AUTHORS DIGEST

of the scientific and applied contributions of the work of
Chief Assistant Professor Eng. Polina Ilieva Milusheva-Mandadzhieva, PhD

submitted for participation in the competition for the academic position of "Associate Professor" in the field of high education 5. Technical sciences, professional field 5.1 Machine engineering, scientific specialty "Applied mechanics (Mechanics of coatings)", published in Sate gazette № 5/17.01.2020 г.; date of publication on the website of University "Prof. Dr. Asen Zlatarov" Bourgas - 17.01.2020 г., with term of three months after the publication in SG.

SCIENTIFIC PUBLICATIONS IN SPECIALIZED JOURNALS AND SYMPOSIA AND CITATIONS

For participation of the competition, 40 scientific publications have been submitted (Appendix 1) of which 10 in referred and indexed in world-known databases with scientific information (Scopus) (Indicator B 4.) and 30 in non-referred journals with scientific reviewing Appendix 1 (Indicator G*8.). of all the 40 publications, 13 have been published in English language, 27 in Bulgarian, for 18 of them the applicant is the single author and in 22 – coauthor. 28 of the scientific publications submitted have been reported at conferences – 1 abroad and 27 at international and national conferences held in Bulgaria.

The citations found are 32 in scientific papers (Appendix 4), among which 5 classified for Indicator D*12 and 27 for Indicator D14.

One participation in international scientific and educational project classified for Indicator E19 and 5 participations in topics elaborated at the Scientific Research Sector of the University "Prof. Dr. Asen Zlatarov", Bourgas (p.9 of the submitted documents).

Two patent applications have been submitted and published in the official bulletin of the Patent Authority (Indicator E25). (p.14. Documents according to article 70(8)).

The indicators mentioned are in accordance with the declaration of minimum score by indicators.

SCIENTIFIC AND SCIENTIFIC-APPLIED CONTRIBUTIONS

The main scientific and scientific-applied contributions of Chief Assistant Professor Eng. Polina Ilieva Milusheva-Mandadzhieva, PhD are in the field of mechanics and materials science and they can be summarized in the following directions:

1. *Deposition of metal, graphene and wear resistant coatings onto polymeric materials*
2. *Studies on the mechanical characteristics of deposited coatings and surface properties of thin layers.*
3. *Simulation studies and optimization of mechanical constructions with deposited coatings.*
4. *Other directions.*

1. Deposition of metal, graphene and wear resistant coatings onto polymeric materials

The proper choice of materials and rational design of the elements of mechanical constructions are an important stage in the cycle research-implementation and the achievement of high technical and economical degree and operation reliability depend on. The sparing use of raw materials of high quality and high reliability of the end product can be realized only by the use of advanced technologies and achievements.

The requirements towards the materials used for production of various construction elements and products are constantly increasing. This is the reason imposing innovative changes in all fields of technology to overcome

the discrepancy between the modern requirements and the limited capabilities of the materials and technologies used.

A solution of this problem is to use polymeric materials on which thin layer of metal or graphene coating is deposited.

In modern production of elements and products the use of the combination of these materials is more and more often noticed.

Replacing the metal elements with elements made from metalized plastic, one can achieve rational use of metals and their use in such quantities and only there where their metal properties are needed, reduction of cost, save materials and energy, as well as reduction of product weight.

Polymers with metal and graphene coatings deposited on them are increasingly used worldwide.:

- In electronics and microelectronics – for manufacturing printed circuits which are used practically in all branches of the economy;
- In electrical engineering – as shields reflecting radiation with various wavelengths;
- Materials for astronautics and aviation: all types of materials for screen-vacuum insulation, including mats, composite materials based on polyamide strips and metalized materials;
- Metalized sheets and rolls, such as panel heating elements, sun protection and heat reflecting coatings for the households;
- Mirror sheets based on plastics with deposited layer of aluminium, chromium or other metal for manufacturing three-dimensional letters, outdoor elements, complex products for outdoor advertising, decoration of halls' interior, etc.;
- Elements of car interior and exterior: dashboard, panels and other interior elements; car radiator grills, wheels covers; body parts, parts of household appliances and office equipment; structural parts of electric devices, switches, aircraft equipment; plumbing equipment, etc.
- For decorative purposes in households – door handles, furniture fittings, discs, bumpers, decorative elements, lighting fixtures etc., as imitation of metal elements.

The studies and the implementation of structural polymeric materials with metal or graphene coatings aiming to use them as machine building elements: gears, plain bearings, bushes, etc. are limited.

The aim of the studies in this field was to develop new materials and improve the properties of these in use today. Based on innovative decisions, new composite materials are offered to overcome the discrepancy between modern requirements and the limited capabilities of the materials and technologies used nowadays.

The main contributions in this field can be summarized as follows:

Scientific contributions:

- A scientifically based study of the processes for deposition of metal coatings onto polymeric materials PS/SB190 crystal, PS/SB793 shockproof and POLIPOM®-POM by magnetron sputtering in vacuum was carried out, as well as the possibilities for optimization of the deposition processes. The effects of the technological regimes for deposition of the coatings were established (adhesion, hardness, wear resistance) for the component system polymer – metal coating. Practical regimes for magnetron sputtering of the metals X18H9T, Ti and Al were developed which can successfully be used for deposition of coatings onto various construction materials. The morphology of the deposited coatings was registered and studied.
- A scientifically based study of the processes of deposition of Ni-Cr and TiN coatings onto polymeric substrates PS/SB190 crystal, PS/SB793 shockproof and POLIPOM®-POM by direct current magnetron sputtering in vacuum was carried out. The values of the regime of cathodic sputtering were determined experimentally. The effects of the basic parameters of the process – voltage, temperature, vacuum depth and duration of the sputtering process on the deposition regimes were studied. The coating adhesion was studied and conclusion was made for additional optimization of the technological parameters of the deposition regime.
- A scientifically based study of the processes of deposition of Pt-SiO_2 resistive layers onto polytetrafluoroethylene substrate by high frequency cathodic sputtering was carried out. The changes of

the electrophysical parameters of the layer were determined after thermal treatment. The rate of layer deposition was determined experimentally by studying the processes of sputtering of the metal structure, transfer and condensation of the vapors on the substrate. The effects of some basic parameters of the deposition process were determined – voltage, temperature, vacuum depth and duration of the pre-deposition and the deposition on the regimes of deposition of Pt-SiO_2 resistive layers.

- A scientifically based study of the processes of deposition of copper nano-coating by high-voltage technology of deposition under vacuum onto the polymeric material Polikes®PA6 G was carried out, as well as the possibilities to optimize the deposition processes. The regimes of deposition of copper nan-coating were experimentally determined. The morphology of the deposited coating was registered and its structure was subjected to X-ray phase analysis. Practical optimized regimes for high-voltage sputtering of Cu were developed which can successfully be used for deposition of copper nano-coatings onto different polymeric materials.
- A scientifically based study of the processes of preparation of graphene and deposition of single layer of graphene onto polymeric substrate. For this purpose, high-voltage technology for electrode sputtering in vacuum onto the polymeric material PS/SB793 shockproof was used the regimes of graphene coating deposition were experimentally studied and established. The microstructure of the deposited coating was registered and studied and the surface of the graphene coated substrate was investigated IR spectroscopy. The results obtained were analyzed and specific optimal regimes of high-voltage carbon sputtering were developed which can successfully be used for preparation and deposition of graphene coating onto different polymeric materials.
- A scientifically based study of the processes of deposition of wear-resistant aluminium oxide coating onto polyamide structures Polipa®PA6 and Polikes®PA6G. It was proved that the deposition of coatings on these materials by magnetron ion sputtering is unsuitable. Due to the super strong gas release from these polymers, the coatings obtained were of low quality. On the other hand, they are widely used due to their high molecular weight and cross-links. They are resistant to bending, wearing and breaking. They are suitable for operation under high load for long periods. To solve this problem, a new approach was suggested and a new method for deposition of wear-resistant coating onto polymeric surface. The essence of the method is that the coating is deposited using fluidized bed of aluminium oxide Al_2O_3. Aluminium oxide is characterized by stable hexagonal α-phase called corundum or α-aluminium oxide. this phase is thermodynamically stable form, resistant to acids and bases, low heat conductivity, high hardness (hardness 9,0 Mohs), excellent insulation properties, refractor period and good thermal properties. The aluminium oxide particles can be fluidized and can be heated to temperatures at which, after the immersion of the sample in the bed, partial melting of the polymer takes place. The aluminium oxide particles penetrate the melted zone. The molten material wraps the particles of the reinforcing phase and, on decrease of temperature, binds them in dense structure. The effect of fluidized bed temperature and sample treatment time on the depth of surface melting and the thickness of the coating obtained were studied. Using microscope analyses, the disposition and the thickness of the aluminium oxide coating were determined, as well as the interface between the wear-resistant layer and the polyamide surface. The coating structure was analyzed and particular optimal regimes of operation were developed which can successfully be used for preparation and deposition of wear-resistant coating onto various polymeric materials.

Scientific applied contributions:

- The possibility to deposit metal coatings of X18H9T, Ti and Al by magnetron sputtering in vacuum onto the polymeric materials PS/SB190 crystal, PS/SB793 shockproof and POLIPOM®-POM was proved.
- The possibilities for particular application of X18H9T and Ti coatings deposited onto machine elements manufactured from the polymeric material POLIPOM®-POM was proved which outlines new opportunities for practical implementation of the vacuum technology.
- The possibility to deposit metal coatings of TiN onto polymer substrates POLIPOM®-POM by direct current magnetron sputtering in vacuum was proved.

- The possibility for particular implementation of TiN coatings for improving the wear-resistance of the materials and for the needs of optics as reflecting selective coatings was proved.
- The possibility to deposit Ni-Cr coatings onto polymeric substrates PS/SB793 shockproof and POLIPOM®-POM by direct current magnetron sputtering in vacuum was proved.
- The possibility to use alloyed targets obtained by recovering nickel and chromium from industrial waste waters was proved. The use of vacuum technology for deposition and recovery of precious metal with mitigation of the impact on the environment is economically and ecologically expedient processing.
- The possibility to deposit Pt-SiO_2 resistive layers onto polytetrafluoroethylene by high frequency cathodic sputtering was proved.
- The possibilities for particular implementations of the technology for high frequency cathodic sputtering in vacuum for creation of thin film resistive layers and their implementation in hybrid and monolith integral circuits was proved. The electrophysical parameters of the layers obtained were proved to undergo substantial changes after thermal treatment. It was proved also that the planar cathodic target makes the realization of the process quite simple which provides opportunity for its implementation in industry.
- The possibility to deposit copper metal coating by high-voltage cathodic sputtering in vacuum onto polymeric material Polikes®PA6 G was proved.
- The possibility for particular implementation of the technology for high-voltage sputtering in vacuum for improvement of the electric and capacitive characteristics of polymer surface by deposition of copper nano-coating which outlines new opportunities for practical implementation.
- The possibility to deposit wear-resistant aluminium oxide coating onto polyamide structures Polipa®PA6 and Polikes®PA6G by fluidized bed technology was proved.
- The possibility for particular realization of the fluidized bed technology for deposition of wear-resistant coatings onto Polipa®PA6 and Polikes®PA6G was proved which outlines new opportunities for practical implementation. A technology and optimal hydrodynamic conditions of bed fluidization were developed.
- The possibility to deposit graphene coatings by high-voltage sputtering of graphite onto polymeric material POLIPOM®-POM was proved.
- The possibility for particular application of graphene coatings deposited onto polymeric material POLIPOM®-POM was proved which outlines new opportunities for practical implementation aimed to improve the electric and capacitive characteristics of the surface and develop electrodes for supercapacitors of new generation.
- It was proved that the time for deposition of the coatings depends on the thermal resistance of the polymers.

A total of 12 scientific papers were published in this field, among which 5 in journals referred and indexed in world-known databases with scientific information (SCOPUS) [B4.(3,4,6,8,10)] and 7 in referred journals in Bulgaria [Г*8.(2,4,13-15,18,28)] in Appendix 1.

2. Studies on the mechanical characteristics deposited coatings and surface properties of thin films.

The modern tendencies in industrial development require new technical and economic solutions in order to improve the performance reliability of the products. One perspective direction for meeting these requirements is the use of metalized plastics.

The metal layer deposited onto polymeric material protects it from UV radiation, decreases water and oxygen permeability. These properties of the metal coatings also protect the polymeric materials from rapid ageing. The deposition of metal coating onto polymeric material results in improved mechanical properties of its surface layer. This widens the assortment of plastic products and allows their purposeful use for, e.g. manufacturing of highly loaded elements and mechanisms.

Effective technologies were developed for deposition of coatings by both magnetron sputtering in vacuum at processing temperatures below the melting temperature of the substrate and at lower temperatures using the fluidized bed technology which results in significant improvement of the mechanical properties of the contact surface at comparatively low cost.

This solution provides opportunity to replace expensive metal products with the new structures obtained the use of which results in reduction of the cost and weight of the products, saving materials and energy, rational use of metals while preserving the tensile and technological characteristics of the products.

The aim of the studies in this direction was to investigate the tensile and the mechanical characteristics of the metal coatings on polymeric materials obtained. Based on the optimal regimes for coatings deposition suggested, the achievement of better mechanical characteristics was proved.

The main contributions in this direction can be summarized as follows:

Scientific contributions:

- A scientifically based study of the adhesion of X18H9T, Ti and Al coatings deposited on PS/SB190 crystal, PS/SB793 shockproof and POLIPOM®-POM. The adhesion tension was studied by the normal tensile strength method and calculated on the basis of detached areas which were determined by scanning the destructed surface. The values of the adhesion tension obtained were analyzed and classified for different regimes of coatings deposition. Conclusions were made about the dependence between the coating adhesion and the cathodic cleansing of polymeric surface. For the materials PS/SB190 crystal and PS/SB793 shockproof, it was found to improve when the technological regime involves additional treatment with oxygen with excluded treatment by “cathodic cleansing” while for the material POLIPOM®-POM – when “cathodic cleansing” was included in the technological regime and no additional treatment with oxygen was carried out.
- A scientifically based study of the hardness of coatings of doped steel X18H9T, titanium and aluminium deposited on the polymers POLIPOM®POM, PS/SB793 shockproof and PS/SB190 crystal was carried out. These materials are widely used in engineering projects, they show good construction properties and chemical resistance which provides opportunities for their use in various fields of industry. The new technologies offers polymer based materials which guarantee long-term use at temperatures significantly higher than 260°C, as well as radiation resistance, excellent thermal stability, non-flammability, good electrical insulation properties, etc.
- A scientifically based study of the hardness of metal coatings of small thickness which is a hard task due to the penetration of the hardness tester indenter in the inter-grain space but not in the central zone of the grains. It was proved that the problem can be solved only by using nano- hardness testers for measuring the microhardness of coatings with thickness in the range from 3 to 0,7 μm.
- The regimes and conditions for carrying out the studies were selected depending on the tensile properties, the thickness and adhesion of the coating studied. The nano-indentation tests performed were simple, fast and non-destructive. These methods allow carrying out tests at small and very small loads in order to control the rate of indenter penetration into the material, measuring directly the values of the elastoplastic characteristics of the materials, estimating the anisotropy, etc.
- A scientifically based study of the wear resistance of coatings of doped steel X18H9T, titanium and aluminium onto POLIPOM®POM, PS/SB793 shockproof and PS/SB190 crystal by the weight method. The method selected gives real idea about the wear resistance of the materials as a process of mass loss from the contact surface between the elements of the product and depends on the conditions it operates in (friction and load) and the properties of the materials used. Experimental tests were carried out to find the dependence on the operation duration until preliminarily set or certain limit value of the wearing is observed. The regimes and the conditions under which the tests were carried out were selected taking into account the real operating conditions of the coating studied. Aiming to accelerate the research process, certain abrasive was added in the form of powder, paste or other. The values obtained were analyzed and classified and conclusions were made about the kinetics of the change of coating mass under different regimes of coating deposition.

- Thorough experimental studies were carried out and the influence of the technological conditions for deposition of the coatings were established and the basic mechanical characteristics were determined, e.g. the normalized modulus of elasticity E^*, the degree of the plastic deformation energy W_r, the total deformation energy W_t and the hardness *HV* for coatings of X18H9T, Ti and Al.

Scientific applied contributions:

- It was proved that the optimal regimes of magnetron sputtering of the metals X18H9T, Ti and Al developed, are a prerequisite for the achievement of better values of the mechanical properties and can be used for deposition of coatings onto various polymeric construction materials.
- It was proved for magnetron sputtering that the cathodic cleansing and the preliminary treatment of the polymeric surface before the deposition of the coating exert substantial effects on the values of the mechanical characteristics. It was proved that optimal values of the mechanical characteristics of PS/SB190 crystal, PS/SB793 shockproof were obtained when the technological regime does not include cathodic cleansing while for POLIPOM®POM – oxygen treatment.
- It was proved that precise and correct measurements of the hardness of thin coatings deposited onto polymeric surface can be obtained only by using microhardness tester which allows penetration of the indenter on the central zone of the grains rather than on the inter-grain spaces.
- It was proved that the substrate material has substantial effect on the wear resistance and adhesion of the coating.
- The effect of the technological conditions for deposition of the coating on the elastoplastic characteristics of the product was proved.

In this direction, a total of 19 manuscripts were published, among which 6 in journals referred and indexed in world-known databases with scientific information (SCOPUS) [B4.(1,3-5,7,9)] and 13 in journals referred in Bulgaria [Г*8.(1,3-10,13,21,25,29)] in Appendix 1.

3. Simulation studies and optimization of mechanical constructions and deposited coatings.

Metallization of polymers is widely used in modern industry. The methods for deposition of metal coatings on plastics, as well as the advantages and disadvantages of this technology are described in details in the literature.

In the cases when the deposition of metal coating is used to improve the tensile properties of the contact surface of the polymer, it is very hard to predict what thickness the coating should have to guarantee the mechanical properties of the surface. The experimental study of this problem is very expensive and long procedure which can be avoided using modern computer technology. With a physical model of the pair “coating – substrate” at hand, a method for simulation prediction of the mechanical properties for different coatings and at certain thickness is developed.

The aim of the research in this direction was to develop reliable method for simulation and prediction of the mechanical properties of metal coating deposited onto polymers and the possibility for optimization of the deposition process. Based on innovative solutions, a new approach is suggested for prediction of the mechanical characteristics of the new materials.

Another priority in this direction is the study of the performance and optimization of the constructive characteristics of mechanical assemblies using computer modelling and investigation of the 3D models.

Many modern highly efficient machines and devices work with dangerous and aggressive media under high pressure and temperature. Possible accidents related to incorrectly selected materials or improperly selected design might cause great material losses, human casualties and environmental damage. Therefore, it is necessary to take into account a number of requirements regulating the technical and economic, exploitation and ecologic indicators and the requirements for safety, reliability and durability of the product. The details and the elements of the structure must be calculated and designed in such a way as to ensure trouble-free operation and sufficient

durability of the machines and devices and their units. For this purpose, they must have sufficient tensile strength, good endurance for fatigue, resistance to vibrations, low wearing and damping, resistance to thermal, chemical, mechanical, erosion and corrosion effects of the environment.

Besides, the operation conditions and the load on individual elements of the structure should be taken into account and the coefficients of durability, strength and resilience should be calculated with sufficient reserve. These of them which are expected to be subjected to higher risk of wearing and destruction must be situated in such a way as to be easily accessed for unmounting and replacement on repair works.

The safety coefficients should also be consistent with the consequences which would occur in case of possible accidents. The highest coefficients should be chosen in the cases when an accident could result in human casualties and great material losses.

The aim of the studies in this direction is, using computer modelling, to simulate operation conditions and load on the structure and select the optimal constructive characteristics to improve the performance, reliability and the strength characteristics of the equipment. On the basis of many simulations, a new approach is suggested for prediction of the mechanical characteristics of the structures studied.

The main contributions in this direction can be summarized as follows:

Scientific contributions:

A scientifically based study on the prediction of the mechanical properties of the coatings deposited was carried out. Modern computer technology was used to develop physical model of the pair “coating – substrate” based on mathematical model describing the strains generated in the system under the influence of an external load.

A new approach for prediction of the mechanical properties of metal coating deposited onto polymeric substrate and the possibilities for optimization of the deposition processes. For this purpose, a method for simulation prediction of the mechanical characteristics of the deposited coatings was suggested. Its use allows shortening the period of experimental testing for determination of desired thickness of the coating which is an expensive and quite long procedure.

Using the method of simulation prediction of the mechanical properties of the deposited coatings, the influence of the technological conditions on the process of coatings deposition, on some basic technological characteristics (adhesion, hardness, wear resistance) of the component system polymer – metal coating was established.

The possibilities for particular application of the simulation model for prediction of the mechanical characteristics of metal coatings deposited onto machine elements manufactured from the polymeric material POLIPOM®-POM was proved which outlines new opportunities for practical implementation of these technologies.

A scientifically based study of the technologies for prediction of the mechanical characteristics, studies on the performance and optimization of the design characteristics of mechanical assemblies using computer modelling and investigation of 3D model was carried out. Modern computer technologies were used to develop physical model of a mechanical structure and mathematical model describing the strains generated in the system under the influence of external loads.

Scientific applied contributions:

The possibility to use computer technology for prediction of the mechanical characteristics of the deposited metal coatings by magnetron puttering in vacuum onto the polymeric material POLIPOM®-POM was proved.

Physical and mathematical models were developed describing the strains generated between the substrate and the coating under the influence of the external load and the adhesion.

A reliable method for simulation and prediction of the mechanical properties of metal coating deposited onto polymer and the possibilities for optimization of the thickness of the deposited coating to achieve the desired thickness were outlined.

Complex external loads of normal force, bending and twisting moments of the pair “substrate-coating” were simulated. Criteria for the stability of the system were the allowable strains of the materials in the system. The

results obtained by the simulation were compared to the experimentally determined ones by the deposition of X18H9T, Ti coatings onto polyacetal POLIPOM®POM and good coincidence was observed between them.

Based on the computer simulation, optimal thickness of the X18H9T and Ti coatings was predicted and suggested. The use of the simulation method shortens the period of experimental studies, saves funds and time and offers an opportunity to deposit quality coatings onto various elements.

Physical and mathematical models were developed describing the strains generated under the influence of the external load in the assembly of axial bearing unit of steam turbine working on Freon with electric generator mounted within the turbine.

A reliable method for simulation and prediction of the loads in the structure was developed aiming to optimize the design of the geometric characteristics of the shaft, turbine wheels and the stator of the generator according to the desired results.

Complex external loads of normal force, bending and twisting moments of the elements included in the assembly were simulated. Criteria for the stability of the system were the allowable strains and the resilience of the materials of the system.

Using the simulation results obtained, a radial-axial bearing assembly of a turbine was designed. The turbine has built-in electric generator with electric power of 16 kW and it works with Freon 507A under heat-carrier pressure at inlet 1,5 MPa and debit of 0,122 kg/s.

The simulation results obtained were compared with experimental data registered during turbine operation and good coincidence was observed. This indicated that the approach suggested for the dimensioning and the constructive design of radial-axial bearing assembly can be used for design of non-standard equipment.

The use of the method for simulation prediction shortens the period for creating the experimental prototype and the testing of the construction which makes it expedient and economically advantageous with respect to time and financial resources.

In this direction, a total of 4 scientific papers were published, among which 1 in journal referred and indexed in world-known databases of scientific information (SCOPUS) [B4.(2)] and 3 in journals referred in Bulgaria [Г*8.(26,27,30)] from Appendix 1.

4. Other directions.

4.1 The ever-increasing degree of automation and computerization of processes in various fields of human activity, the use of new materials, as well as the influence of external factors of a random nature, place increasing demands on the reliability of systems. This is the reason for the deepening of the research in the field of reliability.

The increasing use of polymeric materials in critical structures and elements is a prerequisite for expanding the investigation towards their reliability. The reliability of the mechanical structure made from polymeric material subjected to ageing by solar radiation was investigated. To study the polymeric structure deformation, “flow (motion) of matter” in the vicinity of certain point M is defined. A general equation was derived to describe the motion of the matter of polymeric type structure without reaching its destruction. Particular solution was obtained for the value of the deformation of a structure located in horizontal plane.

During the design, maintenance and exploitation of aircrafts, a task is commonly set to increase the reliability of both the existing models of aircrafts and the newly designed ones. One possible decision is to implement composite materials. The replacement of individual elements, assemblies and units manufactured from steel with ones made from composite materials allows reducing the aircraft weight and the construction ageing rate, thus to significantly increase the aircraft technical resource and reliability. In terms of mechanical properties, the composite materials are superior to the traditional metal alloys since they are significantly more resistant to fatigue, due to which the possibility for destruction of the structure caused by the appearance and propagation of cracks is greatly reduced. The only disadvantage is the shrinking of the volume of the internal compartments of the aircraft (civil and military).

During the period of their operation, ships are subjected to a number of external influences which could be of permanent of random nature. Despite the incessant development of the methods, techniques and technical means ensuring the safety of shipping, significant maritime accidents occur every year which leads to losses of million tons of goods, spillage of petroleum products and other damages to the environment and human casualties. Of certain interest is the problem of ships viability after failures of some or all their systems and units. Recently, special attention is paid to the problems arising by the estimation of its hull after violation of its integrity due to external influences or impacts of different nature. After the impact, beside ship's hull, its machines, mechanisms, equipment are damaged with possible loss or injuries of the crew. The damage leads to reduction of ships serviceability and, in some cases, its total loss. The preservation of the main functions of the vessel and the carrying out its mission after damage from impacts is important for both civilian ships and warships.

4.2. The motion of a point in space can be described by the vector, coordinate or natural methods. The three methods are interconnected and, to some extent, equivalent. Carrying out the research in a coordinate system, the motion of a point can be regarded in polar, cylindrical, as well as in spherical coordinates.

There is a wide range of fields of human knowledge which require precise control of not only the velocity and acceleration, but also the next derivatives of higher order – also known as jerk, snap, crackle, etc. The visualization of such type of quantities is of special importance for the studies on various movements, from human body to the Universe as a whole.

A kinematic method was suggested which allows, using a developed integral graphics, to replace the motion graph – segment with closed curve which can be defined as "unfolded or polycentral motion graph" of snap or crackle. The result of the kinematic method suggested can rapidly and efficiently be related to its real motion graph. The kinematic method suggested expands the possibilities for detailed studies and analysis of the changes, it is practical and understandable and its results are comparable to these obtained by other methods; besides, it complements and develops them without their mutual exclusion.

4.3. The dependence on fossil fuels as the main and almost the only energy carrier in the fields of transportation and generation of energy for many years has urged profound research in the field of alternative energy sources. The combustion of fossil fuels generates harmful emissions and exerts adverse effects on the environment, including global warming. This makes it necessary to look for replacement of some of the conventional fuels for diesel engines and opportunities for fast and effective solutions leading to improvement of their operation and making them more environmentally friendly. One solution in this direction is the use of hydrogen as an additive to the fuels with the resulting effects. Possibilities for fast and efficient solutions for the diesel engines leading to improvement of their operation were researched.

4.4. Waste waters from numerous extracting and processing plants, as well as these where galvanic coatings are deposited, are usually characterized by high concentration of heavy metals, e.g. Cu, Ni, Cr etc. The direct separation of non-ferrous metals carried out by sedimentation, evaporation, etc., suggests further processing of the waste product obtained which should be then supplied to metal processing plants or to bring it to a form which can be safely stored. This is why the possibility for their extraction by another approach – electrolysis – was investigated. Since the metal cations Cu^{2+}, Ni^{2+}, Cr^{2+} have quite different affinities, copper can be separated by immediate electrolysis while nickel and chromium can be recovered by electrolysis only after concentrating the solution which is done by ultrafiltration. The membrane method was used for separation which, beside the opportunity to concentrate the model solution, allows reducing the energy consumption of the process. The electrolytic recovery starts with nickel and after completion of nickel electrolysis proceeds with the precipitation of chromium. By the electrolytic recovery, the metals are separated directly on the cathode. The cathodes obtained can be used as targets for deposition of metal coatings using magnetron sputtering in vacuum.

Scientific contributions:

- A scientifically based study of the deformation of the matter of polymeric structure was carried out. A general equation was derived for the motion of the matter of the polymeric structure without its destruction. Particular solution for the value of the deformation of a structure located in the horizontal plane was obtained.

- The possible solutions of the task for improvement of aircraft reliability was studied and analyzed with respect to the use of composite materials. With their implementation, reduction of mass and level of ageing of aircraft structure is achieved which is a prerequisite for significant increase of their technical resource and reliability.
- A scientifically based study of the working capacity of a ship after impact has been made on the basis of simplified idealization where the ship was modelled as a system consisting of subsystems containing its basic elements. Expressions of the function of failure distribution were derived. A mathematical model for determining and predicting the serviceability of the ship after impact.
- A scientifically based study was carried out and kinematic method was suggested which expands the opportunities for analysis and estimation of the dynamic changes at snap and crackle points in the cases with special motion of a point.
- An integral graph was developed where the graph – segment is replaced by closed curve which was defined as “unfolded of polycentric graph”.
- A scientifically based study of the possibilities to use hydrogen as alternative additive to the fuel with the resulting effects leading to improved performance and environmental friendliness of the diesel engines
- A scientifically based study of the effect of hydrogen on the process of combustion and the emissions from diesel engines.
- A scientifically based study of the possibilities to recover Cu, Ni and Cr from model solutions of industrial waste water by electrolysis was carried out.
- A scientifically based study of the processes of recovery of heavy metals and a technology for purification off waste waters was suggested

Scientific applied contributions:

- A mathematical apparatus for theoretical determination of the deformation of polymeric construction located on horizontal plane and subjected to ageing by solar radiation was derived.
- The possibility to improve aircraft reliability due to the use composite materials was proved.
- A mathematical model which can be used for estimation of the reliability if a ship including also the possibilities to repair failed systems was suggested.
- A mathematical formulation for determining the function of the distribution of failures was suggested which can be used to estimate the probability of serviceability after impact.
- The possibility for to use the kinematic method suggested for analysis and estimation of the dynamic changes in a snap at point in cases of special motion was proved.
- The possibility for to use the kinematic method suggested for analysis and estimation of the dynamic changes in a crackle at point in cases of special motion was proved.
- The relationship and comparability between the results obtained by the kinematic method suggested and ones used until now was proved.
- The possibility to use hydrogen as additive to the fuel for diesel engines aimed to provide smoother, more economical and environmentally friendly combustion in them was proved.
- The possibility to recover Cu, Ni and Cr from model solutions of industrial waste waters by electrolysis was proved.
- The possibility for implementation of the technology suggested was proved.
- The possibility to use the cathodes obtained by recovery of copper, nickel and chromium from industrial waste waters as targets for deposition of metal coatings by direct current magnetron sputtering in vacuum was proved.

A total of 9 papers were published in this direction, among which 7 in referred journals in Bulgaria [Г*8.(11,12,16,17,22-24)] and 2 in reviewed journals in Bulgaria [Г*8.(19,20)].

EDUCATIONAL AND LECTURING ACTIVITY

Documents describing the educational and lecturing activity of Chief Assistant Professor Eng. Polina Ilieva Milusheva-Mandadzhieva, PhD (Appendix 2) have been submitted as follows:

- Information about the participation in the development of educational curricula for the last three years:
  - New curricula for the educational and qualification degree of "Bachelor" full-time form of education – 5 pieces;
  - Updated educational curricula for the educational and qualification degree of "Bachelor", full-time form of education – 7 pieces.
- Information about the courses of lectures developed for the last three years:
  - For the educational and qualification degree of "Bachelor", full-time and part-time forms of education – 2 pieces;
  - For the educational and qualification degree of "Master", full-time form of education – 2 pieces.
- One textbook (Indicator E23.) and 1 handbook (Indicator E24.) have been published.
- Guidance of three graduating students.

Chief Assistant Professor Eng. Polina Ilieva Milusheva-Mandadzhieva, PhD is member of the Union od Scientists in Bulgaria and member of the Editorial board of the Journal "Science, Education, Culture", ISSN 1314-717X. (Documents according to article 70(8)).

Elaborated by:
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