223 logic input and output module of computer (Fig. 5). Every recognized gesture gives separate logic signal for robot control system. Program of robot written in RAPID language checks states of all logic inputs and implements routine corresponding to the gesture.

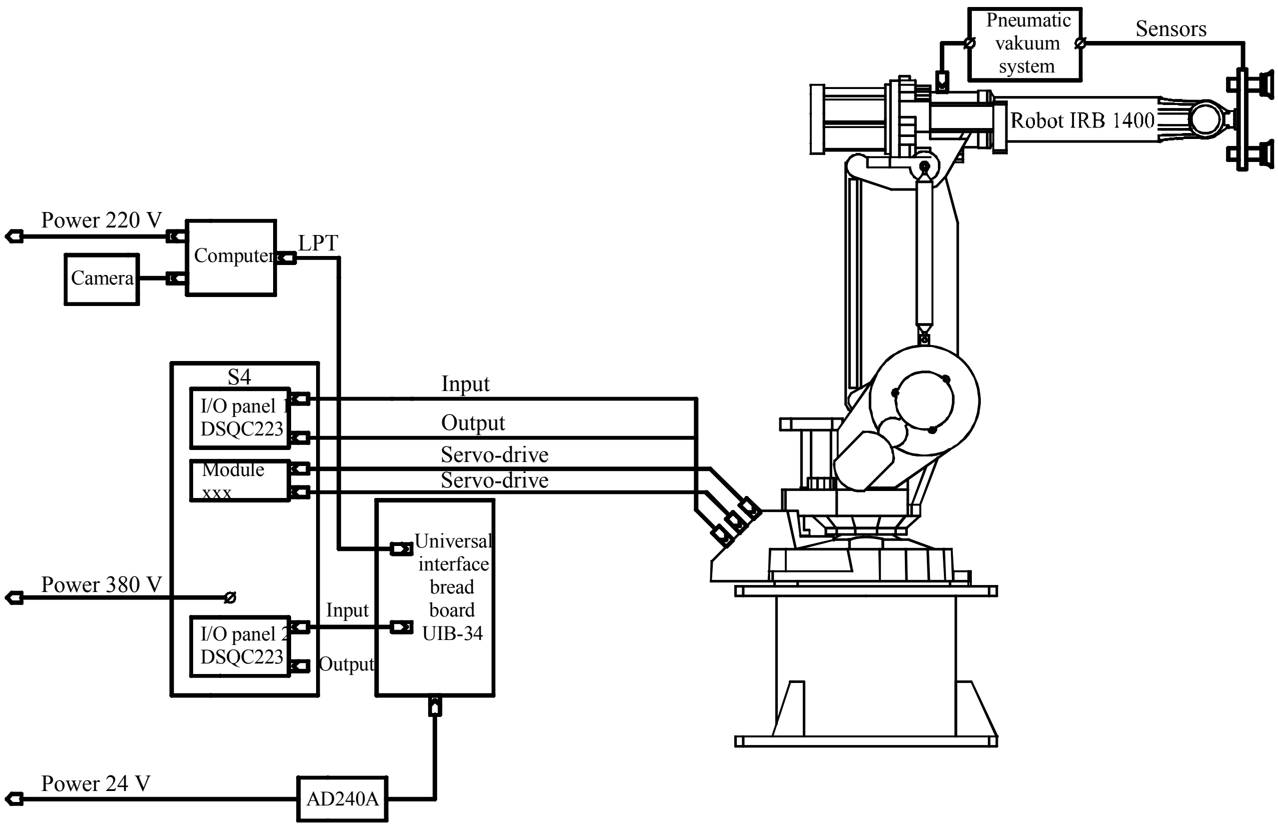


Fig. 5. Structural scheme of experiment

8. Conclusion

1. In the collection of gestures there are ten unique different gestures: initial, control (up, down, right, left, forward, back, press, release) and ending.
2. System of recognition of hand gestures is designed efficiency of which reaches 100% when all the working conditions are maintained.
3. It is proved that industrial robot can be controlled using designed system of recognition of gestures.

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Proceedings of 6th International Conference ITELMS'2011

Research of Statistics of Dangerous Goods in Road Transport

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Abstract

Transportation of hazardous materials and products, often at risk to the environment and human health. It depends on the matter of physical, chemical, toxicological and ecotoxicological properties and behavior. Are responsible for the safety of natural and legal persons who are under the Transport statistics may appropriate preparation for the prevention of accidents. The presented data make us believe that chemicals and products will be transported properly, but there is still some degree of risk, resulting from physical materials, and other chemical properties and environmental factors. All legal and natural persons engaged in hazardous materials and transportation products, to assess their risks and take preventive measures, since the responsibility for such material in negative consequences for humans and the environment lies with them, even in cases where compliance with these rules. Therefore, this article aims to provide transport of dangerous goods by road transport statistics, to analyze the load distribution of risk grades to compare two different regions of Lithuania in accordance with dangerous goods transported by statistics.
KEY WORDS: *dangerous cargo, dangerous goods, transport statistics.*

1. Introduction

In Lithuania 50 percent of the total cargo are dangerous goods. About 70 percent of the total amount of transportation of dangerous goods are in transit of goods. The majority (about 54 percent) of hazardous cargo in Lithuania are transported by rail, about 25 percent by car traffic and about 1 percent - by air [1].

Dangerous goods – the specific substances or products that can explode, cause fires, damage vehicles and cause damage to human health or the environment while loading, unloading and transporting them.

Dangerous cargo on domestic and international routes by road transport are in accordance with the Treaty on the International Carriage of Dangerous Goods by Road (ADR), A and B of the technical requirements of Annexes [2].

In Republic of Lithuania dangerous goods are transported in accordance with the Government of the Republic of Lithuania by 2000 23rd of March Resolution No. 337 „Transportation of dangerous goods by roads in Republic of Lithuania“ [3].

If there is an imminent risk to public safety, transport participants must immediately notify the emergency rescue services and provide the necessary information that the Authority would take appropriate action.

Each company in Lithuania, which are concerned with the transport or packing, loading, filling or unloading, shall appoint one or more of the transport of dangerous goods safety advisers, who are responsible for the risk inherent in such prevention.

If there is some accident during transportation, loading or unloading dangerous goods and it affects people, property or the environment, the consultant who has collected all necessary data must prepare an accident report to the company's management or, if necessary, to the local authority. This report does not replace the company's management reports that may be required under any other international or national legislation.

In addition to the material values of care, it is necessary to ensure that personnel working with dangerous goods, the safety of their harmful effects on health and the environment.

Dangerous cargo transportation safety issues in the analysis of individual units within the logistics system, found the material loss, which directly affect the business economy [4].

Statistical control of hazardous cargo data helps avoid losses or to minimize them. Logistic theory of the material values of safety issues are addressed sufficiently, and their relations to economic issues are undisclosed.

Dangerous Goods flow loss reduction is directly related to the proper preparation for their transport and storage.

Dangerous cargo transportation statistics research helps to ensure compliance with safety standards.

2. Investigation of dangerous goods transportation indicators in Lithuania

In the year of 2010 the total amount of cargo by type of freight (international, cabotage, transit) in all modes of transport (road, rail, water, air) were 44716 thousand tons of cargo from which 30912 thousand tons are inland transportation [5].

According to statistics on the carriage of goods can be concluded that the most hazardous cargo are transported by rail. In the year of 2009 the total amount of dangerous goods which were transported by rail transport was 10481 thousand. tons and 4461 thousand tons of them were internal traffic.

Internal transportation – transport from one to another point in a country.

International transportation - transportation services between the two locations (loading and unloading) in two different countries.

The amount of dangerous goods transported by road transport only accounts for 25 percent of the total number of transported goods. However, according to unofficial statistics, the number is much higher since a large part of the shipment of dangerous goods exempted without the requirements of ADR. These exceptions apply only to the transport of packaged dangerous goods in accordance with the Treaty on the International Carriage of Dangerous Goods by road provisions. The damage during the accident to the environment and human health is higher than normal cargo.

Goods transported by road are classified on the basis of standardized goods for transport statistics (NST / R), in which the goods are grouped into 24 NST / R goods groups.

Dangerous goods are classified in accordance with International Carriage of Dangerous Goods by Road Classification (ADR) in which the goods are divided into nine classes [2].

Table 1

UN Class of dangerous goods

UN Class	Dangerous Goods	Division(s)	Classification
1	Explosives		
2	Gas		
3	Flammable liquid		
4	Flammable solids	4.1	Flammable solid
		4.2	Spontaneously combustible substance
		4.3	Substance which in contact with water emits flammable gas
5	Oxidising substances	5.1	Oxidising substance
		5.2	Organic peroxide
6	Toxic substances	6.1	Toxic substance
		6.2	Infectious substance
7	Radioactive material		
8	Corrosive substances		
9	Miscellaneous dangerous goods		

By 20th of January of each year all companies which are transporting dangerous goods must submit reports on their activities to the State Inspectorate of Road Transport. The reports shall be with all transported, loaded, unloaded and temporarily stored dangerous goods in cargo volumes and routes and frequency of routes.

The analysis of dangerous goods by road traffic statistics from 2003 to 2010 (Fig. 1.) shows that the freight transport volume in 2003 reached a peak during the period amounted to 2581.5 thousand tons. Crossing point for the economic crisis the amount of transported dangerous goods have declined significantly. In 2009 it was transported 1692.1 thousand tons, and even fewer in 2010 – just 1680.3 thousand tons.

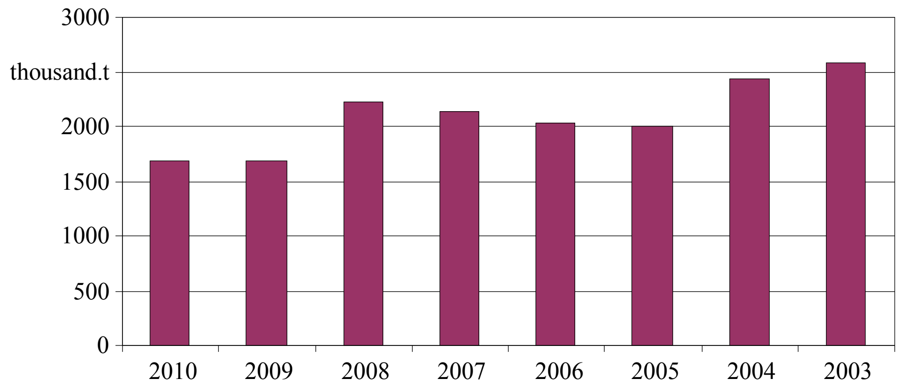

Fig. 1. Statistic of dangerous goods from 2003 to 2010

Table 2 provides statistics on transport of dangerous goods data from 2003 to 2010, according to the classes of dangerous goods. It appears that the majority of shipments of dangerous goods belongs to 3rd Class (Fig. 2.). This group contains flammable liquids.

Table 2

Statistic of dangerous goods (thousand. t)

Year	2010	2010	2010	2009	2008	2007	2006	2005	2004	2003
	Panevezys	Klaipeda	**Lithuania**							
Dangerous goods, total	103,3	129	1680,3	1692,1	2229,3	2141,5	2030,7	2002,4	2430	2581,5
1 class	0	0	0,86	0,8	1,3	1,6	0,2	7	2,8	45,7
2 class	7,1	41,3	348,2	353,4	308,9	337,1	448,3	337,6	299,6	390,8
3 class	85	83,3	1201,2	1222,7	1793,6	1609,2	1372,5	1283,2	975,6	1227,8
4.1 class	0,01	0,09	..	..	..	..	43,6	46	997,4	667,4
4.2 class	0,002	0,05	..	..	..	..	0	2,9	1,8	1,9
4.3 class	0	0	..	..	..	..	..	0	0	3,8
5.1 class	0,004	0,1	..	..	..	..	19,6	3	0,2	7,3
5.2 class	0	0,198	..	..	..	..	0,4	0,4	0,4	0,8
6.1 class	0,07	0,04	..	..	..	..	..	3,1	3,3	5,9
6.2 class	0	0	..	..	..	..	..	0	0	0
7 class	0	0	..	..	..	..	..	0	10,9	18,7
8 class	0,2	1,3	44,9	43,3	30,3	16,2	14,4	29,7	29,4	2,2
9 class	10,9	2,6	85,1	72	95,1	177,4	131,7	289,5	108,5	209,2

.. – where is no data

In 2008 the highest performance in its class content – 1793.6 thousand tons. In 2003 and 2010 the freight carried by much less – respectively 1227.8 thousand tons and 1201.2 thousand tons. It is possible that dangerous goods being transported for much less because their prices increase. In the year of 2003 a liter of 95 gasoline cost 2.41 LTL and diesel 2.09 LTL. In the year of 2010 prices increased almost twice: one liter of 95 petrol cost 4.68 LTL and diesel 4.41 LTL. On average in 2010 the price of fuel rose by 15.2 percent.

In Fig. 3 you can find data of 2nd class hazardous cargo from 2003 to 2010. This class includes gas. Transported volume of gas occupies the second place according to the classes of dangerous goods. It appears that this group of cargo volume in the test period is changing slightly. The largest quantity was shipped in 2006 (Fig. 2) – 448.3 thousand tons. The minimum quantity of cargo was transported in 2004 – 299.6 thousand tons. In 2010 it was transported 348.2 thousand tons of 2nd class cargo.

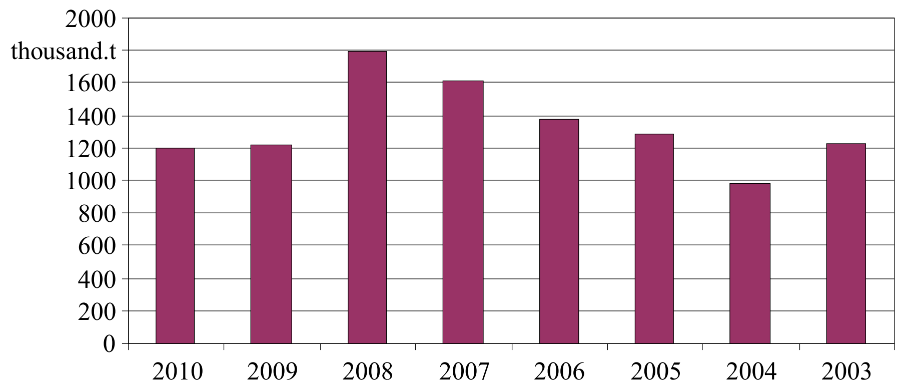

Fig. 2. Statistic of dangerous goods of class 3

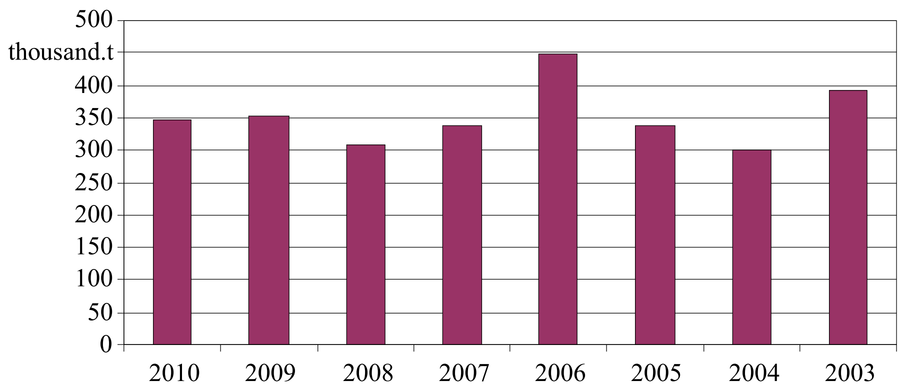

Fig. 3. Statistic of dangerous goods of class 2

In Fig. 4 you can see data of 8th class hazardous cargo. This class includes corrosive materials. This is probably the only hazardous goods of which carriage rates significantly increased. In 2003 it was only 2.2 thousand tons and in 2010 it reached 44.9 thousand tons of 8th class cargo.

The 9th class data of hazardous goods are shown in Fig. 5. It is all other kind of hazardous substances and products. The largest quantity was shipped in 2005 – 289.5 thousand tons. In 2010 and 2009 the volume of cargo traffic is less by almost a quarter: in 2010 – 85,1 thousand tons and 2009 - 72 thousand tons of 9th class cargo.

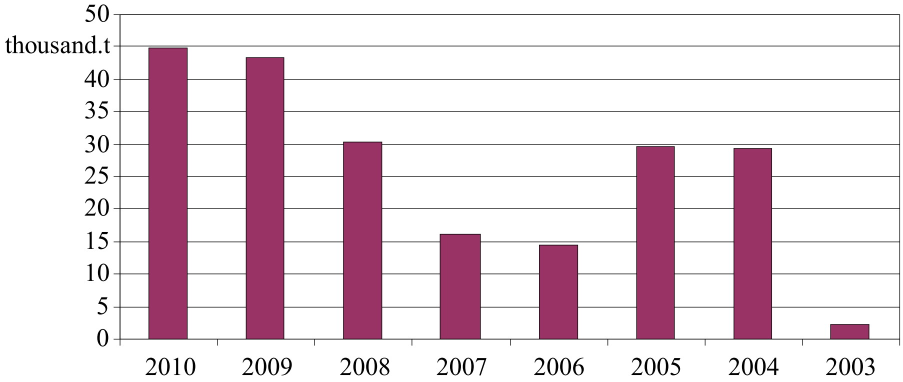

Fig. 4. Statistic of dangerous goods of class 8

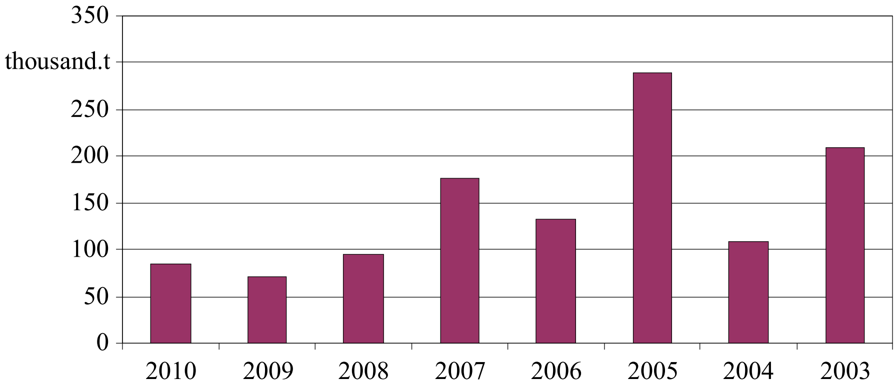

Fig. 5. Statistic of dangerous goods of class 9

There was no traffic of 6.2 class goods (infectious substance) during this period. The remaining classes of dangerous goods data are not analyzed further because the transported quantities are limited, and some data is not exist.

The paper also examines two different regions of Lithuania: Klaipeda and Panevezys dangerous goods transport, in order to assess the region's geographical position and international traffic of dangerous goods transported affect the quantity and range.

Panevezys region was chosen because of the highway Via Baltica. Through this region freight flows by north - south and west – east directions.

Klaipeda region was chosen for its geographic location and an international seaport. A large part of the cargo is transported from there by rail and sea.

According to available data (Table 2) it is clear that a substantially different regions but the total cargo volume is similar. Both of Klaipeda and Panevezys regions in 2010 the total amount of transportation of dangerous goods in quantities of over one hundred thousand tons – the Klaipeda region of 129 thousand tons and 103.3 thousand tons in Panevezys region.

There was no traffic of 1, 4.3, 6.2 and 7 classes of goods in both regions. In Panevezys region there was no transportation of hazardous goods of class 5.2 and in Klaipeda region it was transported 198 tones of this class cargo.

According to the statistics of the year 2010 in Klaipeda and Panevezys regions it was mainly carried 3rd class of substances which are flammable fluids JT No. 1202 diesel and JT No. 1203 gasoline. Klaipeda region decreased by 83.3 thousand tons and 85 thousand tons in Panevezys region.

It was also carried a significant amount of 2nd class goods which are gas. „Gas – it is a substance which pressure of vapor at 500°C higher than 300 kPa (3 bar), or to 200°C at normal pressure of 101.3 kPa is fully gas" [3]. In Klaipeda region it was carried 41.3 thousand tones and 7.1 thousand tons in Panevezys region.

A very few dangerous goods of classes 4.1, 4.2, 5.1, 6.1 are transported. In 2010 both of Klaipeda and Panevezys regions the freight carried by only about 0.01 to 0.1 thousand tons. These classes of freight transported to the minimum, because Lithuania is not being produced and not using these dangerous substances.

A little more goods were transported of class 8. Klaipeda region decreased by 1,3 thousand tones of them and in Panevezys region it was transported 0,2 thousand tons of them.

In Klaipeda region it was transported 2,6 thousand tones of 9th class of dangerous goods and 10,9 thousand tons in Panevezys region. This is a wide range of hazardous substances and products. Their demand is low.

It is very important that there is no traffic at all of 1st class (explosives and explosive manufacture) and 7th class (radioactive materials) of dangerous goods. These are goods that can be used not for its intended purpose, for example for terrorism, and which could lead to serious consequences such as injuries or massive explosions.

3. Conclusions

About 25 persent of goods are transported by road. During the 2003 – 2010 period, the road transport of dangerous goods were mainly transported in 2003. According to the classification of dangerous goods classes it was mostly transported 3rd class of cargo. This group contains flammable liquids.

Second class of dangerous goods are gases. This group of cargo volume is slightly in the research period of change. The largest quantity was shipped in 2006.

There was no traffic of 1, 4.3, 6.2 and 7 classes of dangerous goods in Lithuania or it is lack of data about that. 4.1, 4.2, 5.1, 6.1 dangerous goods transported in a very few.

Total cargo volume is similar in Klaipeda and Panevezys regions. The total amount of transportation of dangerous goods in quantities is over one hundred thousand tons.

According to the 2010 statistics in Klaipeda and Panevezys regions of the dangerous goods transportation in the distribution of classes it is the same as in whole Lithuania.

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Proceedings of 6th International Conference ITELMS'2011

Selection of Steel Type for NPP Units Various Equipment

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Abstract

Low cycle fatigue strength of the structures is governed by the metal behavior in stress concentration regions. The stress level in these regions can considerably exceed the material yield strength. According to modern method of estimation structure endurance is identified using the fatigue crack initiation conditions on the basis of Coffin-Langer's equation, applicability of which has been experimentally supported by testing materials of different strength level.
KEY WORDS: *low cycle, fatigue.*

Analysis of damaged cases for pressure vessels and piping has been shown that the main factors to nucleation of fatigue cracks are:

- service conditions (number of cycles during operation);
- concentration of stresses in more loaded areas;
- quality of base metal (crack, lamination, et. al.) and welds (crack. pore, slag inclusion, et. al.).

Low cycle fatigue strength of the structures is governed by the metal behavior in stress concentration regions. The stress level in these regions can considerably exceed the material yield strength. According to modern method of estimation structure endurance is identified using the fatigue crack initiation conditions on the basis of Coffin-Langer's equation, applicability of which has been experimentally supported by testing materials of different strength level. As it is shown in Ref. [1] for the approximate calculations the following equation may be used:

$$\frac{E}{4\sqrt{N}} \cdot \ln \frac{100}{100-\psi} + \frac{UTS}{2} = S_a \tag{1}$$

where $S_a = e_a E$ is allowable amplitude of alternating stress intensity; e_a is total strain amplitude; E is modulus of elasticity; UTS is ultimate tensile strength; ψ is reduction of area.

S_a value in the most stressed region of the structure can be obtained if the strain concentration factors are known:

$$K_{\varepsilon\, max} = S_a / \sigma_{nom} \tag{2}$$

where σ_{nom} is calculated mean stress intensity.

These factor values characterize design quality of the most heavily stressed units in typical structures. The estimated and experimental data obtained by different investigators has shown that for pressure vessels the values of the strain concentration factor vary in the region 2.5 to 5 depending on the type of the structure.

As the trend to use high strength materials for pressure vessels becomes increasingly pronounced, it is of particular interest to analyze structure endurance as a function of design quality and tensile properties of the materials used, starting from present standards (ASME Code, for example) and holding true the equation (1). For this purpose on the basis of the equation (1) and taking into account the relationship (2) a diagram for fracture conditions of pressure vessels versus the material properties and $K_{\varepsilon\, max}$ values was constructed. In this case the assumption was made that for vessels:

$$\sigma_{nom} = \frac{UTS}{2.6} \tag{3}$$

In this case equation (1) will be

$$\frac{E}{4\sqrt{N}} \cdot \ln \frac{100}{100-\psi} + \frac{UTS}{2} = \frac{UTS}{2 \cdot 2.6} K_{\varepsilon\, max} \tag{4}$$

The relationships for $N = 5 \cdot 10^3$ cycles given in Fig. 1 were plotted taking into account safety factors 20 suggested by ASME Code, that is the most typical lifetime for power units. Figure 1 shows also a scatter band of mechanical properties for various structural steels for pipelines (20, 16MnSi, 16MnNiMo, 10MnNi2MoVA).

Separate points for these steel in the band corresponding to mechanical properties of certain best known materials are shown in this Figure. It is evident from Figure that to retain given structure endurance leaving invariable design quality of a vessel, it is important by increasing material strength to raise its ductility. However, in reality material strength is accompanied as a rule by a certain drop of ductility. In this connection, in structures with *UTS* = 400-500 MPa the required endurance is provided in practice even for most unfavorable values of $K_{\varepsilon\,max}$. When increasing the strength level of the material used with accompanying mean stress level raise, it is necessary to decrease $K_{\varepsilon\,max}$ value to maintain structure endurance.So if the number of cycles $5 \cdot 10^3$.

Then for production of the most heavily stressed structure units $K_{\varepsilon\,max}$ should be 3.5 for materials having $UTS \leq$ 700 MPa and 3 to 3.2 having *UTS* = 900-1000 MPa.

The considerations mentioned above are based on purely formal analysis. The drawback of the latter is that the assumed safety factor 20 includes all integrated factors which are effective in structure production and operation. The consideration of pressure vessel fractures has shown that metal fabrication defects or various surface imperfections in the most heavily stressed units constitute the main reason of this phenomenon. Taking into consideration this fact in the present paper it was attempted to look over the requirements imposed upon the material in connection with its local production or metallurgical imperfections. Some relations are given by Langer [2] who evaluated the correlation of structural material endurance and crack size for different strain concentration factors on the basis of Peterson's hypothesis. Such analysis is applied to fatigue when metal is in elastic region. It is known that the material in stress concentration zones is in elastic-plastic region, therefore the analysis given above needs refinement [3, 4]. Using the calculated method it is possible to estimate the requirements to designed arrangement of structure units on the criterion of fatigue crack nucleation from materials with different strength level [4]. The results of the calculation for endurance $5 \cdot 10^3$ cycles are presented in Fig. 2.

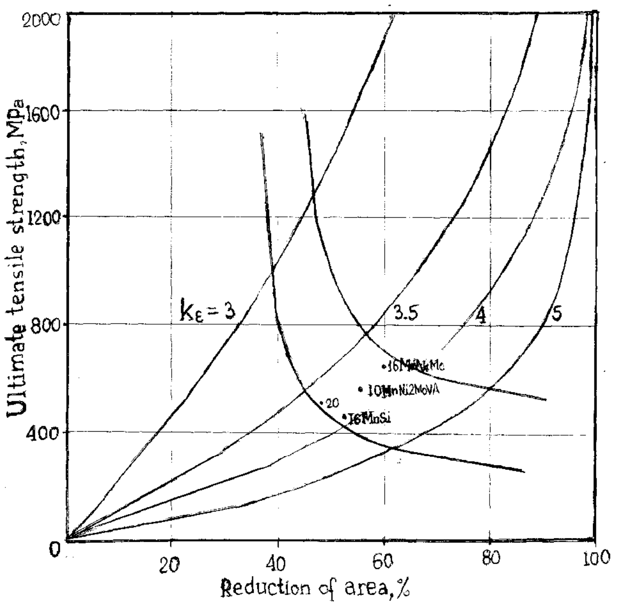

Fig. 1. Diagram of pressure vessel fracture condition

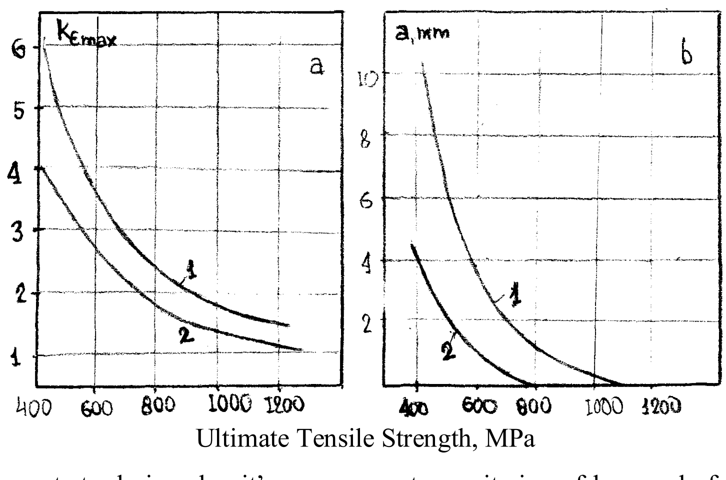

Fig. 2. Change of requirements to designed unit's arrangement on criterion of low cycle fatigue in dependence from strength material: a – at variation of fatigue crack size (1 – a=2 mm; 2 – a=4 mm); b – at variation of strain concentration factor (1 – $K_{\varepsilon\,max}$ = 3; 2 – $K_{\varepsilon\,max}$ = 4.5)

As can you see to arrange this endurance it is not possible to use the materials with ultimate tensile strength more than 600 MPa. Thus with increasing strength level of materials it is necessary to decrease the maximum level of stress concentration factor $K_{\varepsilon\, max}$.

Conclusion

1. Selection of steel type for NPP units various equipment on criterion of low cycle fatigue must be performed in dependence from strength material level and stress concentration factor. With increasing strength level of materials it is necessary to decrease the maximum level of stress concentration factor $K_{\varepsilon\, max}$.
2. The most heavily stressed structure units $K_{\varepsilon\, max}$ should be 3.5 for materials having $UTS \leq 700$ MPa for pressure vessels and piping.

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Proceedings of 6th International Conference ITELMS'2011

Moisture Motion Kinetics in Floor Structures on the Ground

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Abstract

The paper presents an investigation of water in concrete floors on the ground, it's dependence on composition of concrete and floor construction.
KEY WORDS: *concrete, moisture, structure, moisture weight content, pore, capillary, floor, ground.*

1. Introduction

The most difficult assessment related to individual parts of the building is the persistence of environmental effects of humidity. Floor of the building is affected by ground water, hygroscopic, condensing and operating humidity [1]. Building humidity, which floor gets with mixtures of concrete, is mostly used for concrete hydration processes. Poor quality of the building floor insulation can affect a less severe moisture from the soil. Therefore, the moisture content of concrete floors is more variable compared with other building structures. Sometimes there are various operational problems (e.g. alkali concrete corrosion to occur, the reaction zone is sufficient to 90 ... 95% relative humidity) on the humidity, although floors are equipped with proper flashing and the direct migration of water is prevented. However, these problems also may be caused by water vapor diffusion in the concrete.

2. Surface of concrete floor hardening with hydraulic cement and small aggregate mixtures

During the time parts of the building are affected by various loads. Floor gets the biggest loads. Composition of concrete and casting methods may have influence to concrete's strength, wear resistance, density, freeze, sedentary, water.

Concrete can withstand big loads, but if concrete floors are in places that have strict requirements, it is recommended to cast floor with hardened under-layer. Technology of concrete floor with hardened under-layer casting is simple. In a freshly poured and smooth concrete surface special mixture is rubbed, which increases technical characteristics of concrete: compression resistance, impact resistance, ensures lesser content of dust, improves the overall picture.

Dry hydraulic cement and minor aggregate mixture is rubbed smooth into concrete surface until it is not hardened and smoothed.

While rubbing, mixture is absorbed into concrete surface and makes it more compacted. After the last grinding most of pores in concrete surface are closed and freeze resistance increases. Floors like this can be used for 15- 20 years. Floors made with dry gelling agents can withstand very big loads – even the caterpillar equipment.

Concrete floor with harder surface can be used in:

- Workshops, warehouses;
- Trade areas;
- Garages;
- Parking lots.

3. Lithium-based concrete floor surface hardening

Lithium-based concrete hardeners react with calcium molecules in concrete pores and make strong and very stable silicate compounds, which maximize the reactivity of lithium. They also react with calcium hydroxide, coating the basis with tri-calcium silicate compounds, which traps moisture in the inside of concrete. These compounds block micro-pores of concrete to form a barrier for moisture penetration.

All modern concrete hardeners have 3 main features:

1. hardening of the surface;
2. surface protection from dust;
3. surface isolation.

These features are the result of chemical reactions that are between silicates, Portland cement and calcium hydroxide in concrete pores. During reactions, crystals form and fill all empty pores in jelly concrete, making it harder and more resistant to environment affection.

Today all concrete hardeners are silicates-based, which chemical composition is based on sodium, potassium, magnesium and lithium molecules. The main difference between those silicate types is size of molecules. Further molecules are given from bigger to smaller:

1. sodium molecules;
2. potassium molecules;
3. magnesium molecules;
4. lithium molecules.

Size of molecules is very important, because it describes how deep hardeners can penetrate into the concrete and how systematic they react. Performance features and durability depends on molecules size. Small lithium molecules deeply penetrate into concrete pores and make concrete harder. Potassium and sodium molecules are bigger, so they aren't able to penetrate into concrete pores as deep as lithium molecules and after reaction on the concrete surface remain lime migration tags.

Hardeners, without lithium in their composition, don't let to form silicates and alkali reactions in concrete pores. Silicon dioxide in concrete reacts with alkali and a gel is formed, which, if reacts with water, expands. Such reaction causes huge pressure and concrete starts to crack. Cracks accelerate depreciation of concrete protective layer. Micro-cracks let water to penetrate into concrete surface under-layer and may cause metal corrosion, freezing and other problems.

4. Changes in the concrete floor on the ground during the exploitation

Floor on the ground is the only construction, which has full or partial contact with moist, warm subsoil surface or any other soil surface. Therefore the external moisture load to the floor on the ground is very different from the other constructions. In many cases moisture to the concrete floor on the ground falls because of movement of the rising capillary water [2].

Tests of the moisture harm to the concrete floor on the ground showed that temperature's and moisture's behavior in concrete floor is difficult. The mechanisms of water and moisture movement in the floor on the ground, through it and in the neighboring layers are different and depends on temperature. Structural moisture in massive concrete floor changes with indoor temperature and moisture.

Water in material is divided into groups by it's molecular ties. It is very important, because not all water that is in material, take part in chemical reactions.

Surface of concrete leverage layer underneath heated building is warm and content of water vapor in the pores in most cases is bigger than content of water vapor in indoor air, especially in winter. According to tests, gravel, which grain diameter is minimum 1 mm, effectively stops capillary rising. Double layer of polystyrene foam also prevents capillary rising, but polyethylene layer underneath concrete floor isn't appropriate, because it slows drying process of the concrete.

5. Boundary conditions

Indoor air. Moisture content in indoor air depends on moisture content in outdoor air, the occupancy of the building, moisture emission through the building, ventilation, hygroscopicity of the building materials, moisture movement through the building or room, the content of during drying process evaporated moisture.

Subsoil. The subsoil surface in contact with the floor structure of a heated building is relatively warm throughout the year, especially underneath the central part of the slab. The temperature of the subsoil underneath the concrete floor on the ground is close to the inside temperature, if thermal insulation is not used. In some cases, especially if there are un-insulated hot pipes underneath the floor, subsoil temperature can be even higher than indoor temperature. Temperature of the subsoil underneath insulated floor depends on floor's, subsoil's and foundation's thermal resistance, indoor and outdoor temperature. It means that in normal conditions vapor diffusion flow moves from warm and wet subsoil to relatively dry indoor air.

Construction moisture. One of the most important moisture sources for concrete floors on the ground is construction moisture in concrete. Normally concrete mix has a big content of water and because of that concrete's drying process is quite long. Drying period is especially important in constructions where it's going only to one direction, such as concrete floor on the ground. Concrete drying period can take a long time, even a year. Moisture in concrete in drying process depends on concrete properties and conditions of drying.

Critical moisture levels. Many building materials have critical moisture levels. If moisture content is bigger than critical level, possibility of damages appears. For concrete floor on the ground connection between floor covering and concrete layer is very important. Critical moisture levels [3]: 1.wood and wooden elements: RH_{crit} = 80%; 2. vinyl floor coverings: RH_{crit} = 80%; 3. cork tiles (a. without vinyl layer on the underside: RH_{crit} = 80%; b. with vinyl layer on the underside: RH_{crit} = 85%); 4. ceramic tiles: RH_{crit} = 100%.

6. Test methods

To verify moisture content changes in concrete in operating conditions two buildings were chosen. The first one was a new building without any floor defects. In this building for the first time moisture was measured two weeks after concrete casting. In the second building floor defects were reported. In this building for the first time moisture was measured 6 months after concrete casting. In the first building all area of the floor is insulated with PAROC rock wool. In the second building by external walls 1 meter width and 10 centimeters thick layer of polystyrene foam was used. Floor's constructive layers are given in the first table.

Table 1

Constructive layers of floor on the ground

Buildings	Floor's constructive layers
Floor on the ground 1st building	Polished reinforced concrete, class C20/25, 120 mm thick
	Flocked flashing
	Class C20/25 concrete leverage layer 40mm thick
	Gravel 100 mm thick
	Compacted soil
Floor on the ground 2nd building	Polished reinforced concrete, class C20/25, 50 mm thick
	Flocked flashing
	PAROC GRS 20 thermal insulation 100 mm
	Rubble 80 mm thick
	Compacted soil

To measure moisture in concrete, moisture meter, based on permittivity measurement, was used. Water consists of polar molecules, which has angular structure. Because of this, water molecule has a constant magnetic moment. The length of this dipole polarization is about 10^{-10} s. Exposed by high frequencies fields, dipole resonates and absorbs energy. Permittivity directly depends on moisture content. While measuring, content of bulk humidity is determined. Moisture weight content is determined by assessing the density of concrete.

Meter T-M-170 was used for test. Its technical characteristics: 1. edges of measuring 0...80%; 2. accuracy 0.1%; 3. temperature of working environment 0°C - 50°C.

Moisture content at industry buildings was measured every two weeks. Measurements were carried out by external walls and in the middle of the building – by inner columns. Changes of measured moisture weight content are shown in Fig. 1 and 2.

Moisture weight content both at external walls and inner columns decreased during the whole observation period. Last measurements were carried out in autumn, when relative humidity is bigger than in summer. This had ant affection to concrete moisture content by external walls.

After tests in building, where defects were reported, lesser moisture content was found in places where thermal insulation was used – by the external walls and entry to the building. After few measurements was observed that at some points by inner columns moisture content increased.

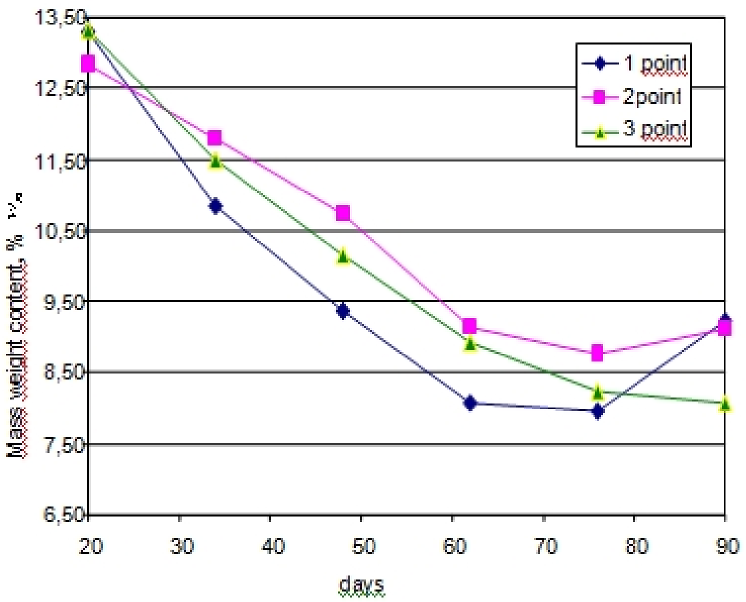

Fig. 1. Moisture weight content changes in concrete floor on the ground of industry building at the points by external walls

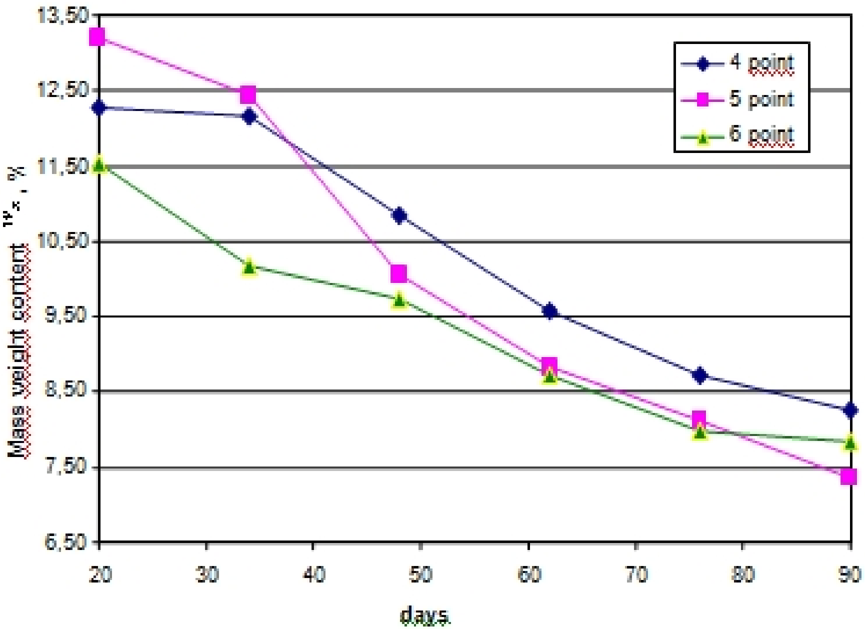

Fig. 2. Moisture weight content changes in concrete floor on the ground of industry building at the points by inner columns

7. Conclusions

1. Moisture content in slab-on-ground structures depends on relative humidity.
2. Size of molecules is very important in hardeners, because it describes how deep hardeners can penetrate into the concrete and how systematic they react.
3. Concrete floor with stronger top layer can be loaded by small loads after week. Full loading is possible in 12 – 28 days after casting.
4. While using hardeners of concrete floor's top layer, concrete becomes more water resistant.
5. Moisture content in concrete floor structures depends on if thermal insulation was used.
6. In drying of concrete constructions (about 10 cm thick) in natural conditions moisture equilibrium becomes steady in 55...75 days, reaching 12…14% of bulk humidity (5…6% of moisture weight content).

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Proceedings of 6th International Conference ITELMS'2011

Frost Effect on the Soil

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Abstract

The paper present an investigation of frost effect on the soil.

KEYWORDS: *Frosts, the soil, upraise.*

1. Introduction

Construction of low-rise light buildings base is sufficient reason and the uppermost layers. Soil strength in terms of the structure foundation can be laid directly on the ground (removal of the vegetable layer). Such the foundation installation method would have advantages: concrete could save; significantly reduce the volume of earthworks; could not lower water, given a high groundwater horizon; foundation become cheaper and significantly reduce labour expenditures.

The foundation lay on the ground is an obstacle that the soils are susceptible to frost effect. Frost heaves the soils. This heaves usually are very different and cause foundation cracks in structures of different sizes, different strains, which are both undesirable operational and aesthetic.

2. The upraise mechanism of the soil in the frost effect

The frost effect for soils asserts when water froze in the soil. While freezing, water increases its capacity; therefore, forces that emerge raise a soil. The soil increases its capacity but this increase is pretty low. While the soil is freezing, the suction pressure occurs in the direction of ice crystals, and then follows the moisture migration towards the ice front in the unfrozen soil zone. This process occurs because of the temperature gradient, ice surface, electro molecular forces of soil particles, and other reasons. For this reason, the total area of the soil's permafrost zone compared to the initial increases. This increase of moisture builds up in the soil front, and soil ices. While soil is icing, its capacity increases as much as it infused the water. This increase can be very large, and it sometimes reaches 50-100%. This process continues until the frost penetrates in the soil and suction pressure is able to provide water for the ice front. The formation of ice lentils causes pressure that is opposite to suction. It promotes water drainage. This pressure can be made by artificial technique, during freezing test, or burden with an example. The pressure that appears during a freezing process, and when water does not move from or to a specimen is called a counteracting pressure. When pressure is greater than counteracting, when ice crystals are formed, water is drained from the ice front. This process results in much smaller ice lentils, and the soil is less movable in compare with the original moisture.

Depending on each soil's mineral granulometric composition, state, hydro geological and climatic conditions soil has a tendency to be raised. This soil feature can be described as soil's upraising.

Soil's upraising depends on its origin, state, and hydro geological and climatic conditions. All these factors are essential for defining soil's upraising.

3. Soils'upraising dependence on origin, composition and state

The principal freezing scheme shows that soil's upraising is directly related to those properties that characterize the soil mineral particles intercourse with water. In particular, the size of soil particles and their mineral composition.

The smaller particles the higher their surface energy, the higher and possible suction pressure, and the higher pressure can be developed by ice crystals; therefore it requires much higher counteractive pressure. If this pressure is exceeded, the water can be drained from the soil. Despite the relatively high suction force with small particles, water migration is very slow because of major surface forces. Thus, it is optimal soil granulometric composition that corresponds to specific hydro geological and climatic conditions.

Natural observations and laboratory experiments showed that frost upraises soils that contains great amount of dust.

Clay soils' upraising highly depends on the mineral composition. Most susceptible to frost is kaolin clay.

However, besides mineral composition, there are other factors that are highly influential to upraising. In particular, it is the amount of anther particles. Dusty dense soils' upraising is two times smaller than upraising of kaolin soils.

Soils, which do not have clay and dust, consisting of sand and larger particles are less susceptible to frost, even under adverse hydro geological and climatic conditions. In such or saturated soils, even low pressure resulting from ice formation, removes water from the ice front.

Soils' state is described by the fold, density, and moisture. These parameters are also important for soil's upraising. The fold shows the distribution of particles in the soil capacity, and it is expressed by the coefficient of soil uniformity. If the soil fold is good and dense, pore size is minimal.

Soil density influence to upraising is heavily dependent on hydro geological conditions. In an open irrigation system, the soil thickens and the upraising increases. In case where permafrost descent below underground water horizon, the soil is fluffier and the upraising is greater.

Soil moisture has particularly importance. Initial moisture has significance for soils that have tendency to upraise. Soil is upraised when moisture is higher than critical. Moisture that does not upraise the soil is called critical moisture. Usually this moisture is slightly lower than plasticity limit's moisture, but that does not mean that such soil does not upraise. Experiments showed that soils drier than critical also has a potential for upraising. This is due to higher activity of particles in the drier soils, when there is temperature oppression. It is estimated that during freezing period not entire water freezes. Strongly physically bounded water freezes only at very low temperatures. In this way, membranous water, when soil is not completely saturated with water, is the main provider of water to growing ice crystal.

4. Soil‘s upraising dependence on hydro geological conditions

Depending on the underground water level position, there are three supplying systems: 1) closed; 2) opened; 3) oppressive.

The closed supply system is when underground water horizon is deep and does not affect freezing. In such soils, when ice lentils are building up, the main role comes to initial moisture, membranous moisture migration, and vapor.

The open supply system is when underground water horizon is not deep and capillary moisture reach freezing front. In this case, water mainly through capillaries gets into ice front.

The oppression supply system is when freezing depth falls below the underground water level. Then a great amount of water inflow at ice front. In these conditions, when soil has a tendency to upraise, a maximal raise will emerge.

5. Conclusions

1. The frost effect for soils asserts when water froze in the soil. While freezing, water increases its capacity; therefore, forces that emerge raise a soil.
2. Depending on each soil's mineral granulometric composition, state, hydro geological and climatic conditions soil has a tendency to be raised. This soil feature can be described as soil's upraising.
3. Soil's upraising depends on its origin, state, and hydro geological and climatic conditions. All these factors are essential for defining soil's upraising.
4. Natural observations and laboratory experiments showed that frost upraises soils that contains great amount of dust.
5. Clay soils' upraising highly depends on the mineral composition. Most susceptible to frost is kaolin clay.
6. Besides mineral composition, there are other factors that are highly influential to upraising. It is the amount of anther particles. Dusty dense soils' upraising is two times smaller than upraising of kaolin soils.
7. Soils, which do not have clay and dust, consisting of sand and larger particles are less susceptible to frost, even under adverse hydro geological and climatic conditions.
8. Soils' state is described by the fold, density, and moisture. These parameters are also important for soil's upraising.
9. Soil density influence to upraising is heavily dependent on hydro geological conditions. In an open irrigation system, the soil thickens and the upraising increases. In case where permafrost descent below underground water horizon, the soil is fluffier and the upraising is greater.
10. Soil moisture has particularly importance. Initial moisture has significance for soils that have tendency to upraise. Soil is upraised when moisture is higher than critical.
11. Depending on the underground water level position, there are three supplying systems: 1) closed; 2) opened; 3) oppressive.
12. The closed supply system is when underground water horizon is deep and does not affect freezing.
13. The open supply system is when underground water horizon is not deep and capillary moisture reach freezing front.
14. The oppression supply system is when freezing depth falls below the underground water level.

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Proceedings of 6th International Conference ITELMS'2011

Investigation of Formation Optical Structures with Electron Beam on Dielectric Background

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Abstract

The paper presents an investigation of formation optical structures with electron beam on dielectric background. Problem with dielectric background was resolved to covering polymer (PMMA) with silver layer.
KEY WORDS: *DOE (diffractive optical element), electron beam lithography*

1. Introduction

Diffractive optical elements are used in the laser technology for formation and decomposition the light beam. Also diffractive optical elements are used in solar elements, data protection tools, etc. They can be fabricated in a wide range of materials viz. aluminium, silicon, silica, plastics, etc. providing the user greater flexibility in selecting the material for a particular application [1]. We fabricated DOE from polymer (PMMA) layer on the quartz substrate. But the polymers are not sufficiently transparent (about 92%) and have low light resistance (200-400 MW/cm^2). Therefore, we need to fabricate DOE from quartz, witch transparency is about 99%. To create optical microstructures in PMMA, we used electron beam lithography to provide high resolution patterning. However, the effect of electron scattering in resist and substrate leads to an undesired influence in the regions adjacent to those exposed by the electron beam [2]. This effect is called the proximity effect [3]. Another problem is the dielectric background. Background for e-beam lithography has not to be dielectric, because electric charge accumulates. It needs to find the mode to take the charge away. Therefore, in this work we aimed to optimize the parameters of e-beam energy, dose, thickness of PMMA and also find the mode to take the charge away to receive correct diffractive optical structures.

2. Experimental

The first step in DOE fabrication is to make a pattern of PMMA on quartz plate. The 100 µm thickness plate of quartz was spin-coated with a 2 µm thickness polymer (PMMA) layer. Then the PMMA was coated with 5-20 nm thickness silver clusters by physical vapor deposition (PVD) method to take away the electric charge. These silver clusters did not obstruct e-beam lithography. Next step was to expose PMMA layer and then etch it with 1:3 MIBK:IPA (methyl isobutyl ketone and isopropanol) from 10 s to 1 min 10 s.

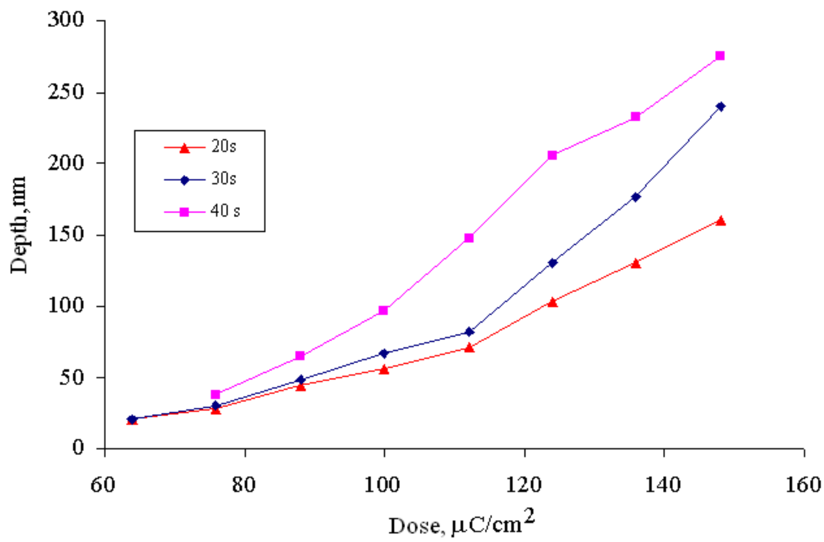

Fig. 1. Structure depth dependence on exposure dose with different etching time

Quartz plate was etched with parallel plate 300 mm diameter Advanced Vacuum Vission 320-RIE reactor with 13.56 MHz radio frequency (RF). Flow rate of etch gases, RF power and chamber pressure were stabilized during process. An anisotropic etching process based on CF4 gases was used for quartz etching. The etching experiments were performed at a flow rate of 25 sccm and a pressure of 20–100 mTorr. The RF power was varied from 100 W, which included a self-bias on the cathode of -170 V, to 300 W (self-bias -320 V).

Prepared samples were evaluated by scanning probe microscopy (Nanosurf EasyScan 2).

3. Results

For e-beam lithography we used 20 kV voltage, doses from 40 μC/cm^2 to 148 μC/cm^2, every 12 μC/cm^2. We got 11 squares with 0.8 μm sides. These results (Fig. 1) were used for DOE structure formation. Now we found that these doses are not compatible for stair structure formation because of proximity effect (Fig. 2).

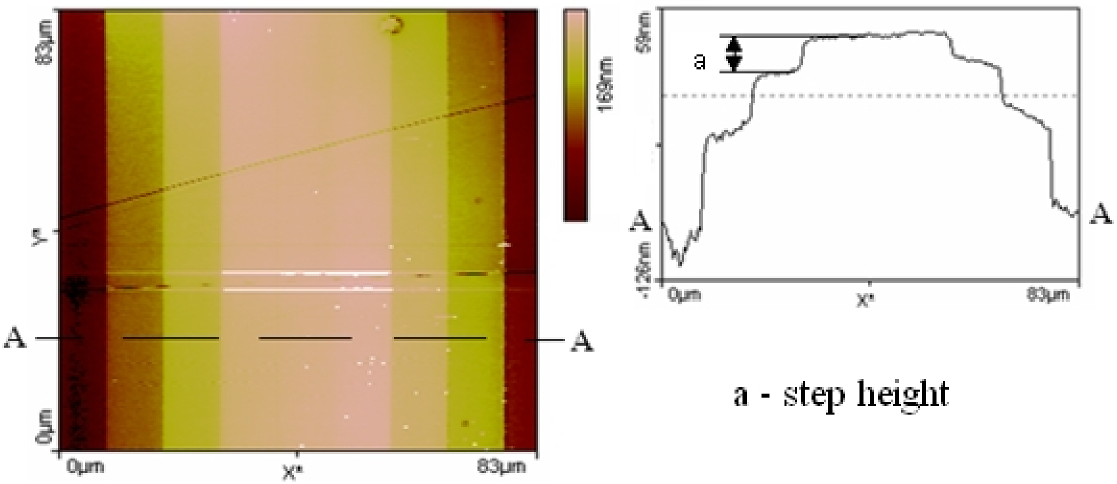

Fig. 2. Measurement of stair structure: each next step is bigger than expected, because of proximity effect

Next stage – the reactive ion etching, which the structure of PMMA transfer to the dielectric base. That the transfer to succeed requires the etching rate selectivity between quartz and resist would, as close to 1:1. On the quartz plate was formed groove through the entire thickness of the resist. Etching was performed at different pressure and power parameters. That to calculate the resist etching rate, groove depth measurements with the AFM were perform twice. The first measurement was immediately after the etching, the second - after cleaning resist. All samples etching time were 10 min.

Fig. 3 and 4 shows etch rates distribution of RF power and pressure respectively.

As can be seen from Fig. 3, there exist intersection point which show etch rate selectivity 1:1.

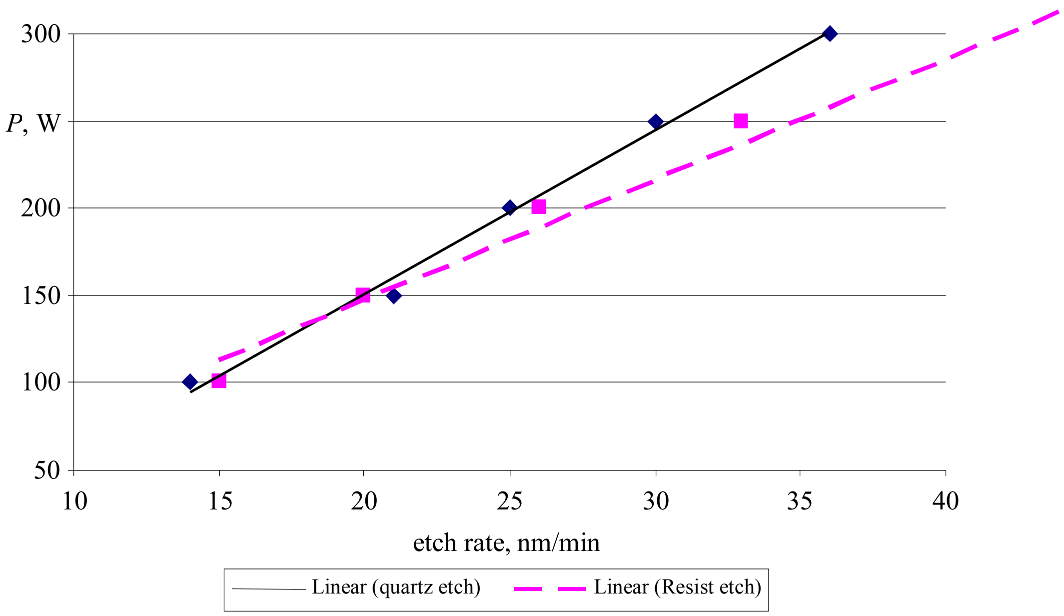

Fig. 3. Etch rate dependence on the plasma power (CF4=25 sccm, p = 40 mbar)

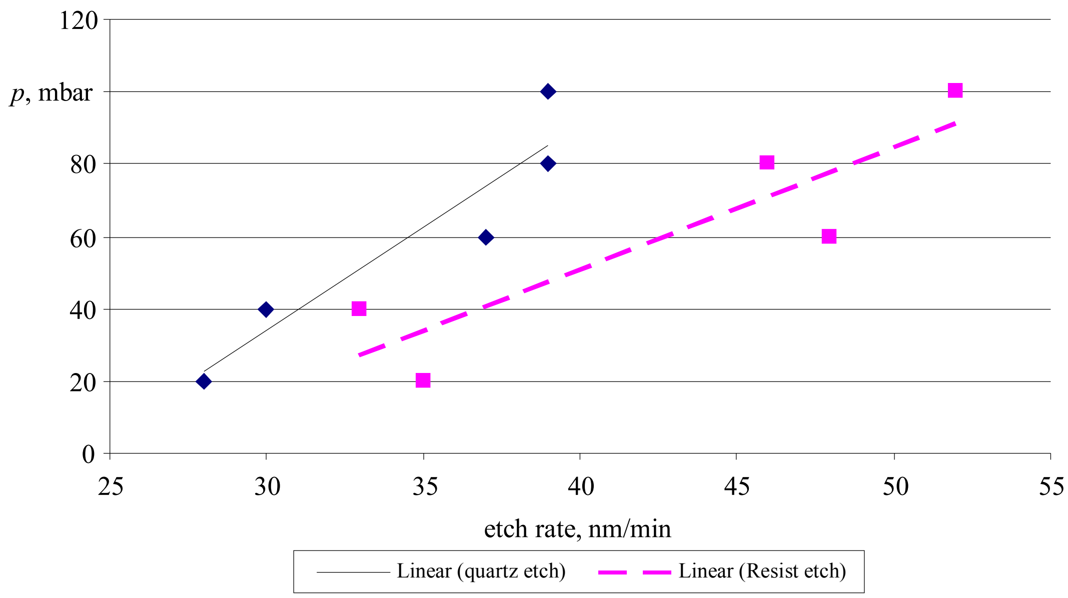

Fig. 4. Etch rate dependence on etching pressure (CF4=25 sccm, P=250 W)

4. Conclusions

E-beam intensity modulation parameters and polymer chemical treatment methods make it possible to obtain the required three-dimensional diffractive optical element profile with 10 - 20 nm (0.5 - 1%) accuracy. Silver coating layer on PMMA made possible to use the e-beam lithography to form PMMA structures on the dielectric ground.

We found a recipe when the etching rate selectivity between the resist and the quartz is 1:1.

Credits

Authors thank to Panevėžys Mechatronics Center for laboratory support and for providing necessary instrument time. This work was partly supported by the Lithuanian Science Council Student Research Fellowship Award to Inga Morkvėnaitė-Vilkončienė.

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Proceedings of 6th International Conference ITELMS'2011

Intelligent Applications in The Development of Sustainable Leadership in Statutory Organizations

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Abstract

The article focuses on the establishment of an infrastructure for sustainable leadership development needed for the statutory organizations. It expends a perception of traditional leadership development. Sustainable leadership development is not only about delivering a programme, making people go through a developmental experience. The development of sustainable leadership is some type of ad hoc that solves specific task and isn't generalizable. Therefore, the development process of sustainable leadership needs to be implemented in a systemic way, as development occurs over time and a single training event and pure study curriculum is not enough.

This paper proposes sustainable leadership development system (SLDS) guidance for military officers'. This proposal is based on best current practice in e-learning and involves intelligent applications for shared decision making in inter-organizational learning. Proposed SLDS employs computer-facilitated collaborative learning; which supports social interaction in intelligent collaborative learning system and sustains institutional work within a variety of decision-making frameworks.

From a technical perspective, we suggest that it is advisable to place a workflow engine at the core of the internet based e-decision making system. This will let to generate and manage personalized and adaptable individual recommendation assesses flows in organizational learning; during the processes of an individual recommendation culling grants the user access to subsequent databases of related resources and services. From a technical perspective the structure of SLDS could be kept comparatively simple and self-controlled in process of logic analysis. The functions and subsystems reside on a networked multilevel infrastructure with strong internet connectivity and a number of databases. . The internet portal systems could be used to provide different types of users by user's type specific and customized services. The databases are designed to collect and analyze data about a number of processes and entities: the tasks & scenarios database; peer review; learning database; computer supported collaborative learning (CSCL).
KEY WORDS: *multidimensional database***,** *computer supported collaborative learning, SLDS architecture.*

1. Introduction

The recent interest in technology-supported development of institutional competency in sustainability represents a convergence of trends. Majority of research and practice proposals lies in application of competence-building technologies. These proposals are based on best current practice in e-learning and involve IICTs for sharing decision making in inter-organizational settings [8]. The most advanced approach towards competence development is computer-facilitated collaborative learning. It supports social interaction in intelligent collaborative learning system and supports institutional work within a variety of frameworks.

The application of intelligent collaborative learning approach into the development of sustainability at statutory organizations brings not only new opportunities but also some new challenges. Firstly, the concept of sustainable leadership in business and institutions of public administration has been developed as an idea of absolute positivism; meanwhile in statutory organizations the development of a sustainable leadership idea is restricted because of the specific functions performed under extreme situations [8, 9]. As the leadership in military is associated with high flexibility versus control and high compatibility with organizational changes versus stability of the system, the objectives for the leadership praxis is changing constantly. Therefore there is a need to find some connections between the changing requirement of the military and institutional leadership development. Such dual situation requires additional in-depth research.

Secondly, the development of institutional sustainability by intelligent technologies requires for new approach in learning and developing process. Traditional e-learning platforms with common educational approaches need to be reconsidered. Current educational practice is based on youth education and is not designed according adults needs and capabilities. Meanwhile one of the most important elements in adults' development is an opportunity for participants to provide feedback and suggestions to other participants. In this view, knowledge-sharing by collaboration and peer-assessment are two main features in institutional competence development. As a solution for this challenging task we used intelligent collaborative system. Intelligent collaborative systems are a traditional area of research that investigates problems of developing intelligent knowledge-sharing systems. Other previous studied of collaborative learning covers mainly the topics on e-learning at educational institutions [10, 11].

Most of these studies employ in-class learning approach by adding few students' e-collaboration features. In an extension of previous studies, our report aims to present a solution for institutional sustainable development by involving a complex of combined tools and methods for communication. Our approach conveys practical interaction between leaders and allows them to collaborate in self-development. The detailed overview of the solutions and activities that deals with the development of sustainability in leadership are discusses in a broader way. Herewith the purpose of this report is to describe the evolution of application of intelligent technologies for the development of sustainable leadership in statutory organizations.

In the next section, we briefly review the literature on sustainability and a framework for sustainable leadership development that provides an empirical foundation for work on application of intelligent technologies.

2. Controversy of Sustainable Leadership in Statutory Organizations: the Challenge for Unified Concept in Institutional Learning

Statutory institutions (police, army etc.) are pressed by social and political environment to adopt and implement decisions based on priorities of sustainable development. At his process institutions are facing the problems of new management referred to as the lack of. This literature on sustainable leadership specifies two major trends. The first trend is represented by the conceptual or normative literature, stipulating the way of integrating sustainable development principles into the activity of statutory organizations [12, 13]. The second trend consists of the literature presenting the results of the empiric research. The major part of this literature pursues the case analysis (learned lessons) [14, 15]. However, the research lacks an in-depth analysis of an organizational behavior, whereas the examination of sustainable development opportunities does not include leadership that has major influence on the decision-making process since is part of the doctrine in these institutions.

The concept of sustainable leadership expands the idea of sustainable development. It boarders the perception of the relationship between an organization and its environment and reveals the coherence of the behavior of an organization itself, i.e. synchronization of internal and external operational principles of an organization [16].

The problem of coherence of operations in statutory organizations is even more important because of their specific functions and the need for specific management. The challenge is that the concept of sustainable leadership in business and public administration institutions has been developed as an idea of absolute positivism; meanwhile in statutory organizations the development of a sustainable leadership idea is restricted because of the specific nature of these organizations [17, 18].

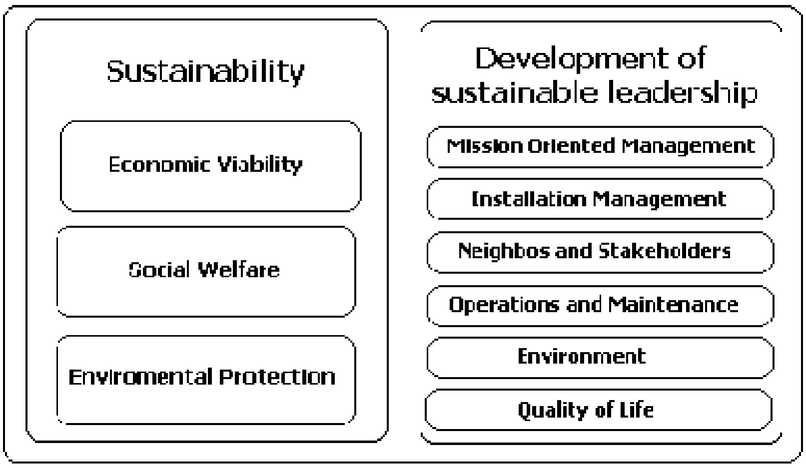

Fig. 1. The dimensions of sustainability and elements in development of sustainable leadership

Fig. 1 provides the interrelations between traditional approach towards sustainability and a development of sustainable leadership in statutory organizations. If we according to Kisson, we can found six categories of activities that describe the sustainability of an organization. These categories are (1) mission, (2) management, (3) stakeholders, (4) operations and maintenance, (5) environment, and (6) quality of life.

In the development of institutional competence for sustainable leadership, all categories transform into studies' curriculum. Accordingly, we created the platform for e-curriculum – the set of courses and their content. The effectiveness of e-curriculum depends on integration of practices and tools into a learning process. Simply providing stand-alone training or tools is not effective as the learning are. They are not reinforced or integrated into the overall training programme. Sustainable leadership development is not only about delivering a programme or administering a feedback tool or making people go through a developmental experience. Additionally, effective development ensures that such practices and tools are used consistently throughout the training. The development of sustainable leadership is some type of ad hoc that solves only specific task and isn't generalizable. Therefore, the development process needs to be implemented as a systemic way, as development occurs over time and a single training event and pure study curriculum is not enough.

In our case, we developed platform for effective sustainable leadership development that consists of many components that are integrated into a coherent system. Many leadership e-development systems combine only few of the leadership practices, but this system is connects people within whole organisation. The core of most development systems is the formal learning program, which serves as a shell under which a variety of practices can be introduced to address the desired training objectives. According to Kwee et. al. (2005) one method of making development more systematic is to design and implement an array of developmental experiences that are meaningfully integrated with one another [20]. As was stated in the introduction many researchers have advocated the need for a holistic approach to the process of leadership development. Hence, four-interacting elements were developed at the initiative stage of development system. (see fig. 2). The elements represents four stage process that was designed for intelligent computer supported learning application. The first stage is a preparation stage. It consists of tests and self-study preparation for participation in collaborative learning. The tests allows us to measure participants' competencies in sustainable leadership (more precisely - in sustainable decision making for sustainable institutional leadership) and to group the according to their capabilities. The stage is performed in self-learning and assessment space. After groups are composes, the first stage of the process is finished.

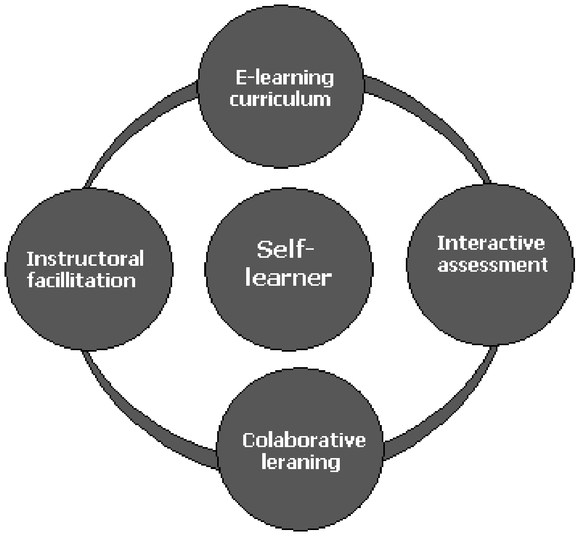

Fig. 2. Conceptual framework for sustainable leadership development system (SLDS)

The second stage consists of task selection and task performance. The task for the group is selected automatically, according to the group competence level. Group performs the task using step-by step approach. Simultaneously, group members are discussing and learning in communication and self-learning spaces. When the task is performed group activities are switched to assessment space. The third stage – communication – comes in parallel with the second. Group members are communicating (by discussing, suggesting, splitting into smaller groups, sharing the information, etc.) and at the same time performing the task (on task space). From the technical standpoint, this stage is most challenging and detail described in next section. The last stage consist of self and peer – evaluation.

3. The Architecture of Sustainable Leadership Development System

The effective leadership development resulted from the systematic design of LD practices and tools into a learning process. Simply providing stand-alone training or tools is not effective as the learning are not reinforced or integrated into the overall training programme. LD is not about delivering a programme or administering a feedback tool or making people go through a developmental experience. Instead, effective LD ensures that such LD practices and tools are used consistently throughout the training. LD should be implemented as a systemic process because development occurs over time and a single training event or programme is not sufficient.

Effective LD consists of many components that are thoughtfully integrated into a coherent system to develop the individual. Many LD initiatives combine two or more of the leadership practices, but these LD initiatives should be orchestrated throughout the whole organisation. The backbone of most leadership development systems is the formal program, which serves as a shell under which a variety of practices can be introduced to address the desired training objectives. McCauley et. al. (1998) suggested that one method of making LD more systematic be to design and implement an array of developmental experiences that are meaningfully integrated with one another.

The first step to this ambition aim is to create the architecture, which will let realize all goals of sustainable leadership development system [1, 2]. The architecture, which allows us: (1) to systematically integrate all existing information that is already collected through the last years; (2) to add new information by even four groups of system stakeholders: system administrator, system developers, system experts and consumers; (3) to create internet delivery infrastructure.

Application of SLDS can be interpreted as a flow of subsequent reclaim of experience that leads the individual person to a level of knowledge and competency. SLDS helps in solving such challenging question as how to increase the military experience. The brainstorming on challenging ideas that we presented above and potential of contemporary IT provided us with new possibilities (Fig.3):

1. Possibility to get in touch with sustainable leadership development system server in remote mode;
2. The databases constantly are up to date with new and actual information;
3. The users can connect at any time to the databases and receive expertise support for his decision;
4. There is the possibility of multi-user connection at the same time.

All this possibilities ensure the simplicity of providing individualized decisions, which includes the analysis of current situation in constantly changing economical conditions. All system is designed to take the individual recommendation how to start a new business or how to find the companions for new business.

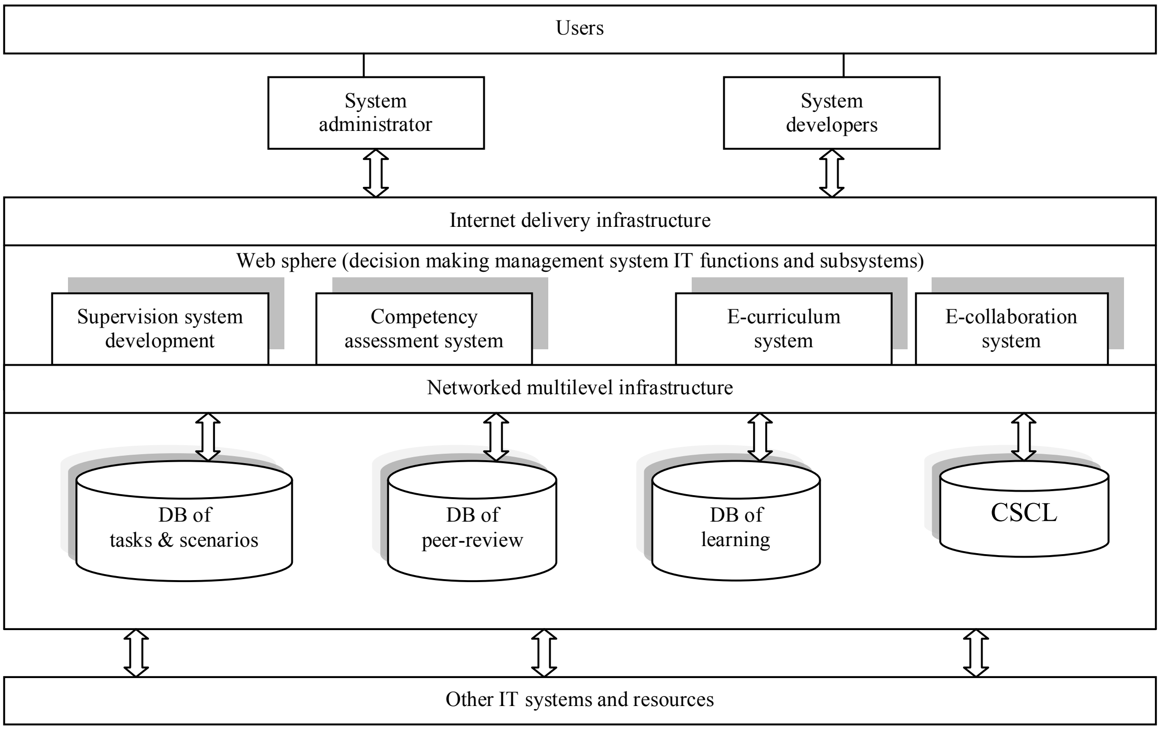

Fig. 3. The management of functions and subsystems information of the framework

Sustainable leadership development system in accordance with input date (hobbies, activities, individual experiences, competence) culls necessary steps such as multilayer tests. The SLDS proceeds in manner when consumer is registered and tested; he is integrated in the date base of system and all date are saving.

From a technical perspective we suggest that it is advisable to place a workflow engine at the core of the internet based e-decision making system [2, 4, 5]. This will let to generate or manage personalized and adaptable individual recommendation development assesses flows and during the processes of an individual recommendation culling – grants the consumer access to subsequent databases of related resources or services. From a technical perspective, the structure of sustainable leadership development system could be kept comparatively simple and self-controlled in process of logic analysis. Figure 3 outlines SLDS functions and subsystems.

The functions and subsystems reside on a networked multilevel infrastructure with strong internet connectivity and a number of databases [5]. The internet portal systems could be used to provide different types of users by user's type specific and customized services. The databases are designed to collect data about a number of processes and entities:

- The tasks & scenarios database – the consumer's readiness for the intended personalized integrating process needs to be evaluated; therefore, his present knowledge and competency has to be evaluated and compared to his objective. The knowledge and competency have to be separated into standard role based competencies and associated knowledge requirements or patterns of behavior [2].
- Peer review database – contains peer assessment information, the individual user profiles, privileges, and data of the user's private information have to be stored. In addition, this database contains personal curriculums, testing results, and individual developing recommendations. The individuals take into account the quantity and quality of their own product or performance in peer assessment. The aim of self and peer assessments is to improve officer's competency to leard the team, and develop individual skills as well as grading individual outcomes.

- Learning database – this database contains the private environments data about user's progress history, and about his qualification. In addition, the assessment objects including their metadata are stored in this db. These objects or "unit of tests" could be structured according to the proposed implementation concept and contain metadata (title, subtitle, creator, description, copyright, study-load), roles (system consumer, system expert), activities objectives, prerequisites, content (steps forward, environment – including knowledge object, announcement object, role information object etc.), method (steps forward structure, conditions). Therefore, knowledge and competency generating sustainable leadership development system and the respective testing modules are assigned to this database [6].
- Computer supported collaborative learning (CSCL) – workflow systems usually use databases for the general definition of workflows (workflow templates) and databases, which contain actual instances or workflow histories. The assessment tools utilized in CSCL are used to measure groups' knowledge of the collaborative processes, the quality of group's products and individual's collaborative learning skills.

The structure of SLDS is very sophisticated. The multiplex date base system always gears up, so we must elaborate the system environment and structure. The important task is to create the Administrator subsystem, which leads to simplicity and integration of administration and author's subsystems to one application [7].

4. The individual recommendation for development assesses flow algorithm

The individual development recommendation assesses flow algorithm schema of sustainable leadership development system, presented in blocs for test program of individually progress recommendation extraction (fig. 4), was expanded by deep analyzing of get results and constructed to draw the individual recommendation for tested participant [2, 4, 5]. Equally, we might say, that Figure 4 shows a steps forward assess flow, which matches the ideas to support conditions in the sustainable leadership development starter's environment process.

The algorithm starts at the "Start-registration" field, which traditionally is constructed for main guidelines: at first let us to indicate the tested person after finishing all testing, at the second the test program is designed to present the scores for everybody, who started the registration. The first bloc is constructed for the self containment as process logic and analysis of consumer objectives. There are determining learning objectives and prerequisites for consumer progress.

After preliminary tasks evaluation the second bloc task is to evaluate the tested persons and to send them to 4-th bloc. The 2-th bloc results influence on other algorithm steps. The program user can be sent from "level 1-th" (bloc 3-th) directly to the "level 2-th" (bloc 4-th) or to "individual phase" (bloc 5-th). The "individual phase improves and develops individual skills as well as grading individual outcomes.

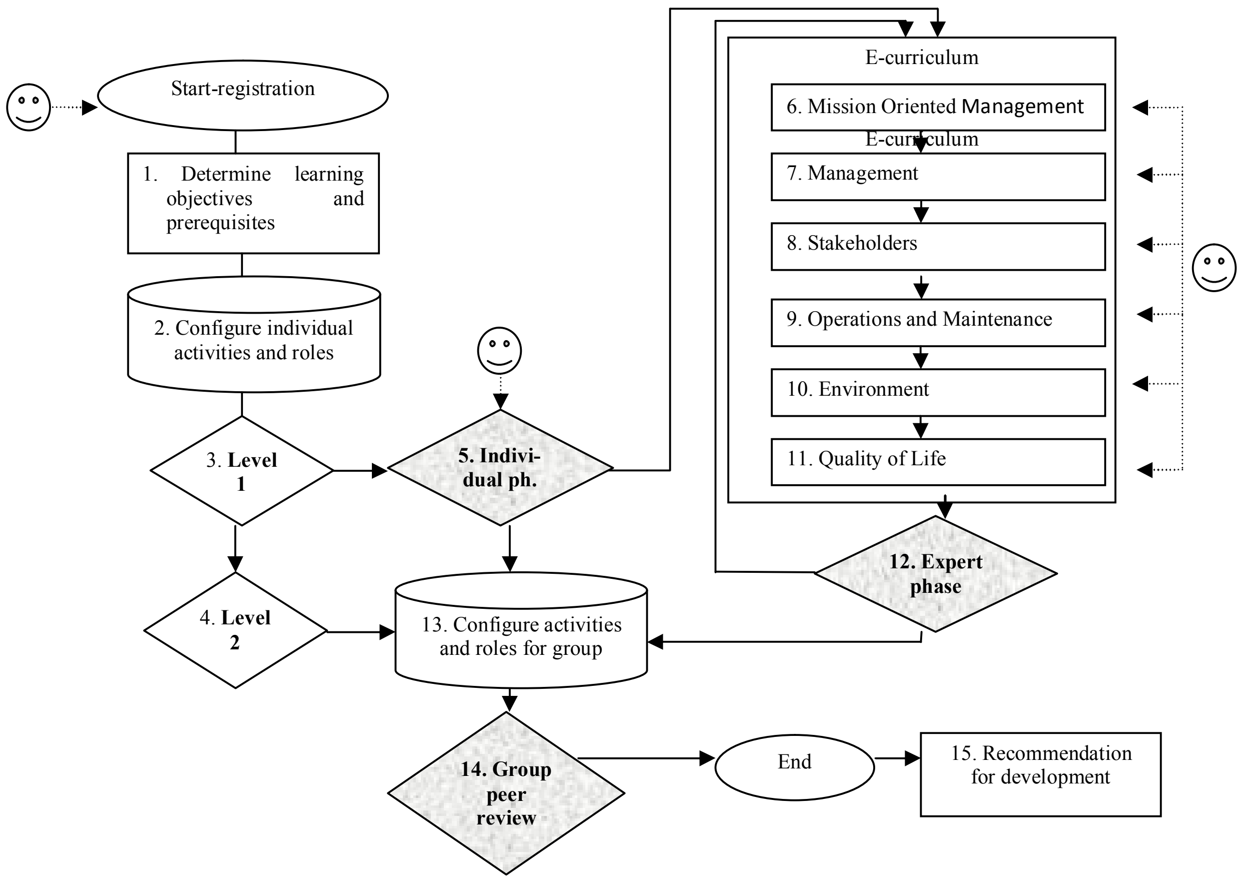

Fig. 4. The individual recommendation assesses flow in the decision support system

There are many tests, that can inform user about the get scores of tested factors, but to solve the problem in this easy way nowadays is not popular. Therefore, for constructing the not ambiguity conclusion in this test algorithm was realized multiplex intellectual task solving schema with the direct work of user and test program and expert. This function is marked as the dotted lines, which including blocs from 6-th to 11-th and the 12-th. The experts (12-th bloc) can use discourse analysis to assess the officer's progress of the collaborative process itself. The expert can make use of the dialogue to look for cues of collaboration: support and respect in their criticisms, consideration of other teammates' opinions, negotiation of meaning, demonstration of mutual understanding, achievement of consensus, problem-solving, and time and task management issues. As proficiency develops in progressive stages, the expert can design the assessment to account for the officer's developing competence in progressive steps throughout the online collaborative process.

As you can see in the Figure 4, this algorithm is realized multiplex intellectual task solving schema for two levels developing. The second level is designed in 4-th, 13-th and 14-th blocs. Group work assessment measures the quantity and quality of officer's working as a team. Group work or teamwork is a collaborative learning situation in which users share the task of developing a product presented at the end of the course. Group work is not measured and interpreted independently but evaluated with other assessment tools, and plays a role in assisting learners' to reflect on their learning process. One way to foster teamwork is to engage the members in activities that require them to work together.

After consumers analyzing is done, person can make the decision by getting automated recommendations (bloc 15-th) or can ask for help from experts. This possibility is intended in the SLDS architecture, because there is not only a need to choose the higher level of development, but also to integrate officers into sustainable leadership.

5. Conclusions

In our case, we developed platform for effective sustainable leadership development that consists of divers components that are integrated into a coherent system. Especial attention was given to the peculiarities of sustainability issues in statutory organizations. There are six categories of activities that describe the sustainability of a statutory organization: (1) mission, (2) management, (3) stakeholders, (4) operations and maintenance, (5) environment, and (6) quality of life. According to these categories, organizational leadership e-development system was created. Majorities of leadership e-development systems combine only few leadership practices; whereas proposed system connects people within whole organisation. The core of the systems is the formal learning curriculum, which serves as a shell under which a variety of practices can be introduced to address the desired training objectives. Such complex solution was accomplished with advanced IT methods. In order to improve the quality of individual and team decisions making in statutory organizations, formal SLDS was developed.

The first step in developing the SLDS was architecture design. The architecture allows us: (1) to systematically integrate all existing information that is already collected through the last years; (2) to add new information by even four groups of system stakeholders: system administrator, system developers, system experts and consumers; (3) to create internet delivery infrastructure. SLDS in accordance with input date culls necessary steps such as multilayer tests. The functions and subsystems reside on a networked multilevel infrastructure with strong internet connectivity and a number of databases. The internet portal systems could be used to provide different types of users by user's type specific and customized services. The databases are designed to collect data about a number of processes and entities. The multiplex date base system always gears up, so there is a need to elaborate the system environment and structure. The important task is to create the Administrator subsystem, which leads to simplicity and integration of administration and author's subsystems to one application. From a technical perspective, the structure of sustainable leadership development system could be kept comparatively simple and self-controlled in process of logic analysis.

The individual development recommendation assesses flow algorithm schema of SLDS, was presented in blocs for test program. Deep analyzing of get results expanded the individual progress recommendation extraction. In addition, this algorithm constructed as two interconnected levels, which can to draw the individual recommendation for tested participant. The first level is constructed for the self-containment as process logic and analysis of consumer skills to lead; the second level analyses peer-evaluations, and also evaluates individual's overall motivation to apply their knowledge in a variety of learning situations; the system is designed in the way that allows to take advantage of the fact that individuals have different learning styles.

This sustainable leadership development approach seeks to develop the organizational competence in sustainable leadership. Such competence is needed for today's statutory institutions that are pressed by social and political environment to adopt and implement decisions based on priorities of sustainable development.

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Proceedings of 6th International Conference ITELMS'2011

Two Storage Strategies Analysis of New Cylindrical Automated Storage/Retrieval System

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Abstract

The purpose of this research is to propose a new type of cylindrical automated storage and retrieval system, which can be used for load storage and sequencing. The design concept and principles used in this system are similar to round multi-storey car park systems, but the system is designed to transport loads which are less than a pallet. This paper describes system structure, comparison analysis of two storage strategies using simulation modelling techniques and statistical analysis methods as well as introduces the further research steps for cylindrical AS/RS.
KEY WORDS: *cylindrical automated storage/retrieval system, automated warehouse, logistics, simulation.*

1. Introduction

The warehouse automation greatly enhances the material handling operations resulting in a significant reduction in labour costs and increased system performance. However, the performance is highly influenced by the equipment technical parameters, control algorithms and there are some difficult problems to be solved, such as order sequencing, resource control in the picking process, generating an order picking sequence for each stacker crane, replenishment planning, etc [1, 2].

Order picking process management and optimization remains a largely unresolved problem, which requires much more research to be done [3, 4]. This paper proposes the cylindrical automated storage and retrieval system (AS/RS), which aim is to improve the performance of the order picking process. The cylindrical AS/RS serves as a small storage buffer and a sequencer in the order picking system and consist of the octagonal shape rack and the elevator which is located in the middle and contains a number of independent load handling devices. The design concept and principles used in this system are similar to round multi-storey car park systems [5], but the system is designed to transport loads which are less than a pallet.

Development of analytical models for cylindrical AS/RS would be complicated due to the complexity of the elevator control strategies, thus the simulation techniques have to be used. Simulation modeling techniques and independent samples t-test were used in this research to investigate the performance of the system storage operation applying two different elevator control strategies. For simulation model development and experiments, the Automod software [6] was used, which was integrated with the statistical analysis software SPSS [7] for result analysis.

2. System application, structure and operation

The purpose of the cylindrical AS/RS is to provide a temporary storage buffer in the order picking system and have direct connections to the picking process so that required loads are delivered to the operator in the minimum amount of time. Fig. 1 shows typical application of the cylindrical AS/RS in the order picking and sequencing system of less than the pallet load (cartons, trays, plastic boxes etc.).

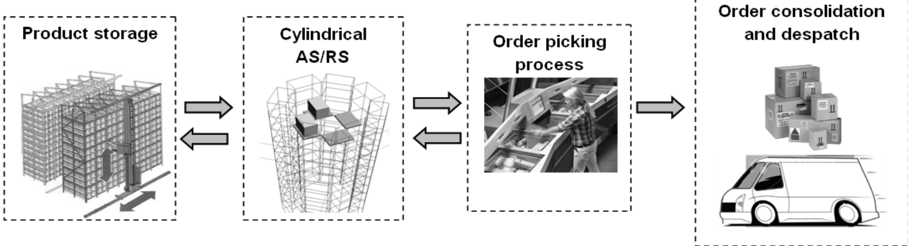
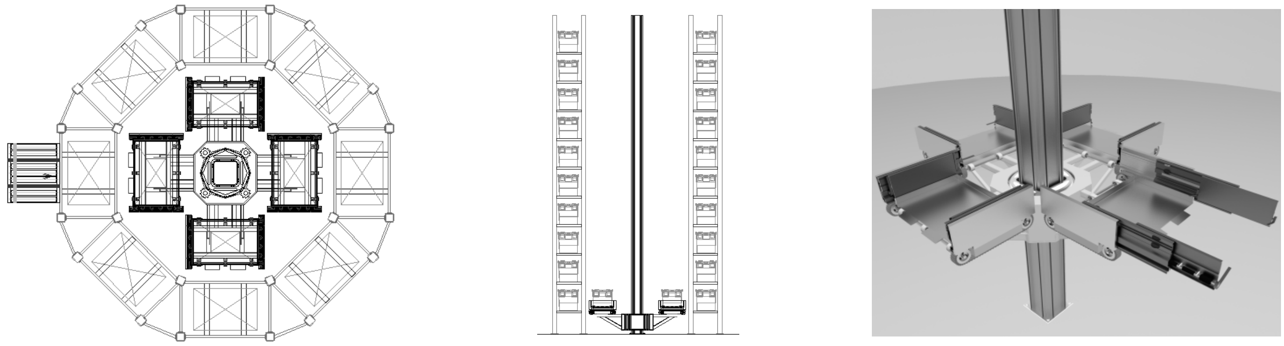


Fig. 1 Typical application example of the cylindrical AS/RS

Cylindrical AS/RS receive products which are required for the currently open orders in the picking from the product storage area (eg. Mini-load AS/RS storage) and stores them in the temporary buffer. When products are required in the picking process, the cylindrical AS/RS sequence them in the right order and sends to the operator. After product picks are completed, the product load returns to the sequencer and if it is required in the picking after relatively small amount of time, it is put in the temporary storage buffer, otherwise it returns to the initial product storage. After all product picks for the order are completed, the order is consolidated and despatched.

As illustrated in Fig. 2, the cylindrical AS/RS consist of the cylindrical octagonal shape rack and the elevator, which is located in the middle and contains a number of independent load handling devices (LHDs).



a b c

Fig. 2 Cylindrical AS/RS structure: a – top view; b – side view; c – elevator visualization

The cylindrical AS/RS elevator is able to move in vertical direction (upwards/downwards) as well as rotate the set of LHDs in any direction (clockwise/counter-clockwise) and it also can perform both moves simultaneously. All LHDs operate as a single elevator unit and any of them can access any storage location in the rack by doing a set of travel and rotation moves.

The operation of the cylindrical AS/RS can be described by specifying storage and retrieval cycles. The typical storage cycle:

1. If the elevator is not located at the infeed level, it travels to that level. Before travelling to the infeed level, the elevator starts to rotate to the position which will allow picking the maximum number of the storage loads at the infeed level simultaneously.
2. Elevator arrives to the infeed level and picks the maximum number of loads for the current position simultaneously.
3. After performing a single pick, elevator checks for available capacity and rotates the elevator in the required position to maximize the simultaneous picks. Depending on the control strategy, the elevator can replicate the Step 3 until all LHDs are occupied or can proceed to storage after a defined amount of rotations.
4. Elevator travels to the storage location of each onboard load and transfers it off the LHD. Each storage operation will contain a number of travel and rotation moves.

Steps for the typical retrieval cycle can be defined as following:

1. Elevator starts moving from the dwell point state to the location of the retrieval request. Before travelling to the retrieval location, elevator starts to rotate to the position which will allow picking the maximum number of the retrieval loads at the same level simultaneously.
2. Elevator arrives to the destination level and picks the maximum number of loads for the current position simultaneously. Elevator continues the Steps 1 and 2 until all LHDs are occupied with retrieval loads or it proceeds to the outfeed level after defined amount of picks.
3. Elevator travels to the outfeed level and transfers loads of the elevator in the specified sequence, which is determined by the order picking process. Every load transfer off the elevator might require rotation move and elevator continues Step 3 until all LHDs are empty.

The cylindrical AS/RS elevator proposes the following improvements compared to standard AS/RS crane:

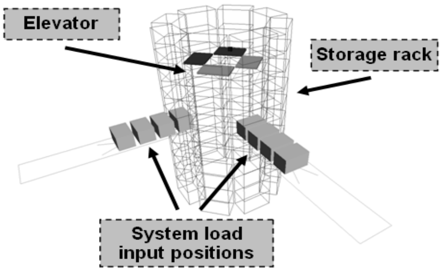
- Elevator has 4 independent LHDs which are able to transfer up to 4 loads on/off the elevator simultaneously.
- The number of infeed/outfeed points is not limited in this system and can be located in any location of the rack.
- In a certain system configurations, the elevator is able to transfer off and transfer on a number of loads simultaneously at the infeed/outfeed level.

This research investigates only two storage operation strategies of the cylindrical AS/RS.

3. Simulation model

A simulation model of cylindrical AS/RS is essential in order to investigate system performance for different equipment parameters, control algorithms and utilization. System considered in this research contains the following objects: 2 system load input positions, 1 elevator with 4 independently operated LHDs and rack with 80 storage locations (10 levels, 8 locations per level).

The simulation model was build using AutoMod software that provides true-to-scale 3-D simulation of manufacturing and distribution operations. This simulation tool can model complex manufacturing and automation systems, whether they are in operation or planning stages and enables to detect potential bottlenecks, optimize system performance through experimentation and “what-if” scenarios, verifies if system will work as designed, etc.



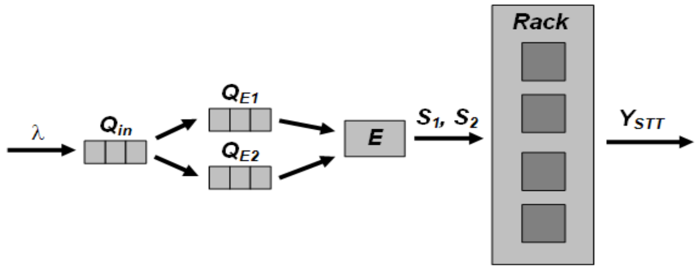


Fig. 3 Cylindrical AS/RS simulation model: a – graphical visualization; b – flow diagram

Fig. 3 shows the simulation model of the investigated cylindrical AS/RS with the following parameters:

- λ – average system load input rate (loads/h) - interarrival times between loads have the exponential distribution,
- Q_{In} – input queue with infinity capacity, where the storage load enters system,
- Q_{InEi} – queues before the elevator, where loads wait until being picked by the elevator, i = 1,2,
- E – elevator resource, which can achieve the maximum vertical speed 3 m/s (acceleration – 4 m/s^2), maximum rotation speed 30 deg/s (acceleration – 60 deg/s^2) and transports up to 4 loads at a time.

Loads arrive to the cylindrical AS/RS system from the external storage system in the warehouse and are put to the input queue Q_{in} before they get into system input positions. If the required system input conveyor queue Q_{InEi} has enough remaining capacity, the load is put on the conveyor and travels to elevator, otherwise it stays in queue Q_{in}. At the end of the system input conveyor load is assigned a destination level x_i and storage location y_j in the level x_i using discrete uniform distribution. The load claims elevator resource and waits for the pickup. Elevator picks up a load and transports it to destination level x_i and storage location y_j and completes the storage operation. Elevator handles storage requests using FIFO rule.

For each storage operation, cylindrical AS/RS is always performing a number of vertical and rotation moves. This paper investigates the following storage strategies:

- S_1 – the amount of vertical travel is minimized. Before selecting a next storage transport, the elevator always tries to choose the one which requires minimum vertical travel.
- S_2 – the amount of rotations is minimized. Before selecting a next storage transport, the elevator always tries to choose the one which requires minimum rotation amount.

The following performance measures of the cylindrical AS/RS are considered in this research:

- Y_{STT} – time of the storage operation of each load (s) – time interval from load entering queue Q_{in} to being put to the rack location,
- Y_{ECT} – elevator cycle time (s) - time interval from elevator picking loads at infeed level to storing them in the rack locations,
- Y_{UE} – elevator utilization factor – proportion of time the elevator was performing a movement of any type,
- Y_{EE} – elevator efficiency – the number of loads elevator transported to storage locations per single storage cycle.

4. Experimental results

System simulation results were analysed with SPSS software. Table 1 shows descriptive statistics for the performance measures for all investigated system load input rates $\lambda \in$(350, 400,450, 500, 550, 600) loads/h and indicate that the average storage operation time (Y_{STT}) was smaller for the S_2 storage strategy and the difference varied from 2.4% to 21.2% compared to strategy S_1. The smallest difference between the average storage operation time (Y_{STT}) for storage strategies S_1 and S_2 was achieved for λ = 350 loads/h, the average elevator utilization factor (Y_{UE}) was 0.66 – 0.67 and it transported 1.34 – 1.37 loads per storage cycle on average (Y_{EE}). The largest difference between the average storage operation time (Y_{STT}) for storage strategies S_1 and S_2 was achieved for λ = 600 loads/h, the average elevator utilization factor was 0.95 and it transported 3.10 – 3.22 loads per storage cycle on average (see Table 1). Similarly results were obtained for the average elevator cycle time (Y_{ECT}), which is correlated to the Y_{STT} (see Table 1).

The independent samples t-test is used to compare the difference in the means of the average storage operation time (Y_{STT}) for storage strategies S_1 and S_2 and for different system load input rates. The null hypothesis about the difference between the two means was tested and 95% confidence intervals were calculated. Results are presented in Table 2 and Fig. 4, and conclude that the difference between the average storage operation time (Y_{STT}) for storage strategies S_1 and S_2 for all experiments are statistically significant (all p-values < 0.01). For example, for system load input rate λ = 500 loads/h, the 95% confidence interval of the difference between the average storage operation time (Y_{STT}) for storage strategies S_1 and S_2 is (1.967; 3.843).

Fig. 4 represents the 95% confidence intervals of average storage operation time Y_{STT} and average elevator cycle time Y_{ECT} for storage strategies S_1 and S_2 and different system load input rates λ.

Table 1

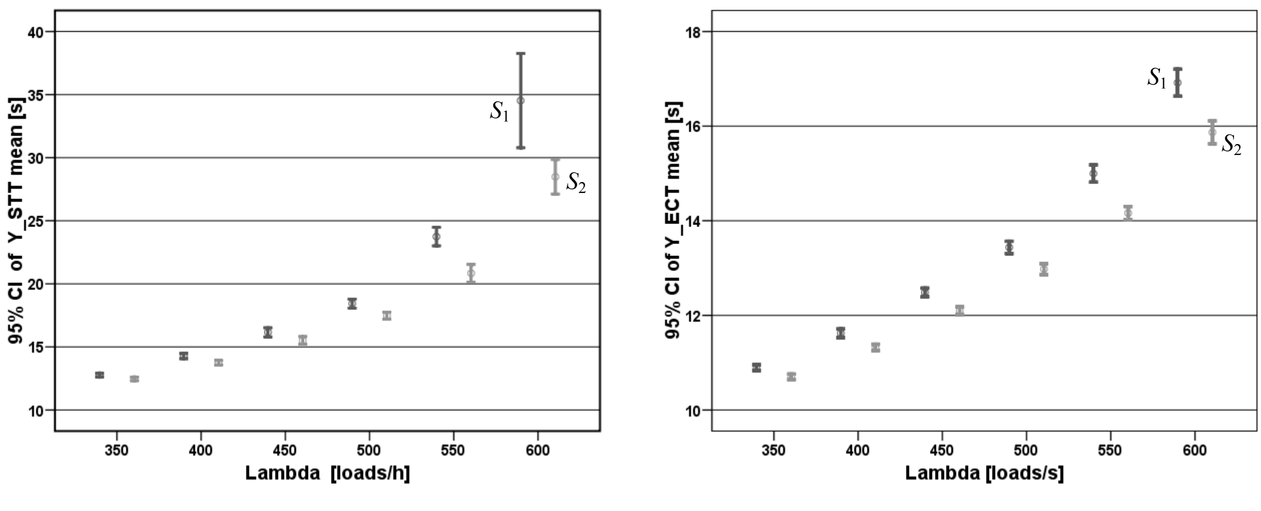
Descriptive statistics of simulation results

λ, loads/s	Y_{STT}				Y_{ECT}				Y_{UE}		Y_{EE}	
	S_1	S_2	Diff	Total	S_1	S_2	Diff	Total	S_1	S_2	S_1	S_2
	Mean				Mean				Mean		Mean	
350	12.76	12.46	2.4%	12.61	10.89	10.70	1.8%	10.79	0.66	0.67	1.36	1.34
400	14.27	13.75	3.8%	14.01	11.62	11.32	2.6%	11.47	0.75	0.74	1.67	1.63
450	16.16	15.51	4.2%	15.83	12.48	12.10	3.2%	12.29	0.81	0.80	2.00	1.95
500	18.43	17.47	5.5%	17.95	13.43	12.97	3.5%	13.20	0.86	0.85	2.33	2.28
550	23.74	20.83	13.9%	22.29	14.99	14.16	5.9%	14.58	0.91	0.90	2.77	2.66
600	34.52	28.48	21.2%	31.50	16.91	15.86	6.6%	16.39	0.95	0.95	3.22	3.10

Table 2

Independent-samples t tests and 95% confidence intervals of the difference between the average storage operation time (Y_{STT}) for storage strategies S_1 and S_2 for different average system load input rates λ, loads/h

λ, loads/s	Levene's test for equality of variances		Independent samples t-test for equality of means					
	F	p-value.	t	p-value	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Upper	Lower
350	0.203	0.657	3.48	0.003	0.302	0.086	0.119	0.484
400	0.253	0.621	4.37	0.000	0.522	0.119	0.271	0.773
450	0.111	0.743	3.11	0.006	0.649	0.208	0.210	1.087
500	0.404	0.533	4.68	0.000	0.956	0.204	0.526	1.385
550	0.032	0.861	6.51	0.000	2.905	0.445	1.967	3.843
600	9.120	0.007	3.43	0.005	6.036	1.757	2.182	9.899



a b

Fig. 4. Confidence intervals of average storage operation time: a – 95% confidence intervals of average storage operation time Y_{STT} for storage strategies S_1 and S_2 and different system load input rates λ; b – 95% confidence intervals of average elevator cycle time Y_{ECT} for storage strategies S_1 and S_2 and different system load input rates λ

5. Conclusions and further research

This paper proposed the cylindrical automated storage and retrieval system, which is designed to improve the performance of the order picking process. By using Automod software, the simulation model of cylindrical AS/RS was developed, which allowed testing the effects on the system's performance for different storage strategies.

Independent samples t-test was applied to compare the difference in the means of the average storage operation time (Y_{STT}) for storage strategies S_1 and S_2 and for different system load input rates. Results showed that the difference between the means of Y_{STT} for different storage strategies increases as the system load input rate increases and all differences are statistically significant ($p < 0.01$). 95% confidence intervals of the difference of Y_{STT} means were also calculated.

The current research on cylindrical AS/RS provides the introduction into the investigation of this system. The next valuable step is to add the retrieval operation and investigate the overall system performance, when both storage and retrieval operations are active. The further step is to compare this system to the existing alternatives and provide the evaluation.

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Proceedings of 6th International Conference ITELMS'2011

Algorithm for Increasing Traffic Capacity of Level-Crossing Using Scheduling Theory

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Abstract

In this paper authors present heuristics algorithm for level-crossing traffic capacity increasing. The genetic algorithm is proposed for this task solution. To create control centre and installed embedded intelligent devices on railway vehicles are proposed to control its motion speed and operate with level-crossing barriers. Algorithm is tested using computer. Results of experiments show big promises for rail transport schedule fulfilment and level-crossing traffic capacity increasing using proposed algorithm.
KEYWORDS: *genetic algorithm, intelligent transport system, level-crossing control, rail transport.*

1. Introduction

Nowadays in cities number of vehicles is increasing day by day. Traffic jams are the main reason for a lot of problems for public transport like delays, inefficient usage of energy etc. Fulfillment of the schedule in such conditions is unforeseen and service level of public transport is going down. In cities, where mixing the road and rail transport, is often to seen conflicts between these types of transport. Road transport is forced to wait at the closed level crossing while the train goes pass level crossing. This downtime negative impact on urban transport and is a one of the source of public transport delays. In Riga such a conflict place for many years is Sarkandaugava's level crossing, between the stations Mangali and Sarkandaugava. Morally and physically outdated equipment and methods are still used to control this level crossing. Since this railway line are busy with passengers and rolling stocks transport, traffic jams in this part of city is significant and the current situation is disaffecting as for Railway Company, for City council as well.

On the one hand the city traffic requests to ensure a continuous traffic flow on the streets, on the other hand rail transport have to ensure passengers and cargo in accordance with the schedule. Since the movement of these various transport systems organized by various organizations, in practice possible often conflicts, which mode of transport should be the priority? Therefore some solutions to fulfill the schedule are necessary. There are some different ways to reach the goal.

The first possible solution is to organize railway transport flow at night, when the road transport unit's amount has fallen to a minimum. This method is not acceptable, since rail transport should be followed the schedule.

Another solution is to build a bridge over railway, but this project implementation will take lot of time and resources. Therefore this solution increase expenses of City council and railway transport companies and this project not to confirm in current economical situation.

In previous papers authors proposed several solutions such as optimal speed and schedule control [8][9] and "green wave" [10], which allows the transport units to switch the traffic lights and transport units moving on the route without any additional braking on the traffic lights, thereby taking into account the schedule.

In this paper new improved algorithm for rail-crossing capacity increasing and schedule completion [3] is proposed.

Optimal train traffic organization on the given rail line is very important to reduce vehicle standby time, i.e. increase the level crossing capacity. The existing control system analyzing shows, that the level crossing is closed before the deadline, required by the security rules. Analysis of timetable shows, that according the existing schedule the trains, going in opposite directions, passing through the rail-crossing one by one. Due to this lack the level-crossing total time in a closed position is longer than might be.

2. Problem formulation

Following hypothesis is run for problem solving: the existing schedule adjustment could reduce the level-crossing time position in a closed position.

If railway transport units moving on the route appropriate optimal schedule this could decrease city transport standby time on railroad crossing, increase railroad crossing traffic capacity, eliminate often braking and acceleration, finally save energy [12].

The purpose of this research is to create algorithm for rail transport moving control on the route according predefined schedule.

Object of research is the city and rail transport system.

Main tasks of research are:

- to define structure of rail transport with built-in intelligent devices;
- to create mathematical model for existing control system;

- to develop algorithm for schedule fulfilment for rail transport;
- to create computer model of proposed system.

Proposed rail transport control system consists of control centre, trains and level-crossings with built-in intelligent devices as shown in Fig.1. Control centre receive signals from each railway transport units about current location, moving speed and other parameters, according predefined schedule, data and algorithms control centre calculate and send through GSM transmitter relevant signals to each transport units about optimal moving speed and for each level-crossing closing units about optimal closing and opening time.

The fragment of existing railway transport movement schedule is shown in Fig.2.

This scheme describes correlations between movement timetable and object location. Level-crossing location in this scheme is market as line “level-crossing”. As can be seen in time area A, railway transport units numbered as 6108 and 6109 moving in different directions cross the rail-crossing one by one.

Such a motion algorithm is reason for irrationally waste of time. Judging from the scheme as soon as the passengers train No.6108 has crossed the level-crossing and it could be opened, from the other direction is already approaching passenger train No.6109 and the level-crossing barrier must be closed again. No car or truck can cross the level-crossing and traffic jam on this point only increasing. Level-crossing barrier total time staying in close position graphically could be expressed as shown in Fig.3.

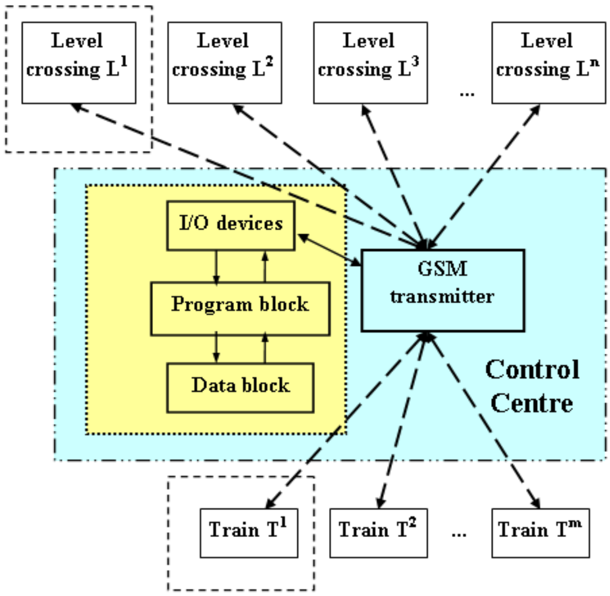

Fig. 1. Rail transport system control scheme

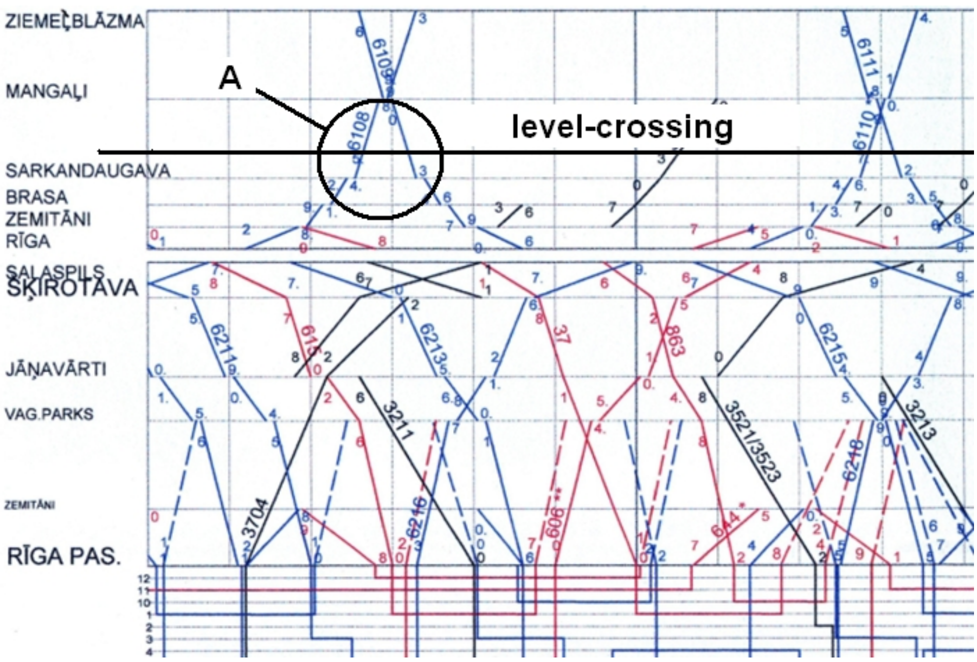

Fig. 2. Existing railway transport movement schedule

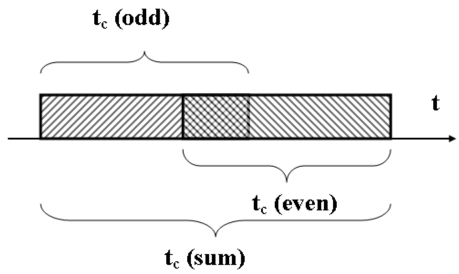

Fig. 3. Level-crossing barrier total time staying in close position

As can be seen from this scheme barrier staying in close position total time $t_c(sum)$ for couple of railway transport units is expressed as following:

$$t_c(sum) = t_c(odd) + t_c(even)$$

One of the scheduling theory methods for total schedule fulfillment decreasing is timetable rearrangement method. In case of railway transport it means to change departure time from previous station. Since train in odd direction arrive in level-crossing area little later or/and train in even direction arrive in level crossing area little earlier, the result of such timetable rearrangement could significantly decrease barrier staying in closed position total time as shown in Fig.4.

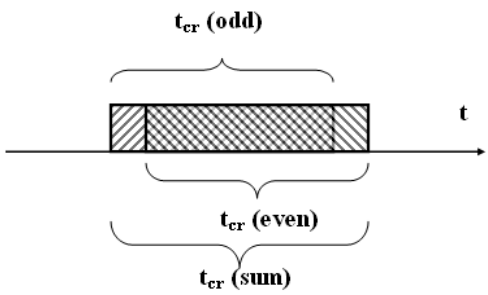

Fig. 4. Level-crossing barrier total time staying in close position for rearranged timetable

In case of rearranged timetable total time t_{cr}(sum) is expressed as following:

$$t_{cr}(odd) + t_{cr}(even) = t_{cr}(sum) < t_c(sum)$$

3. Mathematical model for algorithm

Following objects are given:
$ST = \{ST_1, ST_2, \ldots, ST_k\}$ is set of stations;
$LC = \{LC_1, LC_2, \ldots, LC_m\}$ is set of level crossings, where each level crossing is between two stations ST_i and ST_j;
$RS = \{RS_1, RS_2, \ldots, RS_n\}$ is set of rolling stocks;
$SCH = \{Td_{ST}^{RS_1}, Td_{ST}^{RS_2}, \ldots, Td_{ST}^{RS_n}\}$ is set of scheduled departure time for each rolling stock at the station ST before level-crossing (depends on movement direction).
Infrastructure constants:
S_{ST_i, ST_j} is distance between stations ST_i, ST_j (m);
$S_{ST, LC}$ is distance from station ST to level-crossing LC (m);
$t^{calc}{}_{clos}$ is minimal time to close the level-crossing (s);
d is directions: $d \in \{odd, even\}$;
$R^d = \{R1, R2, \ldots\}$ is set of routes in each direction d;
Sc_R^d is distance from level-crossing to closure control point for each route R in each direction d (m);
So_R^d is distance from level-crossing to opening control point for each route in each direction (m);
tc_R^d is time delay between crossing the closure control point and level-crossing closure for each route in each direction (s);
to_R^d is time delay between level-crossing closure and route opening for each route in each direction (s);
Sst_R^d is distance from opening control point to the station for each route in each direction (m).

Rolling stock RS constants:
id^{RS} is id number;
t^{RS} is type;
d^{RS} is direction;
R^{RS} is route;
Lw^{RS} is length of wagon (m);
NwRS is number of wagons;
LRS is length of train (m);
VRS is initial speed (m/s);
VmaxRS is max speed (m/s);
TdRS is scheduled departure time (min);
TaRS is scheduled arrival time (min);
aRS is acceleration (m/s²);
bRS is deceleration (m/s²).
Equations for each RS:

$$t_a = (V_{\max} - V) / a \tag{1}$$

is acceleration time to maximal speed, (s);

$$S_a = (V_{\max} - V) \cdot t_a / 2 \tag{2}$$

is acceleration distance to maximal speed, (m);

$$S_{const} = |(S_{ST,LC} - Sc_R^d)| - S_a \tag{3}$$

is distance of movement with constant speed to the closure control, (m);

$$t_{const} = S_{const} / V_{\max} \tag{4}$$

is time of movement with constant speed to the closure control, (s);

$$t_{total} = t_a + t_{const} \tag{5}$$

is total time from starting movement to the closure control, (s);

$IF \quad S_{ST,LC} >= Sc_R^d \ THEN$

$$t_{clos} = Td \cdot 60 + t_{total} + tc_R^d \tag{6}$$

$ELSE$:

$$t_{clos} = Td \cdot 60 - t_{total} + tc_R^d \tag{7}$$

is level-crossing closing time, (s);

$$S_{clos} = S_a + S_{const} + tc_R^d \cdot V_{\max} \tag{8}$$

is distance from movement starting to closing point, (m);

$$S_{clos,LC} = S_{ST,LC} - S_{clos} \tag{9}$$

is distance from closing point to level-crossing, (m);

$$t_{clos,LC} = S_{clos,LC} / V_{\max} \tag{10}$$

is time of movement from closing point to level-crossing, (s);

$$t_b = V_{\max} / b \tag{11}$$

is braking time from maximal speed, (s);

$$S_b = t_b \cdot V_{\max} / 2 \tag{12}$$

is braking distance from maximal speed, (m);

$IF \quad S_b > Sst_R^d \ AND \ t^{RS} = 'with\ stop' \quad THEN$

$$t_{const}^{last} = (Td - Ta) \cdot 60 - t_a - t_b \tag{13}$$

is last wagon movement time with constant maximal speed, (s);

$$S_{const}^{last} = V_{\max} \cdot t_{const}^{last} \tag{14}$$

is last wagon movement distance with constant maximal speed, (m);

$$So^{last} = S_{ST1,ST2} + L - Sst_R^d - S_a - S_{const}^{last} \tag{15}$$

is distance from last wagon braking point to opening control point, (m);

$$t_{br,op}^{last} = \frac{-V_{\max} + \sqrt{V^2{}_{\max} + 2 \cdot (-b) \cdot So^{last}}}{(-b)} \tag{16}$$

is time from last wagon braking point to opening control point, (s);

$$t_{open} = t_{clos} + t_a + t_{const}^{last} + t_{br,op}^{last} \tag{17}$$

is level-crossing opening time, (s);

ELSE :

$$S_{clos,open} = (S_{ST,LC} - S_{clos}) + So_R^d + L \tag{18}$$

is distance from real closing point to opening point, (m);

$$t_{open} = t_{clos} + S_{clos,open} / V_{\max} \tag{19}$$

is level-crossing opening time, (s);

IF $to_R^d > 0$ *THEN*

$$t_{clos} = 0 \tag{20}$$

is level-crossing closing time, (s);

$$S_{clos} = S_{ST,LC} \tag{21}$$

is distance from movement starting to closing point, (m);

$$S_{clos,open} = S_{clos,LC} + So_R^d + L \tag{22}$$

is distance from closing point to opening point, (m);

IF $S_a <= S_{clos,open}$ *THEN*

$$t_{open} = t_{clos} + t_a + (S_{clos,open} - S_a) / V_{\max} \tag{23}$$

ELSE:

$$t_{open} = t_{clos} + \sqrt{2S_{clos,open} / a} \tag{24}$$

is level-crossing opening time, (s).

4. Algorithm for task solution

Genetic algorithm for task solution is proposed.

General steps of genetic algorithm are following:

Step 1. Randomly generated schedule. According to genetic algorithm operation sequence, the first step is random initialization of possible schedule population.

$$SCH = \{sch_1, sch_2, ..., sch_p\} \qquad sch_i = \{x_1, x_2, ..., x_k\}$$

Step 2. Evaluate schedule according fitness function. Each randomly generated schedule is evaluated by fitness function

$$V^S = \{F(sch_1), F(sch_2), ..., F(sch_p)\}$$

Step 3. Arrange schedules according evaluate. At this step randomly generated schedules are rearrange appropriate to this evaluating value

$$\overline{SCH} = \{\bar{s}ch_1, \bar{s}ch_2, ..., \bar{s}ch_p\} \qquad F(\bar{s}ch_1) = \max(V^S)$$

Step 4. Select the best schedules for elite set. From rearranged schedules predefined amount of best schedules are selected for elite set

$$Sch_E \subset \bar{S}ch$$

Step 5. Select schedules for crossover. Predefined amount of schedules are selected for crossover from elite set

$$Sc = \bar{S}ch$$

Step 6. Use crossover for new schedules generation. Appropriate predefined crossover conditions create the new generation of schedules

$$i, j = \overline{1, p} \qquad \bar{s}ch_i \ \Pi \ \bar{s}ch_j \rightarrow sch'_i = sch_{ij}; \quad sch'_j = sch_{ji}$$

Step 7. Mutation, random changes in schedules

$$x_j^{s'_i} = x_j^{s'_i} + 1; \quad sch'_i \in SCH'; \quad j = rand(\overline{1, k}); \quad i = rand(\overline{1, p})$$

Step 8. Evaluate new schedules population according fitness function

$$V^{S'} = \{F(sch'_1), F(sch'_2), ..., F(sch'_p)\}$$

Step 9. Combine result of new population and elite set

$$SCH = SCH_E \cap \bar{S}CH'$$

Step 10. Arrange new populated schedules according evaluation

$$\overline{SCH}' = \{\bar{s}ch'_1, \bar{s}ch'_2, ..., \bar{s}ch'_p\}, \qquad F(\bar{s}ch'_1) = \max(V^{S'})$$

Step 11. Deleting the worst schedules

$$SCH = SCH / \{sch_{p+1}, sch_{p+2}, ...\}$$

Step 12. Stop criterion. The whole process will stop when the generation equals to the-defined time, numbers of population and other criterions.

Fitness function for Genetic Algorithm:

Fitness function is expressed as following

$$F(X) = f(\Delta t, T_\Sigma) \rightarrow \min$$

where: $X = \{x_1, x_2, \dots, x_n\}$ is deviation of the original schedule SCH (s); $\Delta t = \sum_{i=1}^{n} x_i^2 \Big/ n \rightarrow \min$ is average deviation from original schedule SCH (s); $T_\Sigma = \sum_{j=1}^{u} \Delta t_{closed} \rightarrow \min$ is total summary time, when level-crossing is in close position (s); u is number of intervals between level-crossing closing and opening.

Restrictions related with railway safety

Check of the new schedule to avoid time crossings on the same railway track.

Compare each train $i = \overline{1, n}$ with other $j = \overline{1, n}$ trains in the same direction: $d_i = d_j$, $i \neq j$.

Step 1.

$$Td_{check} = Tdi + xi; \qquad Ta_{check} = Tai + xi$$

Step 2.

IF ($Tdj + xj < Td_{check}$ AND $Taj + xj > Ta_{check}$) OR ($Tdj + xj > Td_{check}$ AND $Taj + xj < Ta_{check}$) OR
($Tdj + xj > Td_{check}$ AND $Taj + xj > Ta_{check}$ AND $Tdj + xj < Ta_{check}$) OR
($Tdj + xj < Td_{check}$ AND $Taj + xj < Ta_{check}$ AND $Td_{check} < Taj + xj$) THEN
Schedule failed
ELSE
Schedule successful

5. Computer Experiment in Developing of algorithm

Existing system structure investigation

The level-crossing of Sarkandaugava in Riga is selected for the computer experiment with the 24-hour train schedule.

The structure of level-crossing and elements location on the route are shown in Fig. 5.

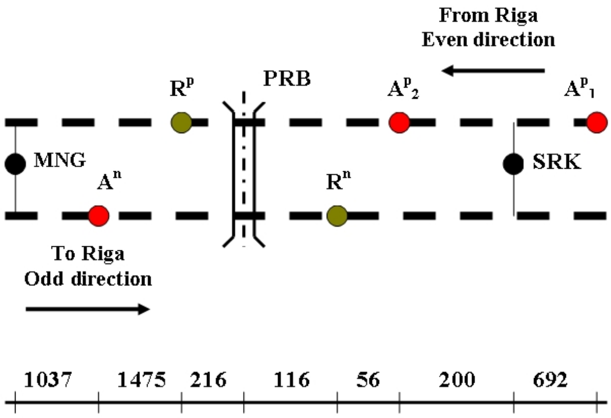

Fig. 5. Structure of the level-crossing. Where: $ST = \{MNG, SRK\}$ are two stations Mangali (*MNG*) and Sarkandaugava (*SRK*); $LC = \{PRB\}$ is one level-crossing *PRB*; $RS = \{RS_1, RS_2, \ldots, RS_{26}\}$ are 26 trains between two stations in time period between 3pm and 7pm; $R^{odd} = \{R^{odd}{}_1\}$ is one route in odd direction; $R^{even} = \{R^{even}{}_1, R^{even}{}_2\}$ are two routes in even direction; $S_{MNG,SRK} = 3100$ m; $S_{MNG,\ LC} = 2728$ m; $S_{SRK,\ LC} = 372$ m

Train types $t^{RS} \in$ {Cargo, Pas}. "Cargo" is rail transport units without stop at *SRK* station. "Pas" is rail transport units with stop at *SRK* station.

Routes' characterized parameters are shown it Table1.

Table 1

Routes' parameters

	Sc	***So***	***Sst***	***tc***	***to***
$R^1{}_{odd}$	1691	116	256	40	0
$R^1{}_{even}$	1064	216	2512	0	0
$R^2{}_{even}$	172	216	2512	0	13,5

Since in existing structure of level-crossing in Sarkandaugava the approaching points *An*, *Ap*1 and *Ap*2 are located too far or too close from the level-crossing, some time constant are necessary for secure level-crossing operate in close mode. Table 1 with *tc* marked delaying time constant for closed in odd direction, and with t0 marked the untimely time constant for closing in even direction.

All necessary numerical values of all 90 rolling stocks on Sarkandaugava-Mangali stage for calculations are combined in the Table 2.

Parameters of genetic algorithm

Following parameters are selected to implement genetic algorithm:

- Random selection
- Uniform crossover
- Crossover rate = 0.8
- Mutation rate = 0.02
- Bits for one variable = 5
- Population size = 100
- Number of generations = 1000
- Limits for x: -5 < X < 5

In order to avoid too big changes in schedule is set to permissible summary average deviation from original schedule is not over by 10 minutes.

Table 2

List of rolling stocks

	id	*t*	*d*	*R*	*Lw*	*Nw*	*L*	*V*	*Vmax*	*a*	*b*	*STd*	*Td*	*Sta*	*Ta*
RS_1	3648	cargo	even	Reven1	20	45	900	8.61	8.61	-	-	SRK	902	MNG	908
RS_2	3650	cargo	even	Reven1	20	40	800	7.38	7.38	-	-	SRK	938	MNG	945
RS_3	3654	cargo	even	Reven1	20	40	800	7.38	7.38	-	-	SRK	1015	MNG	1022
RS_4	3649	cargo	odd	Rodd1	20	57	1140	0	5.17	0.1	-	MNG	904	SRK	914
RS_5	3651	cargo	odd	Rodd1	20	35	700	0	12.92	0.1	-	MNG	929	SRK	933
RS_6	3655	cargo	odd	Rodd1	20	35	700	0	12.92	0.1	-	MNG	999	SRK	1003
RS_7	3657	cargo	odd	Rodd1	20	57	1140	0	5.17	0.1	-	MNG	1030	SRK	1040
RS_8	3663	cargo	odd	Rodd1	20	57	1140	0	5.17	0.1	-	MNG	1137	SRK	1147
RS_9	6136	pas	even	Reven2	-	-	120	0	20.7	0.6	0.8	SRK	928	MNG	931
RS_{10}	6138	pas	even	Reven2	-	-	120	0	20.7	0.6	0.8	SRK	966	MNG	969
RS_{11}	6140	pas	even	Reven2	-	-	120	0	20.7	0.6	0.8	SRK	980	MNG	983
RS_{12}	6142	pas	even	Reven2	-	-	120	0	20.7	0.6	0.8	SRK	1003	MNG	1007
RS_{13}	6144	pas	even	Reven2	-	-	120	0	20.7	0.6	0.8	SRK	1045	MNG	1048
RS_{14}	6146	pas	even	Reven2	-	-	120	0	20.7	0.6	0.8	SRK	1066	MNG	1069
RS_{15}	6148	pas	even	Reven2	-	-	120	0	20.7	0.6	0.8	SRK	1085	MNG	1088
RS_{16}	6150	pas	even	Reven2	-	-	120	0	20.7	0.6	0.8	SRK	1116	MNG	1119
RS_{17}	6133	pas	odd	Rodd1	-	-	120	0	20.7	0.6	0.8	MNG	919	SRK	922
RS_{18}	6135	pas	odd	Rodd1	-	-	120	0	20.7	0.6	0.8	MNG	947	SRK	950
RS_{19}	6137	pas	odd	Rodd1	-	-	120	0	20.7	0.6	0.8	MNG	981	SRK	984
RS_{20}	6139	pas	odd	Rodd1	-	-	120	0	20.7	0.6	0.8	MNG	1008	SRK	1011
RS_{21}	6141	pas	odd	Rodd1	-	-	120	0	20.7	0.6	0.8	MNG	1024	SRK	1027
RS_{22}	6143	pas	odd	Rodd1	-	-	120	0	20.7	0.6	0.8	MNG	1045	SRK	1048
RS_{23}	6145	pas	odd	Rodd1	-	-	120	0	20.7	0.6	0.8	MNG	1065	SRK	1068
RS_{24}	6147	pas	odd	Rodd1	-	-	120	0	20.7	0.6	0.8	MNG	1090	SRK	1093
RS_{25}	6149	pas	odd	Rodd1	-	-	120	0	20.7	0.6	0.8	MNG	1120	SRK	1123
...															
RS_{89}	3668	cargo	even	Reven1	20	40	800	7.38	7.38	-	-	SRK	1388	MNG	1394
RS_{90}	3671	cargo	odd	Rodd1	20	57	1140	0	5.17	0.1	-	MNG	1397	SRK	1407

Result of genetic algorithm implement

As shown in Fig. 6 all selected genetic algorithm parameters are entered in appropriate machine code. According to the genetic algorithm steps the computer experiment results are summarized in Table 3.

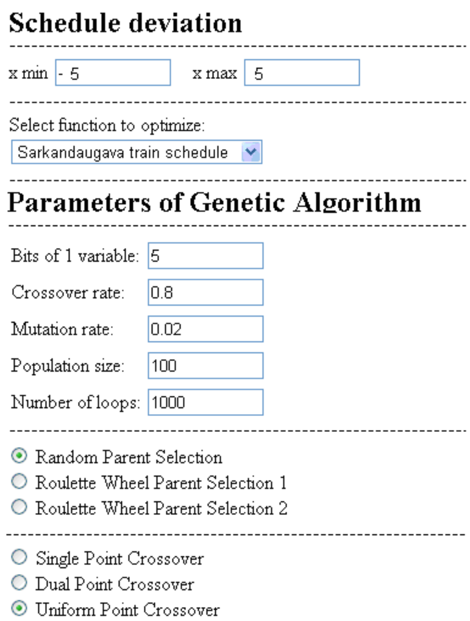

Fig. 6. Entering genetic algorithm parameters

Table 3

Computer experiment results (calculated in 33422 seconds)

Train	Direction	Route	Original depart time	Original arrival time	Deviation	Result depart time	Result arrival time	Level-crossing closed
3605	odd	R1	1:09	1:19	-3	1:06	1:16	1:10:52 - 1:19:16
3607	odd	R1	1:31	1:35	3	1:34	1:38	1:38:09 - 1:39:39
3611	odd	R1	2:38	2:48	3	2:41	2:51	2:45:52 - 2:54:16
3615	odd	R1	3:08	3:12	2	3:10	3:14	3:14:09 - 3:15:39
3619	odd	R1	4:12	4:16	2	4:14	4:18	4:18:09 - 4:19:39
3621	odd	R1	4:37	4:47	-2	4:35	4:45	4:39:52 - 4:48:16
6101	odd	R1	6:00	6:03	-2	5:58	6:01	6:00:05 - 6:02:34
3627	odd	R1	6:32	6:42	-4	6:28	6:38	6:32:52 - 6:41:16
3629	odd	R1	6:50	6:54	4	6:54	6:58	6:58:09 - 6:59:39
6103	odd	R1	6:58	7:01	4	7:02	7:05	7:04:05 - 7:06:34
6105	odd	R1	7:30	7:33	-2	7:28	7:31	7:30:05 - 7:32:34
6107	odd	R1	7:45	7:48	1	7:46	7:49	7:48:05 - 7:50:34
6109	odd	R1	8:30	8:33	3	8:33	8:36	8:35:05 - 8:37:34
6111	odd	R1	9:29	9:32	-1	9:28	9:31	9:30:05 - 9:32:34
6150	even	R2	18:36	18:39	3	18:39	18:42	18:38:47 - 18:39:38
3658	even	R1	19:20	19:26	3	19:23	19:29	19:21:40 - 19:25:41
6152	even	R2	19:42	19:45	-1	19:41	19:44	19:40:47 - 19:41:38
6154	even	R2	20:21	20:24	2	20:23	20:26	20:22:47 - 20:23:38
6156	even	R2	20:58	21:01	-5	20:53	20:56	20:52:47 - 20:53:38
3662	even	R1	22:00	22:07	-5	21:55	22:02	21:53:26 - 21:58:22
6158	even	R2	22:37	22:40	1	22:38	22:41	22:37:47 - 22:38:38
3668	even	R1	23:08	23:14	3	23:11	23:17	23:09:40 - 23:13:41
6160	even	R2	23:36	23:39	-2	23:34	23:37	23:33:47 - 23:34:38

Original total time of closed level-crossing
T_{orig} = 14892.070033683 s

Total time of closed level-crossing
T_{sum} = 10447.344239586 s

6. Conclusions

Analyzing the data from algorithm conclusions are:

- compared with the original schedule changed schedule total level-crossing time in the closed position has been decreased from 248 min (14892 sec) to 174 min (10447 sec);
- changed schedule average deviation is not over 10 minutes;
- genetic algorithm can be used to solve public and cargo transport flow organization tasks.

Schedule changes in ratio + / - 5 min give possibility to significantly reduce the level-crossing being in closed position, thereby significantly increasing the capacity of the level-crossing.

To reduce level-crossing being in closed position give several possibilities:

- increase city transport flow through level-crossing;
- increase rail passengers and cargo transport flow on the route Mangali – Sarkandaugava without negative effect on current city transport flow.

To define saving up energy and take in notice all restrictions and meets requirements is necessary to implement additional researches.

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Proceedings of 6th International Conference ITELMS'2011

Change Dynamics of Traffic Accidents and Casualties in Lithuania: Analysis of Secondary Data of 2006-2010

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Abstract

The article examines a social phenomenon of traffic accidents in Lithuania. Analysis of secondary statistical data (2006 – 2010) is presented, while reviewing the general statistics of Lithuania. Furthermore, comparative analysis of this phenomenon is carried out while distinguishing individual cities of Lithuania. Transport represents one of the elements of economy of the Republic of Lithuania. It would be difficult to envisage Lithuania and the whole world without transport and its benefits
KEY WORDS: *vehicle population; traffic accidents; number of injured and killed.*

1. Introduction

Scientific problem. The article examines a social phenomenon of traffic accidents in Lithuania. Analysis of secondary statistical data (2006 – 2010) is presented, while reviewing the general statistics of Lithuania. Furthermore, comparative analysis of this phenomenon is carried out while distinguishing individual cities of Lithuania. Transport represents one of the elements of economy of the Republic of Lithuania. It would be difficult to envisage Lithuania and the whole world without transport and its benefits. The number of vehicles is growing yearly as well as their concentration and intensity. This affects the increase in the number of traffic accidents and the casualties. Traffic accidents negatively affect the economy of any country and its residents. The described aspects of the phenomenon under consideration require scientific analysis and statistical evaluation.

Object of the article. Change dynamics of traffic accidents and casualties in Lithuania (2006 – 2010).

Purpose of the article. To present the change dynamics of traffic accidents in Lithuania and the casualties of traffic accidents (2006 – 2010).

Tasks of the article:

1. To review the dynamics of traffic accidents while identifying its determinants and taking into account the statistics of the largest cities of Lithuania.
2. To identify the factors that determined the traffic environments.
3. To conduct an analysis of personal data of accident casualties, while assessing the tendencies of the largest cities in Lithuania.

Methods of analysis: scientific literature analysis, comparative analysis of secondary statistical data.

2. Change dynamics of traffics

After examining the information provided by Lithuanian Police Traffic Supervision Authority on statistics of traffic accidents that occurred in Vilnius, Kaunas, Klaipėda, Šiauliai and Panevėžys in 2006 – 2010, such as the number of accidents and number of the injured and victims, the article reviews the traffic accidents that occurred in the largest cities of the Republic of Lithuania, i.e., Vilnius, Kaunas, Klaipėda, Šiauliai and Panevėžys in 2006-2010 and the change dynamics of the casualties.

When analyzing the accident rate, the number of vehicles and population represent an important indicator.

It can be stated that a sudden increase in the number of road vehicles (two-wheel moped, three-wheel moped, motorcycle, motorcycle with a sidecar, three/four-wheel motorcycle, four-wheel motorcycle up to 350 kg, four-wheel motorcycle up to 400 kg, passenger car, bus up to 5 t, bus exceeding 5 t, cargo vehicle up to 3.5 t, cargo vehicle above 3.5 t, cargo vehicle above 3.5 t to 12 t, cargo vehicle above 12 t, trailer up to 0.75 t, trailer, semi-trailer above 0.75 t up to 3.5 t, semi-trailer above 3.5 t and up to 10 t, semi-trailer above 10 t) had a negative impact on traffic safety in the country roads and city streets.

Over the last 5 years, the number of vehicles in the largest cities of the Republic of Lithuania – Vilnius, Kaunas, Klaipėda, Šiauliai and Panevėžys – has been increasing, except in 2010, regardless of the number of residents decreasing (see Fig. 1).

However, compared to the entire Lithuania (see Fig. 2), we can see that although the Lithuanian population is shrinking, the number of vehicles is increasing rather fast. Comparing 2006 and 2010, the number of vehicles went up by as many as 15.33 %, although the Lithuanian population decreased by 2.21 %.

Table 1

Change of the vehicle population in Lithuania and in its largest cities:
Vilnius, Kaunas, Klaipėda, Šiauliai and Panevėžys in 2006-2010

Cities	Number of vehicles				
	2006	2007	2008	2009	2010
Vilnius	326660	349292	370426	390069	385319
Per 1000 residents	590	630	666	697	688
Kaunas	197911	199798	206517	220001	218902
Per 1000 residents	548	558	580	625	627
Klaipėda	100762	100592	103093	105393	104575
Per 1000 residents	538	540	557	576	571
Šiauliai	67909	67083	68097	72924	72586
Per 1000 residents	526	524	536	583	580
Panevėžys	60176	61215	64057	70988	70237
Per 1000 residents	523	532	561	628	627
Lithuania	1815 749	1838 385	1938 468	1 963 055	2144548
Per 1000 residents	534	543	576	586	644

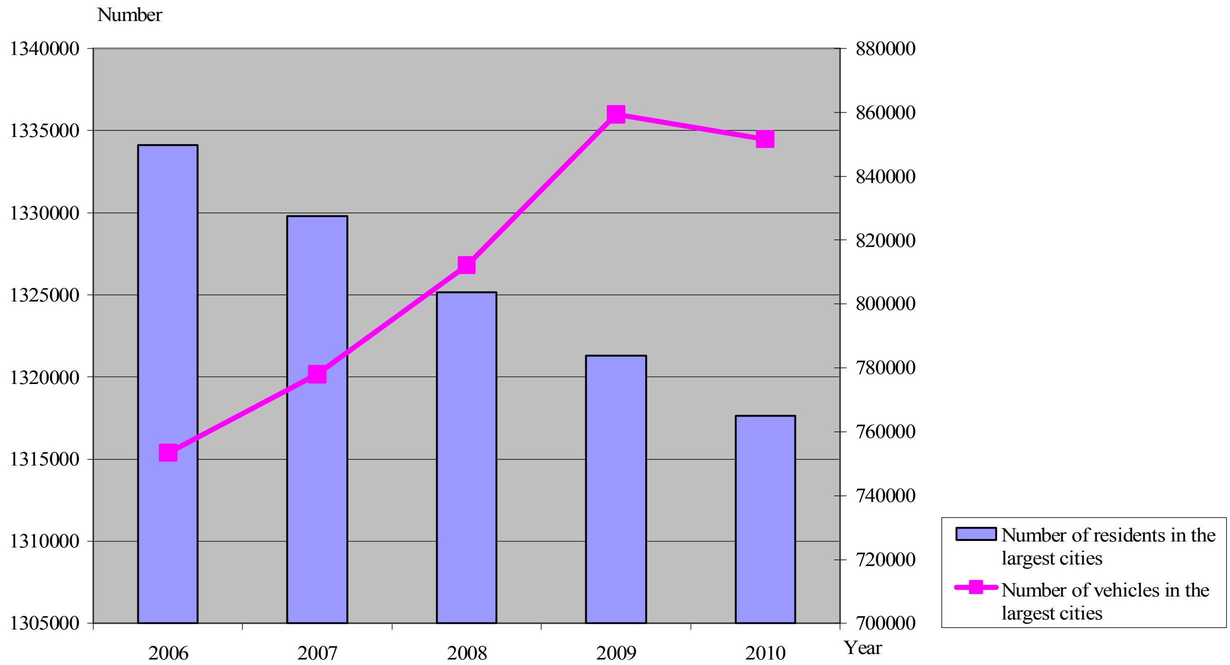


Fig. 1. Dynamics of vehicle number and population in the largest cities of Lithuania

The increasing number of vehicles negatively affects the statistics of accidents. The change dynamics of traffic accidents and the casualties in 2006-2010 is presented in Table 2.

It can be stated that the sudden increase of the vehicle population had negative impact on traffic safety in the roads and city streets.

Over the period of five years, the biggest number of traffic accidents per 1000 residents was recorded in Kaunas and Šiauliai, the smallest – in Vilnius and Klaipėda. However, the total number of accidents in Šiauliai and Panevėžys in 2007 was higher than in 2006. A large reduction in the number of recorded accidents in Lithuania and all largest cities of the country occurred in 2008. It cannot be discounted that from that year it was no longer required to inform the police about the accident, if no more than two vehicles collided and no one was injured or killed. The drivers in this case have to inform the insurance company in which the vehicles are insured. It is noteworthy that the number of accidents went up in Panevėžys (see Fig. 3f) and reasons should be sought. All over the country the number of recorded traffic accidents has been decreasing since 2006 regardless of the number of vehicles going up (see Fig. 3, a).

During 2006 – 2010, 10731 accidents were recorded in the largest cities of Lithuania, in which 410 people were killed and 12270 sustained injuries. People sustain injuries; the society sustains large moral and material damages. Order and traffic safety on the roads mostly depend on the drivers. The majority of traffic accidents are caused by the drivers' errors. Drivers' errors include incorrect, premature or delayed actions or absence thereof when driving a vehicle under rapidly changing conditions and particularly in dangerous situations. Drivers' behavior is affected by a multitude of factors – road, surroundings, vehicle and alcohol. However, the actions of the driver are of the utmost importance. Other participants of traffic – pedestrians, cyclists, in particular if they are inebriated – also cause significant hazard. When an accident occurs, one should think, whose fault that was. The driver is not always solely responsible; the behavior of other traffic participants contributes, too. The rules and provisions of moving should be compulsory to drivers as well as pedestrians and children.

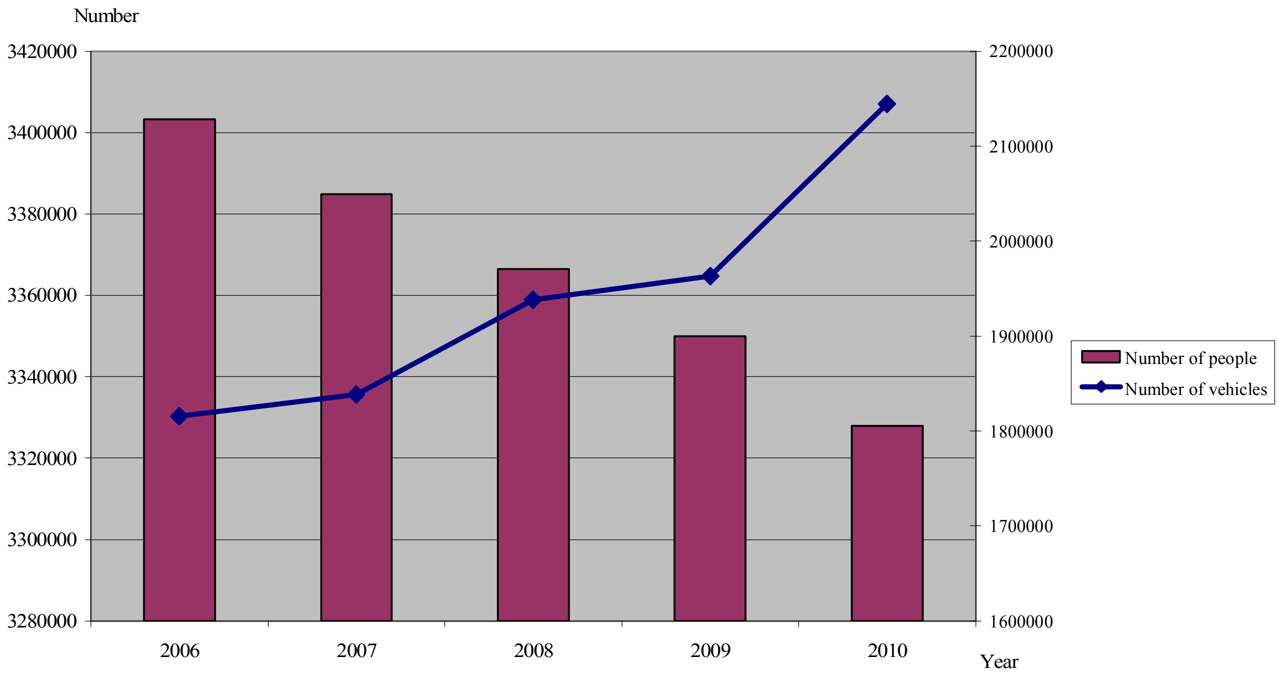


Fig. 2. Dynamics of vehicles and residents in Lithuania

Table 2

Dynamics of the number of traffic accident casualties in 2006 – 2010

Cities	Number of traffic accidents					Number of the injured					Number of the killed				
	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010
Lithuania															
In total	6588	6448	4796	3824	3625	8252	8043	5818	4456	4328	760	740	499	370	300
Per 1000 residents	1,93	1,9	1,4	1,14	1,08	2,42	2,38	1,72	1,33	1,3	0,22	0,22	0,15	0,11	0,09
Per 1000 vehicles	3,63	3,51	2,47	1,95	1,69	4,54	4,38	3,00	2,27	2,02	0,42	0,40	0,26	0,19	0,14
Vilnius															
In total	1005	907	662	518	520	1177	1031	756	561	579	45	68	43	30	22
Per 1000 residents	1,8	1,6	1,2	0,9	0,92	2,12	1,86	1,35	1	1	0,08	0,12	0,07	0,05	0,04
Per 1000 vehicles	3,08	2,60	1,79	1,33	1,35	3,60	2,95	2,04	1,44	1,50	0,14	0,19	0,12	0,08	0,06
Kaunas															
In total	850	817	708	641	570	992	980	823	736	654	27	17	19	13	9
Per 1000 residents	2,35	2,3	2	1,8	1,63	2,74	2,73	2,31	2,09	1,87	0,07	0,05	0,053	0,037	0,025
Per 1000 vehicles	4,29	4,09	3,43	2,91	2,60	5,01	4,90	3,99	3,35	2,99	0,14	0,09	0,09	0,06	0,04
Klaipėda															
In total	348	328	274	248	230	416	374	309	286	264	16	17	8	7	6
Per 1000 residents	1,7	1,8	1,5	1,4	1,26	2,22	2,01	1,67	1,56	1,44	0,085	0,09	0,04	0,038	0,032
Per 1000 vehicles	3,45	3,26	2,66	2,35	2,20	4,13	3,72	3,00	2,71	2,52	0,16	0,17	0,08	0,07	0,06
Šiauliai															
In total	261	265	205	178	163	321	317	260	205	189	8	7	4	5	6
Per 1000 residents	2	2	1,6	1,4	1,3	2,48	2,47	2,04	1,62	1,52	0,062	0,054	0,031	0,039	0,048
Per 1000 vehicles	3,84	3,95	3,01	2,44	2,25	4,73	4,73	3,82	2,81	2,60	0,12	0,10	0,06	0,07	0,08
Panevėžys															
In total	208	214	187	181	183	230	239	209	146	216	7	5	12	4	5
Per 1000 residents	1,8	1,9	1,6	1,6	1,63	2	2,1	1,83	1,29	1,92	0,06	0,04	0,1	0,035	0,045
Per 1000 vehicles	3,46	3,50	2,92	2,55	2,61	3,82	3,90	3,26	2,06	3,08	0,12	0,08	0,19	0,06	0,07

It is noteworthy that Kaunas remains the leader according to the total number of recorded traffic accidents per 1000 vehicles and the number of injured even compared to the indicators for the entire Lithuania (see Fig. 4, a, b, c, d and Fig. 5).

In 2008, Panevėžys was leading according to the number of the killed per 1000 vehicles, whereas in 2010 the number of the injured per 1000 vehicles went up (see Fig. 4e and 6).

The number of the killed per 1000 vehicles in Šiauliai has been increasing since 2008, although the statistical data of 2006-2010 show that from 2007 less traffic accidents have been recorded, hence, the lesser number of casualties (see Fig. 4, 5, 6, 7). In 2007, 114 people were killed in traffic accidents in the largest cities of Lithuania, in 2010 – only 48. The smallest numbers of those killed on the roads during the five year period were recorded in Vilnius, Kaunas and Klaipėda.

Apparently, the impact was made by the active work of police, educational campaign in the media and measures taken by the Ministry of Transport and Communications in the field of traffic safety. It is also possible that the traffic participants became more cautious and responsible. This trend could also have been affected by the coming into force of amendments of the Code of Administrative Offences of the Republic of Lithuania in 2008, which tightened up the liability for breaches of road traffic regulations. Traffic safety is hugely influenced by vehicles and drivers, i.e., direct causers of accidents, as well as the layout of cities and streets.

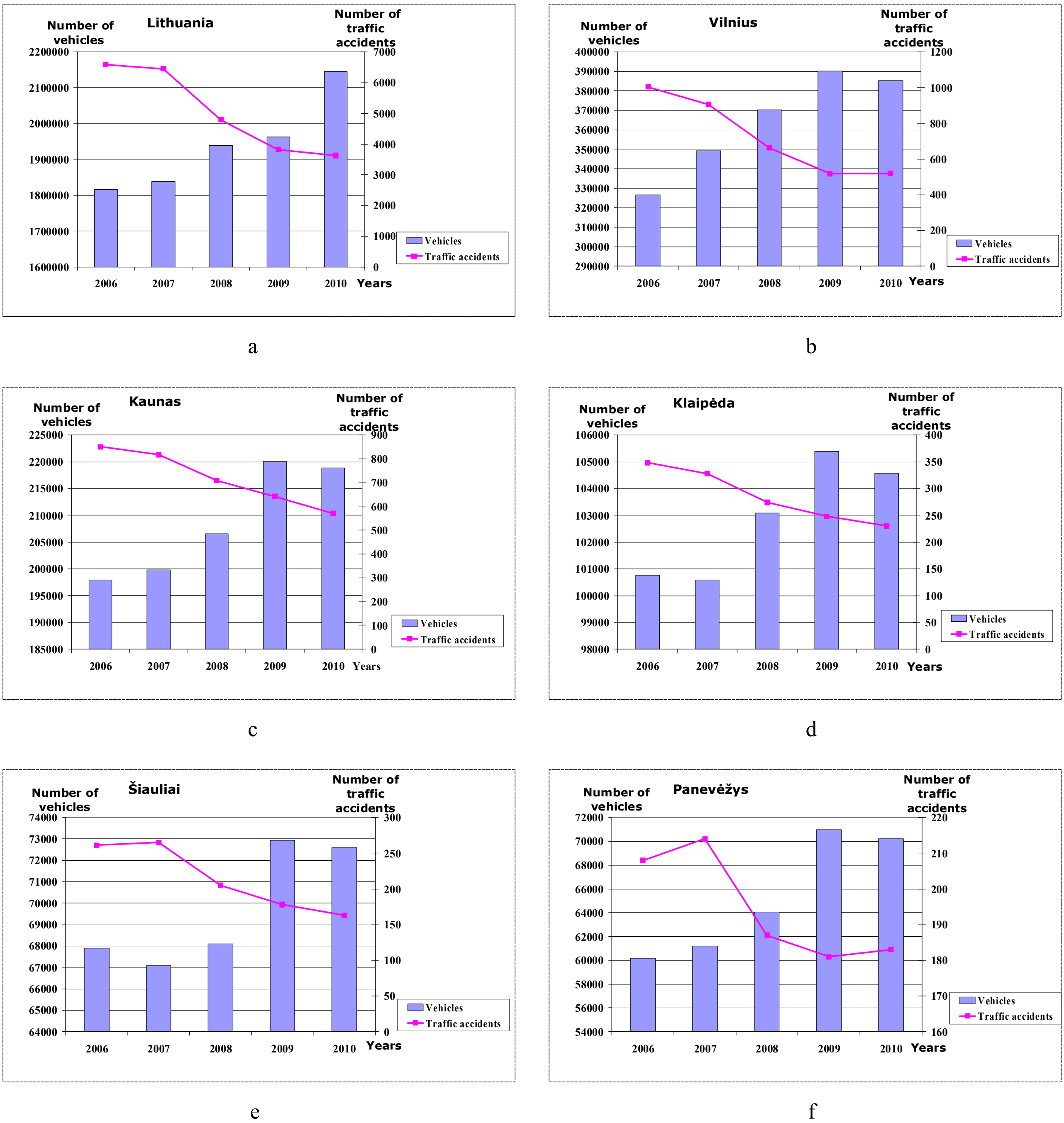
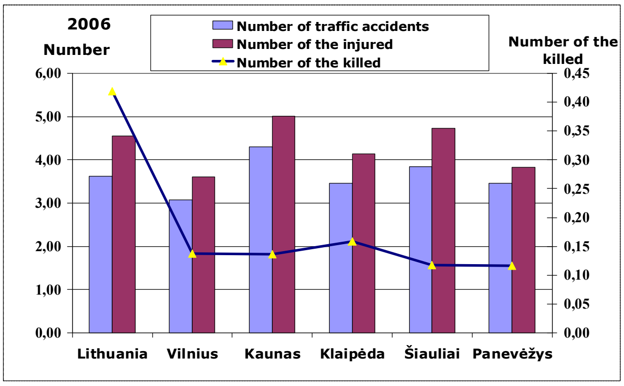
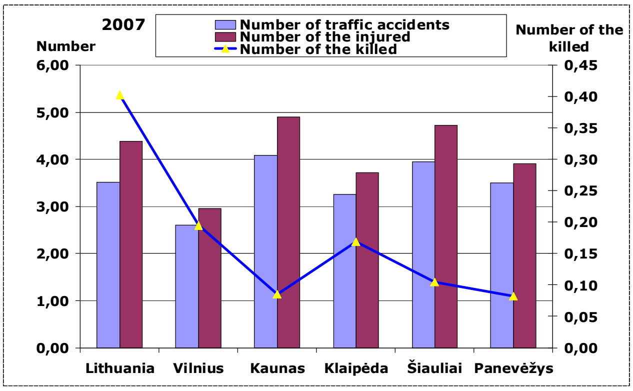


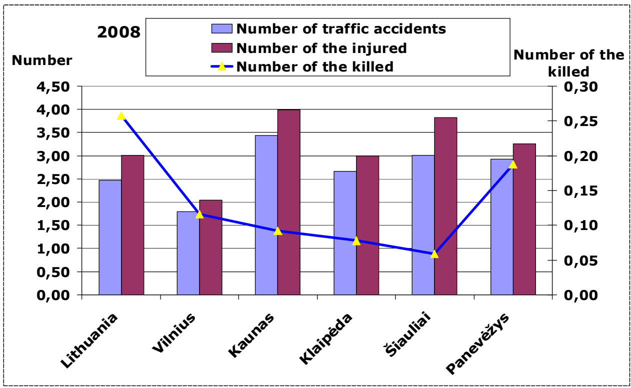
Fig. 3. Dynamics of traffic accidents in 2006-2010 in Lithuania and the largest cities of the country



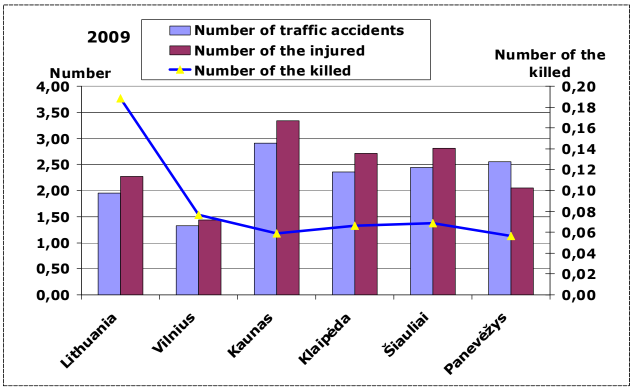
a



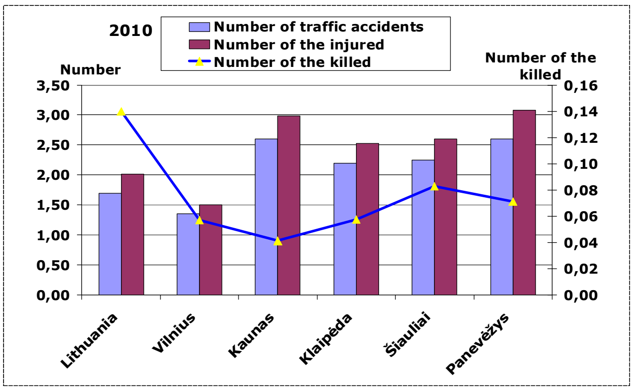
b



c



d



e

Fig.4. Tendencies of the number of accidents, injured and killed per 1000 vehicles by years

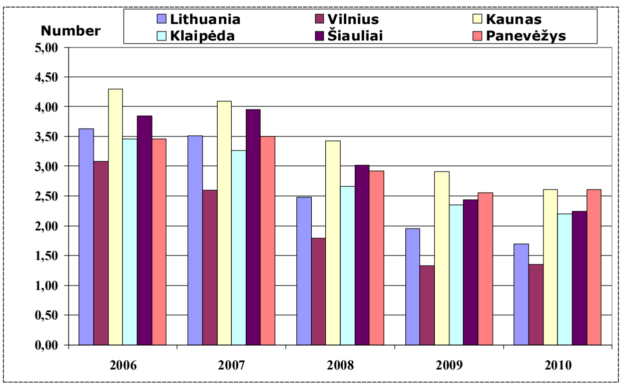


Fig. 5. Change dynamics of the number of recorded traffic accidents per 1000 vehicles

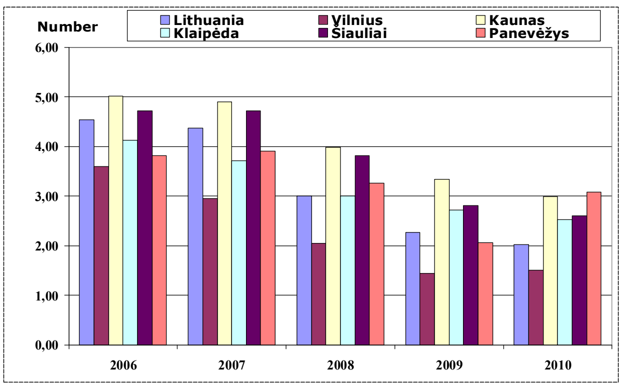


Fig. 6. Change dynamics of the number of the injured per 1000 vehicles

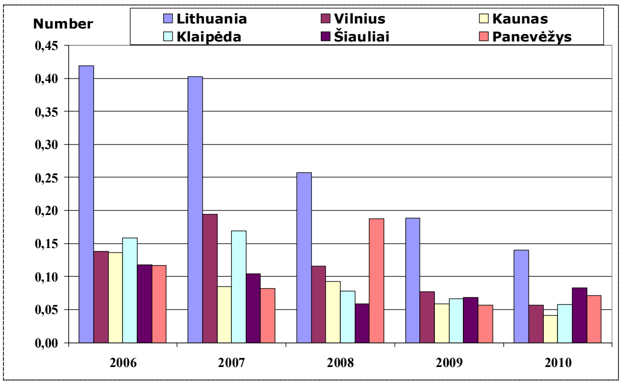


Fig. 7. Change dynamics of the number of the killed per 1000 vehicles

Due to the rapid increase of the number of vehicles and increasing intensity of traffic, it is more and more difficult to ensure safety on the roads and streets of Lithuania. The environment of safe traffic factors is complicated and multipartite; issues of safe traffic should, therefore, be solved on all levels of the state – in the Seimas of the Republic of Lithuania, the Government, municipal institutions, undertakings and traffic participants.

The implementation of traffic safety improvement measures is aimed at mitigation of traffic accident risk and consequences.

While seeking to improve the traffic safety on the roads, it is necessary to evaluate the interaction of the entire transport system, i.e., how the traffic participants, vehicles, roads and environment affect each other. Based on this interaction, measures could be distinguished that are fundamental to the improvement of traffic safety: legislative acts regulating safe traffic; educational measures; engineering measures for traffic safety improvement; measures for the improvement of the state of vehicles. Effective regulation of safe traffic is one of the key factors ensuring safe traffic. Education of traffic participants is highly beneficial: explaining to the society on safe traffic issues; publishing of analysis of traffic accidents and comments; publishing of information on the state of roads, repairs and other works carried out. Safe environment needs to be created on the roads in order to protect the traffic participants.

All traffic participants are responsible for disciplined and safe traffic, and drivers as well as other traffic participants should, therefore, feel the responsibility for their own safety as well as that of others.

2. Conclusions

1. After carrying out the analysis of statistical data provided by Lithuanian Police Traffic Supervision Authority it was established that in 2006-2010 the traffic safety on the roads and in streets of Vilnius, Kaunas, Klaipėda, Šiauliai and Panevėžys was negatively affected by a sudden increase of the vehicle population. The performed research showed that although the Lithuanian population is decreasing, the number of vehicles is growing rather rapidly. After carrying out a comparative analysis of the number of vehicles in 2006 and 2010, it was established that the number of vehicles went up by as many as 15.33 %, although the Lithuanian population decreased by 2.21 %.
2. The environment of safe traffic factors is complicated and multipartite; issues of safe traffic should, therefore, be solved on all levels of the state – in the Seimas of the Republic of Lithuania, the Government, municipal institutions, undertakings and traffic participants.
3. The implementation of traffic safety improvement measures is aimed at mitigation of traffic accident risk and consequences. Prevention of dire accidents was carried out through active work of police, educational campaign in the media and measures taken by the Ministry of Transport and Communications in the field of traffic safety. It is also possible that the traffic participants became more cautious and responsible. Another factor could have been could the coming into force of the amendments of the Code of Administrative Offences of the Republic of Lithuania in 2008, which tightened up the liability for breaches of road traffic regulations. Traffic safety is hugely influenced by vehicles and drivers, i.e., direct causers of accidents, as well as the layout of cities and streets. The majority of traffic accidents are caused due to the errors of drivers.
4. The increasing number of vehicles directly correlates with the statistics of accidents. It is noteworthy that Kaunas remains the leader according to the total number of recorded traffic accidents per 1000 vehicles and the number of injured even compared to the indicators for the entire Lithuania. In 2008, Panevėžys was leading according to the number of the killed per 1000 vehicles, whereas in 2010 the number of the injured per 1000 went up. The analysis of secondary statistical data highlighted the tendencies of the number of killed people. The number of the killed per 1000 vehicles in Šiauliai has been increasing since 2008, although the statistical data of 2006-2010 show that from 2007 less traffic accidents have been recorded, hence, the lesser number of casualties. In 2007, 114 people were killed in traffic accidents in the largest cities of Lithuania, in 2010 – only 48. The smallest numbers of those killed on the roads during the five year period were recorded in Vilnius, Kaunas and Klaipėda.

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