Abstracts

P. P. Lepikhin, V. A. Romashchenko, O. S. Beiner, and S. A. Tarasovskaya, "Computational Investigation of the Effect of Reinforcement Schemes and Angles on the Stress-Strain State and Strength of Composite Cylinders under Axisymmetric Internal Explosion. Part 2. Calculation Results for Single- and Two-Layer Cylinders with Symmetrical Reinforcement of the Layers," *Problems of Strength*, No. 3, 5–12 (2019).

The effect of reinforcement schemes and angles on the stress-strain state and strength of single- and two-layer wound composite cylinders of finite length with symmetrical reinforcement of the layers under the internal explosion of a spherical explosive charge in the center of symmetry of cylinders in an air environment has been numerically investigated. The obtained results allow one to choose reinforcement schemes and angles which ensure the highest and lowest initial strength of cylinder according to the maximum stress and strain criteria and the generalized von Mises criterion, as well as circumferential rigidity.

V. S. Hudramovich, V. N. Sydorenko, D. V. Klymenko, U. F. Daniev, and E. L. Hart, "Development of the Normative Framework Methodology for Justifying the Launcher Structures Resource of Launch Vehicles," *Problems of Strength*, No. 3, 13–21 (2019).

The results of the development of normative framework for justifying the launcher structures resource of launch vehicles for placing spacecrafts of various purposes into Earth orbits are presented. Created launch complexes are successfully operated in various countries around the world where space-rocket hardware is well-developed; they represent a set of functionally interconnected mobile and stationary technical objects, control equipment and constructions designed to support and conduct all types of work with start preparation and rockets launching. Their features depend on the type and power of the launch vehicles, infrastructure characteristics (the location of the complex, the nomenclature of space objects, development level in the space-rocket technology area), and tasks which are solved during launching, etc. The solution of various issues, which arise while making the normative framework for justifying the resource of launcher complexes, is caused by the need to consider the problems of strength and resource of heterogeneous elements of their designs and space-rocket technology designs. The main methodological stages of resource justification are defined. The limiting resource is considered to be the critical operating time, or the number of cycles (starts) during this time, after which the specified limiting states are reached in the risky areas of the structure, such as: critical cracks, destruction, formation of unacceptable plastic deformations, loss of stability, growth of corrosion damages, etc. It is noted that the physical nonlinearity of the material and statistical approaches determine the basis for calculating strength and resource. The classification of loads on the launcher complexes is made. The concepts of low- and multi-cycle fatigue are used. In developing strength standards and the basis for calculating the resource, it is reasonable to use up-to-date methods of technical diagnostics, particularly, methods of holographic interferometry and acoustic emission, and fast-converging schemes of methods for numerical operational calculations.

G. V. Tsyban'ov, V. E. Marchuk, and O. O. Mikosyanchyk, "Effect of Textured Dentated Surfaces on 30KhGSA Steel Damage and Life at Fatigue, Fretting Fatigue, and Fretting," *Problems of Strength*, No. 3, 22–32 (2019).

Machines and constructions are noted to contain components, units, and assemblies, which are joined together, forming a large number of contacting pairs. At operating loads, the latter become sources of material damage as a result of fretting fatigue and fretting wear. The safety and long-term operation of those items would require studies on the nature of these processes and search for the methods of reducing their intensity. Investigation for the effect of textured surfaces in the form of a dent (recess) network and electric-spark VK8 alloy embedding over 30KhGSA steel specimen surfaces on fatigue, fretting fatigue, and fretting wear characteristics are presented. The dent network is formed by plastic indentation using a specially developed device. This process initiates residual tensile stresses. Their optimization was carried out with computation-experimental correlation between the geometrical ratios of dent network parameters (spacing between dent rows, in-row spacing, dent depth). Discrete VK8 alloy embedded surfaces were generated with the electric-stark method providing optimum process parameters.Textured surfaces reduce fatigue and fretting fatigue resistance, while enhancing the fretting wear one in comparison with smooth surfaces. Additional treatment of the textured dentated surface with the ion-plasma thermocyclic nitriding method greatly increases the fatigue and fretting fatigue resistance of 30KhGSA steel. Electric – spark VK6 alloy embedding results in worse fatigue and fretting fatigue properties, which is determined by the surface formation technology and difference between embedded particle and base metal characteristics.

L. A. Khamaza, "Generalized Diagram of the Ultimate Nominal Stresses (Endurance Limits) and the Corresponding Dimensions of the Non-Propagating Fatigue Cracks for Sharp and Blunt Stress Concentrators," *Problems of Strength*, No. 3, 33–46 (2019).

The paper generalizes the original data and the experimental data from the references on the investigation of the mechanisms of initiation and behavior of the non-propagating fatigue cracks in the stress concentrators of various shapes and dimensions. The dependence of the ultimate nominal stresses (endurance limit) and their corresponding dimensions of the fatigue cracks on the theoretical stress factor for the stress concentrators of various shapes and dimensions is proposed to be schematically presented in the form of the generalized diagram. The ultimate stresses should be understood as the endurance limits only within the zone of sharp concentrators provided that their value does not depend on the theoretical stress concentration factor. The limiting dimensions of the non-propagating cracks in the zone of sharp stress concentrators should be understood to mean the maximum dimensions of the cracks that are consistent with the ultimate stresses. The generalized diagram indicates the fact that the nominal endurance limit decreases in the zone of blunt stress concentrators, while the dimensions of the non-propagating cracks increase with an increase in depth and decrease in the concentrator radius (with the increase of the theoretical stress concentration factor), whereas they are controlled by the concentrator depth within the zone of sharp concentrators. With the increase of the concentrator depth, the ultimate stresses decrease, while the dimensions of the non-propagating cracks increase. At the constant depth of the concentrator, the ultimate stresses and dimensions of the non-propagating cracks are independent on the notch radius and value of the theoretical stress concentration factors.

O. M. Herasymchuk and A. I. Novikov, "Microstructure-Based Model for Sharp Stress Raiser-Related Fatigue Stage Length Assessment," *Problems of Strength*, No. 3, 47–61 (2019).

A model for evaluating the fatigue life of specimens/structure elements with sharp stress raisers/defects is presented. The model permits of computing the number of cycles to fatigue crack initiation and its growth from a sharp stress raiser to failure at a constant stress span with the only application of characteristics of static strength and microstructure of the initial material. The model can be used to assess the fatigue life of components that contain structural stress raisers and defects stemming from their manufacturing technique (surface roughness, surface cuts, scratches, and microcracks). The model reliability was verified with experimental results taken from the literature, calculations appeared to be in good agreement with experimental data. Fatigue curves to a grain-size crack initiation and to fracture of smooth specimens and those with a chemically-notched blunt raiser that simulates the casting defects in aircraft components were calculated. The two sets of specimens from a Ti–6Al–4V titanium alloy differing in the cross-section (rectangular and cylindrical) and in microstructure (different grain sizes were examined). Smooth specimens exhibited the test surface roughness $R_v = 10$ and 19 μm (average dent depth), which was assumed to be a sharp raiser for calculations. The model need not long-term and labor-consuming high-cycle fatigue tests to construct the fatigue curve.

I. B. Chepkov, S. V. Lapitskii, A. V. Gurnovich, A. A. Maistrenko, B. A. Oliyarnik, and A. V. Kuchinskii, "Thermofluctuational Fracture Mechanism in Solids in the Presence of an Active Medium," *Problems of Strength*, No. 3, 62–70 (2019).

The paper addresses an approach to the physical notion of failure of solids in the presence of an active medium (a destructive compound), which is based on two successive steps. The first one is to go from considering a body as an elastic or viscoelastic continuum to studying it as an atomic-molecular system. The second step that follows the investigation of the atomic structure is to take into account the influence of atomic motion in a solid during the study of mechanical properties of solids (at high temperatures, in a wide range of loading speeds, under cyclic and vibrational loads), which is based on the experimental data on ultimate strength and yield stress of metals. A mechanism of crack initiation in a loaded metal under the action of destructive compounds is discussed. The capillary and diffusional propagation of a molten liquid-metal compound along grain boundaries and structural defects in a solid metal in combination with the viscous flow of the melt over its surface are shown to dictate the crack propagation into metal structure. The pattern of the affecting destructive factor has been clarified.

R. V. Kravchuk, O. A. Katok, V. V. Kharchenko, A. A. Kotlyarenko, and M. P. Rudnyts'kyi, "Determination of the Mechanical Characteristics of the Metal of the Equipment of Nuclear Power Stations from Hardness Measurement and Indentation Data," *Problems of Strength*, No. 3, 71–77 (2019).

The main normative documents for the nuclear power industry of Ukraine, which regulate the determination of mechanical characteristics from hardness measurement data, are considered and analyzed. It has been shown that the use of these documents for monitoring the technical condition of the equipment of nuclear power stations (NPSs), in particular of the metals of the bypass pipeline of the high-pressure pump of the core emergency cooling system (ECS) (08Kh18N10T), coil from the welded joint zone of the Du 600 inlet branch pipe of the IRA30S02 non-return valve, and the body shell of the dismounted PV2500-97-10A (09G2S) high-pressure heater calls for their more detailed justification. To determine the mechanical characteristics of metals and to increase the reliability of their evaluation in nondestructive monitoring, a standard developed by the Pisarenko Institute of Problems of Strength of the National Academy of Sciences of Ukraine is used. According to this standard, the evaluation is made not only on the basis of hardness measurement data, but also by the method of instrumented indentation. It has been shown that this method is more efficient for the determination of the strength characteristics of steels. The difference between the ultimate strength and yield strength values according to this standard and those obtained in tensile tests is not over 8.6% and not over 6.6%, respectively. When diagnosing the technical condition of the metal of pipelines, indentation tests allow one to determine strength characteristics not only in the axial and tangential directions, but also in the radial direction.

V. R. Skal's'kyi, V. F. Makeev, O. M. Stankevych, S. I. Vynnyts'ka, and O. S. Kyrmanov, "Express-Method of Ranking of Polymer Materials by Energy Criterion Identification of Fracture Mode," *Problems of Strength*, No. 3, 78–89 (2019).

To provide the functional adequacy, aesthetic qualities, and durability of the process of restoration of the elements of the dentofacial system, it is required to have the information on the properties of dental materials (physical, chemical, mechanical, technical, biological, etc). The method of acoustic emission (AE) is successfully used in the investigations of the materials' properties providing live information on the development of damage or fracture. The dental polymers of the provisional prosthetic solution have been tested to determine their strength, plasticity, fracture toughness, water absorption, shrinkage, and microhardness. The authors have made a comprehensive ranking of polymers based on the experimental results. Using the energy identification criterion of fracture modes the percentage of brittle fracture for each material has been evaluated during tensile loading. The paper proposes a new express-method of the ranking of polymer materials, which allows one to significantly reduce material costs and time for experimental investigations.

N. V. Bondar and V. V. Astanin, "Creep of Textile-Reinforced Composite under Static and Cyclic Loads," *Problems of Strength*, No. 3, 90–99 (2019).

The paper considers the creep of a textile-reinforced thermoplastic composite with a glass filler under the action of a combined short-term cyclic and long-term static tensile load at room temperature. The investigations were carried out on glass-fabric-reinforced polypropylene specimens, which were made by autoclave molding. The creep of the composite was experimentally investigated under a cyclic load at different amplitudes. The creep kernel has been calculated from experimental data according to the Boltzmann superposition principle. Other creep models of materials have been analyzed based on data from a review. The laws governing the short-term creep of polypropylene under the action of a static load have been determined. A behaviorial model of the composite under investigation under the considered conditions is proposed. Numerical calculations have been made with the aid of the proposed model using experimental results taken from other works, and a good agreement between them has been established. The peculiarities of the creep of textile-reinforced polypropylene under the considered conditions have been determined. The range of application of the model has been determined.

G. V. Krechkovs'ka, O. T. Tsyrul'nyk, and O. Z. Student, "Change in the Mechanical Characteristics of Pipe Steels after Exploitation on Gas Mains," *Problems of Strength*, No. 3, 100–113 (2019).

The laws governing change in mechanical characteristics under tension in air of steels of different strength levels in the initial state and after long-term exploitation on gas mains have been established. Because of in-service degradation, ductility characteristics decrease, and strength characteristics increase. The higher the strength level of steel in the initial state, the weaker the effect of change in its characteristics. In spite of the longest-term exploitation, the ductility characteristics of X70 steel did not practically change, whereas those of 17G1S and X60 steels decreased greatly after less long-term exploitation. These effects are caused by the structural peculiarities of steels. Indeed, a texture was detected both in the axial and in the diametral section of pipes made of these steels. The length of almost continuous rows of pearlite grains in the axial direction reached 500 μm and in the transverse direction 40 μm. The increased etching of interfaces between ferrite and pearlite grains both along and across the pipe rolling direction was attributed to damages along these interfaces. Such damages were traps for hydrogen and hindered its diffusion redistribution in the cross-section of pipes. Hydrogen accumulated in them promoted lamination along interfaces and facilitated strain localization in the most weakened sections. Signs of the in-service degradation of steels of different strength levels have been detected fractographically. Firstly, it is the textured nature of specimen fractures at the macrolevel as laminations in the pipe rolling direction, which are caused by in-service damages of steels. We believe that hydrogen absorbed by the metal during long-term exploitation and accumulated in defects along interfaces gave rise to them. Secondly, in the central part of mode I fractures, large and flat lens-shaped areas with small dimples, which accumulate hydrogen at the bottom, which facilitated the destruction of partitions between them, were detected. Thirdly, within the boundaries of the conical parts of the fractures of all steels under investigation, amid shear mode small parabolic dimples, large flat dimples with the characteristic relief of the parallel traces of the rise of slip bands to their surface are observed. We suppose that this proves their existence in the section of specimens as early as before tensile test. The above structural and fractographic features of degradation are inherent in all steels, particularly in 17G1S steel, whose hardening was accompanied by a greater decrease in ductility due to degradation.

P. O. Marushchak, M. G. Chausov, A. P. Pylypenko, and A. P. Sorochak, "Effect of Shock and Vibration Preloading on the Deformation and Fracture Behavior of 17G1S-U Steel," *Problems of Strength*, No. 3, 114–125 (2019).

The procedure of evaluating the crack resistance of 17G1S-U shee steel after shock and vibration loading was advanced and experimentally tested using the method of complete deformation diagrams. The technical potential was employed to provide the growth of a mixed mode (I+III) macrocrack on the specimens with an identical central circular hole, which guaranteed the self-similar macrocrack propagation. The complete deformation diagrams displayed initial almost straight sloping down sections. In real constructions of gas mains, rather long macrocracks can arise after this fracture mode. The advanced procedure permits of reliable assessment of energy variations spent for a (I+III) mode crack propagation under any complex combined loading. The straight descending branch slope of the deformation diagram is established to be used for evaluating crack resistance variations of pipe steel subject to thermomechanical loading. Shock and vibration loading of a high frequency (1-2 kHz) is shown to essentially influence the crack resistance of pipe steel and plastic strain in the vicinity of a stress raiser. The impact of a power pulse on the material is dependent on its prestrain level through static tension and damage of its initial structure correspondingly. The controlding factor in mechanical properties is the intensity of the power pulse. Basic fracture mechanisms of steel were established on the basis of examination of specimen fractures with scanning electron microscopy. The shock and vibration loading is evidently accompanied by energy contribution not only to the existing damages of the material but also to the initiating ones, which causes the localization of deformation and growth of pores in their vicinity. Since the energy accumulation can contribute to the modification of the material in the vicinity of those damages, the shape and sizes of ductile tear dimples are the informative parameters for evaluating the strength and plasticity of examined steel.

I. Abbas, F. Alzahrani, A. N. Abdalla, and F. Berto, "Fractional Order Thermoelastic Wave Assessment in a Nanoscale Beam Using the Eigenvalue Technique," *Problems of Strength*, No. 3, 126–139 (2019).

This paper presents an analytical approach associated with Laplace transforms and a sequential concept over time to obtain the increment of temperature in nanoscale beam with fractional order heat conduction clamped from both ends. The governing equations are written in the forms of differential equations of matrix-vector in the domain of the Laplace transforms and are then solved by the eigenvalue technique. The analytical solutions are obtained for the increment of temperature, displacement, lateral deflection, and stresses in the Laplace domain. Numerical simulations are provided for silicon-like nanoscale beam material, with graphical display of calculated results. The physical implications of distributions of physical variables considered in this article is discussed.

J. Y. Tian, G. Xu, H. J. Hu, and M. X. Zhou, "Effects of Undercooling and Transformation Time on Microstructure and Strength of Fe–C–Mn–Si Superbainite Steel," *Problems of Strength*, No. 3, 140–152 (2019).

A metallographic method, dilatometry, and X-ray diffraction were applied to investigate the effects of undercooling and holding time on bainitic transformation, microstructure, and strength of Fe–C–Mn–Si superbainite steel. The results indicate that the strength of the samples decreases and the elongation increases with the isothermal transformation time, resulting in an increase in the product of the tensile strength and the total elongation. Therefore, the prolongation of the transformation time can improve the comprehensive property of the sample. In addition, the morphology of bainite changes from granular bainite to lath-like one with a decline in the isothermal transformation temperature, leading to an increase in strength. The elongation first increases and then decreases with a decrease in the isothermal transformation temperature. Finally, the sample shows the best comprehensive property when it is austempered at an intermediate temperature (350℃). The data presented here are instrumental in optimizing the technology of austempering treatment in industrial production.

Q. Y. Jiang, "Improvement of Microstructure, Hardness, and Mechanical Properties of Cobalt-Based Amorphous Coating via Laser Cladding," *Problems of Strength*, No. 3, 153–165 (2019).

This study analyzes cobalt (Co)-based amorphous claddings made of H13 die steel via the laser cladding technology. It also explores the evolution of the microstructure and properties of the Co-based amorphous coating at different laser powers, as well as its microstructure, hardness, and corrosion resistance. The results show that the upper and middle layers of the cobalt-based amorphous coatings are dominated by the amorphous phase, which is mixed with the crystalline phase. At the laser power of 467 W, the amorphous coating exhibited the most excellent performance. The main crystalline phases were $FeNi_3$, γ-Co, and Cr_2Ni_3 phases. The upper layer of the amorphous coating had the largest content of 81.15%. The maximum hardness of the coating was 1192.5 $HV_{0.2}$ in 3.5 wt.% NaCl solution, while its corrosion resistance was significantly improved.

J. Liu, Y. H. Liu, Q. Zhao, J. Dong, and D. X. Yang, "Axial Compressive Strength Experimental and Numerical Studies of Full-Scale Specimens Simulating GFRP Composite Bushing Column," *Problems of Strength*, No. 3, 166–181 (2019).

To study the axial compressive performance of glass fiber-reinforced plastic (GFRP) composite structure, a full-scale axial compression experiment was conducted on GFRP composite bushing (GFRP-CB) column specimens. The axial compressive mechanical properties, failure mode, and load–displacement curves obtained and analyzed. It is found that brittle fracture occurs in the GFRP-CB column specimens. Diagonal cracks as the main failure mode appears at the upper part of the GFRP pipe. Moreover, the maximum stress in specimens is less than the compressive strength of the GFRP composite material. The steel casing remains in the elastic state during the entire loading process. Based on the strength theory of transversely orthotropic material, the finite element method was used to scrutinize the influence of eccentricity and diameter–thickness ratios on strength of specimens. Numerical results illustrate that the ultimate bearing capacity of the eccentric compression specimens decreases with the eccentricity ratio. Reduction in diameter–thickness ratio can improve the ultimate bearing capacity of the specimens. As the diameter-thickness ratio decreases by 20%, the ultimate bearing capacity increases by 20%. Finally, an equation for calculating the ultimate bearing capacity of the GFRP-CB column is proposed according to test results. The calculated and test results are fairly consistent, which indicates the effectiveness and accuracy of the proposed equation.

A. V. Rane, K. Kanny, A. Mathew, T. P. Mohan, and S. Thomas, "Comparative Evaluation of Processing Techniques on Mechanical Strength of Carbon Black (N220) Filled Poly (Lactic Acid) Composites," *Problems of Strength*, No. 3, 182–200 (2019).

Carbon black filled poly (lactic acid) composites attracted significant interest due to their superior structural and functional applications. Properties of carbon black filled poly (lactic acid) composites depend on physical and chemical interactions within composites. In this study, interactions within carbon black (N220) filled poly (lactic acid) composites as a function of processing method, filler concentration and its effect on mechanical properties are investigated via mechanical tests. Strong interface interaction at intermediate concentration of 2.5 wt.% carbon black with poly (lactic acid) was confirmed through mechanical test. Moreover, 2.5 wt.% of carbon black formed networks within poly (lactic acid) composites, which added the resistance to fracture in the weaker phase, thereby increasing mechanical properties. Beyond 2.5 wt.%, linked skeletal grid was formed leading to more easy fracture path in weaker phase and declined the mechanical properties. Experimental results on density and modulus were compared with the theoretical model. This study gives an insight on interactions emphasizing probable improvement and decline in physical and mechanical properties related to processing techniques and weight percent of carbon black in poly (lactic acid) composites.

R. P. S. Sisodia and M. Gáspár, "Physical Simulation-Based Characterization of HAZ Properties in Steels. Part 1. High-Strength Steels and Their Hardness Profiling," *Problems of Strength*, No. 3, 201–213 (2019).

In the vehicle industry, there is an increasing demand for wider application of high-strength steels. New generations of high strength steels, with higher strength and toughness properties, are continuously developed by the steel producers. They provide good strength-to-weight ratios, acceptable weldability, improved toughness, and sufficient deformation capacity. However, the weldability of high strength steels has still challenges which are as follows: cold cracking sensitivity; reduction of strength and toughness of HAZ; filler material selection. In the HAZ of high-strength steels, hardened and softened zones can be found, where the base material can significantly lose its outstanding mechanical properties. In real welded joints, HAZ properties can be limitedly analyzed by conventional material tests. Therefore, physical simulators (i.e., GLEEBLE) were developed for the examination of different HAZ areas. Another motivation for the application of physical simulators is the time- and material-saving, as compared to real welding experiments. In this study, the weldability, especially HAZ properties of two high-strength structural steels (S960QL and S960M) from the same strength category ($R_{p0.2} = 960$ MPa) and thickness ($t = 15$ mm) were compared and discussed. Two relevant technological variants for gas metal arc welding (GMAW), $t_{8.5/5} = 5$ and 30 s were applied during HAZ simulations and the effect of cooling time on the critical HAZ areas was analyzed. The properties of the selected coarse-grained, fine-grained, intercritical, and subcritical zones were investigated by the optical microscopy and hardness tests.