A B S T R A C T S

of the scientific publications of assoc. prof. Stoyan Dimitrov Slavov, PhD, in regard with participation in a competition, announced in the State gazette, issue 67 from 04.08.2023, for occupying the academic position "Professor" in the field of higher education - 5.Technical sciences, professional direction - 5.1. Mechanical engineering, and study discipline "Programming machines and systems with CAM", for the needs of department of Manufacturing Technologies and Machine Tools of the Technical University of Varna

Twenty-four (24 pcs) publications are submitted for review in the current competition, which are as follows:

- A Monograph, as a habilitation thesis, **B 3.1**;
- Eleven (11 pcs) scientific publications that are referenced and/or indexed in Scopus and/or WoS databases, **Г7.1– Г7.11**;
- Twelve (12 pcs) scientific publications that are issued in peer-reviewed journals, or peer-reviewed conference proceedings, which are non-indexed in Scopus or WoS databases, **Г8.1 – Г8.12**.

The arrangement of the publications abstracts and their identification are made according to the applied list of the publications under the current competition.

B 3.1.

Slavov S.D. , Forming regular reliefs using CNC-machines. A Monograph, 2023, Color - Print, Varna“, ISBN 978-954-760-564-0, 219 pp., (in Bulgarian).

Abstract. The working conditions under which many of the machines parts operates are often associated with cyclic loads, high dustiness, high loads, contact with substances with a corrosive or highly abrasive effect. This imposes increased requirements on their contact surfaces, which traditional finishing processes, such as finish turning, milling, grinding, etc., do not provide for some applications. The Ball Burnishing (BB) process and its variants such as the vibratory BB (VBB) in many of these cases can be a promising alternative finishing technology. Their usage forms specific physical and mechanical characteristics and pattern arranged textures in the surface layer of the material, which significantly could improve the operational behavior of the functional surfaces of some types of parts. With VBB, in addition to improving the physical and mechanical characteristics of the surface layer, the so-called "regular (micro-) reliefs" (RMP) are also formed on it, which further improve the integrity of the working surfaces. Regardless of the fact that the BB and VBB processes have been developed and applied in practice for a long time, the kinematic schemes by which this type of operations are implemented have not yet been adapted to the capabilities of contemporary automated production equipment. The computer numerical control (CNC) capabilities, as well as those of the specialized software, such as computer-aided-manufacturing (CAM) for their automated programming are still not employed widely enough in manufacturing practice.

In this aspect, the problems related to the methods and equipment (hardware and software) for BB and VBB operations implementing in the nowadays digital production processes are could considered as relevant. This allows the necessary complex tool path, to be achieved only by using the machine’s axes interpolation capabilities by using its CNC

control, for various types of surfaces. This will eliminate the need for forced vibrations, as it necessary in the classic VBB operation, and as a result, the BB operation tooling will be greatly simplified. Therefore, a BB's operation could be performed on the same machine along with the previous forming operations, which will result in a reduction in the production cycle time per unit of product. The choice of methods and methodologies for determining the topographic parameters of the resulting PMPs are also an interesting area for research, as well as what is the influence of the mode parameters of the (vibration assisted) PPD operation on them.

The main purpose of the monograph is to develop methodologies for forming RMRs based on the BB finishing process for different types of surfaces using the kinematic capabilities of different types of metal-cutting machines with computer numerical control. On second place, it is important to investigate the influence of some of the BB's regime parameters over the resulted RMR's topography characteristics.

To achieve those goals the author has solved the following problems:

- A comprehensive overview and analysis of the existing methods, schemes and tools and specialized machinery for the implementation of the BB and VBB processes was carried out;
- Corresponding mathematical models have been derived and systematized, which allows the calculation of suitable toolpaths of the deforming tool's tip for forming RMRs on cylindrical, tapered, planar and non-planar surfaces having different contours by means of BB.
- Corresponding algorithms have been developed to ensure obtained toolpaths to be with shortest length within the burnished domain of the given surface type. Other algorithms have been also proposed for directly converting the calculated toolpath's data of the BB operations into a numerical control code for the CNC machine tools, and/or for their exportation as polylines for insertion and subsequent use in suitable CAM software.
- The possibilities and specific features of applying the BB process for RMR formation through different types of CNC machines with different number of simultaneous controlled axes have been established.
- The impact direction and the significance magnitude of the main influencing regime parameters of the BB process, using CNC machines, on the topography characteristics of PMRs formed on flat surfaces were investigated.

The approaches and methods that are mainly applied in the monograph are a systematic and process approach. Various methods from the theory of machines and mechanisms, as well as approaches to derive numerical control code for CNC machines, techniques from signal theory, the methodology of factorial experimental designs, statistics, regression and the variance analyses, etc., are also used in individual chapters.

Г 7.1.

Slavov, S.D. and Dimitrov, D.M. Modelling the dependence between regular reliefs ridges height and the ball burnishing regime's parameters for 2024 aluminum alloy processed by using CNC-lathe machine. In IOP Conference Series: Materials Science and Engineering (Vol. 1037, No. 1, p. 012016). IOP Publishing, 2021, February. (Indexed in SCOPUS and WoS)

Abstract. New approach for obtaining regular reliefs onto cylindrical and tapered surfaces, by using ball-burnishing process, performed on CNC-lathe machine having C-

axis installed, is presented. It allows to simplify the burnishing tool and to perform the burnishing operation on the same lathe machine as previous cutting operations.

The first goal of the work is to find a way for effective implementation of the BB process in order to form specific roughness onto cylindrical and tapered surfaces of the parts. The second one is to define a stochastic model and establish the relation between the RR's roughness height (by using Rz-criterion) and the basic regime parameters of BB for a workpiece, made of 2024-T3 aluminum alloy. Both goals were successfully achieved:

The equations for the points coordinates calculation of the needed complex ball tool trajectory are derived. For their approbation, and in order to obtain a stochastic model which established the relation between the ball burnishing regime parameters (deforming force F, and feedrate f) and resulting height (according to Rz criterion) of regular reliefs cells boundary ridges, an experimental investigation is carried out, using 2024-T3 aluminum alloy, and the methodology of the rotatable experimental plans. The corresponding response surface of the model is given and discussed. Conclusions about the advantages and disadvantages of the approach are given, and for the suitable application of the obtained stochastic model.

Г 7.2.

Slavov, S. D., D. M. Dimitrov, and M. Iv. Konsulova-Bakalova. "Advances in burnishing technology." In Advanced Machining and Finishing, pp. 481-525. Elsevier, 2021, ISBN 978-0-12-817452-4, (Indexed in SCOPUS)

Abstract. In the present chapter, the basic characteristics of some types of burnishing processes are considered in terms to obtain both smooth surfaces and also so-called "regular reliefs" onto different workpieces surfaces with different shape, including cylindrical, tapered, planar, and nonplanar (i.e., complex) surfaces. Some contemporary ball burnishing schemes for forming regular reliefs using computer-numerical-control (CNC) turn milling, milling, and multiaxis centers are presented, as well as their advantages and disadvantages in comparison with classical vibratory ball burnishing processes and vibro-tools working with manually operated metal cutting machines. The corresponding mathematical equations for obtaining the needed complex toolpath with optimal length according to burnished surface boundaries are presented. The essential requirements on the CAD-CAM software also are described, as well as an overall algorithm for suitable numerical control programs generation using CAM is also given.

The chapter has outlined several new approaches for implementation (but "no-vibration assisted) ball burnishing process for obtaining the classical types of regular reliefs onto workpiece surfaces with different shapes. They are based on the modern CAD-CAM software, standardized CNC equipment, and burnishing tools with more simple and reliable construction, which makes the burnishing technologies effective, accurate, easy to use, and robust in nature.

The main regime parameters of ball burnishing processes and their influence on surface layer characteristics and regular relief's cells are also presented. The chapter finishes with some general conclusions and recommendations about the ball burnishing process implementation for forming regular reliefs using CNC machines as alternative of other burnishing processes.

Г 7.3.

Slavov Stoyan, Diyan Dimitrov, Mariya Konsulova-Bakalova, and Dimka Vasileva. "Impact of ball burnished regular reliefs on fatigue life of AISI 304 and 316L austenitic stainless steels.", MDPI, Materials 14, no. 10 (2021): 2529. (Indexed in SCOPUS and WoS)

Abstract. The present work describes an experimental investigation of the fatigue durability of AISI 304 and AISI 316L austenitic stainless steels, which have regular reliefs (RR) of the IV-th type, formed by ball burnishing (BB) on flat surfaces, using a computer numerical control (CNC) milling center. The methodology and the equipment used for obtaining regular reliefs, along with a vibration-induced fatigue test setup, are presented and described.

The current work's main goal is to investigate the effect of RR of the IV-th type obtained by BB on the fatigue life of AISI 304 and AISI 316L austenitic steels. Secondly, it aims to study the effects of the main BB process regime and relief parameters and their interactions over fatigue life. Finally, it aims to create a stochastic model for calculation of the probabilities of reaching a certain number of cycles until fatigue failure, for the possible combinations of "low" and "high" levels of the BB regime's parameters for both investigated steels.

The results from the BB process and the fatigue life experiments of the tested austenitic stainless steels are gathered, using the approach of factorial design experiments. It was found that the presence of RR of the IV-th type do not worsen the fatigue strength of the studied steels. The Pareto, t-test and Bayesian rule techniques are used to determine the main effects and the interactions of significance between ball burnishing regime parameters. A stochastic model is derived and is used to find when the probability of obtaining the maximum fatigue life of parts made of AISI 304 or 316L reaches its maximum value.

It was found that when the deforming force, the amplitude of the sinewaves and their wavenumber are set at high values, and the feed rate is set at its low value, the probability to reach maximum fatigue life for the parts made of AISI 304 or 316L is equal to 97%.

Г 7.4.

Dzyura, Volodymyr, Pavlo Maruschak, Stoyan Slavov, Diyan Dimitrov, and Dimka Vasileva. "Experimental research of partial regular microreliefs formed on rotary body face surfaces.", Aviation 25, no. 4 (2021): 268-277. (Indexed in SCOPUS and WoS)

Abstract. The main objective of the current research is to obtain a regression stochastic model between the main parameters of the ball-burnishing operation: deforming force, feed rate, the axial step between adjacent RMR grooves, and the width of RMR grooves, that will provide the required relative area of the surface vibration with regular microreliefs, and, accordingly, the specified operational properties.

The basic regularities in the influence of processing parameters on the geometrical characteristics of the partially regular microreliefs, formed on the rotary body face surface, are established. Combinations of partially regular microreliefs are formed by using a contemporary CNC milling machine, and an advanced programing method, based on previously developed mathematical models. Full factorial experimental design is carried

out, which consist of three factors, varied on three levels. Regression stochastic models in coded and natural form, which give the relations between the width of the grooves and the deforming force, feed rate and the pitch of the axial grooves, are derived as a result. Response surfaces and contour plots are built in order to facilitate the results analysis.

Based on the dependencies of the derived regression stochastic models, it is found that the greatest impact on the width of the grooves has the magnitude of the deforming force, followed by the feed rate. In addition, it is found that the axial pitch between adjacent toolpaths has the least impact on the width of the grooves. Because of the full-factorial experiment, the average geometric parameters of the microrelief grooves were obtained on their basis. When used, these values will provide for the required value of the relative burnishing area of the surface with regular microreliefs, and, accordingly, the specified operational properties.

Г 7.5.

Dzyura, Volodymyr, Pavlo Maruschak, Stoyan Slavov, Volodymyr Gurey, and Olegas Prentkovskis. "Evaluating Service Characteristics of Working Surfaces of Car Parts by Microgeometric Quality Parameters.", MDPI, Machines 9, no. 12 (2021): 366. (Indexed in SCOPUS and WoS)

Abstract. One of the significant part classes in the machine-building industry nomenclature is the “rotary body” class. Parts belonging to this class (such as hydraulic cylinder liners of truck cranes, hydraulic cylinders of clutch control mechanisms, cylinders of car-turning mechanisms, cylinder liners of internal combustion engines, cones of variator transmissions, etc.) mainly work in conjunction with other parts and provide for the transmission of motion from one moving object to another. The purpose of this research is to evaluate the performance of working surfaces of hydraulic cylinder liners with microgeometries that guarantee the maximum oil-absorption power of their surfaces.

The correlation between the service characteristics of the working surfaces of car parts belonging to the rotary body class, and quality parameters—in particular, the height-related roughness parameter Ra—was estimated. Low values of Ra were found to be unable to guarantee an optimal microrelief geometry and, accordingly, high-performance characteristics of the working surface. The oil-accumulation power of the parts was investigated as a primary characteristic of sliding friction using the group of Rk parameters in the Abbott–Firestone diagram, based on the profilogram of the test specimen’s surfaces. The oil-absorption power of the surfaces formed by different technological operations was compared with different microgeometric quality parameter values.

The topography of the working surfaces of car parts that form tribological systems was found to have a more significant effect on the service characteristics of these surfaces than the numerical values of the surface roughness parameter Ra.

As can be seen from these studies, the reduction of surface roughness on the parameter Ra from 1.114 μm to 0.165 μm leads to a deterioration in its performance properties–in particular, in oil accumulation. The formation of a surface structure with a microrelief of the appropriate type allows the increase of oil accumulation by almost two times. Because the technology for forming regular microreliefs does not require special machines and expensive tools, this direction for improving performance properties is extremely promising.

Г 7.6.

Dimitrov Diayn M., Desislava Mincheva, and Stoyan D. Slavov. "Influence of porosity to dynamic Young's modulus of sintered iron. Bayesian approach.", Materials Today: Proceedings (2022). (Indexed in SCOPUS)

Abstract. Sintered metal and composite details made by the classical methods of powder metallurgy (PM) are widely used in many industries. The main consumers are the automotive and agriculture industry. The advantages of PM details are the complex configuration, the low price, the possibility for large-scale production, the use of low energy capacities and last but not least the waste-free production. The main characteristic of sintered components is the porosity, which affects their elastic properties, thermal properties, mechanical strength etc.

In this paper Young's modulus against porosity relation $E/E_o = f(P)$ for sintered Fe and steel powder compacts is discussed. For the experiment beam like ($5 \times 10 \times 50\ mm^3$) compacts, in density range 6.6–7.0 g/cm^3 ($P = 0.12–0.09$), prepared from Fe powder (ASC100.29) are sintered in industrial conditions. Elastic constants E, G, ν are calculated from experimentally obtained fundamental mode shape frequencies, specimen mass and dimensions, using impulse excitation technique (IET). To ensure free beam boundary conditions, supports are placed in mode shapes nodal points. Popular model equation is fitted to experimental data. A Bayesian approach is used for parameter estimation. Fitted model equation predicts reasonably well the data from our and another researchers experiments with pre-alloyed Fe-Cr-Mo powder compacts, but fails for sintered steels prepared from powder mixtures and diffusion alloyed powders with Cu additions.

Г 7.7.

Slavov St., Markov O., A tool for ball burnishing operation with opportunity for wireless transfer of the deforming force values, Acta Technica Napocensis, eISSN 1221-5872, 2023 (Indexed in WoS)

Abstract. There are more and more evidence recently for attempts the traditional machining processes be adapted to the contemporary requirements of the industry. Many research nowadays taking into account the principles laid down in the concept of Industry 4.0 to collect data from the processes, and their subsequent processing in order to extract useful information about the conditions under which it is carried out. Of particular interest are applications that can provide information on process parameters in real time.

The main objective of the present work is to create a tool for ball burnishing of rotary parts, which is intended to work with CNC turning centers, and which is able to send wirelessly data of the instantaneous values of the deforming force, to monitoring the burnishing operation.

The paper describes the construction and operational parameters of a specialized tool for ball burnishing that has capabilities for measuring and wirelessly transmitting the current deforming force magnitude during the burnishing operation. It can be used both for burnishing and for formation various patterns of regular reliefs on rotational surfaces using different types of lathe machines and CNC turning centers. The main construction elements and the principle of adjustment and operation of the tool are explained, along with the electronic components used for measuring and transmitting the deforming force values to

the external client devices. The main advantages and constraints of the tool and opportunities for its future development and improvement are discussed at the end of the paper.

Г 7.8.

Avramova T., Slavov St., Vasileva D., Research on the internal cylindrical surfaces roughness heights processed by a tool with combined effect, Acta Technica Napocensis, eISSN 1221-5872, 2023 (Indexed in WoS)

Abstract. The current article presents the results from conducted experiments on the impact of cutting speed and feedrate on the resulting roughness in the surface layer due of combined cutting and burnishing processing of internal cylindrical surfaces. The double effect processing is carried out using a special designed tool for boring and subsequence surface burnishing based on plastic deformation in the surface layer. Standard workpieces for production of hydraulic cylinders, made of S355 steel are used as test specimens.

The main objective of the present work is to investigate the influence of machining regime parameters (cutting speed S, m/min and feedrate f, mm^{-1}) of a simultaneous cutting and burnishing operation, on the resulting roughness height of the hydraulic cylinders inner surfaces, processed by a tool with combined effect: boring of hole, followed by slide burnishing. As result, stochastic models describing the impact of cutting parameters on the resulting roughness are derived, using the surface response methodology of the design of experiments.

The results, obtained from conducted experimental research reveals the influence of the main regime parameters - speed and feedrate over roughness heights of inner surface of the hydro cylinder like specimens that are processed by using described combined boring and burnishing tool. A positive effect, such as reducing the resulting roughness heights was observed with applying the combined tool for cutting and burnishing of the tested specimens. At the same time, the resulting roughness height is not constant along the length of the cylindrical hole, which means that different contact conditions will occur at both ends. The results obtained from the study will be used for future improvement of the design of the presented tool with double-action.

Г 7.9.

Dzyura Volodymyr, Pavlo Maruschak, Stoyan Slavov, Diyan Dimitrov, Volodymyr Semehen, and Oleksandr Markov. "Evaluating Some Functional Properties of Surfaces with Partially Regular Microreliefs Formed by Ball-Burnishing." Machines 11, no. 6 (2023): 633, eISSN: 2075-1702

Abstract. In the present work, functional properties of three different types of regular microreliefs, formed by ball burnishing process on flat surfaces are evaluated. For their estimation, heights and material ratio curve's criteria were used, according to the international standard ISO 21920-2:2021. The influence of the regular relief's type and ball burnishing process parameters on the surface functional properties were investigated using full factors experimental design. Based on the obtained results, statistical models were derived that describe the dependencies between the topography characteristics and the regular reliefs' types and regime parameters of the ball burnishing process.

The main purposes of the current research are to assess the applicability of the surface texture parameters included in the contemporary international standard ISO 21920-2:2021 from one side, and to investigate how they can be used as an estimation of the functional properties of the three types of partially regular microreliefs formed by the vibration-free ball-burnishing approach. The functional properties of these three types of RMRs were assessed using the topography's height, the bearing capacity, and the lubricants retention ability, based on the correspondent criteria defined from the Abbott–Firestone's MR curve.

Summarizing the results obtained after experimental research conducted, the following conclusions can be drawn:

– Partially regular PMRs, regardless of their type, show about a 10 times higher lubricant retaining capacity than those surfaces that do not have patterns with plastically deformed traces. However, this feature reduces their bearing capacity respectively. Therefore, both the required lubricant retaining capacity and bearing capacity of the burnished surface must be considered when designing the parameters of the ball-burnishing operation.

– Among the different types of RMRs investigated, the I st and III rd types of RMR demonstrated a better combination of functional properties than the II nd type of RMR which produced the lowest results in terms of the functional properties. Therefore, future research must be focused mostly on these two types of RMRs.

– The standardized methodology for the calculation area of the dales and the R_{ak2} criterion included in the EN ISO 21902-2 standard are not very suitable to RMRs, due to the difference between the shapes of the MR curves. As shown from the empirically built MR curves of the RMRs there was an additional area, which was not taken into account in the determination of the R_{ak2} criterion, and therefore, the functional parameter for the lubricant retaining capacity of the RMRs had an underestimated value. This gives us reason to research in the future other methods for determining the R_{ak2} criterion to take into account that additional unused area of the MR curve.

Г 7.10.

Slavov St., Dimitrov D., Konsulova-Bakalova M., Van L.P.D., Research of the ball burnishing impact over cold rolled sheets of 304 steel fatigue life by using Bayesian rule considering their anisotropy, MDPI, Materials, ISSN: 1996-1944, 2023 (Indexed in SCOPUS and WoS)

Abstract. The present work focusses on the research of the plastic deformation accumulated effect obtained after two different plastic deformation treatments, over fatigue life of AISI 304 austenitic stainless steel. The research is focused on ball burnishing as finishing process in order to form specific, so-called "regular micro-reliefs"(RMR) onto pre-rolled stainless steel sheet. RMRs are formed using CNC milling machine and toolpaths with shortest unfolded length, generated by an improved algorithm, based on Euclidean Distance calculation. The first of the tasks in the present work is related to improving the previously used algorithm for generation of the BB-operation toolpath in regard to minimize its unfolded length. The second one is focused on the impact of resulting mechanical properties anisotropy over the fatigue life of specimens made of AISI 304 austenitic stainless steel after formation RMR from IV-th type by BB. In the current

research, the Bayesian approach is employed in order to evaluate the way of contribution of the BB-process over the fatigue life of the material. The results are expressed by the gain of the fatigue life, as result of applying BB-process, instead by the absolute number of cycles until fatigue failure of the material. In this way, the impact of some test condition factors as small differences and/or imperfections of the prepared test specimens, small fluctuations in the fatigue test regime parameters, etc., are avoided.

Results from fatigue life research show that rolling direction should be taken into account when BB of thin rolled sheets is done. Specimens cut in RD have a longer fatigue life in correlation with a slightly higher strength properties and lower elongation registered by tensile test. This gives us reason to conclude that the fatigue life of researched steel is increased, when directions of pre-rolled plastic deformation and the tool movement during ball burnishing are coincident. It also been found that the magnitude of deforming force has stronger impact over the fatigue life, then the feedrate of the ball tool.

Г 7.11.

Slavov Stoyan, Lyubomir Si Bao Van, Diyan Dimitrov, and Boris Nikolov. "An Approach for 3D Modeling of the Regular Relief Surface Topography Formed by a Ball Burnishing Process Using 2D Images and Measured Profilograms." Sensors 23, no. 13 (2023): 5801, eISSN: 1424-8220 (Indexed in SCOPUS – Q1 and WoS - Q2)

Abstract. Advanced in the present paper is an innovative approach for three-dimensional modeling of the regular relief topography formed via a ball burnishing process. The proposed methodology involves capturing a greyscale image of and profile measuring the surface topography in two perpendicular directions using a stylus method. A specially developed algorithm further identifies the best match between the measured profile segment and a row or column from the captured topography image by carrying out a signal correlation assessment based on an appropriate similarity metric. To ensure accurate scaling, the image pixel grey levels are scaled with a factor calculated as being the larger ratio between the ultimate heights of the measured profilograms and the more perfectly matched image row/column. Nine different similarity metrics were tested to determine the best performing model. The developed approach was evaluated for eight distinct types of fully and partially regular reliefs, and the results reveal that the best-scaled 3D topography models are produced for the fully regular reliefs with much greater heights.

In accordance with the goal set, an overall algorithm for three-dimensional topo-graphic representation of RRs was developed based on two-dimensional images and measurement of profilograms via stylus. A methodology for its application was developed and tested for distinct types of RRs with varying topographic heights and sizes of cell patterns. Nine different approaches for assessment of correlations between measured profilograms and TI rows and columns were examined, and the approach that yielded the highest results (i.e., SMSE) and provided the shortest time for calculation was determined. It was experimentally established that the highest degree of correlation between the compared vectors, when contouring the profile of the topography, was obtained for those RRs with a greater height and a more regular shape of the cell patterns. The methodology proposed here is easily applicable to three-dimensional modeling of these particular topography types of RRs. The worst results were obtained for those RRs patterns that have partially regular reliefs and topographies with low heights, which was also confirmed through the

analysis of equivalence conducted based on the t-Test statistic. For such partially regular topographies, it will be necessary to investigate applications of different techniques for three-dimensional imaging and modeling in the future, including the usage of other types of sensors.

In conclusion, it must be mentioned that the main advantages of the developed methodology are its simplicity, the comparatively low-cost equipment needed, and the shorter time required to achieve three-dimensional representation of the RRs topography. The main drawbacks are related to the low reliability of the obtained 3D models when the topography is not fully regular or its heights are comparatively low. The proposed methodology should not be considered as a replacement for or alternative to the existing noncontact methods for three-dimensional metrological scanning of surface topography. It could be employed, however, to rapidly obtain RRs topography three-dimensional models in order to train different types of neural networks, such as the Generative Adversarial Network (GAN), the Siamese Neural Network (SNN), etc., which will be the future work of this team within the pre-defined project aims.

Г 8.1.

Slavov, Stoyan Dimitrov and Iliyan Velichkov Iliev, Research on the variability of the burnishing force during processing surfaces with 3D shape by using simultaneous 5-axis ball-burnishing process implemented on CNC milling machine, eISSN 2603-316X; vol.1, issue 1; Annual Journal of Technical University of Varna, Bulgaria, 6-12 pp.

Abstract. The present research is focused on continuously measuring the burnishing force during conducting ball-burnishing process for specimens with surfaces with 3D shape, by using CNC milling machine with dual rotary table installed. The main objectives are experimentally determine the degree of variability of the compressive force against its nominal value, as well as to identify the main parameters of the regime of the ball-burnishing process that significantly influence this variability.

For measuring the burnishing force and its variability, the specifically developed ball-burnishing tool with miniature force sensor was used. To assess the degree of influence of the main regime parameters on the variability of the burnishing force, the four factors full factorial experiment design with two levels per factor and four replications per run has been carried out. The experimental results are processed statistically and techniques such as Pareto and ANOVA were used after that, for sorting them by degree of significance.

Based on the conducted experimental research it can be seen that the measured burnishing force variability reaches a maximum of 7 % (± 3.5%) at the nominal preset level of the burnishing force F= 380 N and 21% (± 10.5%), at F= 250 N. Largely, this mainly due to non-optimal contact between the ball-tool and the 3D surfaces of the specimens at lower values of the nominal burnishing force. The adjusted degree of the accuracy of the postprocessor for generating NC code for BB process, as well as to smaller stiffness of the used dual rotary table can also be considered as possible reasons for that.

Г 8.2.

Slavov S. D. "A contemporary approach for obtaining regularly shaped roughness by ball-burnishing process carried out using CNC controlled milling machines.", ISSN 1844 – 640X, Fiabil. si Durabilitate 1 (2017): 349-356.

Abstract. The present work describes the main advantages of the implementation a new approach for ball-burnishing process, for precisely formation of regularly shaped roughness on external planar and cylindrical functional surfaces from machine parts. The considered approach includes the capabilities of contemporary CAM software products for automated programing, and 3-axis vertical or 4-axis horizontal machining centers controlled by CNC. A mathematical model is developed for generating the sinusoidal curves, which represents needed toolpaths and an algorithm for obtaining the NC-code for corresponding machine tools are presented. The principle of the purposed processing schemes for ball burnishing of external planar or cylindrical surfaces is described and conclusions about the advantages of the purposed approach are given. They are as follows:

- The ball-burnishing operation can be executed on every 3-axis vertical or 4-axis horizontal CNC milling centers having standard configuration and CNC control system, without need to use any additional devices or equipment or any software and hardware modifications in the machine tools;
- The accuracy of the obtained toolpaths is much better than the accuracy, which can be achieved using manually controlled machine tools. This is due to the fact that here the ball tool toolpaths are defined by mathematical derived curves, rather than instantaneous values of the regime parameters, as is the case when using manually operated milling machines;
- The time, needed for calculating the curves in SMath Studio, importing and set them as corresponding toolpaths, and post-processing the NC-code using FeatureCAM is within a several minutes, which significantly reduces the preparation time for ball-burnishing process;
- The possibilities for independent control of the parameters involved in the pair of derived equations allows precise adjustment of the shape and dimensions of the patterns with regularly shaped reliefs;
- The ball-burnishing operation can be added directly after other machine cutting operation s, which allowing the overall operating sequence to be performed on the same machine.

Г 8.3.

Slavov S. D., Kirov K. Ya., "Modelling of the characteristics of regular micro-reliefs using a method for rapid prototyping", ISSN 1310-5833; issue 1; Announcements of the Union of Scientists - Varna; Bulgaria, 2016, 76-83 pp. (in Bulgarian)

Abstract. This work is focused on creation of a methodology for rapidly obtaining three-dimensional models of regular micro reliefs, using a suitable CAM software, and the result from 3D simulations of process for ball burnishing on flat surfaces in particular. Required inputs for modelling of regular micro shape roughness are defined. Some of them based on mathematical modelling, while the others obtained by experimental determination of the diameter of impressions from the spherical element of the ball burnishing tool in certain materials at different values for the pressing force. Description of the technical equipment and methodology for per layer 3D printing of the physical models of regular micro shape roughness also is given. At the end of the paper, some conclusions about the adequacy of the obtained physical prototypes, resulting from the proposed methodology are given. They are as follows:

- The modeling of RR using CAM software does not fully reproduce the shape of the real relief obtained after implementing the ball-burnishing (BB) process. However, the prototypes obtained by 3D printing according to the methodology presented in the work can serve for preliminary control of the shape and overall dimensions of RMR's cells at set values of the regime parameters of the BB process according to a new scheme.
- Saving the 3D models of RMR in stereo lithographic (STL) file format by the CAM software requires reducing the dimensional tolerances with which it is simulated in the CAM software in order to obtain prototypes that are more accurate.
- Determining the depth of penetration of the deforming element into the processed surface requires h, requires a preliminary test when changing the diameter of the deforming element D and the type of processed material, which requires the use of additional test equipment.
- The Ultimaker 2+ 3D printer used in the current research is a suitable choice for the research purposes in terms of cost, dimensional accuracy of the models and time to print the RMR's prototypes.

Г 8.4.

Slavov Stoyan and Iliyan Iliev, "Design and FEM static analysis of an instrument for surface plastic deformation of non-planar functional surfaces of machine parts", ISSN 1844 – 640X, Fiability & Durability/Fiabilitate si Durabilitate 2 (2016), 3-9

Abstract. The paper presents the design of a specialized instrument for formation different types of regular micro-reliefs (RMR) on functional surfaces of parts with non-planar macro shape by using the process, called "ball burnishing". The elements of which the tool is constructed have been explained and the results from carried out strength and deformation analysis, obtained by Finite Element Method, conducted using the Simulation module of the SolidWorks are also represented. On this basis, some advantages and limitations of some of the surface plastic deformation process technological parameters are identified and recommendations for its implementation are given.

The results of the static analysis conducted by the finite element method using the Simulation module of SolidWorks, shows that the values of maximum stress, displacement, and the safety factor are within allowable limits. As can be seen from the design parameters, the inclination angle between the axis of the tool and the curvature of burnished surface can be up to 23 degrees without collision occurs. This will ensure trouble-free operation of the designed tool for processing of non-planar surfaces. Main advantages of the proposed constructive solution are relatively simplified design, including a minimum number of parts, and the ability to set up and continuously measuring the deforming forces of the ball while rolling on the treated surface.

Г 8.5.

Slavov Stoyan Dimitrov, and Dimitrov Diyan Minkov, "Experimental research of the effect of the regular shaped roughness formatted by using new kinematical scheme for surface plastic deformation process on the number of cycles to fatigue failure of stainless steel 304L (Cr18Ni8).", ISSN 2413-9335 Евразийский Союз Ученых 4-2 (25) (2016): 11-22;

Abstract. This work presents the results of an experimental research, conducted to identify the level of the effects of certain regime parameters of the finishing process Ball Burnishing (BB), conducted under a new kinematic scheme, using machine tools with CNC control on the fatigue life of the specimens, made of stainless steel grade 304L ASTM (Cr18Ni8). The individual steps of the study methodology and the elements of the used experimental setup are described. The obtained results are reported and the Pareto and ANOVA analyses are performed to clear up the main effects of the tested regime parameters and the significant interaction between them. Based on the obtained results, some conclusions and recommendations, concerning the application of the BB process, conducted under a new kinematical scheme, are made:

1. The presented methodology and setting for experimental investigation based on forced vibrations in cantilevered beam at the first resonance frequency allows relatively fast determination of the number of cycles until the occurrence of fatigue failure of the experimental specimens. It allows to simultaneously testing up to two specimens, which halved the time for experimental research upon receipt of stable and repeatable results.
2. The obtained results shows that the number of cycles to fatigue failure in all specimens with bilateral formed regular reliefs (RR) by new kinematical scheme of BB process is exceed the total number of cycles obtained for the specimens having unilaterally formed RR in the range from 100 to 800%. Compared to the specimens without any RR the exceedance is from 900% up to 14 times.
3. Fatigue cracks in 100% of tested specimens with unilateral RR occurs and evolved from untreated by BB process side of the specimen, which highlights the beneficial influence of this treatment.
4. From researched degree of significance of the regime parameters of the BB process conducted under a new kinematical scheme, it is seen that the greatest effect on the number of cycles to fatigue failure provides the feedrate of the ball tool s, [mm/min], and the next factor is the deforming force F, [N]. As significant, appears the interactions between parameters F and s, and between F and e. Further conducted two-way analysis of variance (ANOVA) confirms identified as significant by Pareto histogram main effects and interactions of the regime parameters.
5. The obtained results lead to the conclusion that the lack of significance of the regime parameters i and e, which are related to the shape and dimensions of the formed cells of the RR formed by SPD process haven't significant effect on the number of cycles to fatigue failure of the specimens. Observed beneficial effect is mainly due to the parameters F and s, related to the change of the microstructure and hardening of the surface layer of the surfaces treated by the SPD process.

Г 8.6.

Slavov S. D., Iliev I. V., "New scheme for superficially plastic deformation process for obtaining textures with regular roughness on the surfaces with complex geometrical shape", ISSN 1310-3946; Proceedings from Technologies section of XIII МНТК "MTM, Bulgarian Scientific and Technical Union in Mechanical Engineering, Bulgaria, 2016, 69-72 pp. (in Bulgarian)

Abstract. This work describes the opportunities and methods for formation of specific roughness patterns on complex surfaces of machine parts by using the multi-axis curve

machining capabilities of contemporary CAD/CAM systems and multi-axis CNC machine tools.

Particularities why it is impossible to use only 3-axis milling machines for the processing of complex surfaces by ball burnishing (BB) process are discussed. The overall consistency for configuring the component for multi-axis curve machining in CATIA is described and the process for formation of specific textures on machined complex surface is graphically illustrated. The following conclusions are given:

1. Due to the fact that the presented approach for the formation of RR on complex surfaces is not bound to specific constructional-technological limitations of a given device for vibratory BB (VBB), the limits of variation of the regime parameters of the process can be wider, in comparison with classic schemes for VBB. This allows more precise control of the shape and geometric characteristics of the forming RR within wider limits to be achieved;

2. The capabilities of modern CNC systems for multi-axis processing eliminates the need to use additional devices, as well as the characteristic VBB process vibration of the deforming element, which improves the processing conditions, the accuracy of the shape and dimensions of RR cells;

3. The time for realization of processing by BB of complex surfaces on multi-axis milling centers with CNC is significantly optimized, as a result of limiting the operation of the tool within the processed areas - i.e. it is not necessary to "cutting the air" as in some VBB schemes.

4. The time length for technological preparation of the processing by BB (including the modeling of the RR, the programming of the movement trajectory of the deforming element, the output of the control program for the CNC machine and the documentation) is shortened by the use of suitable CAD/CAM. This allows specific settings at each stage of the preparation of the NC-code to be made;

5. The operation for the formation of RR by BB of complex surfaces of parts can be added directly to the other processing operations (milling, drilling, etc.), i.e. the workpiece is not need to be moved to another machine, especially equipped for that purpose.

Г 8.7.

Slavov S. D., Methodology for determining the degree of influence of some regime parameters when processing regular reliefs on planar surfaces by method surface plastic deformation under a new scheme on three dimensional roughness criteria, ISSN 1312-0859, Journal of Mechanical Engineering and Technologies, Issue 1/2014, Scientific and Technical Union of Varna and Technical University of Varna, Bulgaria, 2014, 14 – 21 pp. (in Bulgarian)

Abstract. In this work, a methodology for the study of degree of influence of the regime parameters of the model to define the toolpath of the deformation element in the processing of regular reliefs using the ball burnishing process (BB) on flat surfaces is presented using a new kinematic scheme and CNC milling machines. The mathematical model and its parameters, which are used to programming the toolpath, and resulting reliefs topography are established and discussed. A suitable methodology for the determination of some typical 3D-roughness criteria of the formed regular reliefs and identifying those regime parameters with significant influence on the roughness are also been described. The

proposed methodology is supported with an example using prismatic test specimen with regular reliefs formed on its flat upper surface. Comparing the results obtained from it application, it can be concluded that the influence of the parameters on the BB process regime under the proposed new scheme for forming regular reliefs on flat surfaces is largely identical to those that influencing in the process vibratory BB, which are carried out according to traditional vibratory assisted burnishing, using manually controlled machine tools and special designed burnishing devices. The proposed BB scheme does not contain many of the drawbacks of traditional approaches to processing through this process.

Г 8.8.
Slavov S. D., Krastev K. A., and Lefterov E. L., Design and strength-deformation analysis of the device for surface plastic deformation of flat surfaces working on a new kinematic scheme, ISSN 1312-8612; Journal of Mechanical Engineering and Mechanical Science, Issue 20 /2014; Scientific and Technical Union of Varna, Bulgaria, 2013, 113-118 pp. (in Bulgarian)

Abstract. The paper describes the construction of a specialized tool for the formation of regular micro-reliefs (RMR) on flat surfaces, working according to a new kinematic scheme using the method of ball burnishing (BB).

The main goal of the present work is to design and manufacture a device for BB of flat surfaces. The requirements for it, which have been achieved with the developed construction, are as follows:

1. To allow settling in the spindle and work with various models of three- (or more) axis CNC-milling machines;
2. To provide elastic contact with the processed surface and the ability to adjust the force of pressing of the deforming element, as well as work with deforming elements of different diameters, for processing flat surfaces of de-tails of different types of materials (ferrous and non-ferrous metals and alloys) and varying physic and mechanical properties (i.e. different hardness);
3. To ensure minimal radial beating of the deforming element, to achieve a closer to the calculated trajectory of movement, and hence a minimal deviation in the shape and dimensions of the cells of the resulting RMR.

In accordance with them, the article presents the elements of the tool's design, the results of the force-deformation analysis performed by the finite element method and the technological characteristics that can be achieved when using it for processing real surfaces from workpieces.

Г 8.9.
Slavov S. D., Simeonov N. G., Application of CAD-CAM software products for creating and programming of specific toolpaths for machining of flat surfaces, Announcements of the Union of Scientists - Varna; Bulgaria,'1/ 2013, ISSN 1310-5833, 100-107 pp.

Abstract. The paper presents some common problems in the field of automated calculation and programming of specific toolpaths in some unconventional machining

processes. An example of such a process where conventional programming strategies and methods do not give satisfactory results is discussed. An analysis of the advantages and disadvantages of the existing methods was carried out, because of which a methodology was proposed, supported by a practical example of combining the capabilities of modern CAD/CAM software systems to achieve the desired results. The model and methodology proposed by the authors for modeling the toolpath through complex plane curves have the following advantages that are more important:

- Using the computational capabilities of the Mathcad product, the modeling of an optimal tool motion trajectory becomes realistically achievable, not only for forming cells of various shapes and sizes from regular microreliefs (RMRs) by ball burnishing (BB), but also ability for modeling complex plane curves that can be used as toolpaths;
- The created algorithm is capable to generate polylines in DXF format directly from the Mathcad software. In this way the limitation of using specialized modules in CAM software for subsequent automated programming of trajectories in control programs (CP) for metal-cutting machines (MCM) with computer-numerical-control (CNC) is avoided;
- By using both the capabilities of CAD and CAM software, the length of numerical control code (NC-code) can be significantly reduced. This will facilitate the process of their creation and significantly shortens the time for their preparation and execution, even with older models of CNC-machines.

It is concluded that the proposed in this work approach would be useful both for the implementation of applied and research developments, and as a visual aid to support the education of students and doctoral students in the field of modern processing methods in the field of mechanical engineering.

Г 8.10.

Slavov S. D., Simeonov N. G., Methodology for rapidly creating solid models of real objects using 3D scanning method of structured light, Proceedings from Annual Scientific Conference of Angel Kanchev University of Ruse and Union of Scientists - Ruse - 2014, vol. 53 - 2, ISSN 1311-3321, 60 – 64 pp.

Abstract. The paper describes a methodology for rapidly obtaining of solid models, based on 3D meshes scanned by 3D structured light scanner device. Advantages and disadvantages of different methods for 3D scanning have been discussed and a reasoned choice of scan method has been made. A reverse engineering (RE) method is proposed for rapid obtaining an accurate solid model of a real body, by using an affordable optical 3D scanning device and the modeling capabilities of the SOLIDWORKS product (Dassault Systemes).

Based on real sample part, the sequence of work in transforming scanned polygonal mesh into solid model by using the CAD system SOLIDWORKS also was presented. The presented method of obtaining 3D scanned polygonal models of complex prismatic objects, using a scanner using the method of structured light and their subsequent processing to a solid body model through the SolidWorks CAD system allows to achieve geometrically and dimensionally accurate models in a relatively shorter time, than by modeling from scratch. The developed approach would be useful in solving a number of engineering tasks in creating models of details with complex surfaces from real physical objects.

Г 8.11.
Slavov Stoyan, "Opportunities for implementation the vibratory superficially plastic deformation process for cylindrical surfaces using CNC turn/mill centers.",Acta Technica Corviniensis-Bulletin of Engineering 6, no. 4: 41, 2013

Abstract. In the article, some typical disadvantages of the traditional kinematical scheme for implementing the vibratory ball burnishing process are discussed, realized on manually controlled lathe machines, and the possibilities and some difficulties in implementing that process by using two- axis CNC lathes and the more advanced multi-axis CNC Turn/Mill centres. Kinematical parameters of the process having an impact of the toolpath which forms so called "regular reliefs" from different types using the BB process are described, and mathematical functions for its calculating are proposed in accordance with the diameter and length of the cylindrical surface, that will be processed. The necessity of using 4-axis turn/mill centres (with rotary C-axis) is examined. The sequence of steps for automated programming of the attributes of the operation, using FeatureCAM software system, for output the required NC code is proposed.

Г 8.12.
Slavov Stoyan, Algorithm for automated detection and determining the number of cells from regular microreliefs obtained by vibratory plastic surface deformation based on digital image processing methods, ISSN 1313-0226; Internet virtual journal "MTM", Issue 11; Scientific-Technical Union of Mechanical Engineering Bulgaria, 2012, 50-53 pp.

Abstract. The article presents the possibilities of modern methods of digital image processing for automated determination of the number of cells from regular microreliefs obtained by ball burnishing process. A classification of some methods is presented and the advantages and disadvantages of some of them in the processing of sample images with regular microreliefs are discussed. Based on the characteristics of images with regular microreliefs and the capabilities of the considered methods, an algorithm for digital image processing and automated cell counting is proposed. An example result of applying the proposed algorithm is also shown and discussed.