SIMULATION AND CONTROL OF CLOSED-LOOP SYSTEMS WITH INTERNAL RESERVES

S.L. Podvalny, D.V. Logunov, E.M. Vasil'ev

Abstract: here we consider the problem of reproduction of the ability of natural systems to self-repair in artificial objects due to the existence of a closed loop of matter and energy in them. We show that the creation of a closed life cycle in the system presupposes the implementation of the process of restoring resources and their accumulation in the form of internal reserves consumed by the system in unfavorable conditions of existence. We obtained a functional diagram of a closed-loop system and proposed a mathematical model of its functioning in the form of a discrete homogeneous Markov process without aftereffect. We found that the introduction of internal redundancy into the system requires consideration of two alternative options for the system model: the option for the case in which the volume of reserves is limited by the capabilities of the recovery channels in the system, and the option in which the specified limitation is absent. We compiled the graphs of the states of the system for the specified modes of operation and obtained expressions for the final probabilities of these states. On the basis of the obtained final probabilities, we got analytical design ratios for the characteristics of the efficiency of a system with a closed loop. As the main characteristic of the efficiency of such systems, we propose to use the probability of the complete functioning of the system, i.e. the probability of its work using the entire volume of active resources. We present a numerical example that confirms the performance of the proposed model, and carried out a comparative analysis of options for managing the efficiency of a closed-loop system by changing the volume of reserves, the number of recovery processes and the intensity of these processes. We revealed the dominant value of internal reserves while ensuring the specified performance indicators of a closed-loop system

Key words: closed-loop systems, internal reserves, self-healing systems, Markov processes

ESTIMATION OF THE DYNAMICS OF FACTOR CONTRIBUTIONS IN A LINEAR REGRESSION MODEL

S.I. Noskov

Abstract: I developed two algorithmic schemes for estimating the parameters of linear regression with the requirement that the approximation error for a given observation is zero and, on their basis, methods for calculating the dynamic estimates of the contributions of the factors included in the right side of the linear regression model to the values of the dependent variable. One of these schemes is based on solving a quadratic programming problem, and the second involves the use of a weighted least squares method. The iterative process organized in this case involves recalculating the matrix of weighting coefficients for each observation of the processed data sample. I calculated the contributions of the following factors for the regression model of loading on railway transport: the volume of coal production, the volume of exported timber, the working fleet of loaded railway cars (on average per day). I found that the largest influence on the output variable is exerted by the volume of coal production, although this influence has some general tendency to decrease - by almost 4 points over 14 years. Also, the influence of the second most important factor - the working fleet of loaded railway cars, is also weakening by 3 points. But the least significant indicator - the volume of exported timber - has a clear tendency to increase its influence, which has grown by almost 7 points

Key words: regression model, least squares method, significance of predictors, contributions of factors, loading, rail transport

FORMATION OF A SCANNING ANTENNA BASED ON A HALF-WAVE DIPOLE

S.M. Fyedorov, E.A. Ishchenko, I.A. Barannikov, K.A. Berdnikov, V.V. Kuznetsova

Abstract: the article discusses a half-wave dipole with an installed reflector, which allows scanning space using the rotation of the reflector around the dipole. For the resulting structure, we simulated the main parameters, which showed high stability at various positions of the reflector, a constant value of the directivity factor, and the width of the main lobe. The change in the direction of radiation coincides with the current position of the reflector. Compared to the situation when the antenna did not have a reflector, the directivity of the antenna increased since the focusing of electromagnetic waves took place. The efficiency and the front-to-back ratio remain high throughout the entire operating frequency range. The use of the proposed design makes it possible to simplify the design of scanning antennas since the implementation of the proposed design requires only a half-wave dipole and a flat reflector installed at a short distance from the radiation source. In the process of controlling the characteristics, it is required to rotate the reflector around the dipole, while the dipole remains stationary, which makes it possible to increase the efficiency of the proposed design, since it is not required to form complex antenna systems or install a combination of several antennas to focus radiation in one direction from the source

Key words: Reflector, half-wave dipole, scanning antenna

ASSESSMENT OF THE APPLICABILITY OF LARAWAN TECHNOLOGIES FOR THE ORGANIZATION OF A BACKUP COMMUNICATION CHANNEL FOR METEOROLOGICAL SUPPORT OF AIRFIELDS

D.K. Tunegolovets

Abstract: at present, information on the state of the atmosphere is widely used both in the preparation of weather forecasts and in solving many economic problems. An essential feature of meteorological phenomena is their spatial and temporal variability. This makes it necessary to organize observations in such a way that will allow timely noting the occurrence of the phenomenon and monitoring the progress of its development. Statistics show that in the period from 1997 to 2000 there were about 193 aviation incidents, which were caused by shortcomings in the meteorological support of flights. Therefore, the task of improving the quality of meteorological support is urgent. This article shows, based on model and practical experiments, that the LaRaWAN wireless communication channel is able to combine the entire data stream coming from remote meteorological sensors using various communication protocols among themselves. During the experiment, I obtained positive results, proving the possibility of organizing such communication channels for the tasks of meteorological support of airfields. A block diagram for the organization of a communication channel is also provided. At the same time, the laying of cable communications is not required, when the cost of this type of work, including coordination, often significantly exceeds the cost of the meteorological equipment itself

Key words: LPWaN, weather support of airfields, communication channel

IMPROVED MIN-SUM DECODING ALGORITHM FOR IRREGULAR LDPC CODES

A.V. Bashkirov, I.V. Sviridova, T.D. Izhokina, E.A. Zubkova, O.V. Sviridova, D.V. Vasil'chenko

Abstract: we extended an analytical approach to determining the optimal post-processing function for the minimum operation in the MIN-SUM algorithm, previously obtained for conventional low density parity check codes (LDPC codes), to irregular LDPC codes. The optimal post-processing expression for the non-standard case varies from one control node to another, as well as from one iteration to the next. For practical use, it is necessary to approximate this optimal function. Unlike the usual case where one could use a unique post-processing function throughout the entire decoding process without sacrificing bit code performance, it is critical for irregular codes to distinguish post-processing from one iteration to the next in order to achieve good performance. Using this approach, we found that the quality of bit errors from the trust algorithm corresponds to an improvement of 1 level compared to the MIN-SUM algorithm without post-processing. First, we provide an overview and analytical framework for optimal post-processing. Then, we present the optimal post-processing function for irregular codes and discuss possible simplifications. Finally, we show the simulation results and the benefits of the approximation

Key words: stochastic decoding, MIN-SUM algorithm, trust distribution algorithm

IMPLEMENTATION OF ZONE PRINCIPLE IN THE CONTROL SYSTEM OF REGULATION AND MONITORING EQUIPMENT OF SPACECRAFT ONBOARD NETWORK

I.I. Tabolin, R.Yu. Kuz'menko, A.D. Danilov

Abstract: the article describes the application of the zone regulation principle in the development of control system for the regulation and monitoring equipment of the spacecraft's onboard network. We present brief descriptions of the regulation and monitoring equipment and its constituent modules. We show regulation functional diagram of the regulation and monitoring equipment and collaboration of its modules graph with the division into zones. We describe the control system for the regulation and monitoring equipment. We present structural diagrams of the formation of a control action for all regulators of the regulation and monitoring equipment. Zone regulation principle implementation is achieved by the fact that the entire area of possible changes in the control signal is divided into zones of operation. Each type of module has its own zone of operation. This approach provides automatic connection of the required regulators depending on the power balance of the "consumer - sources". This principle provides a continuous change in the control signal depending on the energy balance of the system and parametric disturbances. The system can be considered as quasilinear, which makes it possible to use well-known linear methods of synthesis and analysis of control system. We carried out control loops customization with determined quality indicators separately for each type of the regulation and monitoring equipment modules

Key words: power supply system, control system, zone regulation principle, regulation and monitoring equipment, onboard network, spacecraft

BI-QUAD DUAL REFLECTOR ANTENNA FOR WLAN TASKS

S.M. Fyedorov, E.A. Ishchenko, I.A. Barannikov, K.A. Berdnikov, V.V. Kuznetsova

Abstract: the article discusses a two-reflector Bi-Quad antenna capable of operating in the frequency range corresponding to WLAN Wi-Fi 2.4 GHz. Thanks to the ability to control the position of the reflectors, it is possible to achieve a change in the direction of radiation, which increases the efficiency of using the antenna, and increases the directivity. During control, the cells are rotated, from which the reflective structures are formed, which allows the transmission of electromagnetic radiation, which is formed by the emitter, formed from a copper wire in the shape of the number "eight". The proposed design makes it possible to provide three stable modes of antenna operation: double-sided radiation, when both reflectors are in the open position, in this mode the antenna has the same radiation in both directions with equal directivity; radiation upward, in this mode, the upper reflector is open, which leads to free flow of electromagnetic waves, and reflections occur from the closed lower reflector, as a result of this, the antenna directivity increases in comparison with the situation of two-sided radiation. A similar situation occurs when radiating downward, when the lower reflector is open, so electromagnetic waves are reflected from the closed upper reflector downward, which leads to an increase in the antenna directivity. The proposed design is highly efficient in the operating frequency range

Key words: reflector, Bi-Quad antenna, multimode reflector, Wi-Fi antenna

AUTOMATED RESISTANCE TESTER OF ELECTRONIC MEANS
TO ELECTROSTATIC DISCHARGE

M.A. Romashchenko, D.S. Seimova, M.A. Ivanov

Abstract: the article discusses the main approaches to checking the functionality of electronic devices when exposed to electrostatic discharge. Electrostatic discharge (ESD) is a major contributor to the reliability and performance of electronic devices. This paper proposes an approach to improving the quality of development of electronic products based on an automated device for testing electronic devices for resistance to electrostatic discharges. We present the conceptual structure of a software and hardware complex for assessing the effect of electrostatic discharge on electronic means. The test generator is designed with protective mechanisms to prevent the creation of unintentional radiated or conducted electromagnetic interference of a pulsed or continuous nature to eliminate parasitic effects that could affect the tested or auxiliary equipment. The purpose of the study, within the framework of which the development of the testing device took place, is to increase the reliability of the functioning of electronic devices and devices when exposed to electrostatic discharges. Thanks to the proposed approach, it becomes possible to ensure the effectiveness of testing the structures of electronic devices for resistance to electrostatic discharge on the basis of complex methods of optimal design, taking into account the requirements of international standards

Key words: electromagnetic compatibility, electrostatic discharge, simulation of electromagnetic processes, electronic means, electromagnetic interference

COMPARISON OF THE CHARACTERISTICS OF THE CORRELATION-INTERFEROMETRIC BELLOWS WHEN USING DIRECTIONAL AND NON-DIRECTIONAL ANTENNA ELEMENTS

A.V. Ashikhmin, I.B. Kryzhko, A.B. Tokarev, A.A. Fateev

Abstract: when creating correlation-phase direction finders, as a rule, non-directional antenna elements (AE) are used. To use directional AE measurements, it is necessary to modify the direction finding algorithms. We present the corresponding modifications of the algorithms and we carried out a comparative study of the direction finding accuracy in relation to two-channel correlation-interferometric standard direction finders using flat antenna arrays of directional and non-directional AEs. We also considered the possibility of determining bearings only from energy measurements, which is absent in relation to direction finders with nondirectional AE. We show that the use of directional AEs makes it possible to reduce the probability of occurrence of anomalous errors, to increase the accuracy of direction finding at significantly large values of the elevation angle, which determines the direction to the radio emission source, to reduce the negative effect of refusing to take into account the sphericity of the incoming wave and, consequently, to reduce the size of the near-field zone of a bearer, which is characterized by the appearance of abnormal direction finding errors. In a multi-signal radio environment, the use of the directional properties of the AE also makes it possible to form a direction finding diagram that provides partial suppression of interference signals. At the same time, the effective use of the directional properties of antenna AEs requires the most accurate consideration of their directional patterns (DP). Errors in the description of the pattern can lead to noticeable errors in determining the bearing, therefore, improving the quality of operation of the direction finding system due to the use of directional AEs is accompanied by increased requirements for the determination and accuracy of practical implementation of the pattern of AE

Key words: direction finding, directional antenna elements, amplitude-phase direction finding, correlation-interferometric direction finder

USING A SIXTEEN-CHANNEL EEG RECORDING COMPLEX TO DETECT VARIOUS CHANGES IN THE ELECTRICAL ACTIVITY OF THE BRAIN FOR FURTHER INTERPRETATION

D.V. Zhuravlev, A.A. Provodnikov

Abstract: we carried out the approbation of a sixteen-channel mobile EEG registration complex made based on the materials of an open project. The hardware and software complex for EEG registration allows for non-invasive registration of 16 monopolar EEG channels containing bioelectric signals of the human brain. All the components of the registration complex are structurally located on a helmet-based made of hard plastic. The helmet is put on the head and holds up to 32 screw-in pin electrodes, boards of an electronic device for recording and processing signals, radio transmitters, and batteries. The recorded EEG signals are transmitted in real time via a radio channel (Wi-Fi standard) on a computer for subsequent processing. The EEG signals received in the computer are fed into the MATLAB application software package for subsequent processing. The EEG signals in the computer are formed in the form of standard digital samples and, accordingly, can be transmitted to any data processing program. EEG signals should be subjected to mathematical processing to identify certain states of the brain and form EEG patterns that serve as guidelines for the preparation of control signals to external actuators. During the mathematical processing of the received signals, we analyzed the frequency composition of the EEG, special signal transformations and performed auxiliary operations to identify the necessary EEG signal patterns. First of all, we filtered the received signals by a bandpass filter and an algebraic function of the Daubechy wavelet of the 8th level. Then, we collected control samples of brain activity when performing three types of activities. We found a correlation between the experiments and the control samples. It can be developed to be used to simplify the installation of input parameters of artificial neural networks used for processing and analyzing EEG signals

Key words: neurointerface, EEG, ADS1299IPAG analog-to-digital converter, non-invasive diagnostics, wavelet transform, signal filtering

ASYMPTOTIC METHODS OF ANALYSIS IN ELECTRODYNAMICS

I.A. Barannikov, K.A. Berdnikov, E.A. Ishchenko, S.M. Fyedorov

Abstract: the article discusses the method of geometric diffraction and physical optics, which is one of the most accurate and effective for solving large electrodynamic problems. To analyze the characteristics of the process, we give its mathematical description and, for comparison, a description of the final integration method, which is the most popular and effective for small objects. Thus, we show that the application of the MCI method is impossible for large objects since in the process of grid division, too many cells are created for the calculation, which significantly complicates the analysis procedure. To assess the effectiveness and accuracy of the method, we simulated the antenna element, which is installed on the carrier ship. We calculated the characteristics of the emitter using the method of finite integration, after which we transferred the characteristics of the radiation patterns to the project with the ship, then we carried out the simulation using the SBR method. The final results of modeling showed high efficiency and accuracy of the method, and the ability to set the scanning step allows you to control the simulation time, however, it should be borne in mind that too large a step leads to a decrease in the accuracy of the analysis

Key words: shooting bouncing rays, electrodynamics

DUAL SPHERICAL ELECTRIC FIELD VOLTAGE SENSOR

S.V. Biryukov, A.V. Tyukin, L.V. Tyukina

Abstract: we live in a world of high energy technologies capable of transmitting electrical energy over long distances. This energy cannot be concentrated only within the transmitting energy systems. It spills out in the form of electric fields. These electric fields adversely affect the environment, technical and biological objects. In this regard, it is necessary to control the levels of electric fields, an important characteristic of which is the strength of the electric field. Sensors of the electric field strength are required to sense the electric field. The existing sensors are inconvenient in operation and have a high error in the perception of the electric field strength, reaching $\pm$ 20%. In the work under consideration, the idea of creating a universal sensor of a new type, related to the type of dual sensors, is put forward. Its versatility lies in the fact that it embodies all types of known sensors - single, twin, and now dual. The error in the perception of the intensity of the inhomogeneous electric field of the dual sensors does not exceed + 5% in the entire spatial measurement range $0 \leq a \leq 1$. In this case, the distance d to the field source is limited only by the radius of the spherical base of the sensor, i.e. $d \approx R$. At the same time, for sensors that are part of a dual sensor in the same spatial measurement range, the error is $\pm$ 35%. Using a dual sensor, it is possible to achieve a significant increase in the accuracy of measuring the strength of inhomogeneous electric fields in a wide spatial measurement range in comparison with known sensors

Key words: electric field strength sensor, single sensor, double sensor, dual sensor, electric field strength, field homogeneity error

IMPROVING THE EFFICIENCY OF FINISHING MILLING OF CONCAVE SURFACES ON SMALL-SIZED CNC MACHINES

A.M. Kozlov, G.E. Malyutin, E.A. Malyavin, A.A. Kozlov

Abstract: the development of CNC systems of modern full-sized metal-cutting equipment made it possible to adjust cutting modes, for example, the value of the working feed, directly during processing. However, there is a significant number of the parts in production that, according to their dimensions, are economically unprofitable to process on expensive large machines with a powerful CNC system. Therefore, relatively inexpensive small-sized metal-cutting machines are becoming increasingly used in enterprises. The technological capabilities of such equipment allow processing not only non-ferrous metals and alloys but also steels. A feature of the control of such equipment is the use of simplified CNC systems installed on personal computers that are not able to perform arithmetic operations and this becomes an obstacle to improving the productivity of processing complex surfaces. At the same time, due to their simplicity and low cost, these systems are becoming more and more popular. In the article, we proposed to increase the productivity of processing surfaces of complex spatial shape on such machines based on the calculation of the CAD tool movement by the system by converting the real trajectory into a set of symmetrical segments with known coordinates. This method allows you, with a given processing accuracy, to set the values of the cutting mode parameters close to the optimal ones, to eliminate emergencies associated with tool failure when working with a variable cutting depth formed after roughing and to increase productivity by 15-20%

Key words: volumetric milling, end mill, accuracy, productivity

METHOD OF VECTOR PRIVATE CONTROL OF ASYNCHRONOUS ELECTRIC DRIVE

S.V. Anikin, V.L. Burkovskiy, A.K. Mukonin, D.A. Tonn, V.A. Trubetskoy

Abstract: the article analyzes the problems of vector frequency control of asynchronous electric drive, widely used as an executive element in the framework of modern means of constructing processing complexes developed in the machine-building industry. Here we propose a variant of a frequency-controlled asynchronous electric drive, in which the polar coordinates of the current vector in the stator winding are the controlled quantities. In this variant, the control law is applied, according to which the angle between the current vectors in the stator winding and the flow coupling of the rotor winding does not change. The control of the speed of rotation of the electric drive and the electromagnetic torque is realized by setting the current module of the stator winding. At the same time, the formation of the angle of rotation of the current vector of the stator winding, depending on the modulus of the magnitude of the flow coupling of the rotor coil and the sliding value of the asynchronous motor, makes it possible to keep the angle between the current vectors of the stator winding and the flow coupling of the rotor winding constant, which in turn implements the directional formation of transients in the asynchronous motor. The considered variant of a frequency-controlled asynchronous electric drive can be used in production mechanisms in which speed is not a determining criterion for the operation of the drive, but smooth regulation of the electromagnetic torque and the possibility of its limitation in all operating modes is important. This control method is characterized by the fact that the electromagnetic moment is determined exclusively by the current module of the stator winding, and the slip control circuit is used to implement the law of maintaining the constancy of the angle between the current of the stator winding by the flow coupling of the rotor winding

Key words: electric drive executive, processing complex, asynchronous electric drive, asynchronous motor, control, current vector of the stator winding, flow coupling of the rotor winding, control law

FLOW OF WORKING MEDIA THROUGH THE CHANNELS IN THE BODY OF THE ELECTRODE-TOOL

V.P. Smolentsev, N.S. Potashnikova, I.G. Starodubtsev

Abstract: we considered the mechanism of flow of liquid and gas-liquid working media through a profile tool for combined processing methods. We present typical parts for which electrodes-tools are applicable with an adjustable supply of the working medium to the processing zone, which ensures the mass removal of processing products from the interelectrode gap. Through the use of additive technologies, we solved the problem of making a tool with internal channels of a calculated variable cross-section, providing a stable supply of a liquid (gas-liquid) medium and mass removal of processing products. We propose a new (at the level of inventions) method and electrode-tool with a controlled feed through the internal channels of the working medium, the parameters of which are calculated taking into account the specifics of finishing electro-abrasive machining according to the pattern of copying the profile of the part. Calculated dependencies for describing the mechanism of flow of working media and methods of their use made it possible to design electrodes-tools with profile channels that ensure the use of technological modes for finishing with a tool with controlled supply of media and fulfillment of the criterion of mass removal of processing products. The presented results of calculating the parameters of the flow of working media through channels in the tool made it possible to expand the area of effective use of additive technologies and create new (at the level of inventions) tools for electro-abrasive processing using the copying method and high-performance simultaneous profiling of several surfaces. The possibility of using the energy model for calculating the potential component of energy from the implementation of the power spent on pumping the working medium and the kinetic energy from the rotation of the tool has been proved to obtain the required flow rate of liquid (gas-liquid) media in the processing zone

Key words: working medium, current, channels, electrode, additive technologies, calculation,electroabrasive processing

ANALYTICAL DETERMINATION OF THE MICRORELIEF PARAMETERS FORMED AS A RESULT OF CENTERLESS GRINDING OF THE FULL SPHERE

O.P. Reshetnikova, B.M. Iznairov, A.N. Vasin, N.V. Belousova, G.A. Semochkin

Abstract: in the technological preparation of the operations of finishing processing of parts with abrasive tools, it is very important to predict its results depending on the assigned modes and the purpose of modes depending on the required quality of the processed surfaces. The available numerous reference materials of this nature were obtained in laboratory conditions, are discrete in nature, do not take into account the specific topography of the surfaces of abrasive tools and many other conditions, and therefore are not reliable enough. On their basis, it is possible to plan the technological process only in advance, and then inevitably it is necessary to refine its parameters experimentally, which leads to a significant increase in the cost of the production preparation process. The availability of a reliable analytical method allows you to multiply these costs, and therefore it is urgently needed not only and even not so much when performing scientific research, but in real production. In the article, we analytically determine the parameters of the microrelief formed as a result of centerless grinding of a full sphere. We determined the influence of the nursing process on the formation of the sphere roughness. We present a method for calculating the arithmetic mean deviation of the micro-profile of a spherical surface

Key words: hollow balls, microrelief, centerless grinding, sphere, processing modes, degree of influence

INFLUENCE OF GAS-DYNAMIC TESTING RIG PIPELINES MATERIAL ON THEIR DYNAMIC CHARACTERISTICS

A.V. Savriko, S.N. Lymich, K.V. Kruzhaev, V.S. Levin, A.V. Moskvichev

Abstract: here we give the study of the dependence of the gas-dynamic characteristics of the stand on the pipeline material used. The fundamental factors affecting the performance of the stand are the output parameters-the pressure and flow rate of the working fluid, which directly depend on the friction pressure losses created by the elements of the stand. To assess the degree of influence of materials on the losses of the stand, we selected two types of pipes: polypropylene and metal. Analytical calculations of the pressure loss of the considered pipelines made of various materials have shown that pipelines made of polypropylene are preferable. However, during the experiment, we obtained the opposite data, which showed that a significant number of diaphragms may be present in polypropylene pipelines: in the places of soldering of pipes formed during the manufacturing process. This fact contributes to a significant increase in the resistance values in polypropylene pipelines by 20 % compared to steel pipes, where there are no diaphragms. As a result of the study, we introduced a coefficient that takes into account the influence of polypropylene pipeline diaphragms in the analytical calculation of resistance. To preserve more accurate values taken from gas-dynamic stands, it is more expedient to use metal pipelines in which it is possible to calculate losses with deviations of up to 3 %

Key words: gas-dynamic stand, pressure loss, resistance, polypropylene pipelines, metal pipelines, experiment

INVESTIGATION OF THE PROCESS OF RESTORATION OF DAMAGED PIPELINE SURFACES BY THE METHOD OF SURFACE RIVETING

O.V. Urazov, A.D. Danilov

Abstract: here we present the results of experimental studies of the process of restoration of damaged surfaces of pipelines of various diameters by the method of surface work hardening, which implements the phenomenon of surface plastic deformation, leading to a change in the distribution of stresses along the thickness. At the same time, we carried out a numerical simulation of the knurling process, we determined the optimal values of the following parameters: the depth and strength of the SPD, the speed of the SPD, the feed of the roller, the shape of the working surface of the roller used. The analysis took into account the following physical and mechanical characteristics: work hardening depth, residual stress value, residual stress distribution depth, running time, roller load. We proved the obvious advantage of rollers with a larger profile radius - they allow one to provide the necessary change in the roughness of the machined surface during rolling with a higher feed, which leads to a decrease in the time of the technological process. In this case, in the accepted range of parameters of the running modes (load 2500-3000N, indentation depth 0.04-0.06 mm), the values of the residual stress components turned out to be almost identical for the considered modes for all the considered rollers. We used the results as the basis for the technology of restorative repair of pipelines of various diameters without stopping the production process at the Novovoronezh NPP and an industrial unit with numerical control was created to implement this technology

Key words: surface riveting, roller running-in, surface plastic deformation, residual stress