

**DEVELOPMENT OF SPECIAL SOFTWARE FOR SOLUTION OF TRANSPORT TASKS  
BY MODIFIED GENETIC ALGORITHM USING FREE THREADING**

**S.L. Podval'ny, D.A. Vdovin**

**Abstract:** the article solves the problem of developing special software and algorithmic software for solving transport problems using the genetic algorithm. Criterion selected: minimization of service time with resource constraints. Compared with traditional genetic algorithms, it was required to create some version of the modified genetic algorithm, which uses the second mutation operator, to reduce the probability of falling into a local extremum. The algorithm of the software tool's operation is considered in detail, which allows one to make initial settings for genetic operators (population size, number of iterations) and the basic elements of evolutionary search (selection, crossover inheritance, mutation), and which is especially important when solving large-dimensional problems; save the received routes when re-deciding the movement of the vehicle according to customers in combination with an online database, both for customers and for vehicles. The program was developed in the Microsoft Visual Studio 2017 programming environment, and C sharp was used as the programming language. The software interface is presented. In order to increase the efficiency of processor utilization and, in particular, to increase performance when solving large-dimensional problems, we used elements of parallelization of the computing process, for which the multithreading method was chosen. It is shown in the work that thanks to this approach, the search time decreased by more than 5 times and is comparable with the search time by other methods, for example, by swarm ones

**Key words:** genetic algorithm, software, transportation task, free threading, heuristic algorithm

**CONTROLLING A FLEXIBLE INVERTED PENDULUM  
BASED ON THE SINGULAR PERTURBATION METHOD**

**Z. Hatif Abbas**

**Abstract:** the article presents the data of the original studies relevant to the thematic area of design of mechanical systems using mathematical modeling. We studied the control process of flexible inverse pendulum based on the method of singular perturbations, the kinematics and dynamics of a flexible inverted pendulum. We developed a model of the system of a flexible inverted pendulum based on differential equations in partial derivative and ordinary differential equations with the defined geometrical constraints. To reduce the complexity of the model produced by the "splitting" of the associated dynamics of the system into its component parts – slow and fast subsystems using the method of singular perturbations. For each of the subsystems, we show a corresponding control algorithm. Repressor, using the principle of sliding mode control, was developed as part of a more complex mechanism of control of the slow subsystem. For the fast subsystem, we propose a simple algorithm of feedback control. Due to the performed transactions, unlike the traditional ones, the developed model is much simpler: the boundary conditions contain only boundary information, which simplifies the design of control systems. On the basis of such "composite" models, we propose a method of boundary control, which allows one to simultaneously track the trajectory of the end effector and to suppress vibration. We obtained simulation results that prove the effectiveness of techniques of boundary control. Also, the simulation demonstrated that the developed control strategy shows good results in system interference

**Key words:** flexible inverted pendulum, control, singular indignations, method, mechanical systems, mathematical model

**EXPANSION OF FUNCTIONAL CAPABILITIES OF STATIC CONVERTERS  
FOR ASYNCHRONOUS ELECTRIC DRIVES**

**I.A. Khaychenko, V.V. Babenko, Yu.V. Nefedov**

**Abstract:** the article considers issues of expansion of functional capabilities of existing devices of smooth start-up of asynchronous motors with variable load, individual compensation of reactive power of the local power supply system and increase of its energy efficiency. Existing hardware solves this task only on the basis of separate static devices. Based on the analysis of the structure of the smooth start devices and the principles of voltage control supplied to the asynchronous electric motor through semiconductor switches (thyristors), the expediency and possibility of implementing, on the basis of modern static start-up devices and typical sections of power capacitors, multifunctional static devices of a new class providing the specified parameters of start-up modes of the asynchronous motor with simultaneous compensation of its reactive power is shown. Proposed hardware solution provides simultaneous switching of semiconductor key elements of both asynchronous motor and capacitor bank for case of sharply variable (dynamic) load. A

prerequisite for such switching of the capacitor battery into the network is the implementation of a mode without a throw-off start-up current. It is determined that the implementation of the proposed hardware solution can have a significant economic effect on reducing the cost of equipment while maintaining all technical and energy parameters of automated asynchronous electric drives of pumps, fans, compressors, traction and the like equipment. The efficiency of application of this hardware solution is determined, on reduction of specific cost of equipment within the range from 800 rubles to 2700 rubles per 1 kW of capacity of asynchronous electric drive

**Key words:** asynchronous electric drive with variable load, startup modes, individual compensation of reactive power, thyristor contactors, control system

## **CONTROL SYNTHESIS IN ACTIVE MEANS OF PART ADAPTATION DURING AUTOMATED ASSEMBLY**

**S.V. Kuznetsova, A.L. Simakov**

**Abstract:** an important aspect of the problem of automation of assembly operations is the adaptation of parts. The means of adaptation or correction of the position of the parts are engineering techniques aimed at reducing the mismatch between the compatible surfaces of the assembly components with the aim of pairing. The development of adaptation tools is possible due to the search for new design solutions, improvement of the existing components, and synthesis of motion control algorithms for connected parts. The article discusses the latter direction, namely, the approach to the synthesis of control of the movement of the part in active means of adaptation during assembly. The purpose is to find an algorithm that ensures the accuracy and smoothness of the movement of the part, necessary to prevent jamming, collision, and rebound processes. The control action is synthesized by the modal control method. The method is based on the construction of a mathematical model of the object - the process of adaptation of the part in state variables. The process state variables are the coordinate of adaptation and the speed of movement of the part. The observer structures, i.e. special computational algorithms used when it is not possible to measure (complete or incomplete) process state variables. By means of simulation modeling, the influence of deviations of object parameters and estimates of state variables on the quality of the adaptation process is investigated

**Key words:** automated assembly, part movement on coordinate of adaptation, mathematical model, modal control, observer, control synthesis

## **ANALYSIS OF THE BOUC-WEN MODEL PARAMETER EFFECT ON HYSTERESIS LOOP**

**T.Yu. Zablotskaya**

**Abstract:** in the paper, the peculiarities of parameter setting of phenomenological Bouc-Wen model are analyzed as it is widely adopted for functional description of various nonlinear hysteretic systems and phenomena due to its versatility and feasibility for vast theoretical and engineering scientific fields. Being formulated as a differential equation system, the model enables it to be retuned and adjusted to new operation mode through the equations parameter setting while the model structure remains untouchable. The parameter values influence the hysteresis loop significantly effecting its shape and size and thus, the model response to input disturbance consequently. Identifying the parameter values, the best performance of the model can be set, which means the accurate and adequate behaviour of the model. Therefore, the key parameters of the Bouc-Wen model standard and extended types are studied and classified throughout the paper depending on their values impacting on the shape and size of hysteretic curve and response of the model. The efficient parameter ranges are recommended to provide the adequate model response. The Bouc-Wen response was modelled at various parameter values and inputs

**Key words:** hysteresis, the Bouc-Wen model, parameter identification, modelling

## **AUTOMATIC FORMATION OF A CONTROL ZONE WHEN CONTROLLING THE QUALITY OF THE PRODUCTION OF GLASSWORMS WITH THE USE OF TECHNICAL VISION**

**Yu.N. Matveev, M.M. Alaqabi**

**Abstract:** the article discusses the problems that arise when creating an automated system (AQMS) for continuous glassworm quality control based on optical technologies and methods of technical vision, as well as ways to solve them. The analysis process allowed us to identify specific features of production that should be considered at the stage of obtaining high-quality images of the test object for further processing, selection and identification of defects, determining their location and extent, generating the control actions to the feedback system. These include the high temperature of the object, its strong vibration at high speed along the roller conveyor, the need for a circular view of the workpiece during its movement. This paper describes the methodological provisions for the automatic formation of a visual control zone, taking into account technological limitations. The algorithm for forming a control zone on a digital image of an object in the conditions of its vibration is described. The layout of optoelectronic equipment for a circular view of a continuously

moving hot pipe is developed. The requirements for optoelectronic equipment are justified, taking into account the temperature regime of the control object, its speed of movement and the necessary resolution

**Key words:** defect search, glassworms, quality control, digital images, optical technologies, technical vision

## **IMPROVING THE RELIABILITY OF AUTOMATIC CONTROL SYSTEMS FOR TECHNOLOGICAL PROCESSES**

**A.K. Mukonin, V.A. Medvedev, V.A. Trubetskiy,  
D.A. Tonn, S.A. Goremykin, N.V. Sitnikov**

**Abstract:** automatic control systems (ACS) of many technological processes contain frequency-controlled electric drives (FCED). In some cases, to ensure the continuity of the process, high demands are placed on the reliability of the ACS elements, including the variable frequency drive. It is possible to increase reliability and expand the functionality of the variable frequency drive through the use of a universal frequency converter (UFC). The considered UFC includes a three-phase diode bridge (TPDB), a capacitive filter with a series connection of two capacitors and a voltage inverter (VI) based on six transistor switches. The UFC is fed, in general, from a three-phase network with a zero wire. The versatility of the converter is ensured by connecting the neutral of the network to a common point of filter capacities. The converter can be powered by a three-phase voltage of 380 V or a single-phase voltage of 220 V, while maintaining the connection of the motor winding to the star. In the case of single-phase power, the converter rectifier is a voltage doubler. With three-phase power supply, the UFC provides an increase in the output voltage compared to the classical circuit. The inverter can operate as a three-phase bridge circuit or as a circuit with an average output. The latter scheme allows you to power the motor with currents of various shapes while maintaining uniform rotation of its magnetic field. Commercially available frequency converters often have a series capacitor filter. Such converters are easy to turn on according to the UFC scheme. Experimental studies have confirmed the operability of a drive with a reconstructed frequency converter. Improving the reliability of self-propelled guns with variable frequency drive is ensured by maintaining operability when any two wires of a three-phase four-wire supply network break

**Key words:** automatic control systems, frequency converter, autonomous voltage inverter, variable frequency drive

## **Radio engineering and communication**

## **MODELING OF A LINEAR ANTENNA ARRAY FOR SATELLITE COMMUNICATION OF MODERN TELECOMMUNICATION SYSTEMS**

**S.A. Antipov, V.N. Kostrova, P.V. Nikolaev, Yu.G. Pasternak, K.A. Razinkin, V.I. Chuguevskiy**

**Abstract:** in this paper, we study an electrodynamic model of a linear antenna array of planar rectangular spirals for satellite communications. Based on the specified technical requirements, the antenna array was calculated, and numerical modeling was performed using the finite integration method proposed by T. Weiland. Application of the Dolph-Chebyshev distribution to reduce the level of side lobes. The simulation was performed in the CST MW Studio automated simulation program. As the radiating element of the linear antenna array, a two-arm planar helix with waveguide power was used, made on a Rogers 3003 material with a thickness of 3.04 mm and a permittivity efficiency of  $\varepsilon = 3$ . The appearance of the emitter, the topology of the waveguide divider, and the electrodynamic model of the phased array and its side view are presented. The results of numerical simulation of the main parameters of the antenna array are presented. The parameters were evaluated for the specified technical requirements, a comparative analysis of directivity diagrams for amplitude distributions with a reduced level of side lobes, and the results are presented in the form of graphs. The paper discusses the design features of constructing a phased array antenna, as well as ways to reduce the side lobes by implementing various amplitude-phase distributions

**Key words:** linear antenna array, satellite communication, synthesis

## **METHODOLOGY OF DESIGNING MICRO-STRIP DIRECTIONAL COUPLERS ON INTERDIGITATED STRUCTURES**

**A.V. Ostankov, N.N. Shchetinin, S.Yu. Dachian**

**Abstract:** the article presents the author's methodology for designing a two-loop directional coupler on planar multi-section interdigital structures. The use of interdigitated structures allows significantly reducing the dimensions of the topology, which is especially important for the UHF range. The initial stage of the methodology involves obtaining an equivalent coupler circuit in T- or U-shaped sections with concentrated inductive and capacitive elements, including the calculation of their nominal values. At the stage of transition from an electric circuit with lumped elements to a planar topology, the original analytical relation is used to determine the number of sections of the interdigital structure by the value of the lumped capacity. There is a technique for obtaining analytical relations of a similar content for any other, different from the used, geometric and dielectric parameters of the section. At the final stage, local use of the CAD optimization apparatus is assumed. The combination of parametric optimization and ready-made topological solutions can

significantly reduce the time for designing microstrip miniature couplers. The technique was tested in relation to the design of a directional coupler with an operating frequency of 0.9 GHz. Whereas the area of the synthesized topology of the double-loop coupler is 30% of the area of the traditional topology with a slight deterioration of the main indicators

**Key words:** directional coupler, interdigital structure, equivalent circuit, planar topology, designing methodology

## **METHOD OF DESIGNING CODE COMPARATORS TAKING INTO ACCOUNT A GIVEN LOGICAL BASIS**

**A.A. Pirogov, Yu.A. Pirogova, S.A. Gvozdenko, D.V. Shardakov, B.I. Zhilin**

**Abstract:** programmable logic integrated circuits (FPGAs) are configurable integrated circuits, the logic of which is determined by programming them. The use of FPGAs makes it possible to obtain devices capable of changing the configuration, adapting to a specific task due to their flexible, programmable structure. When developing complex devices, ready-made complex functional blocks (IP-cores) can be used as components for design. The use of software IP-cores allows you to use them most effectively in the final structure, to significantly reduce the cost of design. In this work, we performed modeling of the structure, a temporary analysis of binary comparators performed according to various implementation schemes. In the course of the work, the tools for constructing a digital node circuit using the built-in circuit editor were studied: Using standard library elements, creating your own unique modules, forming buses. A number of project modules were obtained through direct programming in the Verilog hardware description language. Functional modeling of modules, construction of time diagrams of work were performed in the iSim program. Physical verification of the project was carried out on the basis of the Spartan 3E FPGA debugging board

**Key words:** binary code comparator, Carnot map, model, time diagram

## **SYNTHESIS AND ANALYSIS OF ONE CYLINDRICAL LENS BASED ON PARALLEL PRINTED CIRCUIT BOARDS WITH ELECTRICALLY SMALL DIFFUSERS**

**Yu.G. Pasternak, E.A. Rogozin, R.E. Rogozin, S.M. Fedorov**

**Abstract:** the possibility of creating a uniform cylindrical lens based on serially arranged printed circuit boards with applied periodic metamaterial structure was investigated. H-shaped structure located on dielectric substrate is used as cell of periodic structure of metamaterial. On the basis of the performed analysis of open literary and scientific-technical sources, the effect of the size of metal conductors of the H-shaped structure on the values of the actual part of the effective permittivity of the metamaterial is considered. Field distribution in azimuth plane is shown at normal fall of linearly polarized flat wave on lens surface from uniform dielectric and metamaterial. Directed characteristics of lens of irradiator with lens of uniform dielectric and metamaterial are considered for clarification of focal length. Conclusions are drawn on the value of focal distance. The directed and frequency characteristics of a lens from metamaterial at different turn of the irradiator concerning the center of a lens, a lens from uniform dielectric are investigated. Conclusions are drawn about similarity and difference of directional and frequency characteristics of two lenses, about influence of rotation of irradiator relative to lens center on characteristics of lens made of metamaterial. The results obtained in r-bot will be useful in designing lens antennas based on series-arranged printed circuit boards with applied periodic metamaterial structure

**Key words:** uniform cylindrical lens, metamaterial, directional and frequency characteristics

## **INVESTIGATION OF THE INFLUENCE OF THE DISTANCE BETWEEN ANTENNAS IN MIMO ANTENNA ARRAY FOR FIFTH GENERATION COMMUNICATIONS**

**S.A. Antipov, E.A. Ishchenko, V.N. Kostrova, K.A. Razinkin, D.A. Stezhkin, S.M. Fyedorov**

**Abstract:** the article discusses the MIMO antenna array for fifth generation networks (5G), which allows one to work in 2x2 mode. For the design obtained, the main characteristics of the MIMO antenna system were studied: envelope correlation coefficient, diversity gain, and multiplexing efficiency. A study was made of the influence of the distance between the antenna elements on these indicators, according to which conclusions were drawn on choosing the optimal distance between the emitters in the system. Modeling and calculation were carried out using CST Studio Suite. Thus, according to the results obtained, it is proved that when the distance between the elements is 0.5 wavelengths, the maximum MIMO performance of the antenna array is achieved and a subsequent increase in this distance loses its meaning. At the same time, at frequencies of 5G, it was found that the distance between the elements equal to 0.2 wavelength provides the required values of the envelope correlation coefficient to ensure stable operation of the MIMO antenna array. The article presents the images of the structures under consideration, the basic rules for calculating the characteristics of MIMO antenna arrays, graphs of correlation coefficients, gain factors for diversity reception and multiplexing efficiency for different values of the distance between elements are constructed

**Key words:** MIMO antenna array, envelope correlation coefficient, diversity gain, multiplexing efficiency, fifth generation communications

## **DESIGN METHODOLOGY FOR CODE CONVERTERS BASED ON FPGA**

**A.A. Pirogov, Yu.A. Pirogova, S.A. Gvozdenko, B.I. Zhilin, E.V. Syemka**

**Abstract:** addition of numbers in binary code is carried out according to the same rules as with decimal encoding. Regardless of the encoding, addition comes from the low order of the number. During overflow, when the result of adding the values of the same categories is more than one, a transfer is made to the next senior level and addition occurs with the value of this category. Subtraction of numbers in binary code is also similar to the operation of subtraction in decimal coding. In this case, if the value of the digit subtracted is greater than the corresponding digit of the value of the decreasing number, a borrow is taken from the next high-order digit. Therefore, the implementation of the subtraction in a computer is more time-consuming than the formation of the transfer arising during addition. In computing systems, subtraction is replaced by the operation of adding negative numbers, presented in the form of a reverse or additional code. In this case, an extra bit is allocated for the sign, which is the highest bit of the bit grid of the represented binary number (sign bit). For a positive number, the sign digit is zero, and for a negative one. Direct code is a natural representation of a binary number in a binary number system. Adding numbers with the same signs in the direct code is performed according to the usual rules

**Key words:** binary code, reverse code, additional code, modeling

## **STATE AND APPLICATION PERSPECTIVES OF HYPERSPECTRAL EQUIPMENT FOR DETECTION AND RECOGNITION OF VARIOUS OBJECTS**

**I.P. Bostynets, V.I. Lopin, A.A. Rogozin, G.L. Tyurin**

**Abstract:** this paper deals with the application perspectives of hyperspectral equipment installed on space, aerial and ground-based platforms. It presents structure, basic specifications and capabilities of state-of-the-art and advanced hyperspectral equipment to provide detection and recognition of various objects. The paper examines existing diagrams of hyperspectral equipment construction realized on the basis of acoustic-optical and liquid-crystal filters, interferometers and dispersing elements, as well as practical scanning techniques of target environment being observed. In this work, we present the brief evaluation of existing methodical support used for object detection and recognition based on data processing received using the hyperspectral equipment, as well as enumerate main tasks to be accomplished with the help of this equipment. The work outlines the key problems, arising when processing hyperspectral data, as well as methods and techniques to solve them. In this paper, it is shown that advanced methods used to process data provided by hyperspectral equipment enable solving practical problems connected with environmental monitoring, detection and recognition of small-sized objects, false target selection, discrimination between similar classes of objects, estimation of their biochemical and geophysical parameters

**Key words:** hyperspectral equipment, spectral resolution, detection, recognition

## **STUDY OF THE INFLUENCE OF TYPES OF CONDUCTOR MATERIALS ON THE CHARACTERISTICS OF THE PATCH-ANTENNA FOR THE FIFTH GENERATION COMMUNICATIONS**

**S.M. Fyedorov, A.S. Badaev, E.A. Ishchenko, M.A. Sivash**

**Abstract:** the problems of selecting conductive materials for a patch antenna, which was designed in accordance with the frequency range of the fifth-generation networks defined by the FCC - 37 GHz, are considered. The importance of this study is due to the very high frequencies of the IMT-2020 (5G) standard since the characteristics of material losses begin to play a more important role than at low frequencies. The main characteristics of the emitter were determined depending on the type of material used for the manufacture of the conductive element - the scattering matrix (return loss), the voltage standing wave ratio, as well as the main parameters of the radiation patterns for the selected type of emitter. Verification was carried out using CST Studio Suite, during the verification process the material of manufacture of the emitter was changed, while maintaining the material of the dielectric substrate, modeling was performed. Based on the results obtained, tables were compiled according to which it is convenient to compare the characteristics of the antenna depending on the type of material used, according to which it is possible to choose a conductor that is recommended to be applied to the dielectric substrate of the antenna emitter. It was shown that tantalum has the best return loss ( $S_{11}$ ) characteristics, while silver has the highest overall antenna and radiation efficiency. The article contains graphs of the dispersion matrix (return loss), radiation patterns of the patch antenna with the main parameters

**Key words:** patch-antenna, scattering matrix, return loss, voltage standing wave ratio, radiation pattern, conductive materials

## **COMPARATIVE ANALYSIS OF SOFTWARE COMPLEXES FOR DETERMINATION OF MECHANICAL CHARACTERISTICS OF RED**

**A.S. Kostyukov, A.V. Bashkirov, M.Yu. Gostev, A.S. Demikhova, Yu.A. Pirogova**

**Abstract:** determining the reliability of the design of RED is the main task in the design process of new devices. Thanks to this operation, it is possible to select the actual material of the future design, as well as determine the nodal joints vulnerable to wear and damage. In connection with all the above, it is most promising to carry out these studies at the initial stages of device development, which will significantly save resources and time spent on design. Given all these goals, the issue of using specialized programs to determine the reliability of the design of radio equipment becomes relevant. These software products include Creo, SolidWorks, ASONIKA, ANSYS and Nastran about these software environments and will be discussed in this article. The article summarizes about each of the above programs, presents their main characteristics, advantages, and disadvantages. These software products are compared with each other by such an indicator as ease of use and the reliability of the data obtained when conducting a strength analysis of the design of RED. It is clearly shown how these programs are similar, and how they differ. At the end of the article, a comparative table is presented, according to which actual conclusions are made about the advantages and disadvantages of a particular program, and in what working conditions it is better to use each of the above described software media

**Key words:** Creo, SolidWorks, ASONIKA, ANSYS, Nastran, finite element mesh, strength analysis

## **RESEARCH OF GEOMETRIC TRANSFORMATION OF A ROTMAN MICROSTREAM LENS FOR REDUCING OVERALL DIMENSIONS**

**S.A. Antipov, V.N. Kostrova, Yu.G. Pasternak, K.A. Razinkin, M.A. Sivash, V.I. Chuguevskiy**

**Abstract:** in this paper, we study the geometric transformation of the Rotman lens, which reduces the linear overall size by 50%. A description of the principle of operation of the Rotman lens and its schematic image is provided, as well as a model before the geometry transformation and after. With the help of numerical electrodynamic modeling, the characteristics of the original and modified model of the Rotman microstrip lens were evaluated, and graphs of the standing wave coefficient for the voltage of the original and transformed models were presented. So, according to the results obtained, it is shown that the transformed lens in general has a fairly good agreement with the supply line of 50 Ohms, and in some frequency sections even better than the original model, the difference in the transmission coefficient in the studied frequency range does not exceed 0.2 dB. For the above models, the phase difference is 1°, this value is explained by an increase in the electrical length in the model due to the addition of a section connecting two parallel phase conductors. A comparative analysis of the results obtained in the form of electrical parameters of two geometry variants showed the possibility of successful transformation of the Rotman lens geometry in this way to reduce the overall dimensions of the conductor. A comparative analysis of the results obtained in the form of electrical parameters of two geometry variants showed the possibility of successful transformation of the Rotman lens geometry in this way to reduce overall dimensions

**Key words:** Rotman lens, beamforming devices, multibeam communication, lens geometry

## **Mechanical engineering and science of machines**

### **STAGES OF DEVELOPMENT OF ANIMATION SUPPORT OF ROBOTIC MODULE**

**O.I. Popova, G.S. Abdullaev, G.E. Orudzhewa, N.M. Suleymanova, R.A. Yusifov, M.I. Popova, A.V. Demidov**

**Abstract:** based on the analysis of algorithmic and software tools for creating graphical information for animating the mechanical parts of industrial robots in an automated production module, the purpose and main issues of the article are determined. To ensure the productivity and efficiency of technological operations of an industrial robot in a robotic module, a kinematic layout of the main active elements and the trajectory of the arm of an industrial robot were given. The Simpson method determines the zone of movement of the industrial robot arm along an ellipsoidal path. Using the expression to determine the length of the trajectory of the industrial robot, the speed and time spent on the technological operation of unloading an automated transport system are determined. At the stage of the software for creating animations of the active elements of the robotic module, the above developed mathematical model is implemented to determine the length of the trajectory of the industrial robot, coordinate, speed, and the minimum time spent moving the capture of the

industrial robot, on the basis of which computer experiments are carried out with the initial data using software package based on Delphi

**Key words:** animation, industrial robot, robotic module, kinematics, program

## **DEVELOPMENT OF THE DESIGN OF THE COMBINED ELECTRODE-TOOL MANUFACTURED BY THE ADDITIVE METHOD**

**E.V. Smolentsev, V.V. Kuts, M.S. Razumov, D.E. Krokhn**

**Abstract:** the article deals with the issues of electrochemical metal processing technology based on the use of the phenomenon of anodic dissolution. One of the factors limiting the area of rational use of electrochemical processing is the comparative complexity of manufacturing an electrode-tool. This is largely due to the fact that the design of electrodes-tools for electrochemical processing of metals must ensure a constant uniform supply of working conductive liquid to the areas where the processing will take place. Manufacturing complex tools for electrochemical processing requires a wide range of expensive equipment, and the cost of the process may exceed the cost of manufacturing parts. The solution to this problem is to use the capabilities of computer-aided design systems and additive technologies that allow one to implement fundamentally new elements of the design of tools, while eliminating the need for a number of resource-intensive operations performed on expensive equipment. A distinctive feature of this solution is that the body of the electrode-tool is made of plastic with dielectric properties, inside of which and on separate sections of its surface are conductive channels, layers of conductive plastic, on the outer surface of which a layer of galvanic copper coating is applied. For the production of this tool electrode, a special design of a 3D printer was developed with an additional rotating horizontal axis and three positions for installing 2 extruders (one with an installed ABS plastic, the second with a conductive one) and a special nozzle for applying copper electroplating. The use of this 3D printer and the developed software made it possible to implement additive shaping of the combined electrode of the tool. The proposed approach to the design of combined ET, including complex forms, allows one to significantly reduce the cost of materials used for its manufacture and implement the subsequent process of its manufacture by additive methods without using a wide range of expensive equipment, which will also reduce the cost of its manufacture

**Key words:** electrochemical processing, additive technologies, electrode, electroplating

## **IMPROVING THE QUALITY OF THE AIRCRAFT AIR INTAKE AXISYMMETRIC CHANNEL SHELLS**

**V.I. Maksimenkov, M.V. Molod, V.I. Fedoseev**

**Abstract:** the article discusses the necessity to develop axisymmetric shells for the air intake channel of the aircraft, identified in the course of acoustic tests. It was found that the existing equipment does not provide the process of forming thin-sheet shells to the required quality due to the appearance of prints from sectors. The purpose of the research is defined. A device design was developed that allows one to achieve the specified geometry of the detail using elastic insert. The form of an elastic insert and the materials used for its manufacture are considered. The process of shell formation is considered. The stress-strain state of the shell is analyzed. Dependencies for calculating tangential, radial, and meridional deformations are given. The stresses arising in the forming zone are considered, which allowed us to consider the stress-strain state of the shell as flat. The value of the specific pressure in the elastic insert zone is determined. The method of manufacturing axisymmetric shell is developed

**Key words:** device, shaping, axisymmetric shell, elastic insert, deformations, stresses

## **DEVELOPMENT AND RESEARCH OF NEW EQUIPMENT FOR STAMPING HOLLOW PRODUCTS FROM A TUBE BILLET**

**A.Yu. Botashev, R.A. Bayramukov, N.U. Bisilov, E.Kh. Dzhumanazarov, R.S. Malsugenov**

**Abstract:** hollow thin-walled parts are widely used in the construction of machines and apparatuses. To reduce the consumption of material, it is advisable to produce such parts from tube blanks. In existing methods for the production of hollow parts, the deformation of the tube stock is carried out in its cold state. Moreover, due to the limited plasticity of the workpiece, parts of complex shape are produced in several transitions, which increases the cost of their production. We have developed new stamping equipment for the production of hollow products from a tubular billet, performing the stamping process in the temperature range of hot or warm processing, while increasing the plasticity of the workpiece provides stamping of complex shapes in one technological operation. The billet is heated to a predetermined temperature and its subsequent deformation is carried out under the influence of the combustion products of the gaseous fuel mixture. To increase the pressure and temperature of the combustion products, the fuel mixture is pre-compressed directly in the cavity of the tube billet. A study of the thermodynamic processes of the developed device. It was found that the gas pressure on the surface of the workpiece is 50 ... 65 MPa, and its temperature reaches 2600 K. This provides a significant expansion of the technological capabilities of this device. A study was made of the deformation of the pipe billet during the stamping process, while dependencies were obtained to determine the stresses acting in the billet, as well as the required pressure of the fuel mixture, ensuring the implementation of the stamping process

**Key words:** stamping of parts from a pipe billet, gas stamping

## **PECULIARITIES OF INTERACTION OF MICROASPERITIES OF CONTACTING SURFACES DURING FINISHING ANTI-FRICTIONAL ABRASION-FREE TREATMENT**

**Yu.A. Tsekhanov, M.N. Podoprikhin, I.V. Shepelenko, Ya.B. Nemirovskiy**

**Abstract:** the wear resistance of the working surfaces of machine parts depends on the quality of their surfaces; it can be increased by coating. For cast iron engine cylinder liners, a coating applied by the FANT method has proven itself well. On the basis of the theory of cutting mechanics using a model experiment, the main regularities of the interaction of surface microasperities with a tool were established, which make it possible to develop a theoretical model for the first stage of the finishing antifriction non-abrasive treatment (FANT) - microcutting, which will ensure the effective flow of the process and filling the micro-cavities with antifriction material. It is noted that when the cast-iron microroughness interacts with a brass tool, the microasperity's top becomes dull with the formation of a rounding radius. The mechanism of the formation of the rounding radius of microasperity is shown, a significant relationship between the latter and the front cutting angle is established. The phenomena occurring on the rear surface of microroughness are found. The ways of increasing the efficiency of the microcutting process by ensuring the set values of the cutting rake are proved. It is proposed to consider the application of FANT antifriction coatings from the standpoint of a systematic approach and the principles of self-organization, which will make it possible to predict the achievement of optimal quality parameters of the surface layer: equilibrium roughness, favorable microrelief, required hardening and residual stresses

**Key words:** finishing antifriction non-abrasive treatment, micro-cutting, power, cutting angle, contact interaction, anti-friction coating

## **USING THE NATURAL EXPERIMENTAL METHOD FOR OPTIMIZATION OF AUTOCLAVE PRODUCTION**

**Yu.V. Nefedov**

**Abstract:** the article discusses the expediency of conducting full-scale experiments in the small-scale production of polymer-composite materials in autoclave installations, which allows you to obtain the necessary values of parameters for controlling the molding process with less time spent, as well as with the least errors. The main attention is paid to taking into account the factors affecting the dynamics of changes in the basic parameters of autoclaving processes, which depend both on the peculiarities of the installation implementation and on the individual settings of the automatic control system of the main units of the installation. To increase the efficiency of the technological process at the hardware level, it was proposed to use a frequency control system for the electric drive of the main fan of a typical autoclave installation. Such a solution makes it possible to reduce power losses, efficiently coordinate the control of the heating and fan groups of the plant, as well as accelerate the single cycle of autoclave of polymer-composite materials. In turn, the implementation of several autoclaving cycles as a full-scale experiment makes it possible to analyze the obtained data and generate the necessary control parameters for the process of forming the polymer-composite material with sufficient accuracy and with less time. It is shown that this minimization of costs when achieving the specified quality of the polymer-composite material in small production conditions is achieved by adjusting the individual settings of the automatic control system of the heating and fan groups of the autoclaving unit

**Key words:** method of natural experiment, technological process of autoclaving, settings of the automatic control system