

PREVIEW

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“Igor Sikorsky Kyiv Polytechnic Institute”

Modern Science for new industries
China-Ukraine International Symposium on Innovation
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Part 2. Igor Sikorsky KPI expert papers

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Во второй части сборника научных трудов Китайско-Украинского международного симпозиума по инновациям и технологиям приведены результаты научных исследований и практических разработок ученых КПИ им. Игоря Сикорского

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Contents

NEW MATERIALS AND PROSPECTIVE TECHNOLOGIES (<i>Bogomol I., Loboda P.</i>)	4
INFLUENCE OF THERMOMAGNETIC AND THERMOMECHANICAL TREATMENT ON THE STRUCTURE, PROPERTIES AND PARAMETERS OF MARTENSITIC TRANSFORMATION IN SHAPE MEMORY ALLOYS (<i>Demchenko L.</i>)	10
DATA MINING AND ITS APPLICATION FOR TELECOM INDUSTRY (<i>Globa L.S.</i>)	29
VARIOUS ORIGIN WASTES UTILIZATION WITH SIMULTANEOUS ENERGY CARRIERS OBTAINING (<i>Golub N.B., Levzun I.I.</i>)	55
IMPORTANCE OF TOXICOLOGICAL INVESTIGATIONS IN STUDYING OF PROSPECTS OF NEW ANTIFUNGAL AGENTS (<i>Kalashnikova L., Trush M., Hodyna D., Rogalsry S., Metelytsia L.</i>)	60
APPLICATION OF THEORY FUZZY LOGIC FOR DETERMINING THE LEVEL OF INNOVATIVE SECURITY OF UKRAINE (<i>Karaieva N., Annenkov M.</i>)	65
EMERGENCY RISKS FOR INNOVATIVE DEVELOPMENT (<i>Karaieva N.</i>)	71
JAVASCRIPT MAPPING FOR DATA STORED IN DBMS INTERSYSTEMS CACHE (<i>Kovalchuk K., Mykhailova I.</i>)	75
UNMANNED AERIAL VEHICLE ON SOLAR ENERGY (<i>Kozei Y.</i>)	83
WEB SYSTEM FOR MANAGING THE REGISTRY OF ELECTRONIC INFORMATION RESOURCES (<i>Kuzmenko I., Ivaniuk A.</i>)	86
ANALYSIS OF EXISTING SOFTWARE FOR THE CONTROLLING OF WATER OBLIGATION (<i>Sydorenko Iu., Kryvda O.</i>)	93
DEPARTMENT OF CHEMICAL TECHNOLOGY OF COMPOSITE MATERIALS (<i>Svidersky V., Myronyuk O.</i>)	99
MODERN PROBLEMS OF HEAT POWER ENGINEERING (<i>Varlamov G., Romanova, K., Mukhin M., Chebotarev A., Wu Zongyan</i>)	103

1. Reinforced ceramic materials

We propose the original technology of manufacturing of reinforced ceramic materials based on non-oxide refractory compounds developed by the Igor Sikorsky KPI. The structure of these materials represents a ceramic matrix reinforced with fibrous or lamellar inclusions of other ceramic refractory compounds and their combinations (Fig.1).

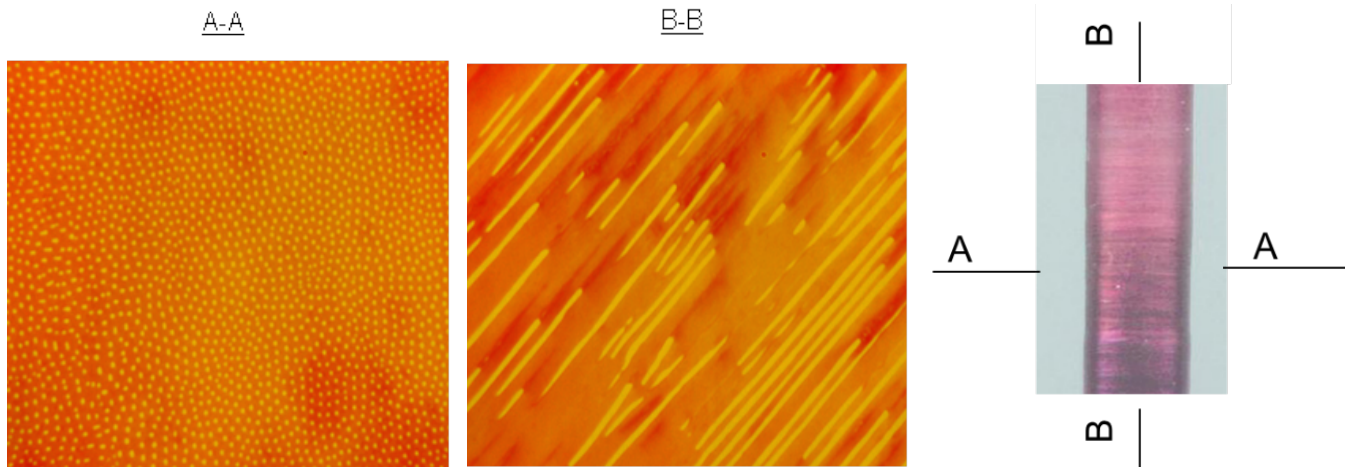


Fig. 1 Microstructure of the reinforced ceramic materials

Synthesis of reinforced ceramic materials of selected systems is carried out by directional crystallization methods, as well as by reaction spark plasma sintering. The process of forming of the reinforced ceramic matrix is carried out directly during the synthesis of ceramic composites due to the effect of self-reinforcement. This approach allows us to realize a high level of mechanical characteristics due to the formation of strong defect-free interfaces between the matrix on the basis of one refractory compound and inclusions based on other refractory compounds that are formed in equilibrium or close to equilibrium conditions. Previous studies on ceramic quasibinary systems show high efficiency of this type of reinforcement. Thus, the strength of directionally reinforced composites based on lanthanum hexaboride reached 1500 MPa. It was also shown that the mechanical properties in such materials are preserved up to

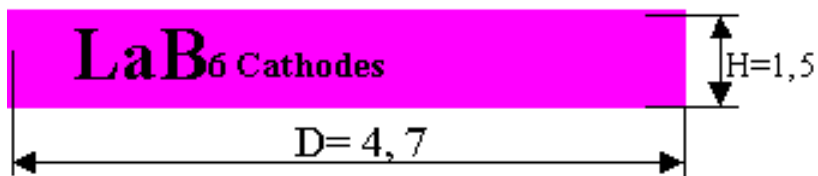
temperatures of 1600-2000 °C.

The ceramic high-temperature structural materials have a significantly lower specific weight, higher resistance to creep and corrosive media than refractory metals. Due to their low specific weight the composites could be used as high-temperature structural materials with an operating temperature up to 2000 °C including an aerospace parts operating under high thermomechanical loads. Using of new ceramic high-temperature structural materials will increase the durability of structural parts of high-temperature equipment, as well as develop new high-temperature processing units with increased efficiency.

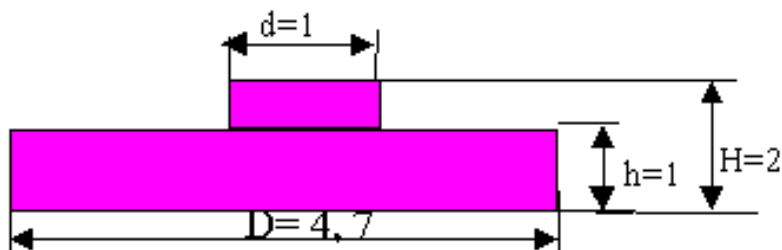
2. Singlecrystalline cathodes from lanthanum hexaboride and electron-beam equipment for technological purposes

Using above described technology we can produce the new types of the ceramic cathode units with the monocrystalline lanthanum hexaboride emitters (Fig. 2), the high-quality structurally perfect monocrystals of the borides of the rare-earth metals, and the directionally reinforced ceramic materials.

- **D4.7H1.5**



- **D4.7d1.0H2.0h1.0**



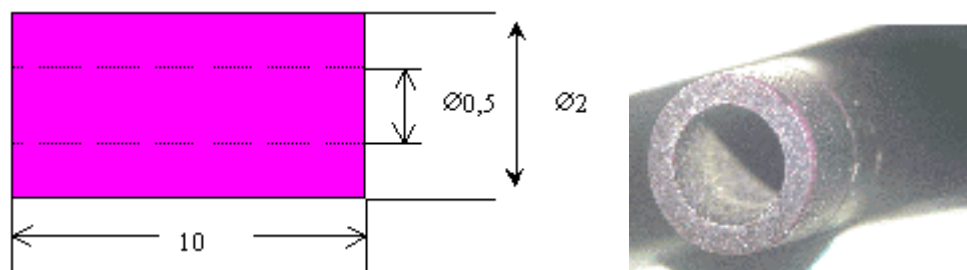


Fig. 2 Lanthanum hexaboride emitters for technological purpose

The monocrystalline LaB_6 cathodes used in the devices of technological purpose allow to get rid of several effects of unstable operation of polycrystalline cathodes bound with a developed grid of borders of grains, geometrical and chemical heterogeneity of an issuing surface, and to increase power and spatially geometrical parameters of the electronic beams by means of use of an anisotropy of issuing properties of hexaboride lanthanum.

We can also produce cathodes and cathode-heating units with the hexaboride lanthanum emitters of different shape: tubes, rings, rods and other articles more complicated in form using the methods of pressing (compacting) and subsequent sintering, plasma spraying and high-temperature compacting of the pre-purified monocrystalline powder, and also by means of junction of the monocrystalline insertions into polycrystalline matrix.

Recommended fields of application: devices of Technological Purpose: welding, melting, welding deposition, heat treatment, high-precision dimensional treatment, refractory and chemically active materials, lithography; Electron-probe analysis; Ecology; Medicine, Electronic-vacuum and gas-discharge systems.

Application of the monocrystalline disc cathodes with orientation of an emitting surface (100) in the installations of welding without change of design, incandescing and spatially geometrical parameters of an electronic cannon allows:

- to increase up to 2-2,5 times the period of service of the cathodes in comparison with the polycrystalline hot-pressed cathodes;
- to increase up to 20-30% the electronic beam's reserve in current;

- to reduce diameter of the beam and ensure stability of its geometrical dimensions in all range of changes of the parameters of the focusing devices of the electronic cannon;
- to increase the depth of fusion at the expense of increase of the specific power of the electronic beam for 20-25%;
- to reduce a heat load upon the constructional elements of the cathode unit and the cannon at large;
- to increase stability of a current and transversal diameter of electronic beam;
- to reduce thermal tensions in the welded material;
- to increase stability of the geometrical sizes and forms of a juncture.

3. New reinforced titanium-based cermet composite of polyfunctional purpose

We propose the reinforced cermet alloy based on titanium developed at Igor Sikorsky KPI for the manufacturing of cutting tools, medical instrument, as a light-weight structural material and protective material for protection against firearms.

The proposed composite material represents the metal titanium matrix reinforced with elongated titanium boride fibers (Fig. 3). The hardness of titanium boride is about 32 GPa which is 30% higher than the hardness of the most used tungsten carbide (24 GPa) the application of which has revolutionized the cutting technology.

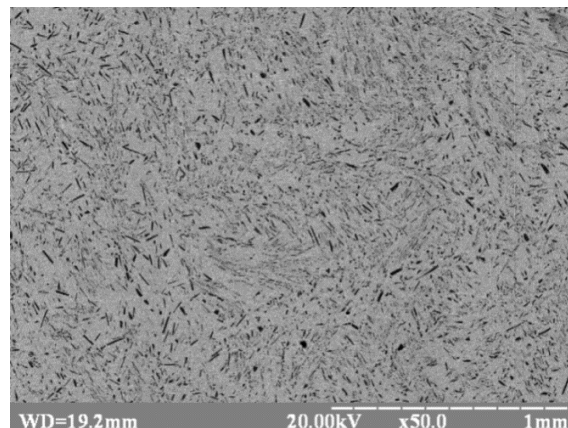


Fig. 3 Microstructure of the reinforced titanium-based cermet composite

The developed cermet composite has increased mechanical characteristics (Table 1) and corrosion resistance which are at the level of the best titanium alloys. In this case, knives from this alloy showed improved performance compared to similar steel (Steel 65G, etc.) during experimental tests at the Poninkovskaya cardboard and paper factory.

Table 1 Mechanical properties of the reinforced titanium-based cermet composite

Alloy	$\sigma_{0,2}$, MPa	σ_B , MPa	δ , %	HV, GPa
Ti-TiB	810	902,3	7	3,25 – 3,98

It is proposed to use developed in the Igor Sikorsky KPI titanium-based cermet composite for the production of spherical reinforced composite powders. The obtained powders are proposed to be used for the production of implants of various purposes by 3D printing methods: selective laser sintering, etc. Using of such powders will significantly improve the physicomechanical properties of the produced implants due to the reinforced composite structure and, thus, extend the life of the implants.

Recommended fields of application: Cutting tool - cutting knives for paper, cardboard, tobacco, textiles, rubber, etc.; Medical instrument (scalpels, scissors, tweezers, clamps, etc.), implants; High-strength, corrosion-resistant structural parts for machine building and aerospace applications; Armor plates for protection against firearm.



Fig. 4 Paper-cutting knife (a) prepared from the reinforced titanium-based cermet composite and industrial equipment where it tested (b)

The main advantages of the knives: low specific weight, high corrosion resistance, effect of self-sharpening, non-magnetic material.

Technical and economic effect: the production technology of metal-ceramic composite does not require a large number of technological operations including additional heat treatment. As a raw material the cheapest titanium sponge can be used. This approach makes this material significantly cheaper in the market compared to other titanium alloys and comparable in price to steels.

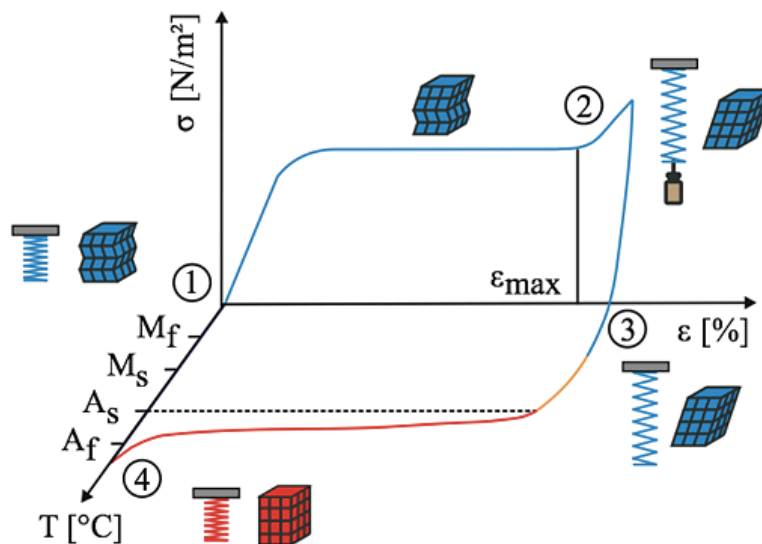
The above described technologies are only the part of scientific work of the Faculty. We are open to collaboration with companies, organizations and universities working in the field of materials science.

INFLUENCE OF THERMOMAGNETIC AND THERMOMECHANICAL TREATMENT ON THE STRUCTURE, PROPERTIES AND PARAMETERS OF MARTENSITIC TRANSFORMATION IN SHAPE MEMORY ALLOYS

Demchenko L.

Introduction

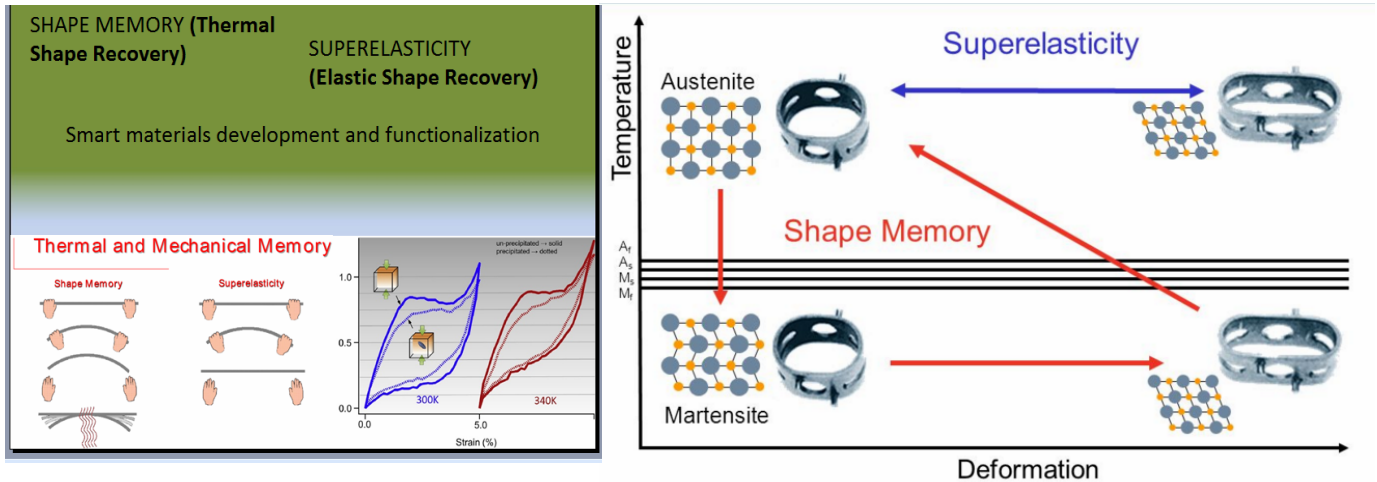
A priority and very promising direction in the field of material science is the development of intellectual materials with functional properties, which include the shape memory effect (SME) and superelasticity (SE). A shape-memory alloy (smart or functional material) is an alloy that can be deformed when cold but returns to its pre-deformed ("remembered") shape when heated. The shape memory effect is realized exceptionally by the martensite transformation (MT).



M_S : Martensite start temperature M_f : Martensite finish temperature
 A_S : Austenite start temperature A_f : Austenite finish temperature

Shape memory (SM) alloys' useful properties are performed work, superelasticity, damping ability. Superelasticity is a property of a material subjected to loading up to a stress

significantly exceeding the yield strength, completely restoring its original shape after removing the load.



The increased interest in materials with the elements of intellectuality, “smart” materials, and the reversible phase structure is due to the possibilities of their various use as active elements (actuators) of micro-sensors and micro-drives, dampers for vibration damping of machines and mechanisms, in power executive mechanisms of various devices, and others. Widespread use of such materials in aerospace and automotive complex, in instrumentation and mechanical engineering, electronics, biomedicine, etc allows them to occupy a priority place in the hierarchy of the most demanded materials.

Prospects for application of newest shape memory alloys are:

- Aerospace complex - engines, smart sensors, power drives, damping of vibrations;
- Machine-building complex - sensors, power drives, actuators;
- Nuclear energy - use in protection systems of overheating of reactors, control;
- Mining industry - manipulators, dispensers of gas or oil flow when drilling wells;
- Medicine - functional materials biocompatible with the human body.

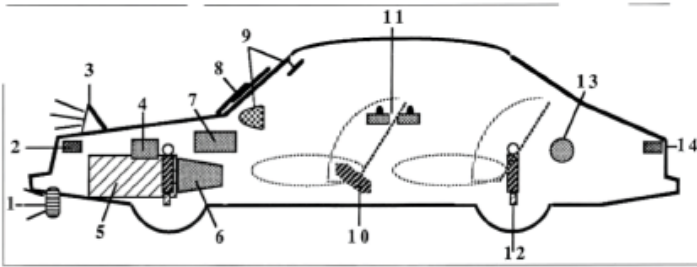
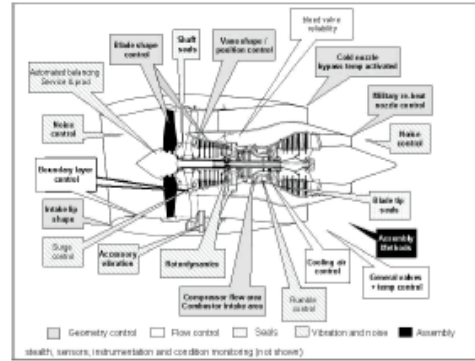


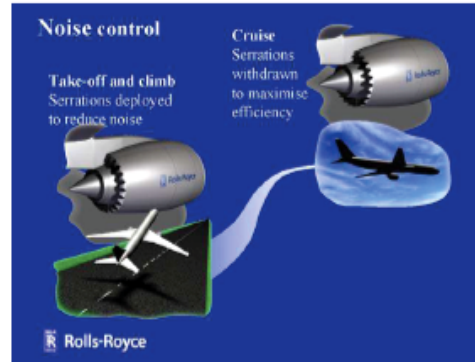
Fig 12 Potential applications for electrical shape memory actuators in automobiles: (1) foglamp louvre; (2) engine hood lock; (3) retractable headlight; (4) fuel management; (5) engine control; (6) transmission control; (7) climate control; (8) wiper pressure control; (9) rear-view mirror adjustment; (10) seat-belt adjustment; (11) central locking system; (12) shock absorber adjustment; (13) filter inlet lock; (14) trunk lock



Venus Rover CAD

Робот для дослідження поверхні Венери (NASA) : T=450°C.

Необхідні силові приводи з ЕПФ – потреба у високотемпературних сплавах з пам'яттю форми

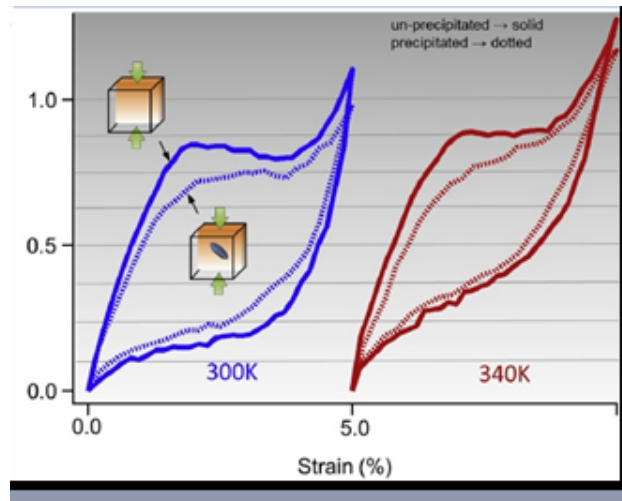
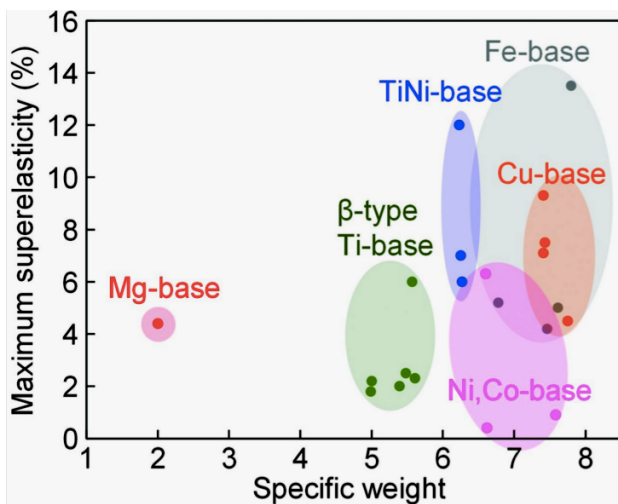


The main disadvantage of well known and widespread shape memory Ti-Ni alloys is the high cost and complexity of production using special vacuum equipment. So, today it is urgent to simplify the method of producing alloys with shape memory effect and replace the expensive components of the alloy to more affordable ones, while maintaining the unique performance properties at a high level.

Fe-alloys provide thermoelasticity of MT in a wide range of temperatures, as well as high mechanical properties, which include the ability to generate significant reactive stresses that exceed the yield strength material, as well as sufficiently large reversible deformations in the shape memory and superelasticity effects under the influence of significant loads.

Ferromagnetic the Fe- and Cu- base have the highest energy values, which are absorbed in one superelastic cycle at constant temperature from the deformation. The significant physical and mechanical properties of these materials take place for the polycrystalline state, which greatly simplifies the technology for their production.

Свойства		стали с ЭПФ	TiNi	Cu-Zn-Al
Физические	Температура плавления, °C		1300	950-1020
	Плотность, г/см ³		6,5	7,8-8,0
	Теплопроводность 20°C		8,6(M);18(A)	84 - 120(A)
	Коэффициент температур. расширения		6,6(M);11(A)	17(A)16-18(M)
	Коррозионная стойкость	высокая	высокая	удовл. (Al, бр.)
Биосовместимость	хорошая	высокая	низкая	
Механические	Предел прочности, МПа	до 1600	800-1100	400-800
	Удлинение при разрыве, %	30	15,5-20 (A) 40-50 (M)	10-15 (M)
	Предел текучести, МПа	до 1100	50-300 (M) 100-800 (A)	150-300 (M) 150-350 (A)
	Модуль Юнга, ГПа	200	28 (M) 75-80 (A)	70 (M) 70-100 (A)
	Усталостная прочность, МПа (N=10 ⁶)		350	270
	Размер зерна, мкм		20-100	50-150
	Мехобработка	хорошая	удовлетв.	плохая
Функциональные	ТИМП, °C		-100 ÷ +200	-200 ÷ +120
	Гистерезис, °C		20-30	5-20
	Обратимая деформация 1-го ЭПФ, %	3	8	5
	N<100		6	1
	N<10000		2	0,8
	N<1000000		0,5	0,5
	многократного ЭПФ, %		4-5	2-4
	Демпфирование, % SDC	-	15-20	30-85
	Псевдоупругая деформация, %			
	монокристалла		10	10
поликристалла		4-10	2	
Макс. реактивные напряжения, МПа		600-900	500-700	
Производительность, Дж/г		1-4	1	
Себестоимость	низкая	высокая	средняя	



The research purpose was to develop the novel functional nanostructured composite materials with shape memory effect and superelasticity and predetermined properties. The research aimed on creating shape memory nanocomposites based on alloys of iron and copper as a new class of functional materials are primarily due to their unique properties and a complex of physical and mechanical properties. The precipitation of nanosized particles of different chemical composition, size and volume fraction during aging is a promising approach to the creation of a new class of high-strength functional materials with SME and SE based on natural nanocomposites. Nanoparticles produced by dispersion hardening do not undergo martensitic transformation, but due to variation in their chemical composition, size and volume fraction it is possible to control simultaneously the mechanical and functional properties of the material and, thus, to obtain nanocomposites with the necessary complex of service properties. In our work we approach the creation of nanocomposite materials with SME based on iron and copper, which by their characteristics are close to the known world analogues. Thus, according to the mechanical properties, such new materials significantly outperform commercial Nitinol based alloys, so in Fe-based alloys, the level of superelastic deformation $>13.5\%$ (Nitinol $\leq 8\%$), the martensite induction stress $>800\text{MPa}$ (Nitinol $\leq 600\text{MPa}$), and as per the magnetic properties they exceed Heusler alloys (magnetization in Fe-based alloys are 3 times bigger and Curie temperature can be varied in the wide range).

The main idea of the research is by changing chemical composition, regimes of preliminary thermomagnetic and thermomechanical treatment of alloys it is possible to considerably affect the process of its decomposition at aging, control a size, volume fraction and orientation of nanoparticles coherently bounded to a matrix of the alloy that can result in significant changes of MT characteristic temperatures and a hysteresis of Fe- and Cu- based SM alloys.

The influence of thermomechanical and thermomagnetic treatment on functional and mechanical properties of Fe-Ni-Co-Ti, Fe-Ni-Co-Ti-Cu, Cu-Al-Mn and others was studied by

our team at Engineering and physical faculty of Igor Sikorsky KPI. We found that the precipitation of nanosized particles of the strengthening phase under dispersion hardening during the aging creates conditions for the formation of a high-strength state and the appearance of high-temperature SE. Our previous experimental studies showed that the ferromagnetic β_3 -phase Cu_2AlMn nanoparticles formed in Cu-Al-Mn alloys when aged in a magnetic field: 1) provide a decrease in stress states that arise under martensitic transformations; 2) contribute to the growth of the effect of elasticity and thermoelasticity. The oriented growth of precipitated phase nanoparticles in the direction of applied magnetic field and the increase of their volume fraction contribute to reversibility of induced martensitic transformation as well. The authors of the project also found that an increase in elastic deformation, as well as thermoelasticity of iron-based alloys, in particular Fe-Ni-Co-Ti, can be achieved by precipitation of γ' -phase $(\text{CoNi})_3\text{Ti}$ particles as a result of aging of high-temperature phase and providing magnetic ordering, which reduces the volume effect $\Delta V/V_{\alpha \leftrightarrow \gamma}$ of martensitic transformation. An additional stimulus to increase these effects can be an additional strengthening of the yield strength of γ (austenitic) and α (martensitic) phases to retain the coherence of interphase boundaries at nucleation and growth of martensitic crystals as a result of combined thermomechanical treatment.

Phase transformations of martensitic type are inherent to a wide class of materials and alloys, which are characterized by structural features, that determine peculiarities of their formation and physical properties. Priority in research of new materials belongs to alloys, in which the structural phase transformations of martensitic-type are realized in a ferromagnetic matrix, such as Heusler alloys, intermetallic compounds Co-Ni-Al, Co-Ni-Ga alloys and Fe-based alloys.

We studied the martensitic transformation and shape memory alloys in systems: Cu-Al-Mn, Fe-Ni-Co-Ti, Fe-Co-Ni-Ti-Cu, Co-Ni-Al, Ti-Mo-S etc.

To get optimal properties, the alloys usually undergo an additional thermal, mechanical or magnetic treatment. The aging of Cu- and Fe- alloys leads to the formation of a system of nanoscale particles of ferromagnetic Cu_2MnAl phase in a paramagnetic Cu_3Al matrix that increases the T_c . The heat treatment, mechanical and magnetic fields allows to control number and size of particles in the alloy, martensitic transformation temperature and hysteresis, which depend on characteristics of precipitated particles.

Materials and methods

Thermomechanical treatment (TMechT) was applied for the Fe-27.2%Ni-17.4%Co-5.2%Ti (wt) alloy. It consists of multiple drawing through dies at room temperature. As a result of rods drawing operations, samples with a different compression degree ($\psi=3.8\dots75.3\%$) were obtained:

$$\psi = \frac{F_0 - F_1}{F_0} = \frac{d_0^2 - d_1^2}{d_0^2} = 1 - \frac{d_1^2}{d_0^2}$$

where d_0 and d_1 are rods diameters before and after drawing; F_0 and F_1 are respective cross-section areas of rods before and after drawing.



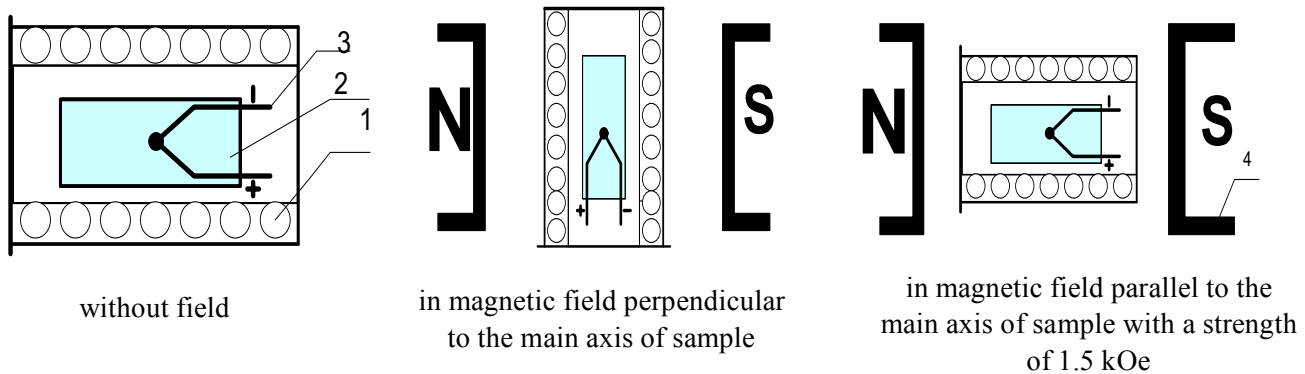
The Cu-Al-Mn alloys: Alloy1 - 85.3Cu-9.2Al-4.3Mn; Alloy2 - 84.7Cu-11.4Al-3.9Mn; Alloy3 - 83.75Cu-12.4Al-3.85Mn (wt%) were smelted in an induction furnace in an argon atmosphere. According to energy dispersive X-ray fluorescent analysis data, the chemical composition of the alloys (wt%) are as follows with error $\pm 0.5\%$. After homogenizing annealing at 1123K for 10 hours, the samples were quenched in water, then were annealed at a constant temperature of 498 K for 3 hours. The permanent magnetic field with a strength of 1.5 kOe was created by the selection of ferromagnetic plates which were spaced by a distance, required for a placement of an electrical heater with a sample in their gap. Thermomagnetic

treatment (TMagT) for aging of Cu-Al-Mn alloys consisted of quenching in water followed by annealing at $T = 473 \text{ K}$ for 3 hours in permanent magnetic field with a strength of 1.5 kOe



1 – electrical heater; 2 – investigated sample; 3 – thermocouple; 4 – magnetic field

Scheme of samples at annealing:



Results and Discussion

When σ reaches certain value which is typical for the specified experiment temperature the dependence $\sigma(\epsilon)$ deflects from linear. Martensite crystals formation in stress field corresponds to this value: 50 MPa for Alloy 1 and 85 MPa for Alloy 2. The phenomenon when a specimen experiences considerable deformations connected with martensite phase formation and recovered upon unloading is called superelasticity. The superelastic deformation value is a sum of constituents of macroscopic shift of all martensite crystals in the operating effort direction. The unloading results solely in partial recovery after deformation because of specimens deformation which occurs in temperature interval $M_s < T_d < A_f$ (T_d – deformation temperature) with the thermodynamically stable martensite in the absence of stress. Heating of deformed specimens up to the temperature which exceeds A_f results in full recovery of initial

shape. With each subsequent loading cycle the martensite formation stress increases as a result of mechanical strain hardening and specimen temperature rise because of the local heating due to interphase boundaries friction. Furthermore, the superelastic deformation extent grows with each subsequent cycle of “loading–unloading”. Total deformation ϵ_{tot} as a result of the phase transition consists of elastic ϵ_{el} , unelastic ϵ_{un} and residual ϵ_{res} deformations (Fig.1) and is described with the formula: $\epsilon_{tot} = \epsilon_{el} + \epsilon_{unel} + \epsilon_{res}$.

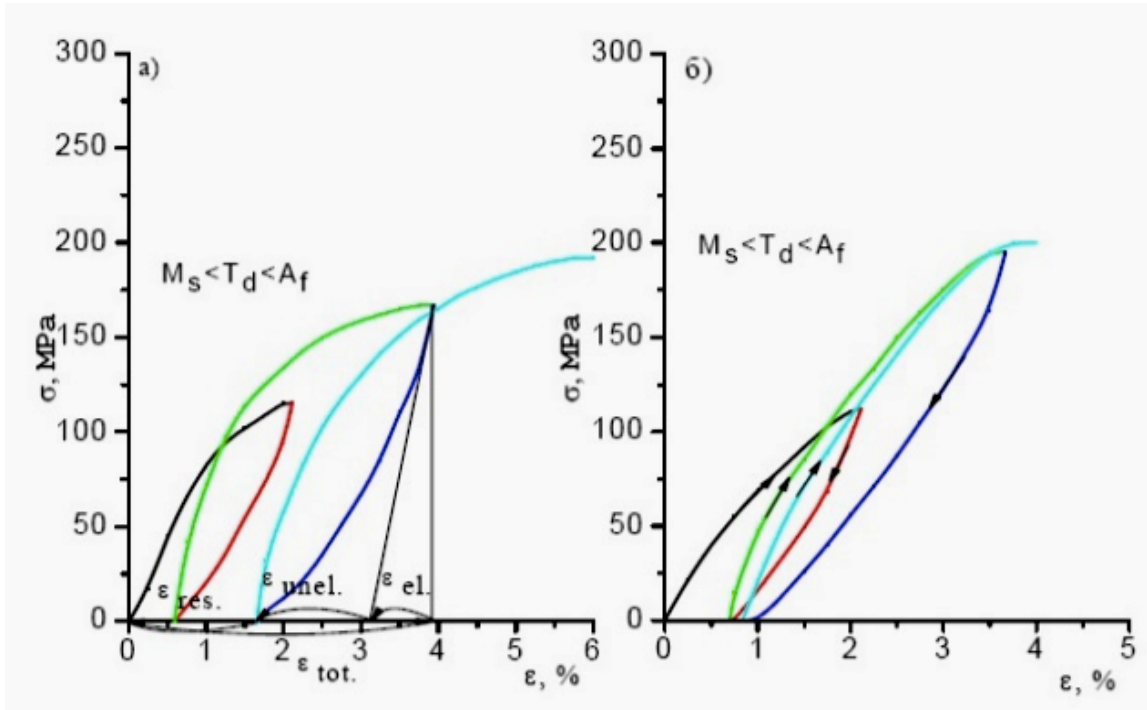
Functional ferromagnetic shape memory materials attracts an increasing attention of researchers due to their unusual deformation behavior resulting in a reversible size change under the influence of temperature, applied external stresses, magnetic fields, and their combination, demonstrating the effects of shape memory, pseudoelasticity or superelasticity, plasticity of transformation, magnetoelastic deformation, etc. The abovementioned properties are widely used in different practical applications.

Reduction of the MT temperature hysteresis width, which is equivalent to increase of thermoelasticity, in polycrystalline alloys of Fe-Ni-Co-Ti type, is achieved by lowering the austenite phase shear modulus, which creates conditions for the reduction of the elastic energy of martensite crystals coherently conjugated to austenitic matrix.

The most common way to increase the strength and plastic properties of ferrous alloys (steels) is a thermomechanical treatment, which combines plastic deformation in the austenitic state with following quenching. The main result of preliminary tensile strain is the decrease of MT start temperature (M_s). MT activation is caused by stresses arising in material at deforming.

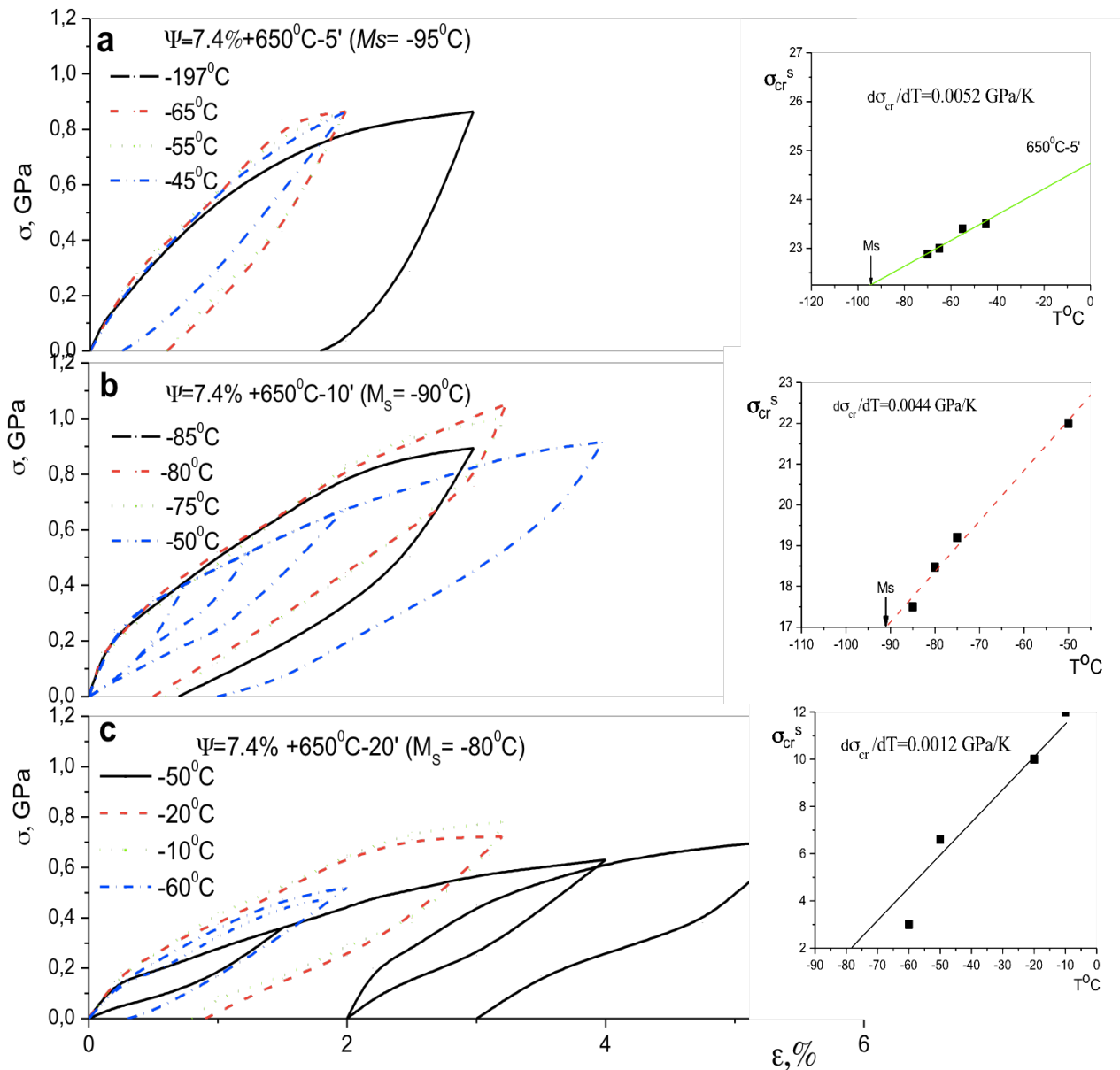
This work is devoted to the study of mechanical behavior of ferromagnetic Fe-Ni-Co-Ti alloy in different structural states. The effect of preliminary plastic deformation and following aging of quenched austenite on characteristics of thermoelastic martensite transformation, as well as on elastic deformation behaviour of martensite and austenite phases were investigated in this work to develop regimes of thermomechanical treatment and to improve the mechanical properties of Fe-Ni-Co-Ti shape memory alloys.

σ - ε dependences was obtained by cyclic loading and unloading of alloys at the deformation temperature $T=300$ K for: a) Alloy 1 – Fe-37.0 Co-15.2 Ni -8.0 Ti-6.17 Cu (wt%); b) Alloy 2 – Fe-36.6 Co-15.2 Ni-6.72 Ti-7.62 Cu (wt%), aging at 500°C, 3 h (Fig. 1)



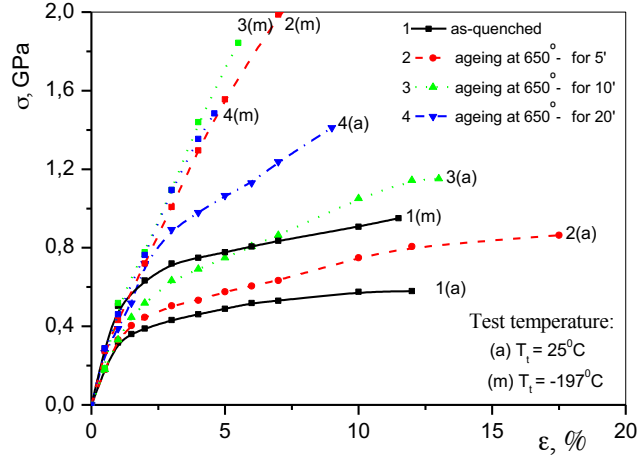
By changing the heat treatment regimes, it is possible to control the parameters of thermoelastic MT and the superelastic deformation in aging alloys. The deformation behavior of such alloys can serve as the basis for their potential application in power executive devices or in the storage of elastic energy.

Deformation behavior of ferromagnetic Fe-27.2%Ni-17.4%Co-5.2%Ti (wt.%): the stress (σ)-strain (ε) curves under cyclic loading-unloading of Fe-Ni-Co-Ti alloy in austenite state with a compression degree of $\psi = 7.4\%$ followed by quenching and then ageing at $T = 650^\circ\text{C}$ for 5 min (a), 10 min (b), 20 min (c) as well as the critical stress value for inducing martensite deformation as a function of test temperature for different TMechT regimes (graphs on the right) (Fig. 2):



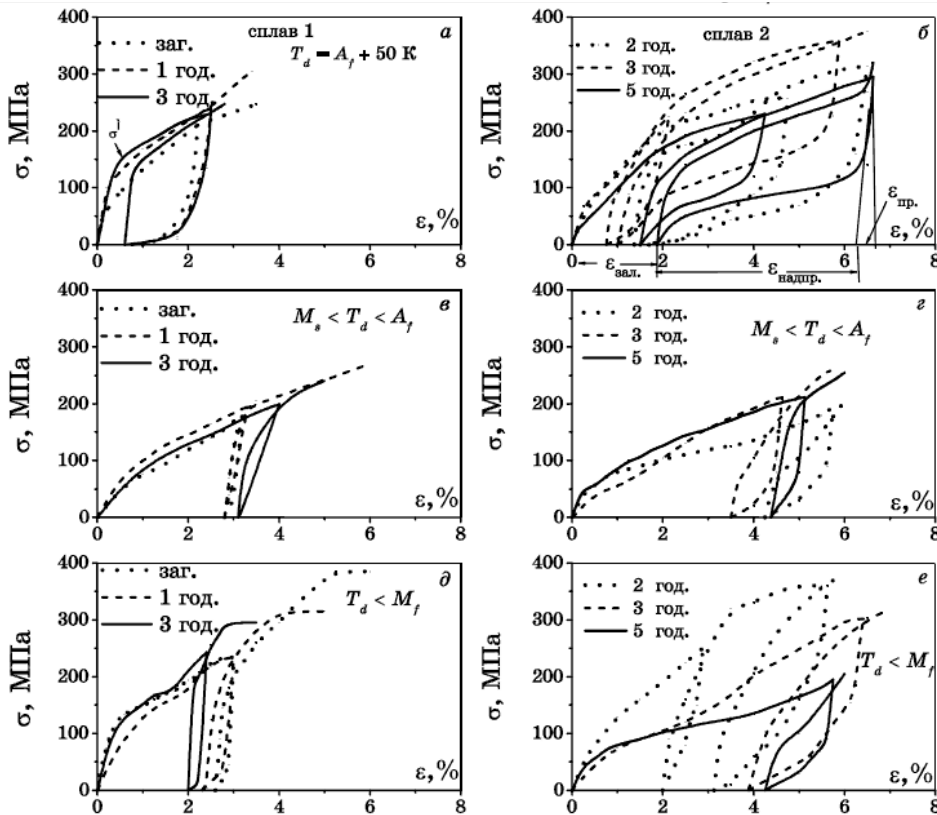
Reduction of the MT temperature hysteresis width, which is equivalent to increase of thermoelasticity, in polycrystalline alloys of Fe-Ni-Co-Ti type, is achieved by lowering the austenite phase shear modulus, which creates conditions for the reduction of the elastic energy of martensite crystals coherently conjugated to austenitic matrix.

The stress (σ) – strain (ε) curves $\sigma=f(\varepsilon)$ (Fig.3) of Fe-Ni-Co-Ti alloy samples after different TMeChT regimes: (1-4) tested at $T_i=25^{\circ}\text{C}$ in austenitic (a) and at $T_i=-197^{\circ}\text{C}$ in martensitic (m) states:



The main result of preliminary tensile strain is the decrease of MT start temperature (M_s). MT activation is caused by stresses arising in material at deforming.

Deformational behavior: σ - ϵ dependences obtained by cyclic loading and unloading for Alloy 1 - Cu-13.1Al-4.5Mn(wt%); Alloy 2 - Cu-12.4Al-5.03Mn(wt%) (Тітенко А. *Nanosystems, Nanomaterials, Nanotechnologies* 2014, т. 12, № 2, сс. 383–394) Fig.4:



The results of X-ray phase analysis (Fig.5a) testify the β_1 -phase (of close to Cu_3Al composition) formation after the cooling (with use quenching in water) as a result of ordering ($\beta \rightarrow \beta_1$) of high-temperature (austenitic) β -phase. The subsequent annealing leads to the Cu-Al-Mn alloy aging accompanying by precipitation of dispersed particles of ferromagnetic β_3 -phase of Cu_2AlMn composition in β_1 -matrix.

After annealing without magnetic field (Fig.5b) there are no reflections observed from β_3 -phase on diffraction patterns that can be explained by a low percentage of this phase in the alloy or/and its high dispersed (nanosized) state.

The annealing in the magnetic field (Fig.5c, d) favours the precipitation of β_3 -phase (Cu_2AlMn) particles in β_1 -matrix, as argued by an appearance of reflections of weak intensity from β_3 -phase at appropriate angles. The weak intensity of reflections can indicate that the particles of precipitated phase are nanosized. Change in sample orientation relative to the magnetic field direction during the aging affects β_3 -phase formation. After annealing in the parallel field, the diffraction lines from β_3 -phase are slightly more intense than after annealing in the perpendicular field that can testify about more amount of this phase in the alloy.

Phase composition of Cu-Al-Mn alloy a)as-quenched; b)annealed without field; c)annealed in perpendicular field; d)annealed in parallel field (Titenko and Demchenko *Nanoscale Research Letters* (2016) 11:237 doi 10.1186/s11671-016-1453-2) Fig.5:

According to the results of measurements of low-field magnetic susceptibility (χ/χ_{max}) of Cu-Al-Mn alloy at different regimes of aging there is a slight increase in the start temperature (M_s) of direct $\beta_1 \leftrightarrow \beta'$ transformation after annealing in magnetic field and a decrease in the width of MT temperature hysteresis (ΔT). The increase in M_s , in this case, is caused by depletion of β_1 -matrix with manganese.

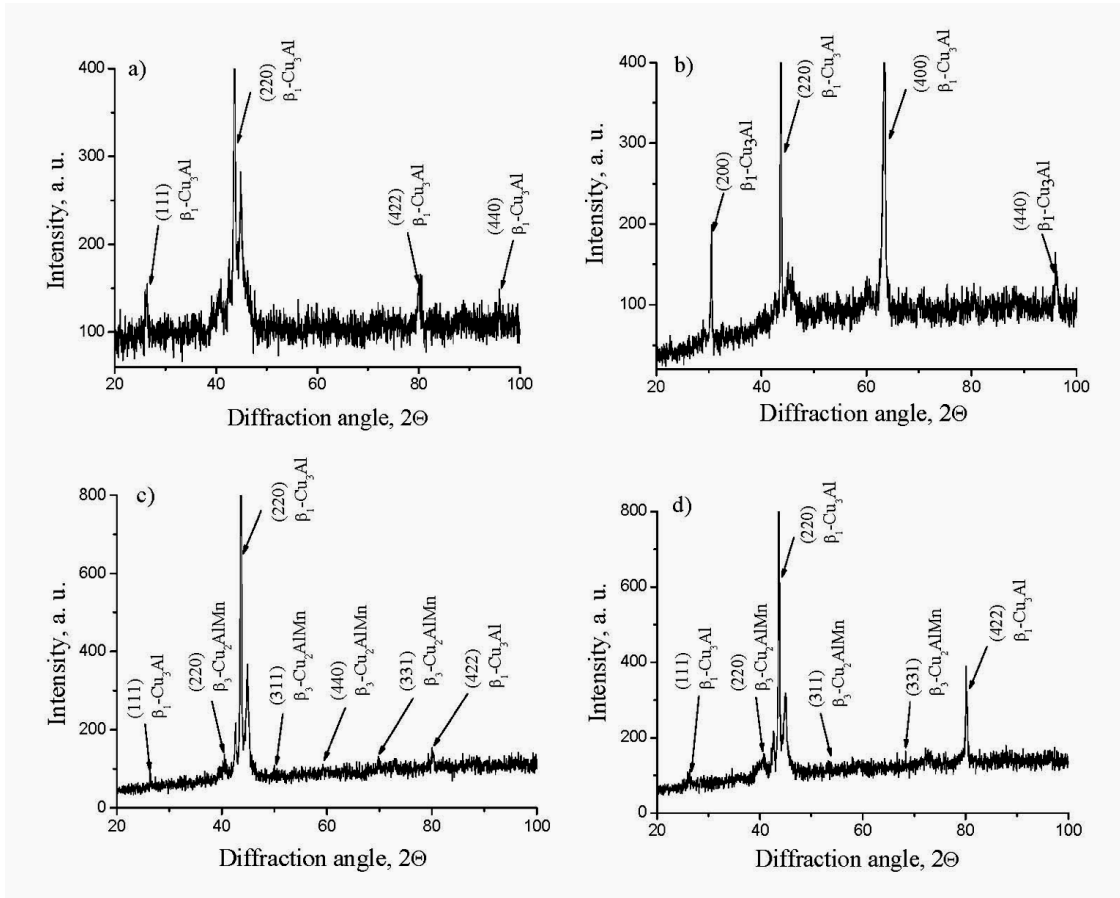


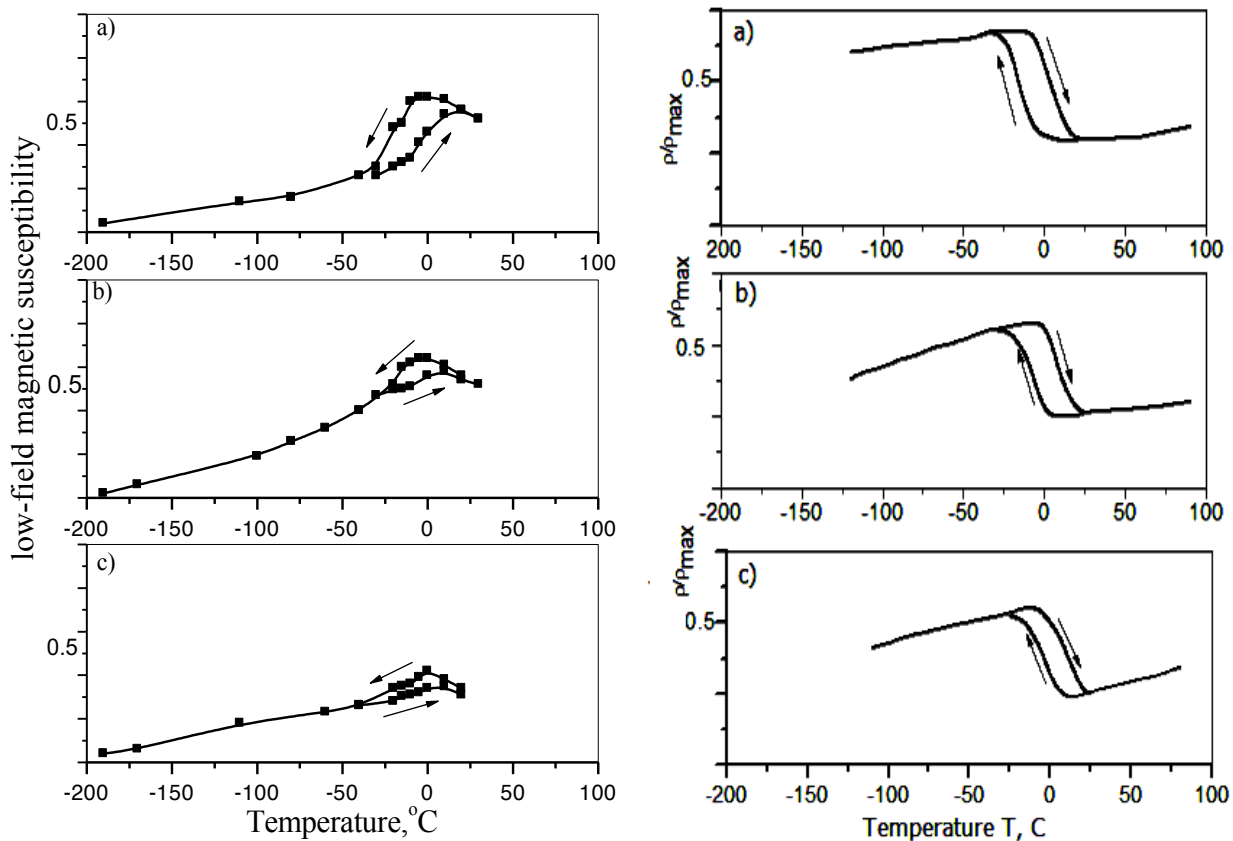
Fig.5

A lower amplitude of a transition jump on the χ/χ_{\max} curves for samples with thermomagnetic treatment is associated with a dominant orientation of nanoparticles which are allocated in a direction of applied external magnetic field. In the case of thermal treatment without a magnetic field, the spherical concentration inhomogeneities are distributed in a sample, mainly, chaotically, in contrast to thermomagnetic treatment, which orders the Cu_2MnAl phase nanoparticles nucleation.

Such effect of thermal magnetic treatment on magnetic susceptibility can be explained by the fact that magnetic characteristics of the investigated alloy are defined by an interaction of nanoparticles of precipitated phase. Nanoparticles that are within the martensite crystals are subjected to considerable coherent stresses caused by a crystal lattices mismatch of martensite and nanoparticles, which leads to magnetic anisotropy of nanoparticles ensemble. The crystal

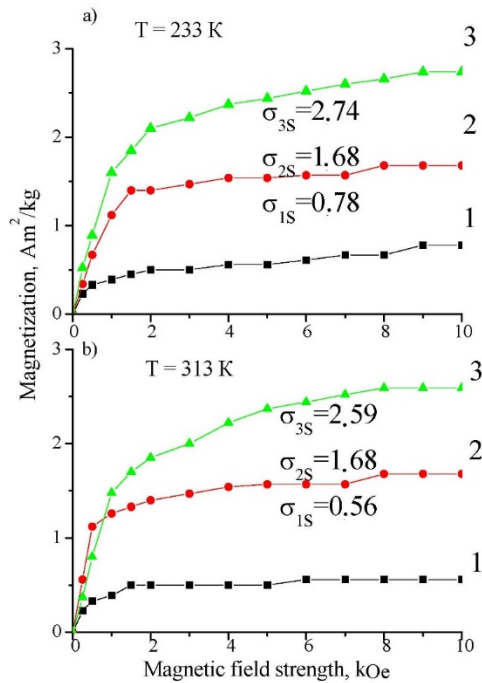
lattice mismatch sharply increases when cubic lattice of the austenitic matrix is transformed into the orthorhombic lattice of martensite, and, thus, the temperature dependence of magnetic susceptibility is caused by a corresponding change in magnetic anisotropy of nanoparticles.

Temperature dependence of low-field magnetic susceptibility and electrical resistance of Alloy1 after aging: a) without field; b) in perpendic magnetic field; c) in parallel magnetic field (Fig.6):

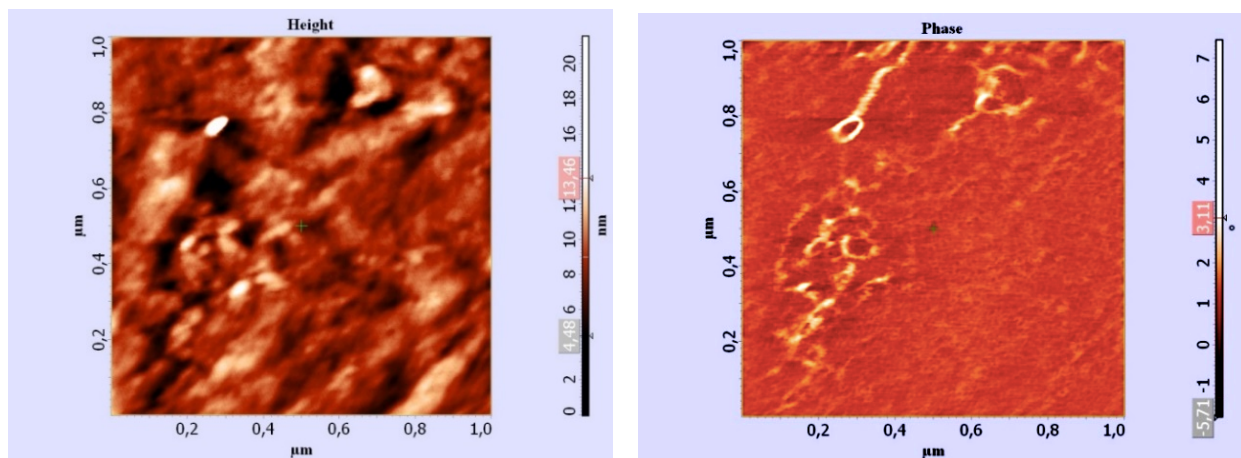


It should be noted, that in the case of applying an external magnetic field, the critical nucleus size and the energy of its formation decreases. At a certain temperature and aging time, the application of magnetic field stimulates the formation of new nuclei, that agrees well with the behavior of magnetization, which, in turn, depends on the amount of precipitated ferromagnetic nanoparticles. A magnetic moment of alloy depends on, as it is known, the magnetic moment of manganese atoms, and the distance between them as well.

Field dependences of magnetization of Alloy1 samples after aging: 1) without magnetic field; 2) in perpendicular magnetic field; 3) in parallel magnetic field; a) in martensite state (-40°C); b) in austenite state (+40°C); where σ is a saturation magnetization (Fig.7):



The microstructures of Cu-Al-Mn alloy surface - force microscopy (AFM) method: a) a surface image in micron scale; b) the same image in phase contrast (Titenko, A.N., Demchenko, L.D., Perekos, A.O., Gerasimov O. Yu. *Nanoscale Res Lett* (2017) 12: 285. doi:10.1186/s11671-017-2052-6) Fig.8:



The size of nanoparticles is in the range of 20÷40 nm.

Conclusions

Preliminary thermomechanical treatment, which consists of drawing with compression degree $\psi=7.4\div 22.5\%$, following quenching and aging at 650°C for $5\div 10$ min, favours the deformation of initial alloy on the channels of phase and twinning plasticity in the testing temperature range of $M_s < T_{test} < A_f$ and corresponds to optimal combination of maximum superelastic strain and one-way shape memory effect in investigated alloys.

The almost full reversibility of superelastic deformation, which is probably due to a high degree of the alloy matrix hardening, that promotes the preferred martensitic transformation behavior under a load versus the plastic deformation behavior, was obtained.

A higher drawing degree contributes to substantial stabilization of austenite due to a significant structure distortion and helps to reduce an austenite grain size that limits martensitic transformation induction both in field of mechanical stresses and temperature.

Applying a magnetic field stimulates the formation of ferromagnetic nanoparticles during the decay of solid solution. Thermomagnetic treatment helps to create effective nucleation centers of nanoparticles in Cu-Al-Mn alloy during the aging of high-temperature phase. Annealing in a magnetic field promotes the increasing of ferromagnetic nanoparticles number in the nonferromagnetic matrix.

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DATA MINING AND ITS APPLICATIONS FOR TELECOM INDUSTRY

Globa L.S.

Abstract

Telecom companies generate amount of data (define as a Big Data). These data consist of call detail data, network data, and customer data. To process such a large amount of data the telecom industry uses the approaches based on Data Mining and statistics. In this research the methods of Data Mining and statistics were analyzed. The approach based on fuzzy rules to organize as fuzzy knowledge base is suggested. The results of fuzzy knowledge base development for Big data of telecom operator analysis based on example of determining the quality of service delivery is presented. This approach reduces the computational load on the system during its operation.

Keywords: Data Mining, Big Data analysis, the quality of service delivery by telecom operator, fuzzy knowledge base.

Introduction

According to research conducted by a number of leading companies in the world [1] the telecom operators are faced with the need to comprehensively consider the influence of various services characteristics (technical, economic, experience of services using by the end user) to clearly understand and manage the processes occurring between the telecom operator and his subscribers. This is especially important due to the rapidly expanding range of provided services and the transition to digital space.

The whole range of this characteristics is too large and complex to collect, process and analyze using the current computing infrastructure. They are characterized by:

- significant volume (from terabytes to petabytes);
- the need for high-speed processing in real time taking into account that their storage volumes should be reduced;

- heterogeneity (data may be structured, unstructured, partially structured);
- the need to meet the requirements of authenticity (this requirement can be broken due to the variety of data sources and methods of their processing, breach of security requirements);
- value (the usage of forecasting and analysis methods to predict the direction of business development).

Telecom companies are investing great money in the development of analytical tools and services.

At the same time, the data analysis to solve the urgent tasks is performed often based on the data obtained as a result of telecom operator economic activity, or based on the sociological surveys, or based on the technical parameters of the operator's infrastructure functioning. Very often deciding whether to invest in a particular part of the system or infrastructure does not take into account the impact and analysis of all possible factors and consequences. As an example it's possible to consider the task concerning the degree of customer satisfaction with the services provision by the operator, it is quite obvious that technical failures affect the degree of satisfaction. So, operator's pricing policy and quality of services provision together influence to the final evaluation of the quality of services by the subscriber.

Previously, applied statistics was widely used in the field of processing knowledge in telecom industry. The statistics evaluated, tested hypotheses, but gave rough and average results. Thanks to technical progress, people began to store huge amounts of information, which was heterogeneous, and naturally, had to be processed. The methods of statistics did not make it possible to predict and control processes and had a highly computational complexity from telecom operator point of view. The telecom operator could no longer solve the tasks by applying statistics. It is necessary to structure large amounts of data and to extract useful information from them in order to:

- analyze this data successfully in the future;
- visualize these data for easy human perception;

- move from data analysis to knowledge application for effective business management, especially in the telecom industry.

Thus, the telecom industry faces the urgency to process, analyze and predict significant amounts of information, characterized by significant unstructured, non-simultaneous receiving data from various sources. Such large amounts of data are called Big Data.

The purpose of this paper is to identify the features of existing mathematical methods named Data Mining that can be used by telecom operators for solving problems arising from new information technology such as IoT, M2M and others. In more detail the method of Big Data processing based on designing the fuzzy knowledge base used fuzzy logic will be considered.

The paper is structured as follows: Section 2 contains state of the art of Big data analysis features and the specifics of this process for telecom operators. Section 3 introduces the proposed approach to Big Data analysis on the example of the telecom operator data. Section 4 presents the results of fuzzy knowledge base development for Big data of telecom operator analysis. Section 5 includes the summary and outlook on future work.

2. State of the art and background

Nowadays, the Data Mining solutions are applied by telecom operators such as network operators and Internet providers with the aim to improve processing of different kind unstructured large data volumes (Big Data) for getting decisions that are more intelligent. Analytics enables telecom and Internet providers to increase economic effectiveness and efficiency in fields of service provisions significantly.

Big Data, defined as data too large and complex to capture, process, and analyze using current computing infrastructure, is now popularly characterized by at least five V's (initially it was described as having three, but two have since been added to emphasize the need for data authenticity and business value):

- volume - data measurement is in terabytes (2^{40}) or even petabytes (2^{50}), and is rapidly heading toward exabytes (2^{60});
- velocity - data production occurs at very high rates, and, because of this sheer volume, some applications require real-time data processing to determine whether to store a piece of data;
- variety - data is heterogeneous and can be highly structured, semi-structured, or totally unstructured;
- veracity - due to intermediary processing, diversity among data sources and in data evolution raises concerns about security, privacy, trust, and accountability, creating a need to verify secure data provenance;
- value - through predictive models that answer what-if queries, analysis of this data can yield counterintuitive insights and actionable intelligence.

Big Data enables new directions for scientific research once limited by the volume of available data. To better address this problem, statistical machine-learning models-which require training data to build and evaluate-are often used [2].

Thanks Big Data, the paradigm for solving complicated problems have been shifted; now the accurate selection of a mathematical model loses its importance because there are big enough data to compensate the model accuracy [3].

Modern Big Data analytics require a transformation from unstructured to structured data that in fact forms the process of "compressing data to their sense" and develops Big Data processing strategy as "data - information - knowledge - prediction". Under such understanding there are the following elements of data processing:

- Data - flows of raw facts such as business operations;
- Information - clusters of facts that are relevant for people such as decision making;
- Knowledge - data/information that are organized to express understanding, experience and learning using previous experience.

Data mining is the process of detecting in raw data previously unknown non-trivial but practically useful and accessible interpretation of knowledge necessary for decision-making in various spheres of human activity . This technology helps to identify hidden links in databases of very big sizes. Since Data Mining has developed based on applied statistics, methods of artificial intelligence, database theory and so there are a lot of application for data processing. However, all this methods and algorithms are not very effective for Big Data processing [1].

Data Mining uses the concepts of averaging over a sample, the concept of templates and so on. However, there is no universal way to determine the meaning and connection of data among themselves, and additional studies are required for each subject area in order to identify these links.

The purpose of Data Mining is to find such models that can not to be found by the usual methods. There are two types of models: predictive and descriptive. Predictive models: positioned on a data set with known results.

These are classification models (describe the rules by which the description of an object can be attributed to one of the classes) and the sequence model (they describe the functions by which the change of continuous numerical parameters can be predicted).

Descriptive models: they pay special attention to the nature of the dependencies in the data set, the mutual influence of various factors, the construction of empirical models. There are easy for human perception.

The types of patterns that Data Mining technology are presented in the paper [2]:

- Association - applies when several events are related. For example, it happens that the subscriber stops using the operator's telecom services because his whole family uses the services of another telecom company. Therefore, the subscriber starts using the company's telecom services that his family uses.

- Classification - the identification of features that will characterize the group to which the object belongs according training based on the already classified objects.
- Clustering - differs from the classification in that groups are not known in advance and Data Mining tools independently identify different homogeneous groups of data.
- Sequence - applies when there is a chain of events related in time.
- Forecasting - creating or finding templates that will show truly the trend of the required indicators behavior in terms of time series. With the help of them, one can predict the behavior of the system in the future.

Because Data Mining has developed at the junction of many areas, it is possible to reuse classes and methods of this technology: neural networks, decision trees, genetic algorithms, limited search algorithms, associative rules, cluster analysis and much more [4]. Moreover, methods of data mining allow to solve the problems of structural engineering design for innovative technical systems effectively in the telecom industry [1]. These methods have much in common with methods for solving problems of classification, diagnosis and pattern recognition. Nevertheless, one of their main distinctive features is the function of the regularities interpreting that form the basis rules for the objects inclusion in equivalence classes. Therefore, logical methods are becoming more common today. There is another important reason to determine the priority of logical methods. It lies in the complex systemic organization of the areas that constitute the application subject of modern information technologies.

The development of intelligent data processing methods for telecom companies is necessary for:

- Reducing the computational complexity of methods for processing big data for the services provision by operator to a subscriber with a given quality of service;
- Operator should to predict the risks that may arise from the operation of the telecom system

- The operator should be able to identify faults in the system and find out the cause of their occurrence

Some of the existing algorithms can be adapted to compute large distributed information arrays. At the same time, serious difficulties can arise with a visual representation of the results - because of the huge amount of information entering the input, the number of dissimilar reports at the output sharply increases. For their convenient presentation, new mathematical methods are needed, which are fundamentally different from report generators used for traditional Big Data processing and storage technologies.

Business analysis is a descriptive process of analyzing the results achieved by a business for a certain period of time and the processing of Big Data allows to get a forecast of the results in the next period and business recommendations for the future. Big Data technologies also allow to analyze more data types than business intelligence tools allowing to focus not only on structured repositories. Although Big Data and Business Intelligence have the same goal (finding the answers) they differ in three aspects:

- Big Data is designed to handle larger amounts of information than business analytics and this is in line with the traditional Big Data definition;
- Big Data is designed to process faster and more variable data, which means deep exploration and interactivity;
- Big Data is designed to process unstructured data the ways of using which just begin to study only after collecting and storing them.

They require new algorithms and dialogue options to facilitate the search for trends in these huge, poorly structured arrays.

In particular, studies [5] argue that when Big Data processing information is handled differently than when conducting a business analysis. When Big Data processing, the result is obtained in the process of clearing data by sequential modeling: first, a hypothesis is built, a

statistical, visual or semantic models are designed, then on the basis of them the correctness of the hypothesis is tested, only then the following hypothesis is advanced. This process requires the researcher either to interpret the visual meanings or to compose interactive knowledge-based queries, or to develop adaptive "machine learning" algorithms capable of obtaining the result that is sought. However, the lifetime of such algorithms can be quite short.

Techniques for Big Data analysis include:

A/ B Testing: the technique in which a control sample is compared with others. In this way it's possible to identify the best combination of metrics to achieve, for example, the best response from consumers to a marketing proposal. Big Data allows to perform a large number of iterations and thus obtain a statistically significant result.

Association rule learning: the set of techniques for identifying relationships that are associative rules between variables in large data sets. It's used in Data Mining.

Classification: the set of techniques that allow to predict, for an example, consumer behavior in a particular segment of the market (making purchasing decisions, outflows, consumption, etc.). It's used in Data Mining.

Cluster analysis: a statistical method of grouping objects by detecting previously unknown common features. It's used in Data Mining.

Crowdsourcing: the technique for collecting data from many sources.

Data fusion and data integration: A set of techniques that allow to analyze social media users' comments and compare them with actual results obtained in real time mode.

Data Mining: the set of techniques that help to identify the most advantageous to the product being promoted or services to the consumer category, identify the characteristics of the most successful employees, predict the behavioral model of consumers.

Ensemble learning: this method employs a number of predictive models, which improves the quality of made predictions.

Genetic algorithms: in these methods the possible solutions are represented as "chromosomes" that can be combined and mutated. As it's in natural evolution the fittest survives.

Machine learning: the field in computer science that aims to create self-learning algorithms based on the analysis of empirical data.

Optimization: the set of numerical methods for redesigning complex systems and processes to improve one or more metrics. It assists in making strategic decisions, for example, the composition of the product line, investment analysis, etc.

Pattern recognition: the set of techniques with elements of self-learning to predict the behavioral model of consumers.

Predictive modeling: the set of techniques that allow to create a mathematical model of a predetermined probable scenario. For example, an analysis of the CRM-system database for possible conditions that will cause subscribers to change provider.

Regression: the set of statistical methods for identifying regularities between changing a dependent variable and one or more independent variables. Often used for predictions and foresights. It's used in data mining.

Sentiment analysis: At the base of techniques for assessing consumer sentiment are technologies for recognizing the natural language of people. They allow to select messages from the general information stream that are related to the item of interest (for example, a consumer product) and to evaluate the polarity of the judgment (positive or negative), the degree of emotionality, etc.

Signal processing: the adopted set of radio techniques that aims to recognize a signal on a background of noise with analyzing it further.

Spatial analysis: the collection of partially borrowed from the statistics techniques for spatial data analysis - topology of the area, geographical coordinates, object geometry. Often the source of Big Data in this case is geoinformation systems.

Statistics: the science of collecting, organizing, and interpreting data, including questionnaire design and experimentation. Statistical methods are often used to evaluate correctness the relationships between events.

Supervised learning: the set of machine-based learning techniques that allow to identify functional relationships in the data sets that being analyzed.

Simulation: modeling the behavior of complex systems, it's often used to predict, forecast and process different scenarios in planning process.

Time series analysis: the set of borrowed all statistics and digital signal processing methods for a time-repeated sequence of data.

Unsupervised learning: the set of machine-based learning techniques that help identify hidden functional relationships in the analyzing data sets. Has common features with Cluster Analysis.

Visualization: Methods of graphically presenting Big Data analysis results in the form of diagrams or animated images to simplify interpretation and facilitate understanding of the results. Visual presentation of Big Data analysis results is crucial to their interpretation. It is no secret that human perception is limited and researchers continue to work the field of improving modern methods of presenting data in the form of images, diagrams or animations.

The most common methods of Data Mining are: artificial neural networks, decision trees, genetic algorithms, nearest neighbor method and rule induction [1, 6, 7].

Big Data can be processed using Knowledge Discovery in Databases systems, this process includes following steps:

1 - acquisition, collection;

2 - pre-processing, clustering and evaluation of the template;

3 - compression based on fuzzy logic, fuzzy knowledge bases design as well as usage real analysis (data output) with processing and prediction [8, 9].

Thus, the evolution of Big Data technology is a natural evolutionary process caused by increasing the information flows, IT-tools for data receiving, storage and processing as well as the needs of businesses that have recognized the need to collect, analyze and store structured and unstructured data. In addition, the development of modern communications is impossible without processing arrays of data without quick response to customer requests.

At the moment telecom operators have to analyze the economic efficiency, analyze the efficiency of the infrastructure functioning based on the additional monitoring system and also should carry out the surveys of subscribers to evaluate the quality of service and determine their satisfaction with this, but the processes of analysis of three components are isolated and not considered in the complex.

3. The approach to Big Data analysis on the example of the telecom operator data

Given the peculiarities of Big Data processing for the telecom industry an approach based on fuzzy logic is proposed for jointly consideration of both clear and fuzzy parameters influence as well as to use the transition from unstructured data to fuzzy knowledge base (FKB) with clearly structured rules.

The main steps of the approach:

Step 1. Data flow formation (obtaining of functional and content dependencies, meta-descriptions formation, degree of parameters influences determination).

Step 2. Fuzzy knowledge base (FKB) designing.

Step 3. FKB reorganization and fuzzy knowledge rules correction with the help of metagraph theory.

Step 4. Fuzzy inference.

Step 5. Fuzzy prediction and foresight.

One of the most difficult steps of the proposed approach is the first step where it is necessary to form, define, structure and classify data streams in order to be able to apply the algorithms of fuzzy knowledge base rules formation that will allow their further usage for decision making and prediction. For this purpose it is necessary to define the parameters for the knowledge base forming as well as the ways of obtaining the values of these parameters.

Input data. In terms of the task of degree of QoS satisfaction by end-user evaluating and the possible churn, the parameters that affect this process is divided into the following groups:

- parameters characterizing the technical state of the system;
- cost of using voice and internet services;
- provided quality of services.

For data collection are proposed to use the statistical sources of telecom operator data for this task realization, they can be:

- technical - functioning monitoring system by telecom operator;
- economic - to use the available economic indicators in the companies;
- sociological - to use available survey data in company.

This data is combined into one or more tables according to the defined parameters' groups to form a fuzzy rule of FKB.

Structuring and classification of this data allows to obtain a table 1.

Table 1.

Structuring and classifying data flows to form fuzzy knowledge base rules

Customer satisfaction (Y1)	Technical parameters (Y2)					Economic parameters (Y3)			
	Connection Success Rate	Connection Block Rate	Connection Drop Rate	Backhaul Accessibility	...	Churn rate	Appetency	Gini index	...

Based on the statistics presented in Table. 1 rules are formed that represent the knowledge (for example, the forecast of changes in the degree of customer satisfaction for future periods), of the form:

$$\ll \text{IF } Y_2 \text{ TA } Y_3 \dots, \text{ THEN } Y_1 \gg.$$

Using such kind of rules, it is possible to predict the technical and economic state of the telecom operator for the next period in accordance with the methodology given in [12]. Let us consider in more detail approach to solving the problem of the degree of subscriber satisfaction with the quality of services.

First of all, it is necessary to define an integral indicator that can characterize the quality of the services provided and how it can be obtained from the data of the network monitoring system. This indicator is considered to be an integral index of the quality of network operation. Such integrated metric should allow to determine further actions to improve the quality of service based on its current value. The integrated quality index of a network's technical infrastructure can be used, for example, to estimate the required amount of cloud resources that need to be plugged in if a resource shortage of existing infrastructure is identified.

Calculation of the integral quality index of the network technical infrastructure.

To solve this problem, it is proposed to use decision-making methods based on fuzzy logic for which fuzzy expert rules are formed, this rules are the basis of the expert system.

Fuzzy rules in such a system can be periodically adjusted to the current state of the technical infrastructure by reconfiguration them during the accumulation of monitoring system data when providing services by the telecom operator.

Since the telecom operator faces a variety of analysis tasks it is necessary to use an approach that uses a group of different mathematical methods and allows you to solve the problem with a specific set of software tools based on the different mathematical methods.

In the proposed approach the assessment of the current status of the services provision process by the telecom operator is performed by determining the fuzzy value ("good", "bad" and so on) of the integral quality index of the network technical infrastructure functioning and consists of the following stages:

1. Obtaining an integral quality index (Y). It is difficult for an operator to evaluate the complex impact of individual service quality indicators because it is necessary to know the degree of each parameter impact on the overall condition of the service delivery system as a whole, so obtaining an integral quality index is a non-trivial task.

2. Formation of FKB using the current values of the integral quality index.

On the basis of the integral quality index Y it is necessary to obtain an assessment of the system state as a whole and to understand the algorithms of its behavior as well as to compress the knowledge or tendencies (based on logical or functional dependencies) that can be used for manage and to make decisions.

3. Using the formed FKB for continuous assessment of the quality of the telecom operator's services provision based on the integrated quality index of the network technical infrastructure functioning during operation.

The algorithm of FKB forming in a generalized form can be represented as follows:

Input data: measurement tables provided by the telecom operator's network monitoring system. The measurement table is a set of parameters that we denote $X_1 \dots X_n$.

It should be noted that $X_1 \dots X_n$ – a set of parameters by which the operator evaluates the overall state of the system, but none of them characterizes the system functioning quality as a whole, namely the output parameter (Y).

1. In order to build FKB it is necessary to divide the measurement table into 3 samples:

-Training sample includes M_1 records, where $M_1 = \{l, k\}$, which is required to form fuzzy logical rules of the knowledge base. In order to form the rules of the FKB it is necessary to determine the value of the integral quality index obtained by the function of desirability denote it as Y_D ;

-A test sample with M_2 records, where $M_2 = \{k + 1, n\}$, which is required to check the quality of the fuzzy logic rules of the knowledge base;

-Examination sample with M_3 records, where $M_3 = \{n + 1, m\}$, which is required for the final verification of the obtained FNB functioning correctness.

2. Generalized algorithm for determining unknown value of Y_D :

- Obtaining Y_D using the desirability function based on M_1 data.

3. FKB formation using M_2 data and obtaining the value of Y_{FKB} .

FKB is formed used the set of rules as: «IF X_1, X_2, X_3, \dots , THEN Y ».

To do this the follow steps should be realized:

1. Clustering

2. Choice of membership function.

3. Obtaining Y_{FKB} based on the selected membership function.

4. IF $|Y_D - Y_{FKB}| > \varepsilon \delta on$, then go to the 2.

5. IF $|Y_D - Y_{FKB}| \leq \varepsilon \delta on$, then the membership function is selected correctly.

Let us consider in more detail the main steps of the proposed approach used one of the real examples.

Input Data (for considered example). The following monitoring system parameters were used to determine the integral quality index (Y):

- *Connection Success Rate* – the success of data connections during data transfer 2G/3G, %;
- *Connection Block Rate* – the percentage of blockages due to congestion 2G/3G, %;
- *Connection Drop Rate* – the percentage of data connection breakages 2G/3G, %;
- *PS Attach Success Rate* – the percentage of procedures successfully completed Attach 2G/3G, %;
- *PDP Context Activation Success Rate* – percentage of successful activation procedures PDP Context 2G/3G, %;
- *Speed DL* – average daily HSDPA data rate to the subscriber, $\kappa\text{bit/c}$;
- *Iub Congestion* – part of BS 3G with high overloads on Iub interface, %;
- *Backhaul Accessibility* – availability of the zone transport network, %;
- *DNS Success Rate* – success of the DNS permit, %;
- *DNS Response Latency* – time of the DNS permit, mc ;
- *Peering Utilization* – the level of load of the peering joint, %;
- *Backbone Abnormal Latency* – exceeding the normal delay between the nodal points of the backbone transport network, %;

On the basis of the integral quality index parameters became possible to form the FKB to evaluate the integral quality index and to predict trends of its change in a short time interval.

The observation table is the input data $T = \{tMI\}$,

where i -th element $ti = (xi, yi)$, $xi = [xi1, xi2, \dots, xik]$ — the input values vector,

yi — the output value,

MI — number of observation,

k — the number of input variables, $x_i \in DX$, $y_i \in DY$.

The values of the data in the table are not the same content and different dimensions. So, they need to be normalized from 0 to 1 and they should be transformed so that the system can evaluate the level of quality of service provision as a whole. To calculate the integral service quality index, it is proposed to use the desirability function by Harrington [11].

FKB forming.

In accordance with the particularities of Big Data processing which have been widely discussed in a number of papers [15, 16] an approach based on fuzzy logic techniques is proposed to jointly account for the effects of both clear and fuzzy parameters as well as to use the transition from unstructured data to the fuzzy knowledge base with a clear structured rules. Using such kind of the rules can significantly reduce the amount of computation during the transmission and processing of traffic data on the network.

Input data: a fuzzy model is defined as a system with input variables $X = \{X_{k+1}, X_{k+2}, \dots, X_n\}$, defined in the input region of considerations $DX = DX_{k+1} \cdot DX_{k+2} \cdot \dots \cdot DX_n$, and one resulting variable Y , which is defined in the resulting reasoning area DY . A clear value that the input variable takes X_i , marked as x_i and as y for output variable Y [12, 13].

Clustering

There are a number of clustering methods. This paper considers the fuzzy c -mean algorithm which is based on minimizing the distance between the observed data x and the centers of clusters. For this purpose, the Euclidean distance is calculated [17]. Let us consider the algorithm of fuzzy c -means in more detail [14]:

Given: Observation table T , number of clusters c , number of observations m , stop parameter ϵ .

Obtain: The fuzzy split matrix F and the matrix of the cluster's centers V .

Step 1. Randomly initialize the fuzzy split matrix F , which satisfies the conditions (1).

$$\forall_{k=1, M} (\sum_{i=1}^c \mu_{ki} = 1), \quad \forall_{k=1, c} (0 < \sum_{i=1}^c \mu_{ki} < M) \quad (3.1)$$

Step 2. Calculate vector of clusters centers v_i .

Step 3. Calculate the distance d_{ki} between the k -th observation from the matrix T and the i -th center of the cluster

$$d_{ki} = \sqrt{t_k - v_i}.$$

Step 4. Calculate the next matrix approximation F ;

Step 5. If $\|F - F^*\|^2$, then exit from the algorithm, otherwise go to **Step 2**.

F^* — fuzzy split matrix obtained from the previous iteration of the algorithm.

As a result of the algorithm the matrix of clusters centers is calculated $V = \{v_1, v_2, \dots, v_c\}$,

where $v_k = \{v_{k1}, v_{k2}, \dots, v_{kn}, v_{kn+1}\}$, v_{ki} — the value of the coordinate of the i -th variable in the k -th cluster,

v_{kn+1} — the value of the resulting variable coordinate in the k -th cluster.

Each selected cluster corresponds to one linguistic rule of the fuzzy knowledge base.

Choice of accessory function

Each linguistic term that is in the antecedent of fuzzy rules is defined by its affiliation function. In research process the Gaussian affiliation function was determined to be the best option for evaluating a generic measure for QoS provided by a telecom operator.

Based on the results of the cluster analysis it is possible to determine the parameters of the membership function by the formulas (2) and (3).

$$a = v_{ij} \quad (2)$$

$$\sigma_{ij}^2 = \frac{\sum_{k=1}^M (\mu_{ki})^m (x_{kj} - y_{ij})^2}{\sum_{k=1}^M (\mu_{ki})^m} \quad (3)$$

Obtaining YFKB based on the selected membership function

After defining the necessary parameters and constructing the membership functions, the FKB rules are formed.

The fuzzy concept $LX_{i,k}$ corresponds to the fuzzy definition « X_i is approximately equal to v_{ij} ». The general presentation of the rule is built in the form of a Mamdani-type rule model:

$$R_j: X_1 \approx v_{j1} \text{ AND } \dots \text{ AND } X_n \approx v_{jn} \rightarrow y \approx v_{jn+1}, \quad \text{where}$$

v_{ji} – the coordinate value of the i -th input variable in the j -th cluster,

v_{jn+1} – the coordinate value of the the resulting variable in j -th cluster, $1 \leq j \leq c$.

FKB using to evaluate the quality of service delivery

The input data for the fuzzy logic algorithm is the variables that contain information obtained by measuring some physical value (this is realized by telecom operator monitoring system). The output of the algorithm produces the outcome variables based on fuzzy inference such as the level of users satisfaction with the quality of service.

The fuzzy logic algorithm converts the values of the monitoring process input variables into the output variables based on the fuzzy product rules.

The main stages of getting fuzzy inference:

1. Fuzzification (transition from precise to fuzzy data) – the procedure using which for all input variables became possible to define the values of the membership function for every of linguistic variable terms to be used in the set of the rules conditions for the fuzzy logic inference.

2. Aggregation is the procedure in which the degree of the condition's truthfulness is determined according to each of the rules of the fuzzy logic inference algorithm.

When a condition of a rule has a simple form then its truth is equal to the corresponding value of the membership function of the input variable to the term used in this condition.

If the condition consists of several sub-conditions as:

RULE <#>: IF « $b_1 \in a_1$ » AND « $b_2 \in a_2$ », THEN « $b_3 \in V$ »,

then the degree of truth is determined by the known meanings of the terms and expressions are used to perform fuzzy conjunction and fuzzy disjunction operations [4].

3. Accumulation is the process of finding the membership function for each of the original linguistic variables. If sub-conclusions that relate to the same source linguistic variable belong to different rules of the fuzzy logic inference system, they are combined into fuzzy sets by expression (4),

$$y = \min\{x_m\} \quad (4)$$

where x_m – the modal value (moda) of the fuzzy set corresponding to the output variable after the accumulation step obtained according to the expression (5).

$$x_m = \max\{\mu(x)\}, \quad x \in [a, b]. \quad (3.5)$$

4. Defuzzification (precise) is a procedure for determining the normal (precise) value for each of the original linguistic variables using the various algorithms given in [18]. The method of the right modal value obtained by the formula (6) is used in the presented research.

$$y = \max\{x_i\} \quad (6)$$

On fig. 1 shows the steps of the obtaining a fuzzy logical inference algorithm that uses the fuzzy knowledge base [19, 20].

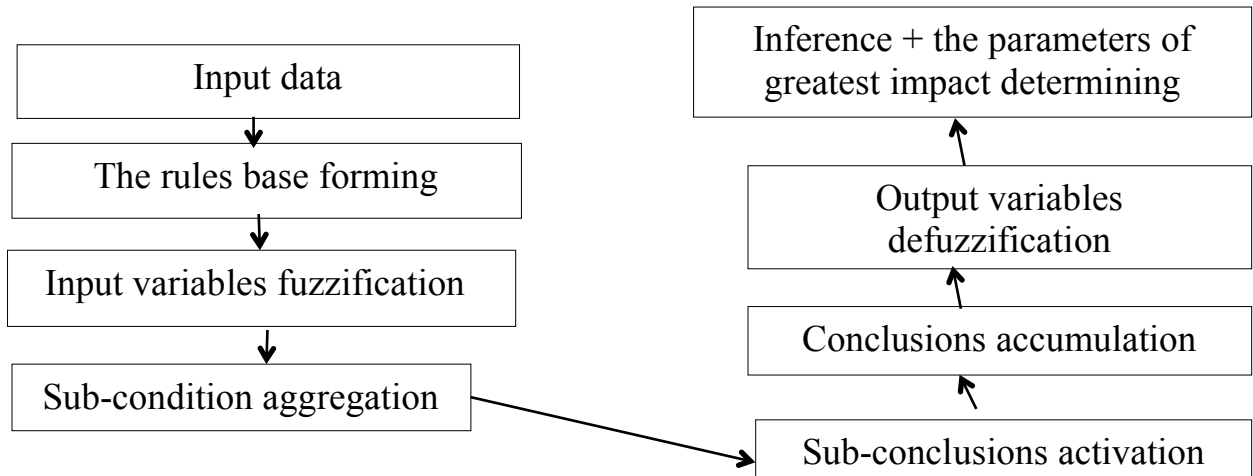


Fig. 1. The algorithm for obtaining a fuzzy logical conclusion

This algorithm is the most common method of logical inference in fuzzy systems based on the minimal-maximal fuzzy set composition which is effective for conventional (non-adaptive) fuzzy systems.

5. The results of fuzzy knowledge base development for Big data of telecom operator analysis based on example of determining the quality of service delivery

To verify the proposed approach, data obtained from one of the Ukrainian telecom operators were used. Natural values are normalized in the range from 0 to 1. The data fragment is presented in table. 2.

Table 2

The example of the output data of one Ukrainian telecom operator

X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀
0,01	0,99	0,98	0,95	0,95	0,98	0,99	0,99	0,008	0,99
0,001	0,995	0,999	0,989	0,9958	0,997	0,997	0,998	0,003	0,996
0,001	0,994	0,999	0,989	0,996	0,997	0,997	0,997	0,003	0,996
0,0006	0,998	0,999	0,981	0,9643	1	0,999	0,999	0,003	0,998
0,088	0,9989	0,9947	0,977	0,9733	0,995	0,982	0,997	0,007	0,997
0,083	0,9966	0,9979	0,982	0,9716	0,999	0,998	0,997	0,0073	0,996
0,0014	0,9949	0,9924	0,99	0,975	0,999	0,997	0,997	0,0072	0,9973
0,0054	0,9978	0,9934	0,98	0,986	0,986	0,995	0,997	0,0044	0,999
0,0008	0,9962	0,9841	0,993	0,977	0,99	0,98	0,998	0,0037	0,9986

X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀
0,0014	0,9923	0,9984	0,984	0,998	0,99	0,99	0,998	0,0055	0,9984
0,004	0,9944	0,9943	0,9987	0,97	0,9971	0,997	0,998	0,0074	0,997
0,0046	0,9967	0,981	0,9778	0,997	0,98	0,988	0,996	0,0067	0,9961
0,0034	0,9959	0,9941	0,988	0,9619	0,983	0,983	0,997	0,0039	0,998
0,0028	0,991	0,9814	0,972	0,986	0,9829	0,994	0,998	0,0069	0,9987
0,0063	0,994	0,995	0,983	0,957	0,986	0,9821	0,9975	0,0068	0,9968
0,0019	0,996	0,991	0,983	0,96	0,988	0,997	0,9982	0,0068	0,9979
0,0029	0,998	0,9929	0,964	0,957	0,9836	0,98	0,997	0,0059	0,9973
0,0001	0,9932	0,9965	0,99	0,951	0,9818	0,995	0,9966	0,0053	0,9976
0,0017	0,992	0,981	0,9966	0,978	0,9826	0,9957	0,998	0,0039	0,997
0,0004	0,995	0,9959	0,976	0,9637	0,999	0,9824	0,997	0,0066	0,9964
0,0002	0,9932	0,9947	0,954	0,986	0,984	0,997	0,9986	0,005	0,9969
0,0045	0,9982	0,9813	0,977	0,986	0,9975	0,9949	0,996	0,003	0,9966
0,0048	0,997	0,984	0,988	0,989	0,9832	0,9872	0,999	0,005	0,9988
0,0064	0,998	0,982	0,98	0,968	0,9835	0,9848	0,997	0,008	0,998
0,0038	0,9973	0,99	0,975	0,985	0,999	0,9817	0,9962	0,008	0,998
0,0023	0,99	0,985	0,972	0,954	0,9877	0,995	0,9976	0,007	0,997
0,009	0,992	0,994	0,968	0,959	0,9812	0,9807	0,9977	0,006	0,997
0,006	0,992	0,997	0,959	0,967	0,996	0,9874	0,9986	0,005	0,9965
0,007	0,996	0,983	0,995	0,955	0,995	0,98	0,998	0,0064	0,998
0,005	0,998	0,994	0,982	0,9719	0,9959	0,9979	0,9983	0,0051	0,9984
...

According to the algorithm for determining the unknown Y, the data were divided into three samples: training, test, exam. From the first sample Y was obtained using the desirability function. From the second sample was formed FKB consisted from the following rules:

IF X₁ = average AND X₂ = not low AND X₃ = not low AND X₄ = not low AND X₅ = not low AND X₆ = not low AND X₇ = not low AND X₈ = not low AND X₉ = not very high AND X₁₀ = not low AND X₁₁ = not low AND X₁₂ = not low AND X₁₃ = not low AND X₁₄ = average AND X₁₅ = not low

TO Y = not low

IF X₁ = average AND X₂ = not low AND X₃ = not low AND X₄ = not low AND X₅ = not low AND X₆ = not low AND X₇ = not low AND X₈ = not low AND X₉ = not very high AND X₁₀ = not low AND X₁₁ = not low AND X₁₂ = not low AND X₁₃ = not low AND X₁₄ = average AND X₁₅ = not low

THEN Y = not low

IF X1 = very low AND X2 = high TA X3 = high AND X4 = high AND X5 = high AND X6 = high AND X7 = high AND X8 = high AND X9 = very high AND X10 = high AND X11 = high AND X12 = high AND X13 = high AND X14 = very low AND X15 = high

THEN Y = high

IF X1 = very low AND X2 = high AND X3 = high AND X4 = high AND X5 = high AND X6 = high AND X7 = high AND X8 = high AND X9 = very low AND X10 = high AND X11 = high AND X12 = high AND X13 = high AND X14 = very low AND X15 = high

THEN Y = high

During the experiment FKB was formed in 4 iterations. Using the third sample the operation correctness of the proposed algorithm was verified, the results of the algorithm fully correspond to the expert estimates.

The proposed approach to data by the telecom operator analysis takes time to set up and form the FNB, but this is compensated by the reduction of computational load on the network during its operation. In addition, this approach reduces the computational complexity in the process of large data volumes classifying, solves the problem of obtaining an integrated telecom infrastructure quality index by a number of parameters provided by operator monitoring system, especially if this data are not logically related.

Conclusion

In this overview the Big Data processing methods relevant for telecom operator were analyzed. There are lot of problems for data processing methods choosing:

- the problem of big data - need mathematical methods for structuring data and knowledge (in future work it's proposed to use ontology) and very important to find methods that do not have high computational complexity.

- the problem of prediction – proposed to use the knowledge base patterns and fuzzy logic.

All of the above problems can be eliminated by developing new methods for Big Data processing that will: successfully analyze these data, a fuzzy knowledge base designing, and visualize these data for easy human perception.

As a result of the considered researches the approach to the estimation quality of services provided by the telecom operator has been proposed by means of the QoS integral index definition, complex assessment of the structured data, the advantage of which are the reduction the data volume that are processed in the Big Data analysis process by the summarization of this information amount to knowledge.

In order to carry out the requested analysis some time is needed for the FNB adjustment and forming and only to compensate for the lower calculating load on the system in the process of its functioning.

This approach reduces the computational complexity in the process of large data volumes classifying, solves the problem of obtaining an integrated telecom infrastructure quality index by a number of parameters provided by operator monitoring system, especially if this data are not logically related.

The further work consists in studying methods of data structuring and fuzzy knowledge base designing for the telecom operator.

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VARIOUS ORIGIN WASTES UTILIZATION WITH SIMULTANEOUS ENERGY CARRIERS OBTAINING

Golub N.B., Levtun I.I.

The scientific work of the Ecobiotechnology and bioenergy Department is aimed at technological solutions development for various origin wastes utilization and processing, wastewater and polluted air purification, soil reclamation and processing using biotechnological, chemical and physical methods. Simultaneously with purification and recycling in the technological process energy carriers are formed such as biogas, hydrogen, biodiesel, and organic fertilizer for agricultural use, which increases crops yield. Technologies are also being developed for biologically active substances production based on micro-algae, which can be used to treat and prevent various animal, bird and human diseases, which makes it possible to reduce the mortality rate of young animals and to grow a more viable generation.

At the same time, the weight gain, egg-laying, and need to use chemical drugs decreases.

That is, the technologies that are developed by the department staff are aimed at obtaining energy carriers, fertilizers and biologically active substances using waste as raw materials, as well as purifying various origin wastewater and land reclamation.

1. Various origin solid waste recycling with simultaneous energy carriers obtaining

For methane or hydrogen production, technologies developed at our department use wastes from food, pharmaceutical, chemical, alcohol, leather, woodworking, agricultural and other industries, as well as household waste, 50% of which is cellulose-containing raw materials.

When processing organic waste by fermentation, research solves the following tasks:

A) Co-substrate selection - in dependence to raw materials composition, it is possible that microelements deficiency needed for bacteria (that serve as destructors of organic raw materials

and methanogens) during development will occur. Such event is typical for tanning, chemical, paper, woodworking, agricultural and other types of industry.

B) Microorganism selection - Is necessary when using waste containing high salt concentrations, have low or high pH, contain substances with antibacterial activity and are inhibitors for certain process stages, it is common for chemical, pharmaceutical, and alcohol production.

C) Increase in decomposition rate of cellulose containing raw materials, for increased nutrients accessibility for microorganisms, which increases energy carrier yield.

When using co-fermentation by introducing necessary nutrients, creation of medium and conditions for microorganisms development and constant pH support - the results were obtained in dependence of raw material composition: biogas yield from 2,5 up to 3,5 m³/kg of dry organic matter with methane content from 65 to 80%, and hydrogen content up to 60%.

When pretreatment of raw materials is applied - process speed increases up to 10 times.

When microorganism selection was conducted - the possibility of biogas production during antibiotics presence or low pH values can be obtained.

Microorganism associations that can tolerate high salt amounts of 7 - 10 g/dm³ were formed.

Dry fermentation solves the task of constant uniform biogas production with high methane content during long period without the need in mixing or heating.

Simultaneous with energy carriers fertilizer is also produced.

The department also conducts adaptation of existing technologies or developing of the new technological solutions for defined composition wastes utilization.

2. Wastewater treatment

Department develops technologies for various origin wastewater treatment (Agricultural, industrial, fish, household wastewaters that can include antibiotics, surfactants and other inhibitors).

Water is purified both from organic substances and nitrogen, phosphorus compounds, as well as from heavy metals with physical, chemical and biological methods - anaerobic, anoxic, aerobic processes, using high aquatic plants, mollusks and crustaceans for fish farms.

As a result of proposed technologies required level of water purification is achieved.

In case of wastewater treatment for energy carriers obtaining microorganisms immobilized on inert surface, or granulated sludge may be used.

Advantages of anaerobic fermentation:

Low rate of sludge generation (0,05-0,10 g biomass per 1 g chemical oxygen demand, near 10% of sludge generated during aerobic purification).

Anaerobic sludge thickens (up to 50 g/L) and dehydrates more effective than aerobic, that with low biomass productivity allows to decrease the volume of excessive sludge up to 15-25 times.

Substrate utilization speed is higher 10-20 times.

Obtained: Wastewater purification level in dependence to pollutants (average of 4-6 g O_2/dm^3) in anaerobic process during 6-10 hours of water retention in reactor – 60-80 % on chemical oxygen demand, up to 70-80% on starting nitrogen content up to 150 mg/ dm^3 when annomox process is applied. Methane content in obtained during wastewater treatment biogas goes up to 70-80%.

Tasks that are solved - technology adaptation for specific wastewater, microorganisms selection - pollutant destructors and energy carrier producers.

During reverse water from fish farms, treatment hydrobionts are used as a feed for fish. This decreases product cost.

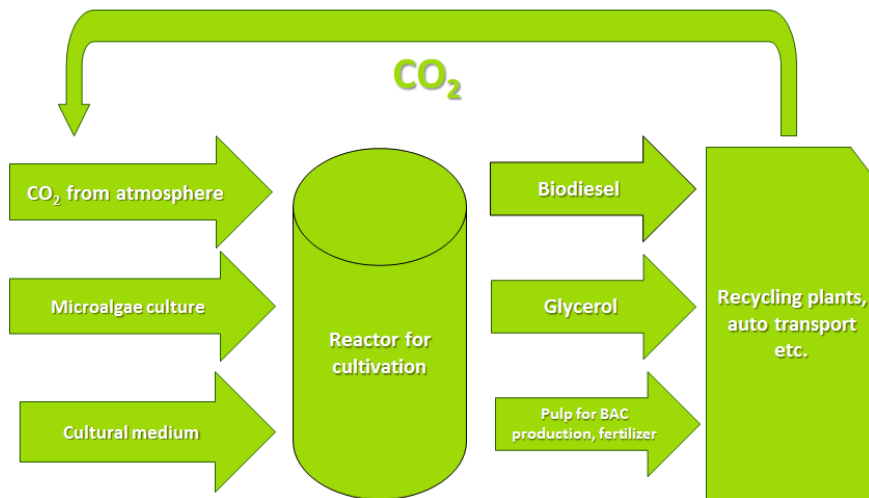
3. Gas emissions utilization

For industry gas emissions utilization that contains oxides of carbon, nitrogen, sulfur, and also to increase the methane content in biogas, it is possible to use microalgae that can use

these compounds as nutrients. At such condition, not only air purification takes place, but also its enrichment with oxygen. Simultaneously with air purification it is possible to obtain biodiesel from microalgae lipids or biologically active substances and unsaturated fatty acids.

Also, microalgae can be used as feed additive for animals and humans, the use of which increases the resistance to diseases stimulates organism growth and development.

Microalgae cultivation and biofuel production



Changing composition of nutrient medium (besides gas emissions, wastes that contain heavy metal or carbon compounds can also be used as a nutrient source for microalgae) and cultivation conditions (lighting, temperature, influence of external factors) microalgae metabolism can be changed for obtaining of required product such as lipids for biodiesel, biologically active substances for growth stimulation and protection from diseases, vitamins, growth factors, cell saturation with metal ions for diseases treatment (for example chrome and zinc - for diabetes treatment, ferrum and cuprum - for anemia treatment)

During gas emissions purification, the following tasks are solved:

- Determination of technological parameters such as flue gases or wastewater pumping rates.

- Selection of microalgae with optimal growth for specific pollutants including carbon containing wastes.
- Determination of cultivation conditions for maximum yield of the target products and wastewater treatment.

When using one of the most common microalgae species, *Chlorella vulgaris*, the lipid content for biodiesel production reaches 55-70%. With our technological cultivation solutions, 93% of fatty acids are saturated, which increases biodiesel quality. Also for CO₂ that occurred during coal incineration, utilization rate reaches 95%, for oxides of sulfur and nitrogen - 98%.

After biodiesel obtaining microalgae waste can be used in a various ways:

- for biogas obtaining (increase in methane yield up to 10%),
- as feed additive for livestock and poultry, that increases disease tolerance increases up to 17% biomass growth and egg laying rates,
- cultural medium waste can be used as liquid fertilizer, as it contains growth factors and other biologically active substances (increases growth rate, tolerance to diseases).

Department also works on developing technologies for soil reclamation from heavy metals and organic polutants.

IMPORTANCE OF TOXICOLOGICAL INVESTIGATIONS IN STUDYING OF PROSPECTS OF NEW ANTIFUNGAL AGENTS

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The toxicity research, including ecotoxicity, of new biologically active agents is an obligatory stage and the key requirement for their application in various areas of human life.

Toxicity studies of various types of biologically active compounds, especially for potential medical applications, using vertebrate biomodels are the most popular considering the presence of significant correlations of toxic effects for the macroorganism. It is known that the genes programming at an early stage of development is highly conservative and quite morphologically similar for all embryos of vertebrate organisms. However, obtaining reliable results of toxicological studies using laboratory animals has some difficulties - these studies are quite costly, time-consuming and, most importantly, limited by current legislation. Now the biomedical researches using the vertebrate hydrobiont zebrafish (*Danio rerio*) plays a key role in modern ecotoxicology and chemical safety and includes the toxicity screening of potential medical agents with a different mechanism of action [1, 2, 3].

It is known that *D. rerio* rather rapidly, in the first 72 hours, completes the process of embryogenesis in comparison with other vertebrate models [4]. In addition, the zebrafish has many organs and tissues that at the anatomical, physiological, cellular, and even molecular levels are similar to mammalian organs, including the brain and central nervous system, cardiovascular system, kidneys, liver, insulin-producing pancreas, adipocytes, intestines, bones, muscle tissue, immune and reproductive systems with ovaries and testes that is regulated by endocrine and paracrine signals [5, 6, 7]. A fully sequenced *D. rerio* genome indicates almost 85% homology to the human genome. An important feature of this organism is the fact that the amino acid sequences of functionally significant protein domains are highly evolutionary preserved [8].

Vertebrate hydrobiont zebrafish (*Danio rerio*) model был использован в исследованиях of series 1,3-thiazolylyphosphonium derivatives as potential antifungal agents against *Candida albicans* ATCC 10231 M885 and clinical fluconazole-resistant isolates of *Candida albicans* and *Candida krusei* (Fig.).

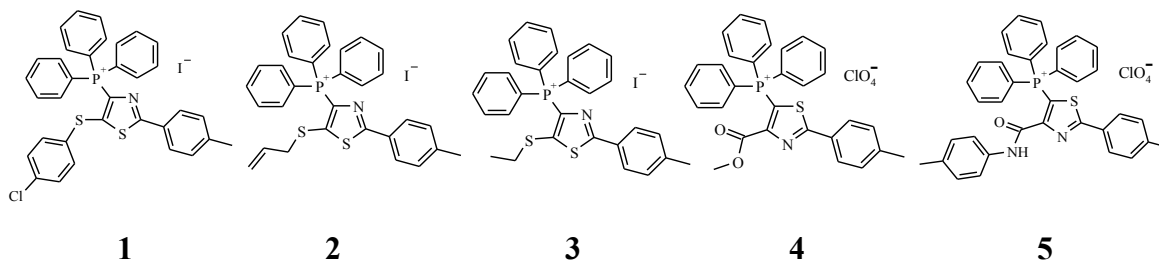


Fig. Chemical structures of 1,3-thiazolylyphosphonium salts

Antifungal properties of the investigated compounds were tested using standard disk diffusion method on Sabouraud agar [9]. The microbial load was $1 \cdot 10^5$ colony-forming units (CFU) in 1 ml. Test samples were prepared in DMSO at concentrations 1,0% with $0.3 \mu\text{M}$ on a disk. The microbial load was $1 \cdot 10^5$ colony-forming units (CFU) in 1 ml 0,1% DMSO.

Acute toxicity of 1,3-thiazolylyphosphonium salts for *D. rerio* was assessed measuring their lethal effect after 96 h exposure in a static test. All tests were performed according to the OECD Guideline no. 203 (OECD, 1992). Fish used in the present experiments were about 2 months old and measuring about 11.8 ± 0.1 mm in length and weighing 2.6 ± 0.2 g. During the experiment aerated water had a pH of 7.3 ± 0.3 (95% CI) and a temperature of 26.5.C. Fish were not fed during the test period. On the day of experiment, 7 fish were placed in glass aquaria containing test or control solution, and the mortality was checked every 24, 48, 72 and 96 hours. Test samples were directly dissolved in DMSO. The concentrations of the investigated compounds were between 0.1 to 100 mg/L. The analysis of studied salts toxicity was conducted according to Passino's classification.

All experimental results were were performed with software Statistica 6.

The results of antifungal susceptibility testing and acute toxicity test using *Danio rerio* are shown in Table.

Table Antifungal activity and acute toxicological effect of studied compounds

Compound	Antifungal activity			Acute toxicity	
	<i>C. albicans</i> ATCC 10231	<i>C. albicans</i> (isolate)	<i>C. krusei</i> (isolate)	LD ₅₀ , DI ^a , mg/L	Toxicity classes ^b
1	17,3 ± 0,6	20,3 ± 0,6	17,0 ± 0,6	2,16 (95%: 1,98 – 2,34)	(IV)
2	30,7 ± 0,3	30,3 ± 0,6	28,0 ± 0,6	0,67 (95%: 0,62 – 0,72)	(III)
3	34,3 ± 0,9	33,3 ± 0,6	31,0 ± 0,3	0,62 (95%: 0,58 – 0,66)	(III)
4	11,7 ± 0,3	15,0 ± 0,6	10,3 ± 0,3	5,46 (95%: 4,95 – 5,97)	(IV)
5	14,0 ± 0,3	17,3 ± 0,6	11,0 ± 0,3	3,32 (95%: 3,10 – 3,54)	(IV)
CPC	17,3 ± 0,3	13,0 ± 0,6	17,3 ± 0,3	0,018 (95%: 0,016 – 0,020)	(II)

DI – довірчий інтервал. Значення статистично достовірно відрізняються від контролю ($p \leq 0,05$); CPC - commercial disinfectant cetylpyridium chloride.

Hazard ranking developed by D.R. Passino and S.B. Smith [10]: < 0,01 mg/L – supertoxic (I); 0,01-0,1 mg/L – extremely toxic (II); 0,1-1 mg/L – highly toxic (III); 1-10 mg/L – moderately toxic (IV); 10-100 mg/L – slightly toxic (V); 100-1000 mg/L – practically harmless (VI); > 1000 mg/L – relatively harmless (VII).

Table shows that phosphonium salts **2** and **3** with high anti-Candida activity especially relative to commercial disinfectant CPC are perspective antifungal agents.

Confirmation of such conclusion are results to the toxicological researches conducted in work. It is very important that toxicological researches of these salts confirms this conclusion. Most active salts **2** and **3** with LD₅₀ of 0.62 and 0.67 mg/l, respectively, are belong to class III

of highly toxic substances, according to the classification of D.R. Passino and S.B. Smith. Moreover, the well-known reference preparation CPC is the representative of II class of extremely toxic of substances. But the less toxic phosphonium salts **1**, **4**, and **5** (class IV of moderately toxic substances) showed also the low activity making them nonactual in further researches.

Thus, 1,3-thiazolylphosphonium salts **2** and **3** are promising highly active and low-toxic anti-Candida agents, the effectiveness of which is almost 2 times higher than the biocidal properties of the extremely toxic (class II) commercial disinfectant cetylpyridium chloride.

The *Danio rerio* used in work is sensitive. The results of classification based on this biomodel define the authentically prospects of further researches of this series of compounds as low-toxiferous antimicrobial agents.

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APPLICATION OF THEORY FUZZY LOGIC FOR DETERMINING THE LEVEL OF INNOVATIVE SECURITY OF UKRAINE

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The strategy of innovative development of national economies is closely linked with leadership in research and development, the emergence of new knowledge and the development of high-tech production and mass creation of innovative products. The development of innovative potential is not only a way of dynamic development and success, but also a means of ensuring the security and sovereignty of the country, its competitiveness in the modern world.

According to the report "The Global Innovation Index 2019: Creating Healthy Lives – The Future of Medical Innovation" [1] Ukraine for 2019 compared with, for example, 2018 dropped from 43th to 47st (out of 129 countries around the world). The assessment uses 80 parameters that give a complete picture of innovative development, including an overview of the political situation, the state of education, the level of infrastructure and business. Moreover, Ukraine hit the 53rd place in 2019 in the Bloomberg innovation rating, having gone down by 7 positions over a year [2]. The innovative index shows how countries are committed to new achievements in various fields of science and its practical application in the life of citizens.

The simultaneous presence of different types of risks (uncertainties) in a complex hierarchical innovation security management system makes it necessary to use Fuzzy set theory to make decisions. The theory of fuzzy logic allows to consider and analyze both qualitative and quantitative indicators. This method involves creation of expert systems for pattern recognition. The decision about referring the security indicators to a particular class the experts make on the basis of their understanding of the required security level and the consequences of deviation from this level. In fact, while making a responsible decision the expert usually operates not only with formal concepts, expressed by a number or numerical formula, but also

with some logical conclusions that can be expressed as: "If there are certain conditions ..., then the situation can be assigned to the following class". To process this kind of expressions a special system, which is based on the methods of the fuzzy sets theory and fuzzy expressions, is developed. This is achieved by introducing a membership function (MF) of fuzzy parameters, which takes values from 0 to 1. Its approximation to 1 means more confidence in expressions and more significant level of its implementation. It is appropriate to use exponential functions, as follows:

$$f(x) = \exp[b(x-c)^2],$$

where b and c - parameters of the function that determine its form.

The proposed mathematical description corresponds to the information nature and reflects its fuzziness. On the basis of experts' or expert groups' statements a database, that describes the situation classes, is formed for innovation security indicators. Thus, any current or predicted situation can be assigned to a particular class by comparing it with already known data, which was entered into the database.

In general fuzzy set characteristic is the MF. Fuzzy set \bar{A} is called the set of ordered pairs or corteges of form $\langle x; \mu_{\bar{A}}(x) \rangle$, where x - element of the universe X , $\mu_{\bar{A}}(x): X \rightarrow [0, 1]$ - (MF) which assigns to each element $x \in X$ a real number in the interval $[0, 1]$, that characterizes the element x grade of membership to fuzzy set \bar{A} .

The larger the MF value $\mu_{\bar{A}}(x)$, the more universal set element x corresponds to the fuzzy set \bar{A} properties [3]. There are many types of curves to determine the MF. The most common MF is triangular, trapezoid and Gaussian function. Triangular MF is determined by three numbers (a, b, c), and its value at the point x is calculated by the formula:

$$\mu(x) = \begin{cases} \frac{x-a}{b-a}, & a \leq x \leq b \\ \frac{c-x}{c-b}, & b \leq x \leq c, \\ 0, & \text{in other cases} \end{cases}$$

at $(b-a) = (c-b)$ we have a symmetrical triangular MF, which is identically specified by two parameters from the triple (a, b, c) .

To determine the trapezoidal MF four numbers are needed (a, b, c, d) , and its value at the point x is calculated by the formula:

$$\mu(x) = \begin{cases} \frac{x-a}{b-a}, & a \leq x \leq b \\ 1, & b \leq x \leq c \\ \frac{d-x}{d-c}, & c \leq x \leq d, \\ 0, & \text{in other cases} \end{cases}$$

at $(b-a) = (d-c)$ this MF takes symmetrical form.

Generalized MF of the Gaussian's type is described by the formula:

$$\mu(x) = e^{-\frac{(x-c)^{2b}}{\sigma^2}},$$

and is determined by three parameters (a, σ, b) . The value $b=1$ corresponds to the standard Gaussian function. This function is preferable due to its three following properties: 1) its similarity to the accumulation; 2) limitation of values that are necessary to comply with the MF properties; 3) infinite definition domain, which greatly simplifies the algorithmic solutions while programming operations on fuzzy subsets.

It is assumed that such FS is quite accurately described by MF. The greater the alternative x grades of membership to FS, i.e. the higher the value, the higher the achievement's goal grade while choosing alternative as a solution. Fuzzy boundary conditions are also

described by the fuzzy subsets. We will define now, what is meant by the solution of the problem of achieving the fuzzy goal. Solving this problem means achieving the goal and satisfying the limitations, moreover, within this setting-up we should talk not only about achieving the goals, but also about the grade of its achievement, taking into account the grade of the limitations accomplishment. The problem mentioned above can be solved by using the Bellman-Zadeh approach. The subject matter of this approach, represented in detail in the works [3] is as follows: let some alternative provides goals' achievement with a grade and satisfy the limitations with a grade. Then it is assumed that the membership grade for this alternative of resolving the problem is the minimum of these values. Thus, the fuzzy solution of the problem of achieving the fuzzy goal is called the intersection of the fuzzy sets of goals and limitations, i.e. MF for the solutions is:

$$\lambda_i = \max_k \left\{ \min_j \left\{ \sup_{x \in X_j} \left(\min \{ \mu_j(x), \nu_{ijk}(x) \} \right) \right\} \right\},$$

where λ_i – the grade of the considered situation membership to class i; X_j – range of parameter j; $\mu_j(x)$ – MF of the considered situation evaluation by the parameter j; $\nu_{ijk}(x)$ – MF of the k expression in the knowledge base by the parameter j to class i.

In other words, to determine the grade of the situation membership to any class, it is necessary:

- to determine the exact upper borders of intersection of the MF for the situation evaluation and expressions on the parameters with the sections of expressions of the class;
- to determine the minimum values of exact upper borders by the sections of expressions of the class (grade of the situation membership to the expressions set);
- to determine the maximum grade of the situation membership by the sections of expressions of the class.

It is offered assessment according to the innovation security level by using the three

classes, which are described as follows:

- 1) normal (n) status - "if all the indicators are better than the threshold values of entering the pre-crisis status, the status is normal";
- 2) pre-crisis (pc) status - "if at least one of the parameters is worse than the threshold parameter of pre-crisis status, and all other parameters are better than the crisis threshold, the status is considered to be pre-crisis";
- 3) crisis (c) status - "if at least one parameter is worse than the crisis status threshold, the status is crisis."

All these expressions can be described mathematically by the following statements:

- *normal status*

$$X_1 > X_{PC} \text{ and } X_2 > X_{PC} \text{ and... and } X_n > X_{PC}$$

- *pre-crisis status*

$$X_c < X_1 < X_{PC} \text{ and } X_2 > X_c \text{ and... and } X_n > X_c \text{ or} \\ \dots X_1 > X_c \text{ or } X_2 > X_c \text{ and } \dots \text{and } X_c < X_n < X_{PC}$$

- *crisis status*

$$X_1 < X_c \text{ and } X_{2...N} = \text{does not matter} \\ \text{or } \dots \text{or} = \text{does not matter and } X_n < X_c$$

where N is the number of parameters.

Logical operations AND and OR (intersection and combination of fuzzy subsets) are defined as follows:

$$\mu(x) = \min \{v(x), \lambda(x)\}, \tag{1}$$

$$\mu(x) = \max \{v(x), \lambda(x)\}. \tag{2}$$

Formula (1) describes the logical operation "AND", and formula (2) – "OR". During decision-making it is necessary to take into account the value of the situation membership grade in all classes, using the concepts of clear membership, membership to some extent and the ε -level membership. Based on the example of the triple class knowledge base, with situation membership grades by the classes $\lambda_1 = 1$, $\lambda_2 = \beta$, $\lambda_3 = \varepsilon_3$, the following expressions can be formulated: the situation clearly belongs to class 1, but to some extent ($\varepsilon_2 < \beta < 1$) it belongs to class 2, the situation does not belong to class 3.

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EMERGING RISKS FOR INNOVATIVE DEVELOPMENT

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The concept of emerging risk has gained increasing attention in recent years. Natural disasters, terrorist attacks and many other conventional risks keep governments around the world on alert; however, they also have to deal with an increasing number of rapidly emerging risks. Technology continues to play a profound role in shaping the global emerging risks [1].

The term "emerging risks" can be understood as new risks or familiar risks in unfamiliar conditions. Emerging risks can be new and unforeseen risks whose potential for harm or loss is not fully known. In looking at the universe of emerging risks it becomes increasingly clear that a significant portion are by their nature not observable by traditional methods, even though their impact will no doubt at some point be felt [2].

Systemic emerging risks present particular risk management challenges due to their low frequency but potentially high impacts that can across innovative development and have economic, political and other impacts. Further, it is difficult to determine when or how an emerging risk can materialize. Emerging risks may be issues that are perceived as potentially significant, at least by some stakeholders or decision-makers, but their probabilities and consequences are not widely understood or appreciated.

According to International Risk Governance Council (IRGC) [3] we can distinguish three categories of emerging risk for innovative development:

- 1) risks with uncertain impacts, with uncertainty resulting from advancing science and technological innovation;
- 2) risks with systemic impacts, stemming from technological systems with multiple interactions and systemic dependencies;

3) risks with unexpected impacts, where new risks emerge from the use of established technologies in evolving environments or contexts.

The IRGC identifies 12 contributing factors on the emerging risks [3]: 1) scientific unknowns; 2) loss of safety margins; 3) positive feedback; 4) varying susceptibilities to risk; 5) conflicts about interests, values and science; 6) social dynamics; 7) technological advances; 8) temporal complications; 9) communication; 10) information asymmetries; 11) perverse incentives; 12) malicious motives and acts.

Concerning the seventh contributing factor, it should be noted Emerging Technologies (Table 1) creates new risks for innovative development, diminishes others, and in turn can be motivated by the need to cope with risks.

Table 1 – Description of the Emerging Technologies [4]

Emerging Technology	Description
3D printing	Innovations in printing using various types of materials to move beyond prototyping and towards increasingly distributed manufacturing and medical applications that range from a greater use of technologies such as contour crafting in construction to the opportunity to develop printed biological materials, such as organ tissues, bone and muscle.
Advanced materials and nanomaterials	Innovation in chemistry and physics resulting in the creation of new material substances, smart materials, 2D materials and other breakthroughs in properties and fabrication ranging from thermoelectric properties and shape retention to magnetic and mechanical functionalities.
Artificial intelligence and robotics	Advances in automated processes ranging from manufacturing to driverless vehicles and automated knowledge work, enabled by highly competent cyber-physical systems and machines that can substitute for human beings to complete various tasks most often associated with thinking, multitasking, and fine motor skills.
Biotechnologies	Innovations in genome editing, gene therapies, and other forms of genetic manipulation and synthetic biology resulting in additions to the registry of sequenced species of animals as well as human DNA, the creation of previously non-existent organisms, and modifications to microbes and organisms for medical, agricultural and industrial applications, including integrating them with electronic and computing advancements.
Energy capture, storage and transmission	Breakthroughs in energy technologies, including advanced batteries and fuel cells, orbiting solar arrays, tidal energy capture, wind and bioenergy, as well as advances in nuclear fusion containment, smart grid systems, wireless energy transfer, and increased fuel cell fabrication efficiencies.

Blockchain and distributed ledger	Developments in cryptographic systems that manage and verify distributed transaction data on a public ledger, increasing transparency and securing an immutable record for application to cryptocurrencies such as bitcoin as well as for verification of varieties of transactions across industries, especially in financial technologies.
Geoengineering	Creation and development of technological processes that intercede in the Earth's geological and climatic systems, ranging from land reclamation to atmospheric seeding in order to influence weather patterns or remove carbon dioxide.
Proliferation and ubiquitous presence of linked sensors	Proliferation and ubiquitous presence of linked sensors, also known as the "Internet of Things", combined with sophisticated large-scale data analytics that will connect, track and manage physical products, logistics systems, energy grids and more by sending and receiving data over widespread digital infrastructures.
Neurotechnologies	Creation of new methods for insight into, and control of, the functionality and processing dimensions of the human brain, allowing for the ability to read, influence and communicate brain activity through various secondary technological dimensions such as smart drugs, neuroimaging, bioelectronic interfaces, machine-brain interfaces and brainwave decoding and manipulation.
New computing technologies	Innovations in materials and assemblages used to process or store digital information, such as centralized cloud computing, quantum computing, neural network processing, biological data storage, and optical computing, including new software development, cryptography, and the cybersecurity processes associated with each.
Space technologies	Technologies that can be used in space that will increase the ability of both public and private entities to access, explore, and create new forms of value such as microsatellites, reusable rockets, integrated rocket-jet engines, optical and imaging technologies, sensor developments, resource exploitation, laser and communications technologies, space exploration and habitat developments, and techno-scientific breakthroughs that are transferable to the marketplace.
Virtual and augmented realities	Development of sophisticated immersive virtual environments that can range from heads-up displays and holographic readouts to fully mixed digital and physical environments and complete virtual worlds and interfaces.

It is often associated with increases in efficiency, and therefore lower use of resources for a given output level. On the basis of the foregoing discussion, that risk assessment for innovative development and management procedures in particular have to be continuously adapted to changing technological structures.

Systematic monitoring of emerging risk for innovative development could help to detect weak signals which otherwise would have gone unnoticed. A team of experienced strategic planners could formulate critical thresholds for a combination of these non-traditional

indicators above which decision makers should consider policy action. Specific critical thresholds depend on the respective cultural and societal context, as well as the government's relative risk aversion.

In conclusion, despite the accumulated knowledge in sciences, economics, and politics, it is a challenge for current decision making regimes to cope with the complexity of interdependencies, and to address urgent questions about the future design of national and global structures that are capable of managing emerging risks for innovative development.

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JAVASCRIPT MAPPING FOR DATA STORED IN DBMS INTERSYSTEMS CACHÉ

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Usually, information used by a company is organized in databases (DB) and each company decides which brand of database management systems (DBMS) to use for their operational tasks. Sometimes, companies need to provide access to this data to external or internal users using web-applications. For the most part, these applications are developed using JavaScript (as well as other approaches, technologies and languages). Thus, software developers require a comprehensive and easy to use tool to access data stored in the chosen DB.

One of the DBMSs used for the purpose of managing corporate data is InterSystems Caché. It is a multi-model DBMS that provides relational, object and hierarchical access to the stored information via built-in languages and language bindings [1]. Although, there is a number of different ways to access data, such as JavaScript API, C++ API, Java API, ODBC/JDBC etc, they have their advantages and disadvantages with regards to working with objects stored in a DB (table 1).

Table 1. Comparison of methods of accessing data

Name	Advantages	Disadvantages
C++ API	supports many operating systems, performance, object access	SQL access is restricted, no cross-platform build
SOAP, REST, web-services	cross-platform, independence from programming language	high call costs, the need to write services in the database, the complexity of maintaining SQL
JDBC, Java API	cross-platform	the need for interoperability with JVM
JavaScript API	cross-platform	no support for the latest versions of node.js
ODBC	cross-platform, thread-safe	the need to use ORM for objects

Considering the advantages and disadvantages mentioned above and the idea that all the data can be accessed using both object and relational model it was decided to use ODBC gateway to create a JavaScript mapper for data stored in Caché DB.

Typical problems that arise when creating a wrapper for information stored in a database are:

- discrepancies between primitive types of database and target programming language. This may be reflected by the inconsistency of the ranges of values as well as the interpretation of the undefined values;
- optimization of navigation;
- search and query optimization;
- reusability of requests.

Thus, there are two major ways to resolve these problems [2].

1. Orthogonal persistence – a pure approach to persistence, in which the mechanisms of persistence and the existence of a database are hidden from the programmer.
2. Explicit query execution – an approach whereby a programmer explicitly calls database related operations.

Therefore, to develop the software that covers both abovementioned solutions one has to think of how this software will sustain transactions, work with objects and execute SQL queries.

Since it was decided to use ODBC at the core of the mapper, there is no problem with sustaining transactions for relational access and executing queries. However, ODBC works exclusively with relational model thus making it necessary to find a way to work with objects.

To make working with objects possible, it was decided to use Active Record pattern. According to it, Active record is an object that wraps a row in a database table or view, encapsulates the database access, and adds domain logic on that data [3]. Considering that

almost the same approach is used by InterSystems to wrap hierarchical data (core representation of data in Caché) into objects and that Caché allows usage of non-atomic attributes (lists and arrays) as class properties, it is possible to use Active record pattern as a way to work with DB objects via ODBC.

Having decided the necessary tools and approaches to development, the extension for JavaScript was created using C++ and it consists of three modules:

- Cacheodbc – implements classes for relational access to DB (classes ODBCStatement, ODBCCConnection, ODBCTransaction);
- Cache-odm – implements object-relational mapping (interfaces Persistent and Session);
- Libnanodbc – C++ library that facilitates ODBC usage by providing object abstractions (connection, transaction, statement) and error handling.

Cacheodbc module implements basic access to DB operations and returns JavaScript objects such as:

- ODBCCConnection – wraps connection to DB and implements methods:
 - connect – connect to DB;
 - disconnect – close connection to DB;
 - query – execute a query;
 - execute – execute a command which doesn't return a result;
- ODBCStatement – wraps query to DB and implements methods:
 - prepare – prepare query;
 - query – execute query;
 - execute – execute a command;
- ODBCTransaction – wraps transaction and implements methods:
 - begin – begin transaction;
 - commit – commit transaction;

- rollback – rollback transaction.

All these methods are non-blocking and each operation is executed in a dedicated thread from pool thread provided by libuv library. Code fragment that illustrates how to connect to the DB and execute a class methods of class Sample.PersonSets is given in figure 1. It is also possible to pass a text of a query explicitly and process the result (figure 2).

```
const connection = require('nc').createConnection();
const dsn = ...;
connection.connect(dsn, () => {
  console.log('Створено з'єднання');
  connection.query("CALL Sample.PersonSets('D', 'NY')", (err, res) => {
    console.log('Результат');
    console.log(JSON.stringify(res));
    connection.disconnect(() => {
      console.log(`З'єднання закрито`);
    });
  });
});
```

Figure 1 – Sample of a call to a class method Sample.PersonSets

```
const r = db.Reader;
class Company extends Persistent {
  averageEmployeeSalary() {
    return r(connection =>
      connection.prepareStatementPromise(`
        SELECT AVG(e.Salary) as value
        FROM Sample.Company AS c JOIN Sample.Employee AS e
        ON c.ID = e.Company
        WHERE c.ID = ?`)
      .then(statement => statement.queryPromise([this.ID]))
      .then(result => {
        if (!result || result.length !== 1) {
          throw {
            'message': 'Query returned invalid result'
          }
        }
        var result = result[0];
        result.value = Number(result.value);
        return result;
      }));
  }
}
```

Figure 2 – Sample of explicit query execution

Cache-odm uses thread pool and synchronization objects (mutex, semaphores, and conditional variables) that are provided by libuv library and manipulates JavaScript objects using its engine (thanks to NAN utilities). Components diagram is shown in figure 3. It provides the use of two main classes – Persistent and Session, and has additional helper classes such as PersistentProxy (watches changes in properties to optimize DB access), ConnectionPool (connection pool to a DB) and Connection (connection to a DB). Last three classes are not public and are used to optimize DB access. Component interaction diagram is given in figure 4.

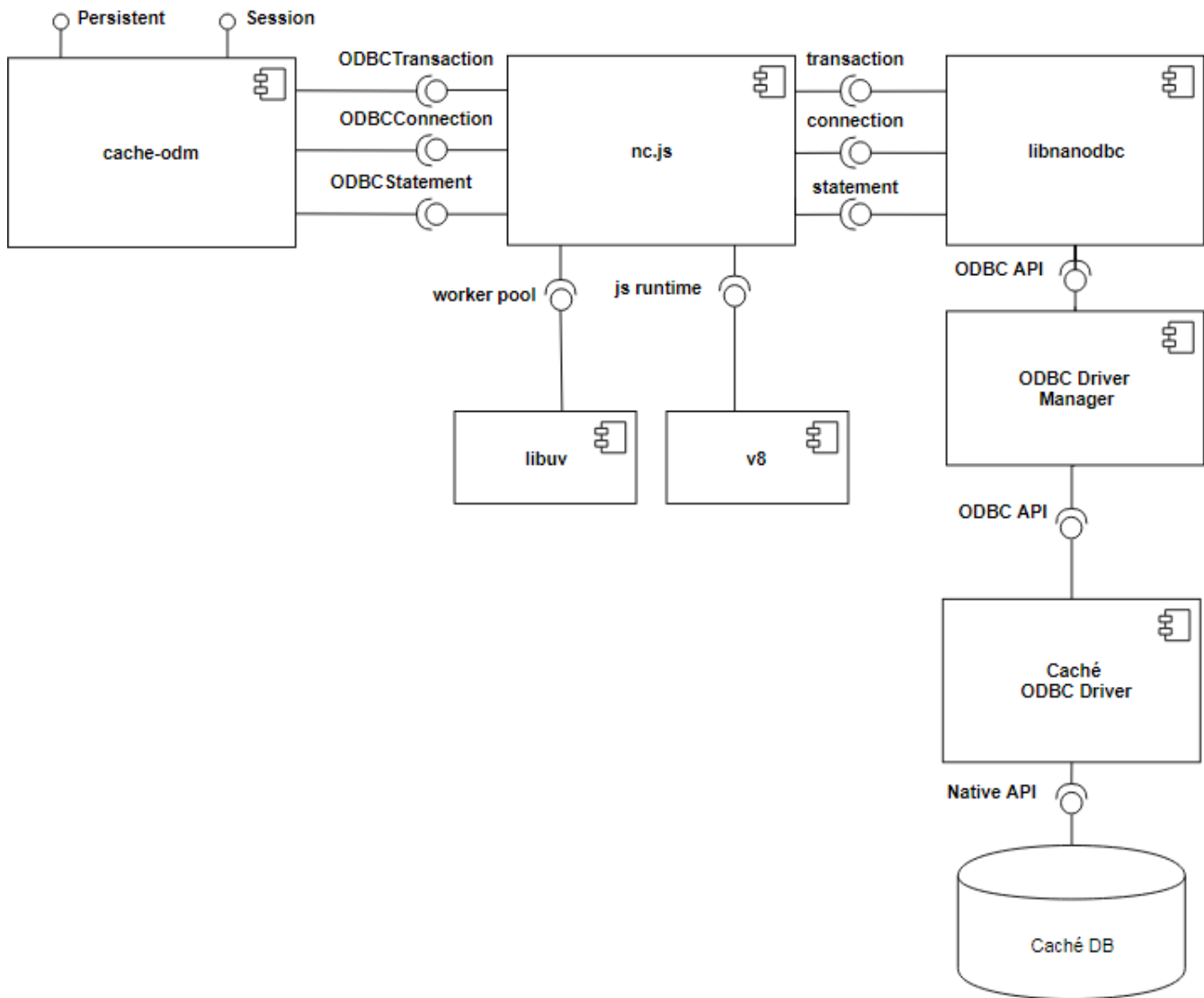


Figure 3 – Components diagram of JavaScript mapper for Caché

Class Persistent in Cache-odm is similar to Caché system class %Library.Persistent that is parent for all persistent objects saved to a DB. It has methods to facilitate object manipulation from DB on a client side:

- save() – method for saving object to a DB;
- attach() – method for attaching an object to current session (receiving data from DB);
- delete() – method for deleting object from a DB;
- existsId(id) – static method that checks if an object with *id* exists in a DB and if it does – returns *true* otherwise *false*;
- openId(id, projection) – static method that returns the object with attributes *projection* from a DB or *null* if such object doesn't exist;
- findBy(map, projection) – static method that returns objects with attributes *projection* from a DB or *null* if such objects do not exist;

findAll(projection) – static method that finds all objects with attributes *projection* from a DB.

Code fragment that illustrates how to process the result of a findBy() method is given in figure 5.

```
const Session = db.Session;
Session.exec(() => Employee.findBy({
  Name: 'Edison,Frances X.'
}))
.map(result => {
  if (result.length === 1) {
    return result[0];
  } else {
    throw Error('Expecting unique result');
  }
})
.tap(employee => {
  console.log(`Employee has title: ${employee.Title}`);
  console.log(`Employee has salary: ${employee.Salary}`);
}))
.finally(() => Session.destroy());
```

Figure 5 – Sample of findBy() method usage

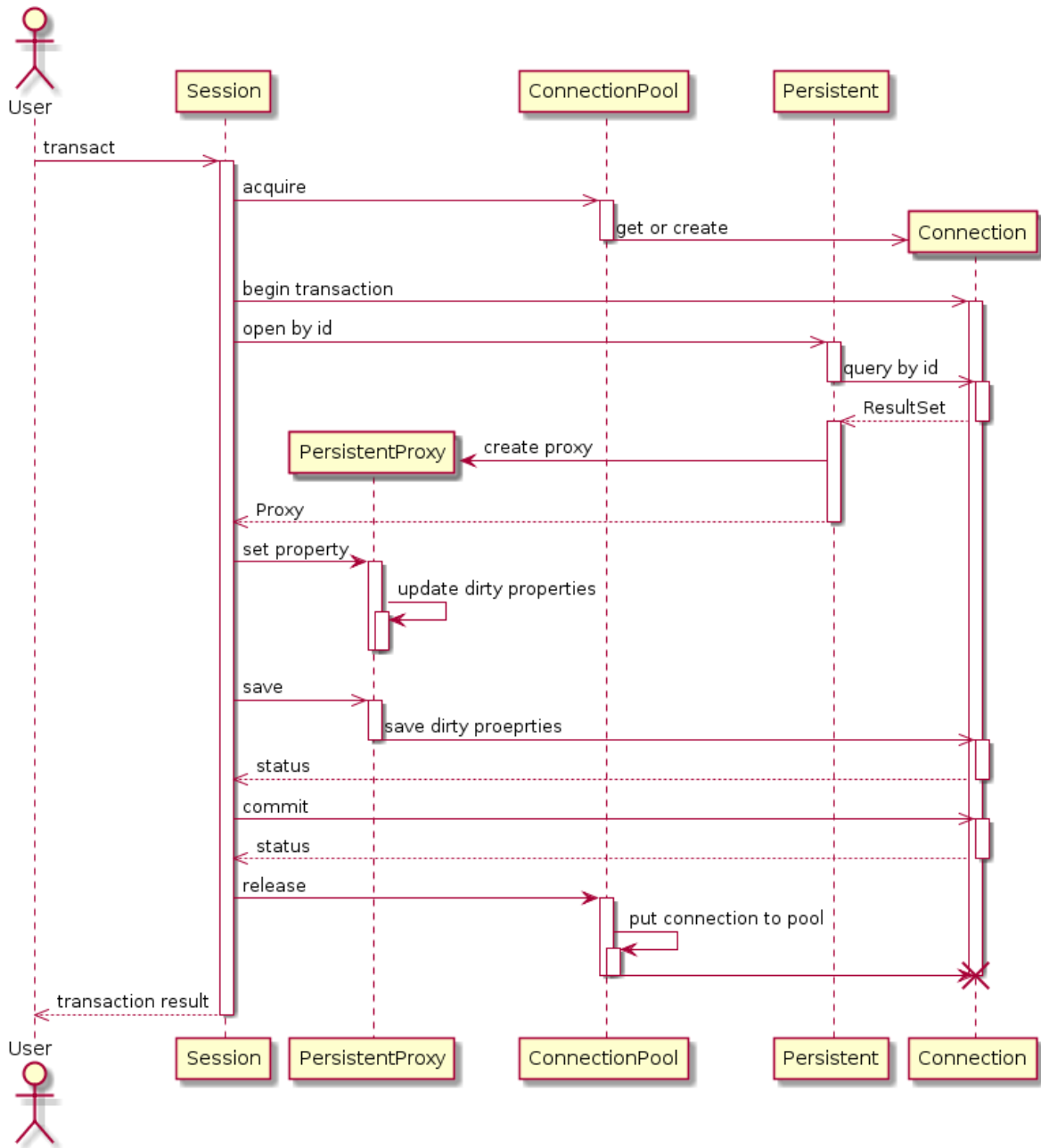


Figure 4 – Component interaction diagram for cache-odm

Thereby, the proposed software covers both abovementioned solution to problems arising while creating a wrapper for multi-model DBMS InterSystems Caché – supports orthogonal persistence (via cache-odm) and explicit query execution (via cacheodbc) thus giving access to information stored in a DB from JavaScript applications by providing both relational and object access.

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UNMANNED AERIAL VEHICLE ON SOLAR ENERGY

Kozei Y.

Solar energy (SE) aircraft, especially as high altitude pseudo-satellites, are no longer positioned as research flying laboratories, but are real-world tools for solving urgent intelligence, monitoring, and communications tasks. However, to solve such problems, there is a need for small unmanned aerial vehicles (UAVs) weighing up to 15kg ("mini" class according to the North Atlantic Treaty Organization (NATO) classification, which would perform long-haul flights (4-6 hours) in the ground atmosphere (at the presence of winds, rising flows) and under harsh conditions of off-air operation (for example, in combat), which significantly affects the choice of aircraft.

Partially described problems solve UAVs with a power plant based on the internal combustion engine. However, the use of this type of engines in comparison with electric introduces a number of negative factors: noise, vibration, thermal noticeability. In turn, long flights with battery power alone are problematic due to their limited capacity.

The use of solar energy offers real prospects for the emergence of an effective UAV on SE, but the task of technical implementation of the flight remains an unsolved problem. The transition to widespread use of this type of aircraft is possible provided that the design and systems of the aircraft will be maximally adapted to extra-aerodrome operating conditions, and the cost of components and materials - minimized without loss of quality. The problem is compounded by the still small efficiency of industrial solar cells (19-21%) and the lack of a comprehensive approach to the determination of the mass-energy and geometric parameters of UAVs in SE.

On the territory of Ukraine there are conditions for the implementation of effective aircraft flights to SE (if the specific annual radiation in Switzerland - up to 1000 kWh / m², and in Germany - up to 1300 kWh / m², then in Ukraine - up to 1550 kWh / m²).

Creating an aircraft for the aircraft is an iterative process of forming the parameters of the aircraft, the effectiveness of which depends on the following tasks: fulfillment of conditions for the implementation and operation of the aircraft for the aircraft (energy balance conditions); efficient use of solar radiation, satisfaction of operational requirements, fulfillment of conditions of durability and rigidity of a design. Geometric, energy, and mass constraints have a significant impact on the main design parameters of UAVs on SE - mass, energy characteristics, flight speed, geometric dimensions, and more. The described parameters have a mutual influence and require a clear definition within the specific task.

For the flight and ground tests, 3 UAV samples were designed and manufactured (fig. 1). The most perfect variant had a take-off mass of 4.2-4.8 kg, a solar power plant of 100 W, a span of 2.1 m, SE - single crystalline elements of size 156x156 mm. to accommodate the SE and more rigid (compared to normal aerodynamic) design.

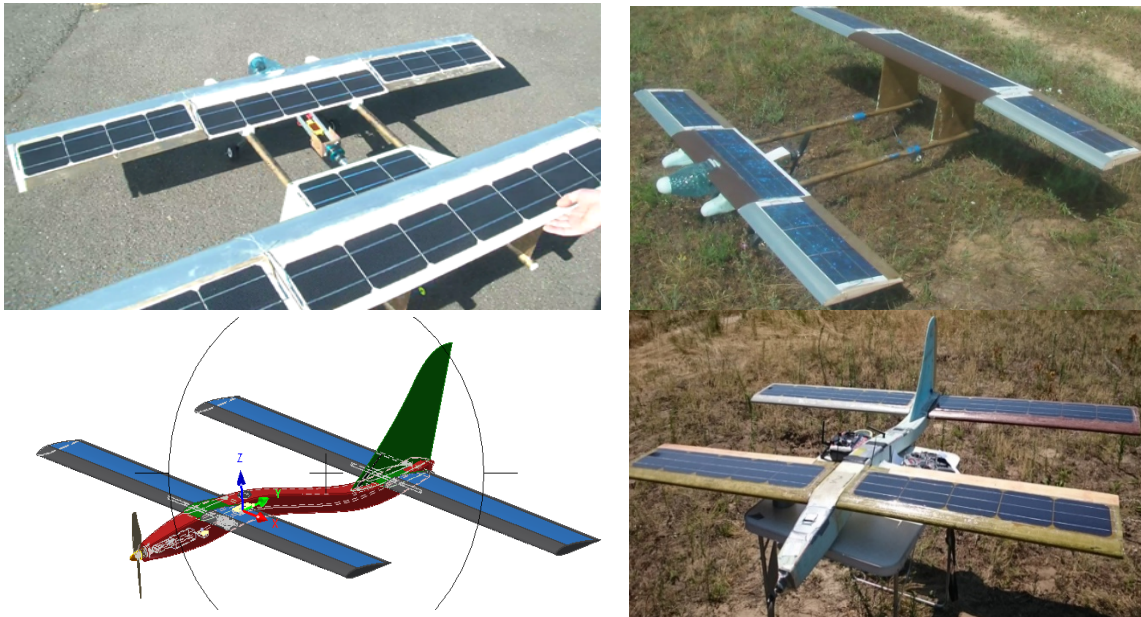


Fig.1. Experimental examples of the UAV on the SE

As SE, industrial silicon elements of size 125x125, 156x156mm were used as monocrystalline and polycrystalline with an efficiency of 19-21%. In this case, the share of solar panels covering the surface of the wing was up to 60%. If the location of the SE on the

elephants (width up to 40mm) is not problematic, then the covering of the bow of the wing was implemented by adding to the main element of the narrow SEs a width of 10, 15, 20, 40mm. The coating has increased by 20%, but the contour of the wing profile has reduced the aerodynamic air quality by 25%.

Tests of UAV samples at SE occurred in the Kiev region. In total, about 30 flights with a total duration of 10 hours have been conducted. At altitudes up to 500 m with speeds 7-15m / s. The onboard equipment fixed the parameters of the system: the orientation of the aircraft, engine consumption, flight altitude, and so on.

When performing the take-off and set-up (up to 500 m), the required power is $P = UI = 10,9 \cdot 35,3 = 385\text{W}$ (engine power is 380W), while maneuvering - up to 176W. The power of the SE in the Horizontal flight - 97-103 W, the consumption of UAV with 82-116 W (estimated value in both cases 100W). Thus: the calculated characteristics of SE were confirmed by experimental indicators; the actual power of the SE is sufficient for the execution of the HF; Takeoff and maneuvering takes place using the power of the onboard battery (up to 75%).

The hourly energy consumption of the battery with a capacity of 3.2 A * h (weight 0.35 kg) after the completion of a series of flights in a circular trajectory with a radius of 150-200 m was 15-23% (0.480-0.736 A * h). The battery power is sufficient to compensate for the shortage during a 4.3-6.7 hour flight.

WEB SYSTEM FOR MANAGING THE REGISTRY OF ELECTRONIC INFORMATION RESOURCES

Kuzmenko I., Ivaniuk A.

Formulation of the problem

A register is considered an information and telecommunication system, which is intended for registration, accounting, accumulation, processing and storage of information about content, location, providing means to access electronic information resources and meeting the needs of legal and physical persons in information services [1].

The problem of creation, exploitation, protection of electronic information resources is extremely acute today. The rapid growth of the number of information resources used by mankind confuses scientists and software developers and forces them to actively seek the solution to the problem of improving the efficiency of information resources exploitation. The main areas of search are streamlining information arrays, developing new storage methods and technologies, accessing information, and securing information.

As the experience of the US shows, efforts to streamline electronic information resources through their cataloging make it possible to integrate the latter with a powerful system of national library directories. Therefore, most of the forces in the cataloging is applied by libraries. The projects InterCAT, CORC, INFOMINE, CATRIONA should be highlighted [2].

OCLC (Online Computer Library Center) is an international organization that brings together over 53,000 libraries in 96 countries and aims to help libraries and other agencies organize world information resources so that knowledge seekers can find them to gain new knowledge. To do this, OCLC helps libraries share descriptions of their collections and creates collaborative frameworks for organizing new knowledge. The main activities of this organization are: Cataloging and Metadata, Collection Management, Digitization and

Preservation, Electronic content, Reference, Resource Sharing, DUNS (Data Universal Numbering System) [3].

Most government-level countries have developed and continue to work on standards for the creation, development and use of information resources. In UK: Government Gateway, Government Internet, e-GIF, e-GMS (e-Government Metadata) – a standard that specifies elements for describing metadata and displaying Dublin Core, AGLS, NGDF, GILS and PRO. In Denmark: infrastructure Infostructurebase, in Sweden: Government Elink (Ge), in Australia: FedLink – government gateway and secured government intranet and so on. So electronic information resources (EIR) are useful and power mechanism and building it are very actual.

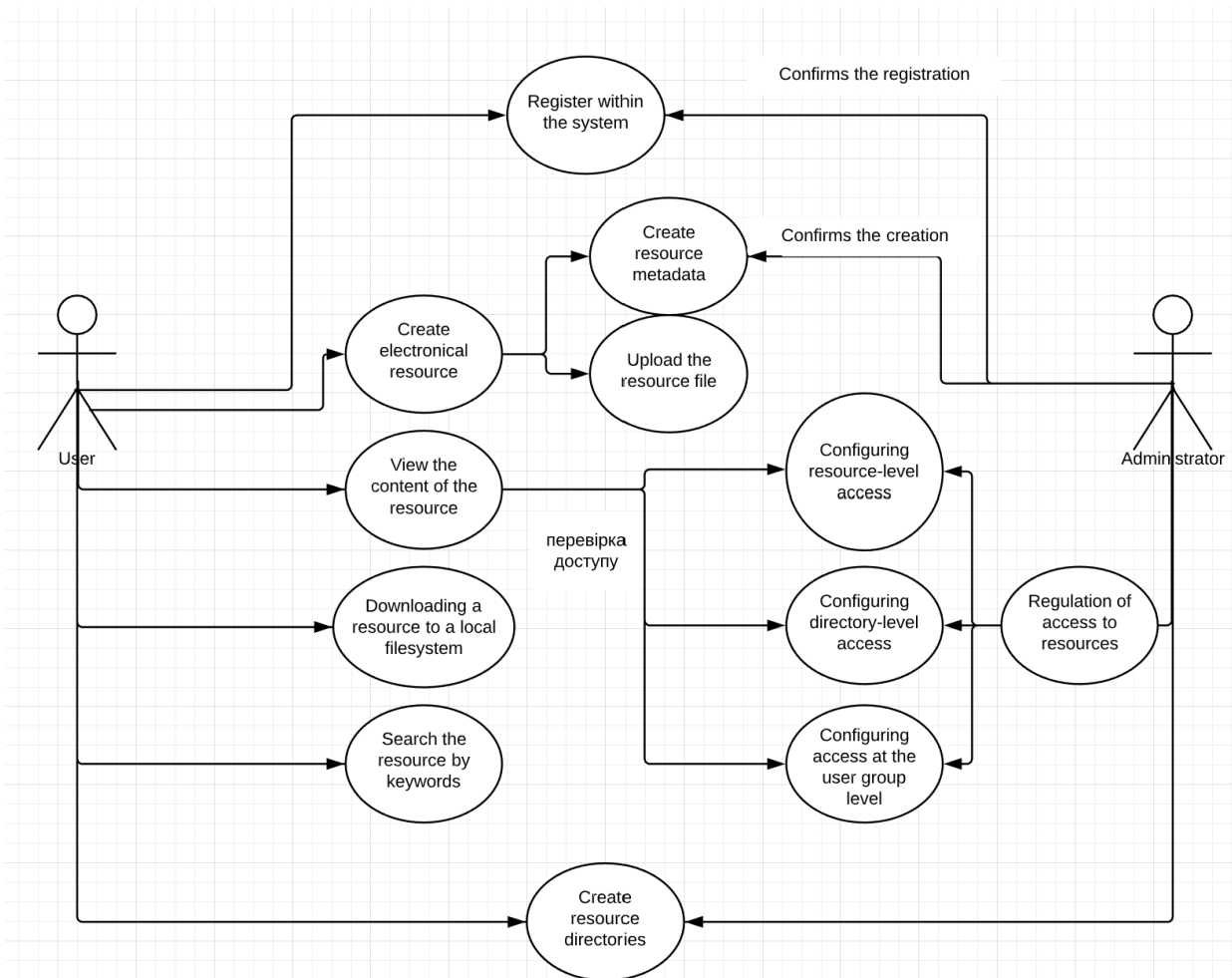


Fig. 1 – Use Case diagram of the web-system

The goal of this web system work was managing the registry of EIR of the university department. It was necessary to analyze the existing registries of electronic information resources, to compose the structure of EIR registry and development a software product that would allow the following functions (Fig. 1): adding a user to the registry; user authentication and authorization in the system; adding a resource to the registry; saving resources metadata in the registry; linking directories of resources and user groups; downloading a resource to a local filesystem; view the resource by direct link.

Therefore, the purpose of the development is to create a web-based system for managing the registry of electronic information resources for departments of «Igor Sikorsky Kyiv Polytechnic Institute» which will be able to solve problems related to a single standardized access to resources, information security, as well as to be able to effectively manage the registry and integrate electronic resources by using the metadata resource schema and, as a consequence, improving their use.

Description of software implementation

After analyzing the problem statement, the main requirements for the system were identified: independent development of different parts of the software to ensure rapid functionality - this raises the need to separate the different parts of the system from each other; architectural capability to extend the functionality of the system without changing the user interface.

So, it was decided to use the modular principle of system architecture on base of object-oriented programming (OOP), which could easily solve problems with future system expansion best meets these criteria. The modular principle of system architecture has the following advantages:

- distributed system development helps to find bugs faster, unlike programs where the

system interacts as a monolithic complex, without the possibility of free modification of its individual element, which leads to low scalability of such systems;

- each module is able to provide a specific set of methods and capabilities for other modules - the so-called module interface, which makes it possible to standardize inter-module interaction protocols;

- the design interface of the module is an invariable element (and can only be changed when the system is redesigned), but the way of implementing this interface may change. This makes it easy to test new features of the module by gradually changing the way the interface is implemented.

The implementation of the modular system requires the correct distribution of the tasks performed between the modules, as well as the optimality of interaction between them, which is achieved by preliminary analysis and design. The task at its core requires a modular solution, as it must provide functionality at the level of the class library for future use.

The data source encapsulates the logic behind In ASP.NET MVC applications. As it is possible to operate a set of entities and models, for management of which many classes of repositories are created. Unit Of Work pattern was used for working with the database. The Unit Of Work pattern simplifies the work with different repositories and guarantees that all repositories use the same data context.

System architecture

A user interface was developed to implement the database created in Microsoft SQL Server 2014 DBMS, Entity framework object-relational mapping was used to access the data, ASP.NET web framework was used to facilitate the construction of the web application. Apache Solr solution was used as a search engine to perform a full-text resource search.

User interface was built using a server engine for rendering Razor Template.

The server side is designed on the basis of OOP and consists of classes that are combined into packages or namespace. JetBrains - Resharper was used to simplify the development and code generation process. C# was used as the programming language for the system implementation.

The project was designed using the MVC template architecture. C# classes are divided into packages: controllers, models and views.

The following metadata schema for the resource (Fig. 2) was defined when developing the system: unique identifier; title (up to 254 characters); a concise description of the content (up to 1000 characters); the language of the resource; the level of secrecy; format (file format in which the dataset is available); the ID of the directory to which the resource belongs; status of the resource; physical path to a resource on disk.

Developing of metadata resource schema needs security mechanism for access to directories and specific resources.

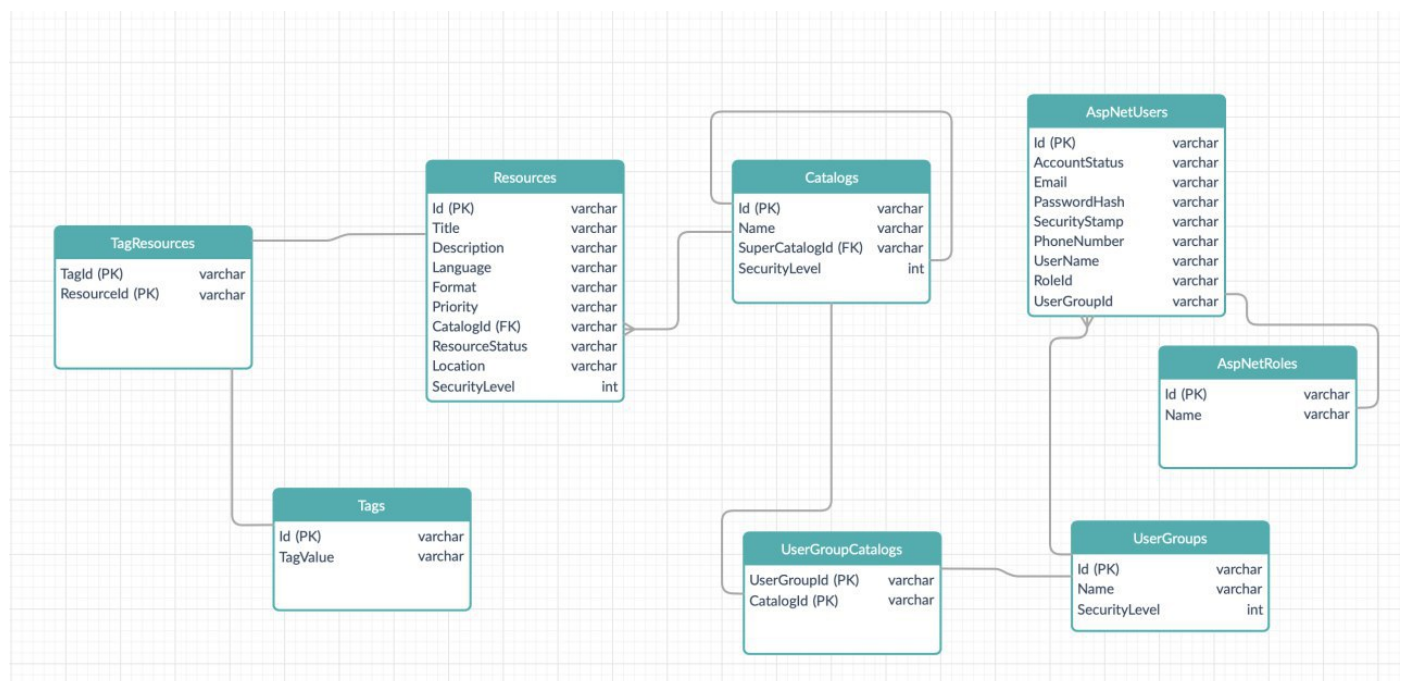


Fig. 2 – Database structure

To ensure the security of resources, it was decided to specify a list of user groups that will have access to the directory when creating the latter. However, another mechanism has been developed to adjust the level of access for individual resources. To do this, when creating a resource, the privacy level is specified. The privacy level is a resource attribute, or a number from one to ten. The same mechanism is present when creating custom groups. Each user inherits the privacy level of the group to which he or she belongs. If the user's privacy level is greater than or equal to that of the property, then the user will have access to the resource (even though the directory to which the property belongs does not allow access to that group of users).

Also, in order to improve quality of the system and facilitate project support in the future, the code style was adhered the SOLID principles.

System description

An entire layer of repository classes was enclosed to interact with the database this encapsulates the logic behind query execution.

Repositories are classes that implement the Dao pattern. Classes also serve to implement business logic.

Views are special classes that are responsible for displaying customer information. .NET representation of this system is built using Razor Template technology, where web page rendering is server-side.

The central entity in the database is the Resources table (see Fig. 2). This table is based on the STI (Single Table Inheritance) pattern. This means that one table serves to aggregate data from the types in the inheritance hierarchy. This table contains the metadata of all system resources. The Users table contains all the user settings. The Catalogs table is used to store directory information. The UserGroups table contains user groups to differentiate access to resources. The UserGroupCatalogs table is a table of links between user groups and resource directories. The Tags table contains keywords that you can use to search for resources. The

TagResources table is a table that links a table of tags and resources. The AspNetRoles table contains information about the role of the user in the system. AspNetRoles and AspNetUsers tables are system tables that use ASP.NET framework in their work.

In general, the system accomplishes the following tasks: registration of the user in the registry; user authentication and authorization; creation of electronic resource in the registry; registration of the resource in the registry; storing metadata resources in the registry; linking resource directories and user groups, uploading a resource to a local file system; viewing the resource by direct link; Uploading a resource to a local computer possibility of full text search on the content of documents.

Conclusions

In this work was built a scheme of metadata registers and developed web-system for managing the registry of electronic information resources. Web interface for access to the register of EIR of the department has been developed too. A mechanism for regulating the level of secrecy of resources was realized. The web-system are provided efficient expansion of the functionality of the already installed architecture for the system updates.

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ANALYSIS OF EXISTING SOFTWARE FOR THE CONTROLLING OF WATER OBLIGATION

Sydorenko Iu.V., Kryvda O.V.,

Extrapolation of the transfer and transformation of oil pollution is one of the key issues in the development of modern technologies in the field of environmental pollution prevention.

There are several complexes used in the world. For example, to calculate the spread of oil pollution in the Baltic region, the operational system "SeaTrackWeb" [3], developed at the Swedish Institute of Meteorology and Hydrology, has been widely used. The model in the online mode calculates the transfer and transformation of oil pollution, gives the estimated parameters of pollution. Such calculations allow the identification of the pollutant vessel and impose penalties.

For the water area of Portugal and Spain there is a model complex MOHID, which includes a three-dimensional hydrodynamic model and a module for the transfer and transformation of oil pollution [4].

To calculate the spread of oil pollution in the Black and Azov seas, the OILTOX model was developed [1; 2], which can be used online. But today, in domestic practice, the development of operational oil models does not have the same development as abroad.

Swedish SeaTrackWeb forecasting technology is designed so that the user enters the oil spill information on a specially created website and the task goes to the Swedish Hydrometeorological Institute, where it is processed and sent back to the customer. This is a commercial oil spill forecasting system. At the same time, the weather forecast is calculated in Sweden, the model of the Baltic Sea currents in Germany, the software for calculating the spread of oil on the server of the Swedish Institute of Meteorology and Hydrology, and the launch of the task for the calculation is realized from any computer connected to the Internet. To work with the system, you must download and install a java application on your computer and register (fig.1).

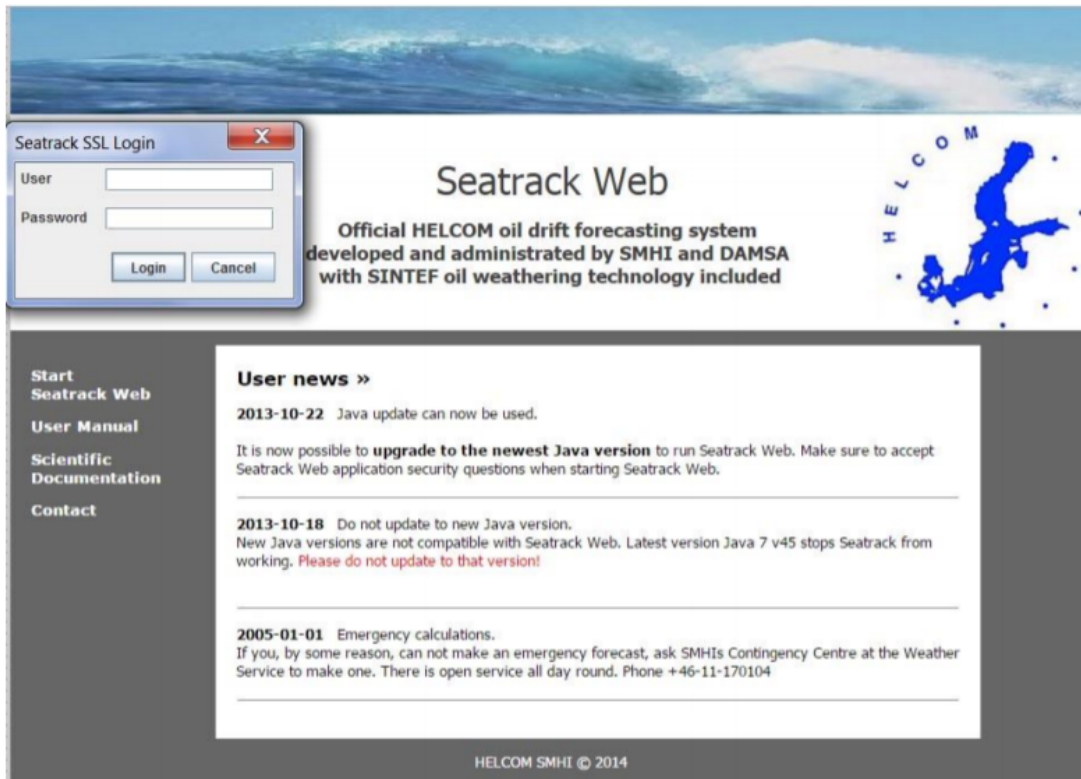


Figure 1 - Starting user interface when working with SeaTrackWeb

The disadvantage of SeaTrackWeb is that the service is only for the Baltic Sea.

The MOHID system consists of a free-surface three-dimensional baroclinic hydrodynamic module, an Euler transfer module, a Lagrange transfer module, a turbulence module, a zero-dimensional water quality module, and an oil dispersion model.

The model consists of more than 40 modules that make up over 150 million lines of code. Each module is responsible for managing certain information. For example, the Model module manages the flow of information between the hydrodynamics module and the two transport modules and the relationship between the nested models. The Hydrodynamic module calculates water level, velocities and water flows, and the Water Properties module controls the evolution of water properties (temperature, salinity, oxygen, etc.) using the Eulerian approach. The Oil Dispersion module simulates the spread of oil due to its thickness gradients and internal oil processes such as evaporation, emulsification, dispersion, dissolution and sedimentation.

Another important feature of MOHID is the ability to run nested models. This feature allows the user to explore the local area, receiving boundary conditions from the "parent" model. The number of models attached is limited by the available power of the computer.

The disadvantage of MOHID is that it is cumbersome, since it consists of more than 40 modules and is written in an old programming language, which makes it difficult to improve and maintain.

The OILTOX model simulates the spread of oil in five interacting phases: oil on the surface, oil in water, oil at the bottom, oil in the suspended state, oil on the shoreline. The Institute of Mathematical Machines and Systems Problems of the NAS of Ukraine and the Ukrainian Center for Environmental and Water Projects are engaged in the development of oil spill response measures in the Black and Azov Seas and large river basins of Ukraine [2]. The OILTOX model describes the main processes of distribution and weathering. The surface oil model describes the propagation due to gravity and surface tension, advection by wind and surface currents, evaporation, emulsification, interaction between oil and shore, suction of oil into the water by breaking waves and overlapping trapped droplets.

The OILTOX model is a Lagrangian model [1] that uses the Gaussian particle representation to describe the thickness of the spot as the sum of the "contributions" from each particle. "Particles" are distributed between phases and have a set of phase-specific properties (volume, density, viscosity, water content, etc.). The Lagrangian numerical algorithm allows to describe the motion of irregularly shaped surface spots at all stages of spreading and the action of continuous sources. Horizontal and vertical turbulent diffusion processes are modeled by the Lagrangian stochastic modeling method.

The modeling system consists of four models: the MM5 weather forecast model, the three-dimensional POM or THREEETOX hydrodynamics model, the WAVEWATCH III wave spectral model, and the OILTOX three-dimensional oil spill propagation model.

The OILTOX oil spill model consists of a calculation part, a database of oil characteristics and a graphical user interface. The database includes information on the basic physical and chemical properties of about 100 types of oil. In conjunction with two-dimensional rendering in the graphical interface, the motion of the oil spot can be imaged using three-dimensional tools based on OpenGL technology. The simulation system can be used in several configurations:

- 1) a separate oil model with user-defined environmental parameters;
- 2) a two-dimensional version with a graphical user interface that uses a database of previously calculated hydrodynamic fields and user-specified meteorological parameters;
- 3) the full version combined with the hydrodynamics model, the wave model and the weather forecast.

The full simulation system was applied to calculate a hypothetical emergency oil spill of 75,000 tonnes of crude oil on the northwestern shelf of the Black Sea (Figure 2).

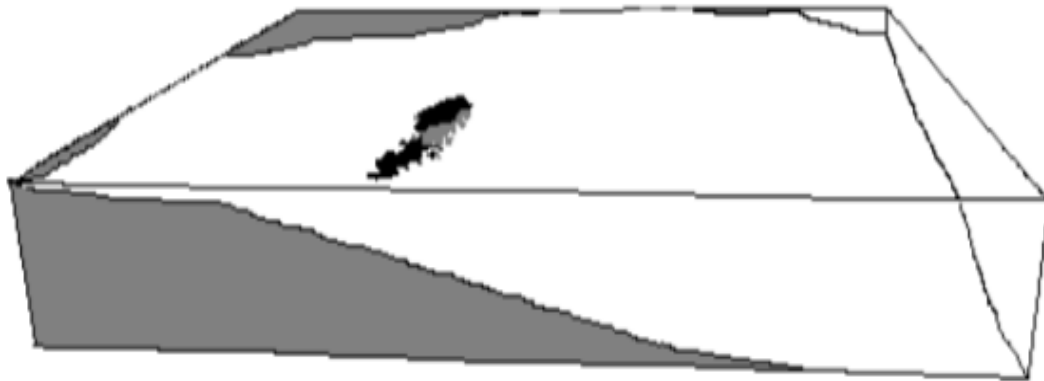


Figure 2 - The motion of the oil slick is represented by a three-dimensional rendering tool

A two-dimensional model with a database of oil types and a graphical shell is applied to the territory of the Dnipro-Bug estuary and the Dnieper section from Kherson to the estuary (Figure 3). In this embodiment, the hydrodynamic fields calculated by the THREETOX three-dimensional hydrodynamic model are used, and the meteorological parameters are set by the user.

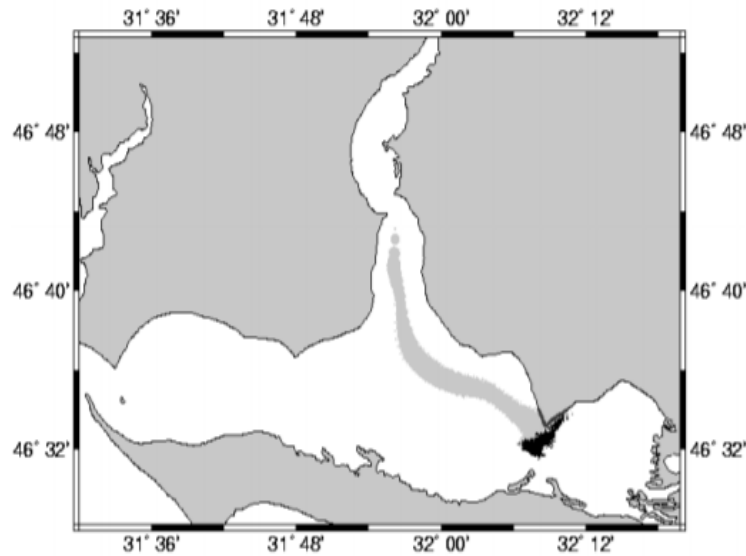


Figure 3 - Simulating the trajectory of the oil movement within 25 hours after the start of the spill

In «OILTOX» model for the study of oil film spread on the surface of the sea, an algorithm is proposed, which takes into account the influence of Langmuir circulation on the surface transport of pollution, describes the motion of the surface spot and the three-dimensional distribution of oil droplets in water and medium fluence. However, the solution of three-dimensional advection-diffusion equations is very cumbersome, and the law of size distribution of oil droplets is difficult to implement. Therefore, there is a need to develop a simple mathematical apparatus that describes the basic mechanisms of oil distribution in the sea and is suitable for practical use. Such a tool can be a device of poly-point transformations.

Conclusions: From the point of view of the peculiarities of the problem, the analysis of existing software products was carried out to determine the possibilities of solving the problem, namely: SeaTrackWeb forecast systems for calculating the spread of oil pollution in the Baltic region; MOHID model complex for forecasting the spread of oil in the coastal zone of Portugal and Spain and the OILTOX model for calculating the spread of oil pollution in the Black and Azov

seas. The disadvantages of these models are analyzed and the necessity of developing a new model based on poly-point transformations is substantiated.

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DEPARTMENT OF CHEMICAL TECHNOLOGY OF COMPOSITE MATERIALS

Svidersky V.A., Myronyuk O.V.

The Department of chemical technology of composite materials is a part of Chemical Technology Faculty. The main research area is Materials Science and Engineering in Polymer Composites, which includes respective compounds, thin layer coatings, adhesives etc. And Inorganic binders and related composites based on cements and gypsum.

The recent topics include:

- 1) functional polysiloxane coatings for anti-corrosion protection, anti-tacking, anti-icing thin films;
- 2) Superhydrophobic polymer coatings, sprayable with conventional paint and coatings equipment;
- 3) Fire-resistant coatings, including intumescent;
- 4) Plastic-inorganic fiber compounds. We are focused, in particular, on carbon fiber-phenolics. The carbon fiber can be from used and chopped carbon plastic waste.
- 5) Surface treatment for different surfaces: metals, plastics, inorganics.
- 6) Functional coatings on polymer base, which include strippable coatings, luminescent coatings etc.
- 7) Special concretes for industrial wells, porous concretes.

We publish our results (you can find some references here), but mostly we focused on the technological solutions for industrial applications. The detailed description of our recent developments below.

Superhydrophobic architectural coating

Based on SiO₂ chemistry, namely modified Stober process, sol-gel technology, which is suitable for effective thin layer structure formation. Surfaces were consequently treated with polymethyl hydrid silane. The water contact angle values achieved was higher than 150° (Fig.1) and relatively small sliding angles – less than 5° were obtained on hierarchical structures. During the study the tasks of surface texture engineering, morphology characterization and surface treatment were performed.

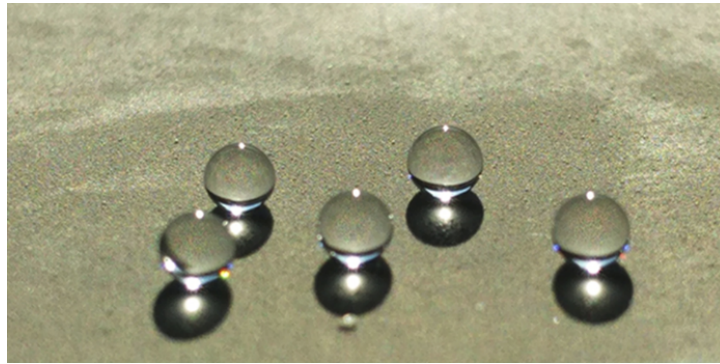


Fig. 1. Water droplets on sol-gel particles surface

Fire protective intumescent coatings

This engineering object is the special purpose fire resistant coating. The main principle of it's action is passive fire protection: in a normal mode it is relatively thick 0,5-2 mm coating, which converts to a carbon foam with the thickness of 30-80 mm in case if heated to 300-400 °C. The main problem of this research was the increase of the foam quality (cell size distribution, swelling factor, char strength) in order to obtain the better performance: protection time, which was determined as the time of reaching of 550 °C by a steel substrate under the coating.

The tasks of main acting components selection and balancing, the use of novel melt rheology modification, the research of surfactants and reinforcement agents (like fibers and platelets) were solved during the study. The resultant product have the expansion factor in a range 30-40 times, operating life (in unactivated state) – up to 15 years and protection time on steel substrate – up to 110 min.



Fig 2. Calcinated foam (the main components are titanium phosphate and silica)

Chopped carbon fibers composites for pressing and moulding

The carbon fiber-phenolic composites, suitable for the processing by the hot pressing and molding were obtained. The waste of carbon plastic, which is cut into flakes may be used as the auxiliary filler of such composite. During the research the task of fiber ordering, interaction optimization on a border between polymer and filler and thermal stability optimization were successfully solved. The materials obtained may be used as the replacement of constructional steel, aluminum in such areas like car industry, aerospace, hydrodynamic equipment. They can withstand heat strikes up to 2800 K, have the bending strength up to 200 MPa and relatively low density – 1350 kg/m^3 in comparison to metals.

Oil spills treatment: hydrophobized perlite

The surface treated perlite can be used as the measure of oil and related products spills collection from the water surface. Having the density of 80-120 g/l it floats on the water and can adsorb up to 2,5 l of oil per 1 kg. The main task, which were solved in the water were the perlite expansion regulation, thus obtaining the required density and particle configuration and subsequent surface treatment, which were performed by the use of functional silanes. The material is stable for long term use in salty water, the oil can be recovered from the material after gathering.

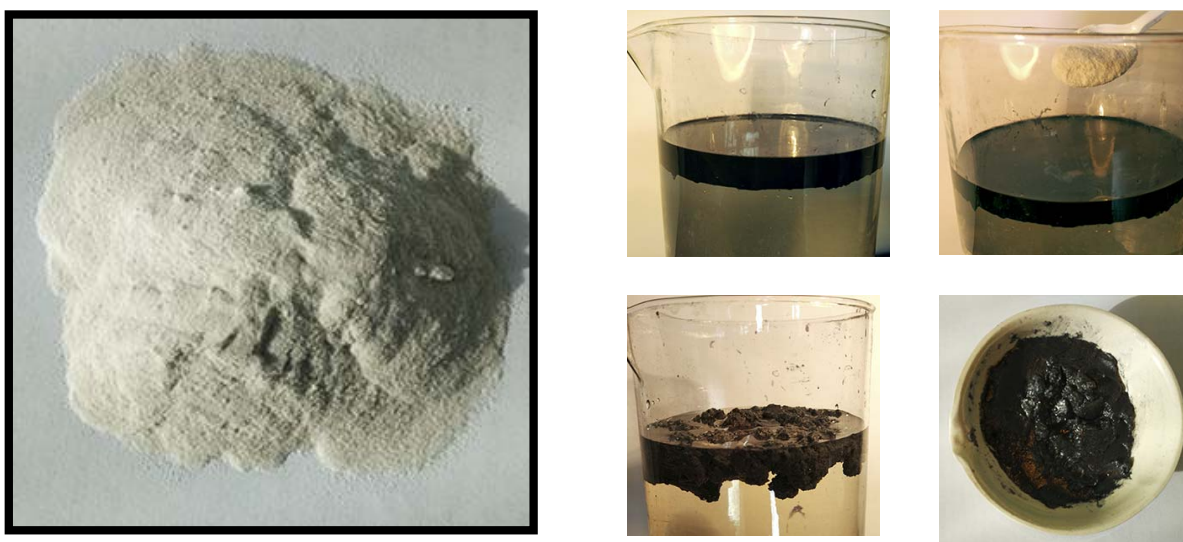


Fig.3. The treated perlite

Surface hydrophobization

The department recent works are also connected with the surface treatment. The treatment agents are mostly of siloxane chemistry with different functional groups. The research is focused on low temperature treatment solutions for such substrates as glass, concrete, natural fiber, metals and plastic.

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MODERN PROBLEMS OF HEAT POWER ENGINEERING

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Abstract

The problems of energy efficiency of energy production along with improving the environmental safety of enterprises are becoming increasingly relevant. One of the ways to solve these problems is the implementation of effective technologies, which include microflame technology of combustion (MTC-technology) of gaseous fuels. The use of MTC technology, in addition to a significant reduction in harmful emissions into the atmosphere, can simultaneously increase the energy efficiency of thermal power plants.

A significant positive effect can also be achieved by using contact energy exchange plants. A striking example of such a plant is the “Aquarius” gas-steam plant, the operation of which exceeds the efficiency of gas turbine plants by 10-12% with a simultaneous significant decrease in the concentration of toxic nitrogen oxides NO_x and carbon monoxide CO in flue gases.

Keywords: energy efficiency, environmental performance, microflame technology of combustion, contact energy exchange.

Introduction

The existence and development of human civilization is no longer conceivable without the production and efficient use of energy. The existence of the energy industry in each country ensures the functioning of all its industries and the economy as a whole. Energy industry is important, among other industries in each country. The energy industry of any country, its work and development is based on objective laws, axioms and principles, the implementation of which is designed to ensure the stable operation of all energy facilities. Recently, the tasks of ensuring the development of civilization without worsening the ecological conditions of the

natural environment on the planet have become more and more urgent. Man has appeared and lives on planet Earth in a particular ecosystem. It is impossible to break the balance in its development and destroy this ecosystem. This can cause the death of not only all living things, but also the person himself.

1. Axioms and principles of power engineering functioning

The existence and development of power engineering in any country is based on objective laws, axioms and theorems [1].

Energy axiom 1 for any country: **“The energy sector must continuously supply all sectors and all spheres of the country's population with heat and electric energy in full”**. Violation of this axiom always leads to failures, emergencies, reduced productivity and can be the cause of crises and disasters.

Energy axiom 2: the energy sector of the economy of any state should be developed with constant consideration for **the need to ensure the energy balance between energy production and consumption**, as an invariable condition for strategic development. The energy produced cannot be stored and accumulated in the form of a strategic reserve, it cannot be destroyed or dumped without consequences. At the same time, its production cannot be instantly or in a short time significantly increased or fully used without a trace, just as it is impossible to break off the interconnected process of energy production and consumption. All energy production and its consumption at each moment of time must be balanced in full.

Energy axiom 3: **“The growth rate of energy production in the energy sector should be ahead of the growth rate of energy consumption by all sectors of the country's economy combined”** [2]. Violation of this axiom can lead to energy shortages, distortions and degradation in the development of individual sectors of the country's economy, and to a decrease in the production of Gross Domestic Product of the whole country.

The primary energy problem of the heat and power industry of any country is the need to constantly improve the energy efficiency of energy production, reduce costs, losses, unit fuel consumption and increase the profitability of energy facilities.

No less important and relevant at present is the problem of reducing the harmful negative impact of energy facilities on the environment: on the hydrosphere, on the atmosphere and on the lithosphere.

It is known that energy production at thermal power facilities (TPF) using fossil fuels is one of the main sources of environmental pollution that occurs in the form of thermal pollution, greenhouse gas emissions and toxic chemicals: CO, CO₂, NO, NO₂, SO₂, C₂₀H₁₂, dust and ash emissions.

Given the relevance of improving the environmental cleanliness of the TPF, it is necessary to make appropriate adjustments to the energy production management system. The new energy industry management system should provide improved environmental safety for energy production. This will succeed if the development of the energy industry is based on some energy principles that are based on the use of the energy axioms defined above.

The first energy principle of energy development – is the principle of ecological balance of development [3]: “The growth rate of energy production (δN_i) should not exceed the growth rate of environmental safety (δg_i)”. The basis of this principle is the need for the advancing development of technologies and the pace of improving environmental safety in comparison with the growth of energy production:

$$\delta N_i - \delta g_{i-1} \leq 0,$$

where $\delta N_i = \Delta N / N_i$ - growth rate of energy capacity,

$\Delta N = N_i - N_{i-1}$ - increase in energy capacity,

$\delta g_i = \Delta g_i / g_i$ - rate of increase environmental safety,

$\Delta g_i = g_{i-1} - g_i$ - increase in environmental safety.

Special attention should be paid to the scenarios, namely:

1st scenario: $\delta N - \delta g_i < 0$ - sustainable improvement of environmental safety of energy production,

2nd scenario: $\delta N - \delta g_i = 0$ – neutral level of environmental safety,

3rd scenario: $\delta N - \delta g_i > 0$ – high risk of environmental problems and natural disasters.

The second energy development principle relates to the sustainable development of the energy industry in any country in the world. It is advisable to take the well-known definition of sustainable development as the basis (UN Commission on Sustainable Development, 1996).

Sustainable development is the systematic coordination of economic, environmental and social development in such a way that the quality and safety of people's lives, environmental conditions do not decrease from one generation to another, and social progress takes into account the needs of each person [4]. This definition is taken as the basis for determining the second energy principle for the development of the energy industry.

Considering simultaneously the two energy principles of the development of the energy industry in any country, we come to the need to formulate a new energy-ecological paradigm for energy development in the world: “Sustainable development in harmony with nature!”.

The new energy-ecological paradigm (NEEP) [5-6] opens up new horizons for the development and implementation of environmentally friendly energy technologies and deepens the understanding of the need to improve all energy production processes.

The relevance of the transition of the energy industry to a new energy-ecological paradigm is obvious in connection with the need for its subsequent development, which is objectively recorded in the energy axioms considered above.

Unfortunately, the current state and operation of energy facilities in many countries is characterized by low values of energy and environmental indicators for a set of objective and subjective reasons and factors, the main ones among them are [7]:

- thermal pollution of the environment;
- emissions of greenhouse gases and toxic chemicals: CO, CO₂, NO, NO₂, SO₂, C₂₀H₁₂, which significantly poison the environment and the world around us;
- dust emissions of ash;
- slag emissions;
- a long period of design, construction and commissioning of energy facilities (7 - 12 years), during which energy technologies become obsolete;
- planned operational period is 25 years. During this time (12 + 25 = 37 years), energy production technologies become obsolete and do not meet new requirements;
- systems for environmental cleaning of flue gases of power plants do not have time to reach new requirements for emissions into the atmosphere;
- significant capital investments are required for the construction of new power plants.

The main directions and tasks of increasing energy efficiency and environmental safety of power plants according to the new energy-ecological paradigm:

- improving the quality of fuel combustion in boilers;
- increasing the efficiency of heat transfer processes in boilers and other units;
- improving the quality of flue gas cleaning;
- improving the quality of staff training.

2. Possible solutions to problems in the heat power industry

It is very important to understand that improving the quality of work of existing thermal power facilities (TPF) is possible only in two ways:

Reconstruction - requires significant capital costs and time;

Modernization - is carried out quickly and does not require significant financial investments. With this method, in boilers, the following systems and parts can be upgraded to improve energy efficiency and environmental safety at the same time:

- burner system and combustion conditions (microflame incineration technology of combustion (MIT-technology) - developed at the National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”) [8];

- flue gas cleaning systems (contact energy exchange technology - developed at the National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”).

3. Microflame incineration technology of combustion of gaseous fuels

This MIT-technology is based on the use of unique Bord nozzle effects and the successful implementation of a set of design features of burners with the implementation of classical methods for producing a homogeneous fuel-air mixture and reducing the emission of harmful substances of nitrogen and carbon oxides (NO_x , CO) in combustion products.

The features of this technology are as follows [9]:

- the unification of the technology is associated with the possibility of creating burner devices according to the same principle of forming their structure with achieving high efficiency and environmental friendliness in the process of burning gaseous fuels for a wide range of regulation and unit heat output of the unit (from 10 to 100%);

- the universality of the technology is emphasized by the possibility of using it with both high energy efficiency and environmental safety indicators for burning various types of gaseous fuels for different types of units: in boilers, contact heat generators and combustion chambers of gas pipe installations with a wide range of stepless power control and for various combustible

gaseous media: natural gas, coke oven, blast furnace gas, associated petroleum gas, biogas, methane gas, hydrogen and their combinations in various concentrations;

- possibility of creating effective systems for burning heterogeneous gas mixtures in one burner and thermal incineration (neutralization) of aggressive and carcinogenic gas media.

Complex of positive effects when using MIT-technology [10]:

- continuous flow motion;
- effective combined mixing;
- the ability to burn highly thermal fuels (such as hydrogen H₂);
- continuous automatic self-regulation of combustion;
- internal recirculation of flows;
- low aerodynamic drag;
- temperature field uniformity.

MIT-technology has been successfully implemented in the following types of industrial plants:

gas turbine units as a part of gas pumping units of types: GTU-10 (10 MW), GT-750-6 (6MW) at gas compressor stations of gas pipelines [11-13];

steam and hot water boilers of type: DKVR 10/13, KVGM-10, KVGM-20, KVGM-100, PTVM-180 [13-17];

heat generators of contact (KAOM-0,5 (0,5 MW); KAOM -1,0; KAOM -2,5) and surface (AOM-1,5 MW; AOM-2,5) types for autonomous heating systems for residential buildings and workshops of industrial enterprises [18-20].

Results of modernization of burner systems on the basis on the basis of use MIT-technology:

1) saving natural gas: in boilers – 5 - 6,5%; in turbines – 10-15%,

2) decrease in concentration and gross toxic emissions into the atmosphere of pollutants in the composition of flue gases (Fig. 1):

nitrogen oxides NO_x from 800 to 50 mg/m^3 ;

carbon monoxide CO from 900 to 5 mg/m^3 (Fig. 1);

3) a wide range of turbine power regulation (from 10 to 100%) with high economic and environmental performance;

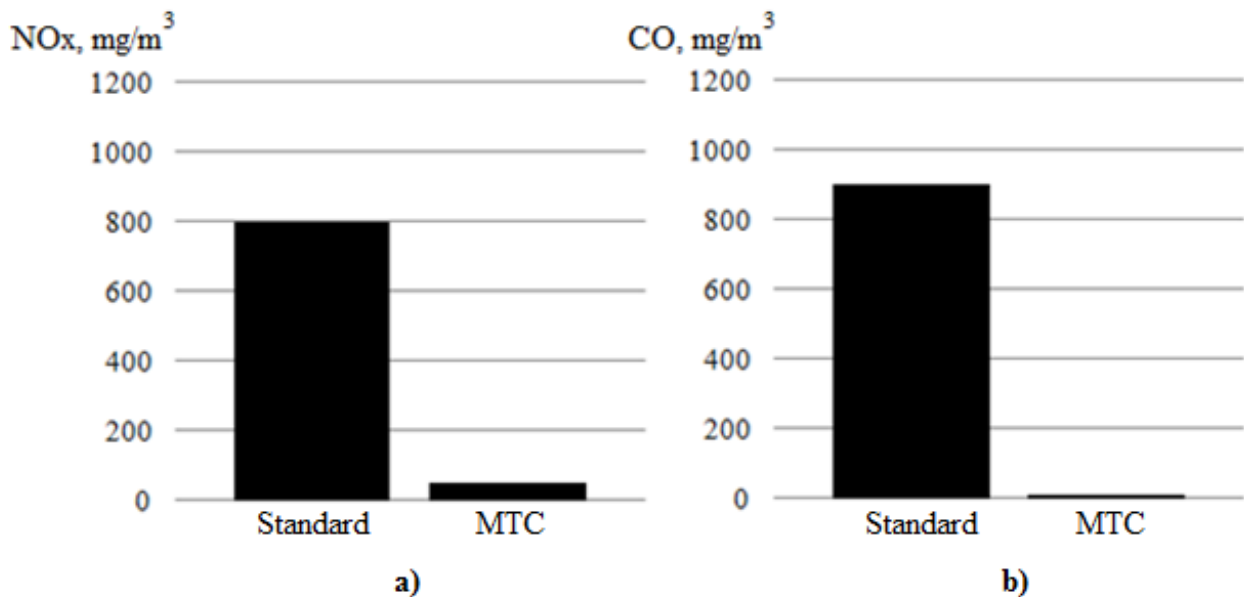


Fig. 1 – Comparison of concentrations of harmful emissions into the atmosphere when using a standard register burner and an MIT-burner (MTC): a) concentration of nitrogen oxides NO_x ; b) CO .

4) a high level of uniformity of the temperature field in the gas combustion zone and a reduction in vibration extend the life of the turbine and can increase the turbine power by 20% compared to the passport by reducing the temperature level and thermoelastic stresses in it;

5) the aerodynamic resistance of the burner system is reduced by 30-35%, which reduces energy costs for driving the fans of boilers and compressors in turbines;

6) the ability to perform upgrades in a short time from 1 to 3 days;

7) the estimated payback period for modernization costs while saving natural gas exceeds 10-15 months. Given the reduction in environmental charges and the increase in equipment life, the actual payback period will be significantly shorter;

8) there is no need to buy and install new turbines.

The combustion of gaseous fuels and the transfer of heat in the boiler furnaces and in the combustion chambers of gas turbines based on the use of the MIT-technology become much more efficient and environmentally friendly (Fig. 2, 3).



Fig. 2 – View of the MTC burner in a boiler with a capacity of 10 MW and the nature of its flame

4. Contact energy exchange technology

The use of contact energy exchange technology allows to obtain a complex positive effect: simultaneously with the increase in energy efficiency (by reducing the temperature of the outgoing gases), an additional environmental effect is obtained – the purification of flue gases from toxic components due to direct contact between gas and water [21].

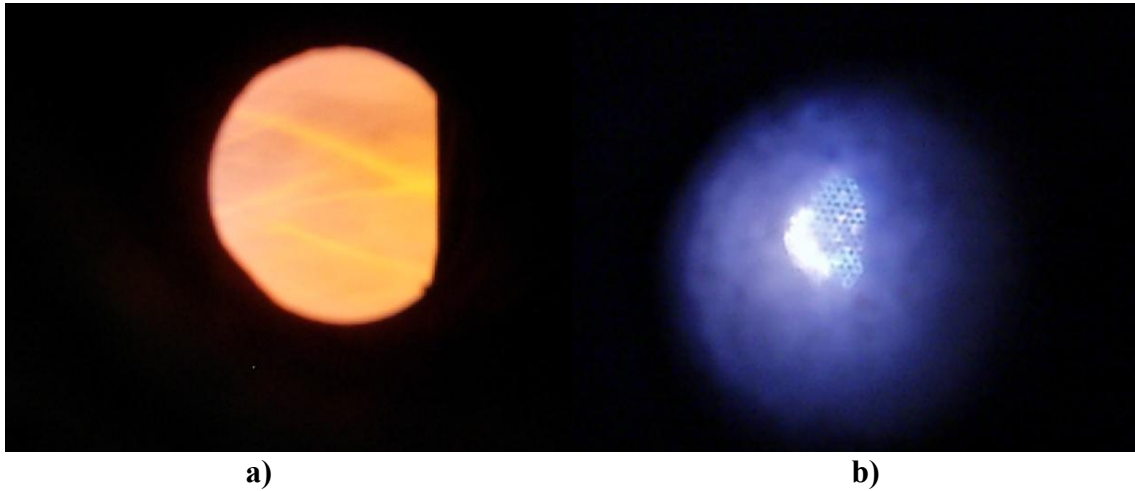


Fig. 3 – The nature of the flame during the combustion of natural gas in the turbine:

(a) for standard (register) technology, (b) for MIT-technology

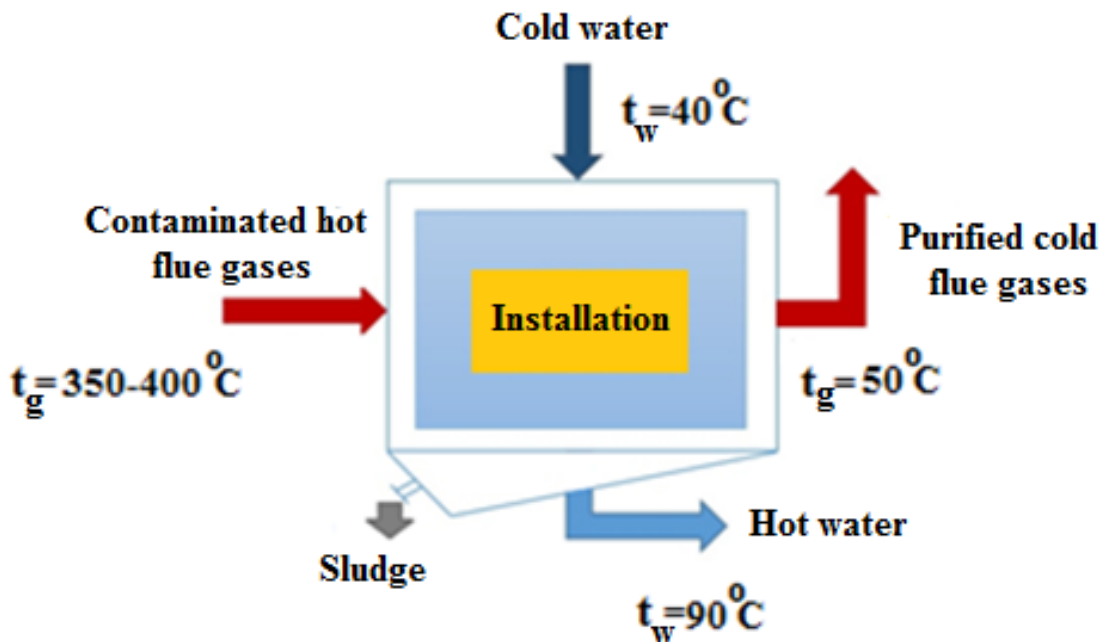


Fig. 4 - Schematic diagram of the implementation of contact energy exchange

The implementation of such energy exchange has been studied in detail by the specialists of National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute” and is successfully implemented in power plants.

The basic technological scheme of contact energy exchange with direct contact between gas and water for steam and hot water boilers is presented in Fig. 5.

Contact energy exchange technology can be implemented in existing boilers operating on any type of fuel by installing contact devices before the smoke stack (see Fig. 6).

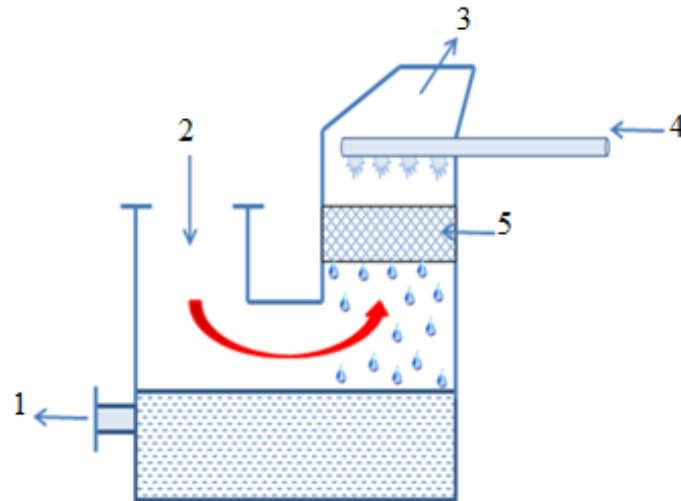


Fig. 5 - Counterflow contact heat exchanger: 1- hot water ($t_w=90^{\circ}\text{C}$); 2- hot flue gas ($t_g=150-400^{\circ}\text{C}$); 3 - purified cold flue gases ($t_g=50^{\circ}\text{C}$); 4- cold water ($t_w=40^{\circ}\text{C}$); 5 – contact nozzle

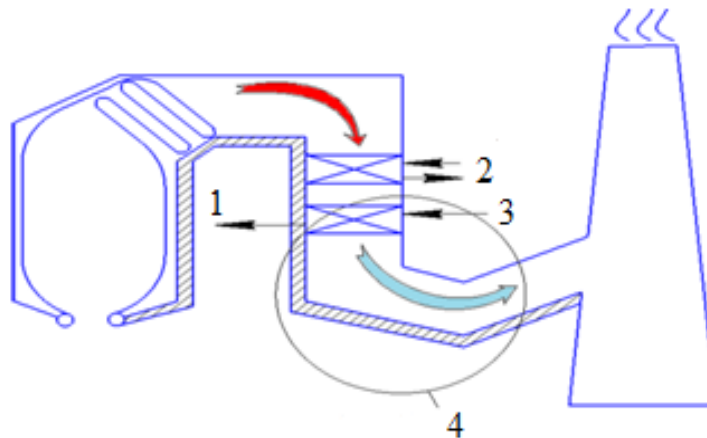


Fig. 6 - Contact heat exchangers used before the smoke stack:

1- hot air; 2- water economizer; 3- cold air; 4- reconstruction area.

The implementation of contact energy exchange technology in coal-fired boilers is an especially urgent task in connection with the need to save fuel and ensure environmental

cleanliness criteria for electricity production. The solution to the problem of increasing the efficiency of energy production in coal-fired boilers with a simultaneous increase in the environmental cleanliness of the power plant is possible with the implementation of contact technology for energy exchange at the outlet of the boiler. (see Fig. 7).

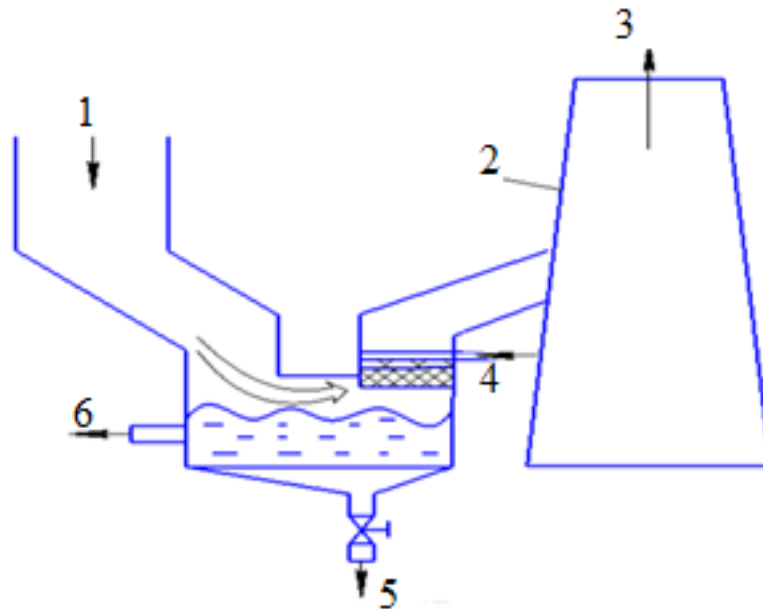


Fig. 7 - Scheme of implementation of direct contact heat exchanger on coal-fired boilers:

1 – flue gas before cleaning, 2 – smoke stack, 3 – flue gas after cleaning, 4 – cold water, 5 – sludge, 6 – hot water

This technology was implemented in the “Aquarius” power gas-steam contact unit, which has been successfully operating as a gas pumping unit at the gas compressor station of the main gas pipeline for 15 years. In the GSU “Aquarius” (Fig. 8), energy exchange occurs using a capacitor with isothermal condensation, and another important process takes place in it. In the process of “wet” burning of natural gas, active hydrogen is released, which enters into a chemical reaction with atmospheric oxygen and forms H_2O . For example, the GSU “Aquarius” with a capacity of 16 MW generates about 30 tons of technically pure water per day, which can be used for various domestic and other purposes (irrigation on agricultural fields, plants).

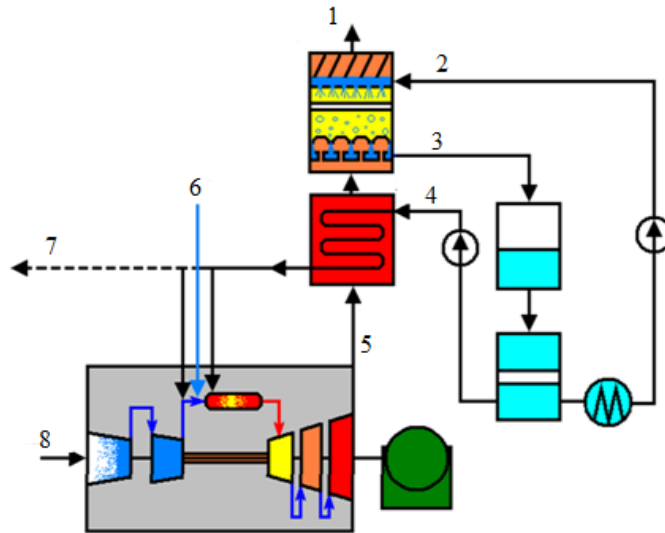


Fig. 8 – Schematic diagram of the gas-steam installation “Aquarius”:

1 - flue gases, 2 - cooling water, 3 - condensate, 4 - feed water, 5 - gas-steam mixture, 6 - fuel, 7 - steam generation, 8 – air

The Aquarius gas-steam installation can be used as an autonomous power station for generating electricity, as a heat-generating installation in cogeneration systems (generating electricity and hot water for heating and hot water supply systems), for driving various installations such as a gas pumping unit (for pumping natural gas through a gas pipeline) etc.

GSU “Aquarius” in comparison with conventional gas turbine units with the same effective power has the following advantages (Table 1).

Table 1 – Comparison of characteristics of standard GTU and GSU “Aquarius”

Main parameters	GSI-16	Aquarius	Parameter change, %
Power capacity, MW	16	16	0
Efficiency, %	30	42,16	+40%
Fuel consumption, kg/hour	3836	2700	-30%
Flue gas temperature, °C	450	45	10 times less
Content of CO ₂ , g/sec	2480	1920	-23%
Content of CO, g/sec	150	55	2,75 times less
Content of NO _x , g/sec	140	40	3,5 times less

Conclusions

1. The implementation of microflame incineration technology of combustion (MIT-technology) gaseous fuels and contact energy exchange technology leads to a comprehensive positive energy and environmental effect.
2. The concentration of harmful and greenhouse emissions (NO_x , CO) is reduced by 3-30 times.
3. The level of flue gas cleaning from ash and dust for coal-fired boilers can reach 99%.
4. Simplicity and low unit costs of implementation.
5. Short payback period (from 6 months to 3,5 years (“Aquarius”)).
6. Increased efficiency (for power plants is 10-12%)
7. The possibility of obtaining additional technically pure water H_2O , which is especially important for the autonomous location of the installation in separate, inaccessible and arid areas and places.

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