

Improving Efficiency of the Surface Plastic Covering Deformation of Billets from Aluminum Alloys

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ABSTRACT

The current work is an experimental study of a new combined technology based on the plastic deformation. The test specimens and the drawplate used in the experiment possess regular microgeometry surfaces and are respectively made of D1T aluminum alloys steel 9XC. In order to implement Grukunov-Kragelskys' basic scientific principle, friction without wear, mineral oil with thickening agent type of Valen will be used. The objective of this paper is to study the power of dynamics, surface layer quality and surface deformation parameters. The research results will be entirely discussed in the last part particularly in the synthesis of an optimal method of machining, as well as the obtaining of a significant effect in the case of preliminary regularization of the roughness of the blank surface, and the reduction of the broaching force by 48 ... 72%. Indeed, The obtained scientifically grounded solutions will contribute in the expansion of the current database regarding the synthesis system of the advanced combined methods.

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1. INTRODUCTION

In work [1,2], the efficiency of the technique by plastic deformation of the surface of solid cylindrical specimens of duralumin D1T is clearly shown. This efficiency is achieved through the joint application of the tool with the regular microgeometry of the exposed surfaces and the innovative metal-clad lubricated. For instance, this consistency realizes the fundamental scientific principle «Grukunov-Kragelskys effect, friction without wear» [3].

In this case, the technique by plastic deformation of the surface was realized with the stretching of the processed long blanks [1,2] on the device, which its construction is given in work [4]. Yet work [5], indicates the efficiency of the technique by plastic deformation of the surface of solid cylindrical specimens of duralumin D1T. This later is attained through complementary self-exerted counter pressure of a similar metal-clad lubricant along the channels of the regular micro-relief of the acting surfaces of the tool [6,7]. In this matter, the technique by plastic

deformation of the surface was achieved with a compression of the processed short blanks on the device (test bench), which its construction is represented in work [5,6] and in Fig. 1.

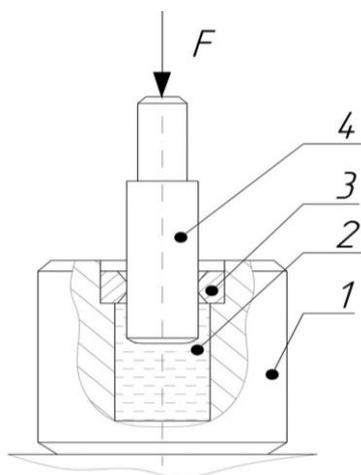


Fig. 1. Device for lubricant counter pressure.

- 1 - Thin - walled cylinder
- 2 - The cavity for lubricant
- 3 - Machining drawplate
- 4 - Blank

Our work aims to expand the range of the metal-clad additive content in the base mineral oils. Furthermore, it was decided to use the samples of the blank with regular surface microgeometry in order to increase the efficiency of the methods by plastic deformation of the surface, following the realization done in work [5], and using the algorithmic procedures "artificial intelligence systems" [8,9], and also taking into account the information in the database [10],

2. METHOD

For a maximum comparability of results, the test bench, represented in work [5], the deforming drawplates of steel 9XC (HRC 58...61) as well as the duralumin D1T (121HB) blanks were used similarly. The working surfaces of the drawplate, with working-channel diameter of $20+0.03$ mm, working and inverse cones of 5° taper, and a calibration strip whose width is 5mm as in work [5], are hardened by a regular micro-relief. This latter is in the form of one-turn helical channels with radius 1,5mm, pitch 0,5mm and depth 6.5 and 10 μm on a section of calibration strip. Longitudinal surface profilograms of the deforming elements were given in Fig. 2. The surface of the test specimens that is to be machined (length 60mm) is preliminary turned

so as to ensure 0.025mm precision of the diameter and surface roughness $R_a = 0.396 \dots 0.415 \mu\text{m}$, be regarded as corresponding to irregular microrelief.

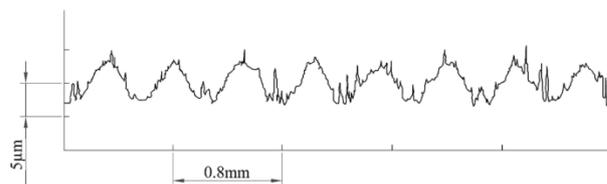


Fig. 2. Longitudinal profilogram of a calibrating strips of deforming die with regular micro-relief: material: 9XC, $S_g = 0,5$ mm, $D_g = 10\mu\text{m}$.

These surfaces of the test specimen were performed in the form of one-turn helical channels radius 1.5 mm and pitch about 0.05 mm. The speed of the methods by plastic deformation is 0.05 m/min. The basic lubricant is I-40 and I-20A mineral oil with the addition of copper-bearing Valen antifrictional metal-plating, realizing «Grukunov-Kragelsky friction effect» [1-7]. The content of the additive «C» by volume was varied in the range 0 ... 50 %.

3. RESULTS AND DISCUSSION

Figure 3 shows the general dependence of the force of the technique by plastic deformation of the surface. Its analysis displays the minimum reduction force corresponds to the plastic deformation of the workpiece with regular micro-relief (partial dependence 4). The growth in the specific force when using a lubricant without an additive, along with the absence of regular micro-relief of the workpiece surfaces and counter-pressure (partial dependence 1) by analogy with [5] is clearly explained by the high viscosity of the material being processed and the low oil absorption of the irregular micro-relief of the workpiece surfaces.

The content of the additive is 50 % (partial dependence 2), more than that even greater specific force of the technique by plastic deformation is also explained by the intensive plasticization of the deformable layer (the «Rehinder effect») by the surfactant components of the metallized additive. Intensive lamination, in turn, is also associated with high chemical activity of aluminium, which forms the basis of the material of the blanks. In addition to this, the maximum specific force with lubricant

backpressure (partial dependence 3) [5] is made clear by the high viscosity of the material being processed and the complete filling of the grooves with regular micro-relief on the acting surfaces of the tool. However, the main reason for the increase in the force of the plastic deformation method, during the absence of regular micro-relief on the workpiece surfaces (Fig. 3, special dependencies 1-3), is a higher and positive wave [11] in the non-contact area resulting in the deformation on the working cone of the drawplate.

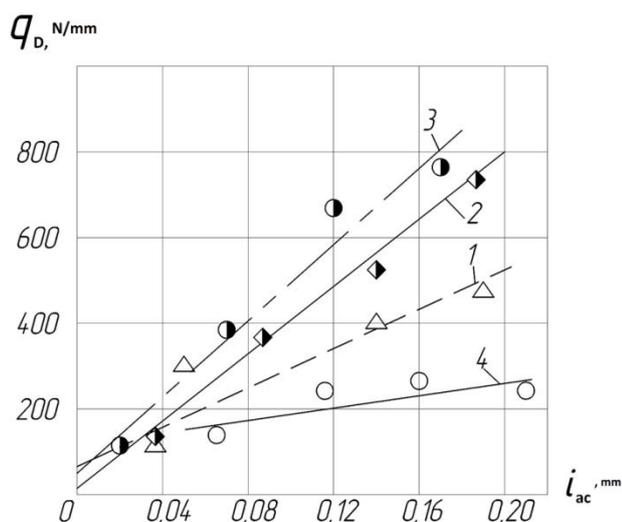


Fig. 3. The dependence of the total force technique by plastic deformation of the surface on the actual absolute deformation i_{ac} .

1. Machining without lubricant counter pressure (I-40), sample-blanks with regular surface micro-relief, $d_g=10 \mu\text{m}$;
2. Machining without lubricant counter pressure (I-40+50 % «Valen»), sample-blanks with regular surface micro-relief, $d_g=10 \mu\text{m}$;
3. Machining without lubricant counter pressure (I-20A + 5 % «Valen»), sample-blanks with regular surface micro-relief, $d_g=6.5 \mu\text{m}$;
4. Machining without lubricant counter pressure (I-20A + 5 % «Valen»), sample-blanks with regular surface micro-relief, $d_g=6.5 \mu\text{m}$.

From the technological point of view [12], the positive wave increases the contact area as well as the processing force. It also prevents the lubricant from entering the deformation zone and shouting more favourable friction conditions, for example, liquid or hydrodynamic. From the point of view of exploitation [12], the positive wave of deformation without contact can result in cracks, on the surface layer of the workpiece, which reduces its quality. Significant effect on the reduction of specific force (48 ... 72

%) (Particular dependence 4, Fig. 3), is explained by a "high oil absorption" by surface with regular micro-reliefs, breaching the continuity of the deformable layer moreover, the positive wave in the non-contact deformation is completely absent (Fig. 5).

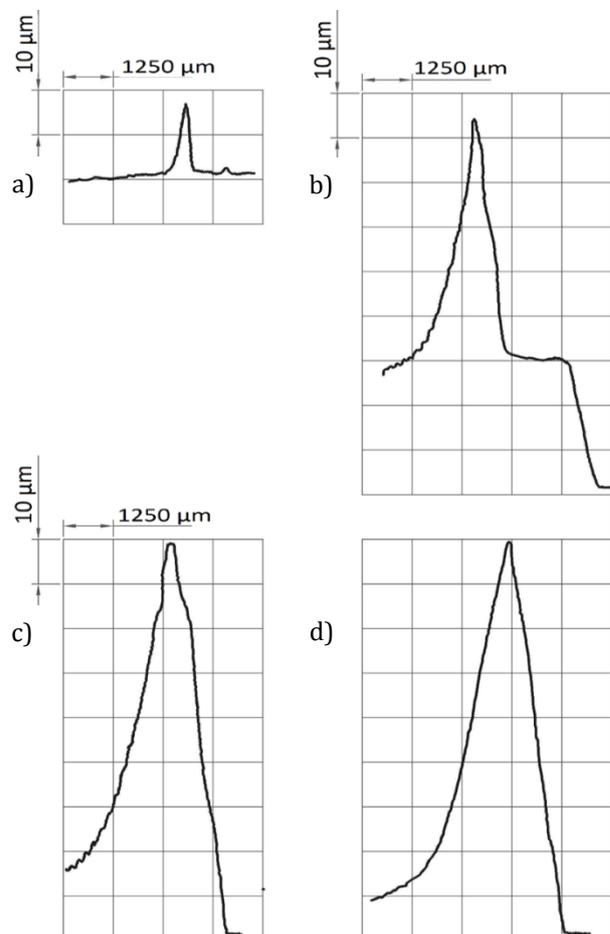


Fig. 4. Longitudinal profilograms of deformation centers (machining without counter pressure of lubricant I-20A + 5% «Valen», sample-blanks with irregular surface micro-relief, $d_g=6,5\mu\text{m}$): a) $i_{ac} = 0.02 \text{ mm}$; b) $i_{ac} = 0.07 \text{ mm}$; c) $i_{ac} = 0.12 \text{ mm}$; d) $i_{ac} = 0.17 \text{ mm}$.

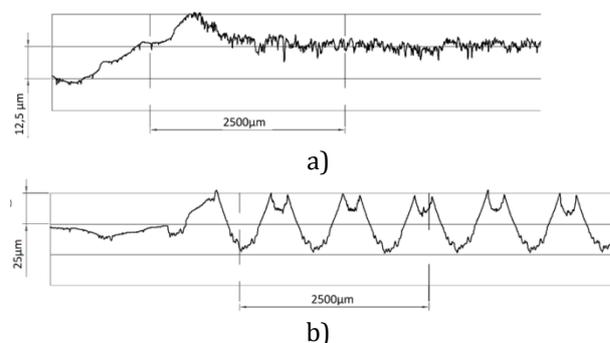


Fig. 5. Longitudinal profilograms of deformation centers in the technique by plastic deformation of the surface sample-blanks with surface irregular micro-relief (a) and regular surface micro-relief (b).

In addition, with the realization of regular micro-reliefs on the surface of the samples, a developed dislocation structure is formed; as a result, it accelerates the chemical reactions. Fig. 6 shows the general dependence of the refinement coefficient on the surface roughness parameter of the workpiece. Its analysis indicates the quality of the part's surface layer as a function of the lubricant technology. It reveals not only the method of its application, but also the content of metal-plating additives and the actual absolute deformation.

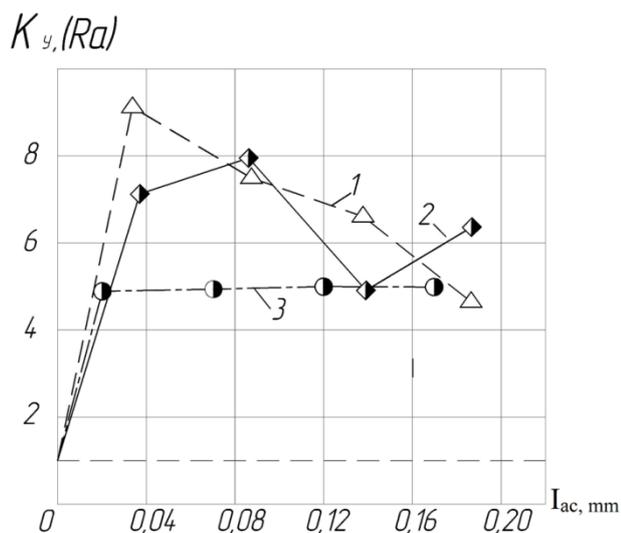


Fig. 6. The general dependence of the refinement coefficient on the roughness parameter of the sample-blanks surface on the actual absolute deformation I_{ac} .



Fig. 7. Appearance of the sample-blanks, obtained by technique by plastic deformation of the surface sample-blanks with regular surface microrelief.

Figure 7 presents the appearance of the sample parts, obtained by the technique by plastic deformation sample blanks with regular micro-relief surfaces. In this case, an intense transformation of the initial regular micro-relief is very visible, with an increase in the absolute real stress I_{ac} . Such a transformed initial regular micro-relief surfaces can have a positive effect on the further exploitation of the obtained product or on the subsequent processing of such blanks, for example, by cutting [13].

After the construction of the diagrams showing the characteristics of the part profiles (Fig. 8), an analysis of the dimensional geometric accuracy and the residual deformation was performed.

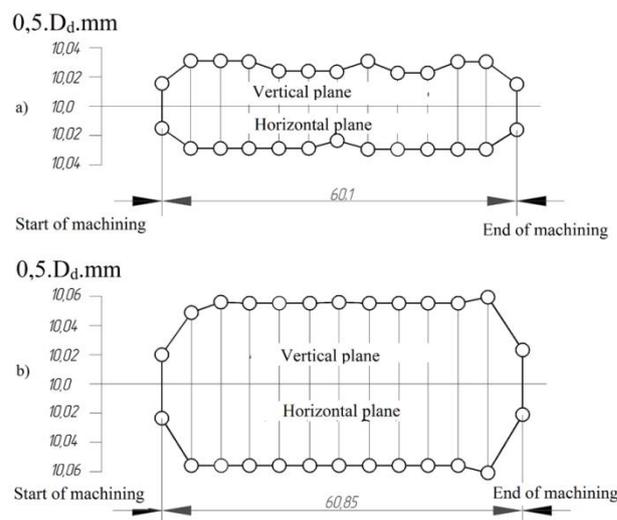


Fig. 8. The characteristic profiles of the sample parts after the technique by plastic deformation of the surface of the sample-blanks with regular surface micro-relief: a) $I_{ac} = 0.065$ mm; b) $I_{ac} = 0.21$ mm.

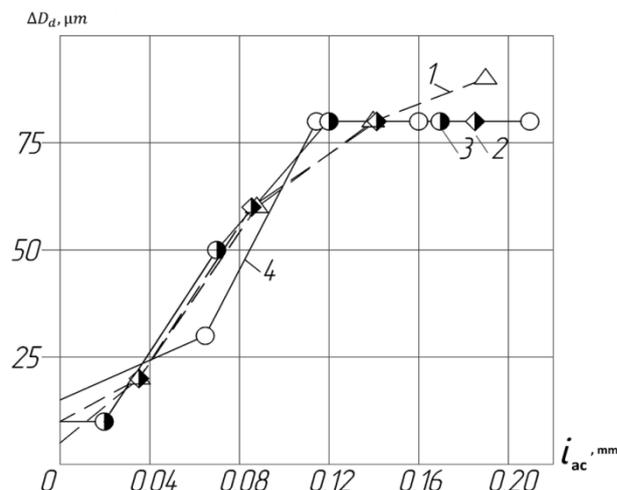


Fig. 9. The general dependence of the scattering field of the sample-parts diameter on the actual absolute deformation (notation as in Fig. 3).

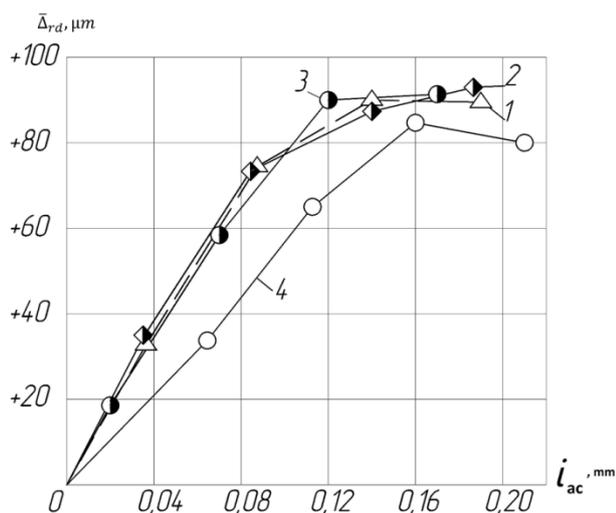


Fig. 10. The general dependence of the scattering field of the mean diameter of the sample-parts on the actual absolute deformation (notation as in Fig. 3).

According to (Figs. 9 and 10), the dimensional accuracy given by the parameter ΔD_d (Fig. 9) depends largely on the deviation of the longitudinal profile (Fig. 10b) and not on the ovality (Fig. 10a) specimens. In this case, the geometric accuracy in the longitudinal section (Fig. 10b) is determined by the crease chamfer at the front end of the workpiece at the start of machining and by the elastic recovery of the rear at the end of machining (Fig. 8).

Using these dependencies, the dimensional accuracy parameter can be represented in the form (μm):

$$\Delta D_d = 2 \cdot (\bar{\Delta}_{ov,d} + \bar{\Delta}_{os,d}); \quad (1)$$

By determining the average diameter of the sample profiles and comparing it to the working-channel diameter of the drawplate, the general dependence of the average diametric residual strains of the samples (Fig. 11) is constructed.

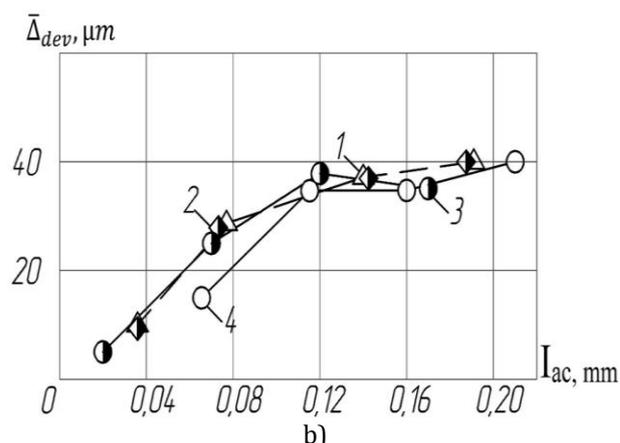
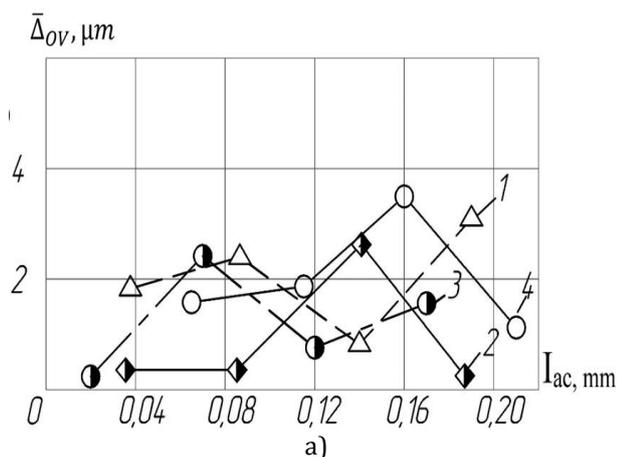


Fig. 11. The general dependences of the average ovality: (a) and the average deviation of the longitudinal section profile; (b) of the specimen-parts from the absolute deformation (notation as in Fig. 3).

The analysis of this general dependence shows that, because of the elastic restoration of the cylindrical surface of the samples, all the average diameters of the residual diametric deformation have a positive value. This signifies that the average diameter of the sample parts is larger than the diameter of the working channel of the corresponding die. However, in the case of the technique by plastic deformation of the surface, a sample blank with a regular micro-relief (partial dependence 4, Fig. 3) leads to a significant decrease in the average residual diametric deformation (partial dependence 4, Fig. 11). The constancy of the deformable volume will lead to a significant relative elongation of the workpiece. The general dependence (Fig. 11) allows adjusting the diameter of the working channel of the drawplate to obtain the piece with the necessary precision. Wherein, the maximum and the minimum diameters of the obtained parts are equal (mm):

$$\begin{aligned} D_d^{max} &= D_l + \bar{\Delta}_v + 0,5 \cdot \Delta D_d; \\ D_d^{min} &= D_l + \bar{\Delta}_v - 0,5 \cdot \Delta D_d \end{aligned} \quad (2)$$

The obtained results expand the database [1,2,5-7,11,12] that is used for the purposeful synthesis of innovative covering machining methods [15-19] based on algorithmic procedures of «Artificial technological intelligence» [8,9,14].

4. CONCLUSION

Based on the literature reviews and the experiments that have been carried out, some conclusions are deduced:

- A significant effect can be obtained in the case of the preliminary regularization of the roughness of the blank surface.
- The obtained results enlarge and enrich the database for the synthesis of the new combined methods.
- The oil content and the method of its use affect significantly the roughness of the blank surface.
- The regular microrelief has a positive effect on the utilisation of both the final part and the machining of the blank part.

REFERENCES

- [1] S.A. Gavrilo, M.A. Zinin, *Using of zero-wear effect with synthesis of metal cladding lubricants for extreme friction conditions*, Blank production in mechanical engineering, no. 2, pp. 21-25, 2013. (in Russian)
- [2] S.A. Gavrilo, *Improvement of surface plastic deformation process using metal-cladding lubricants*, Friction and lubrication in machines and mechanisms, no. 4, pp. 33-39, 2013. (in Russian)
- [3] D.N. Garkanov, E.L. Melnikov, V.G. Babele, *Tribology based on self-organization*, Lambert Academic Publishing, 2015. (in Russian)
- [4] A. V. Schedrin, Z. I. Egorova, A. V. Mayorov, V. D. Davydov, *Combined machining of parts*, Russian Engineering Research, vol. 17, no. 5, 63-65. 1997. (in Russian)
- [5] S.A. Gavrilo, A.V. Shchedrin, *Improved Use of Metal-Plating Conditioner in Combined Machining*, Russian Engineering Research, vol 32. iss. 7-8, pp. 573-576, 2012, doi: [10.3103/S1068798X1206007X](https://doi.org/10.3103/S1068798X1206007X)
- [6] A.V. Shchedrin, A.Yu. Kozlov, *Improving the use of technology metalplating lubricants covering methods of surface plastic deformation tool with regular microgeometry*, Strengthening technologies and coatings, no. 3, pp. 8-12, 2014. (in Russian)
- [7] A.V. Shchedrin, A.Yu. Kozlov, V.I. Voronkov, *Theoretical and experimental study of covering the surface plastic deformation in a counter-metalplacking lubricants*, Strengthening technologies and coatings, no. 10, pp. 11-15, 2015. (in Russian)
- [8] A.V. Shchedrin, V.V. Ulyanov, A.A. Bekaev, V.M. Skoromnov, M.S. Vanyushkina, T.G. Abramova, N.V. Khomyakova, N.Yu. Chikhacheva, *Tribological Principles in the Systematic Design of Competitive Technological Equipment*, Repair, restoration, modernization, no. 4, pp. 15-20, 2009. (in Russian)
- [9] A.V. Shchedrin, A.A. Kostryukov, N.Yu. Khikhacheva, *Artificial technological intellect as the ideological basis of the general system of methods for processing materials*, Strengthening technologies and coatings, no. 6, pp. 20-26, 2014. (in Russian)
- [10] E.S. Sergeev, M.A. Zinin, S.A. Gavrilo, A.V. Shchedrin, V.I. Voronkov A.O. Polyakov, *Influence of the angle of inclination of the acting surfaces of the deforming element on the characteristics of the methods of combined piercing (pulling) of holes*, Strengthening technologies and coatings, 2015. no. 3. pp. 20-24. (in Russian)
- [11] V.A. Kuznetsov, A.V. Schedrin, S.A. Gavrilo, V.I. Voronkov, E.L. Mel'nikov, *Theoretical and experimental researches of encompassing superficial plastic deformation method in conditions of using of metal-cladding lubricants*, Strengthening technologies and coatings, no. 2, pp. 11-17, 2014. (in Russian)
- [12] A.V. Shchedrin, S.A. Gavrilo, I.V. Kosarev, T.V. Smolkina, M.A. Zinin, E.S. Sergeev, *Formation of foci of deformation in the surrounding surface plastic deformation*, Friction and lubrication in machines and mechanisms, no. 10, pp. 3-7, 2014. (in Russian)
- [13] V.M. Yaroslavtsev, *Cutting with advanced plastic deformation*, Science and education: a scientific publication of the Bauman Moscow State Technical University, 2010. (in Russian)
- [14] V.M. Yaroslavtsev, *Development and practical implementation of methodology of search of new methods of material processing*, Bulletin of the Moscow State Technical University, N.E. Bauman, Series Mechanical Engineering, no. 2, pp. 56-70, 2007. (in Russian)
- [15] A.V. Shchedrin, A.A. Bekaev, R. Kulikov, V.N. Skoroinov, V.V. Ulyanov, O. Khrisanov, *Improvement of combined methods of reduction and piercing*, Metallurg, no. 10, pp. 66-69, 2005. (in Russian)
- [16] A.S. Kurenkov, I.M. Sinev, S.A. Gavrilo, A.V. Schedrin, *Design of tool with spherical deforming elements for wraparound combined processing of long billets*, Bulletin of Mechanical Engineering, no. 8, pp. 59-61, 2015. (in Russian)
- [17] A.V. Shchedrin, S.A. Gavrilo, *Perspective methods of combined drawing of solid and hollow profiles*, Repair, restoration, modernization, no. 6, pp. 51-53, 2013. (in Russian)
- [18] A.V. Schedrin, A.A. Kostryukov, N.Yu. Chihachova, K.O. Klimochkin, *Improving the efficiency of the combined treatment of embracing*, Strengthening technologies and coatings, no. 5, pp. 12-16, 2016. (in Russian)
- [19] A.V. Shchedrin, A.Yu. Kozlov, A.A. Kostryukov, *Improvement of the covering surface plastic deformation due to the regularization of microgeometry of the surface of the workpiece*, Strengthening technologies and coatings, vol. 13, no. 4. pp. 162-168, 2017. (in Russian)