JAES | JOURNAL OF APPLIED ENGINEERING SCIENCE | www.engineeringscience.rs
ISTRAŽIVANJA I PROJEKTOVANJA ZA PRIVREDU

Indexed by

STUDYING THE PROCESS OF TOOLING CYLINDRICAL GEARS

Karibek Sherov
Karaganda State Technical University, Faculty of Mechanical Engineering, Department of Technological equipment, mechanical engineering and standardization, Karaganda, Kazakhstan

Bakhtiyor Mardonov
Navoi State Mining Institute, Department of mechanical engineering, Navoi, Uzbekistan

Olga Zharkevich
Karaganda State Technical University, Faculty of Mechanical Engineering, Department of Technological equipment, mechanical engineering and standardization, Karaganda, Kazakhstan

Sergey Mirgorodskiy
D.Serikbayev East Kazakhstan State Technical University, Department of mechanical engineering, Ust-Kamenogorsk, Kazakhstan

Riza Gabdyssalyk
D.Serikbayev East Kazakhstan State Technical University, Department of mechanical engineering, Ust-Kamenogorsk, Kazakhstan

Sayagul Tussupova
Karaganda State Technical University, Faculty of Mechanical Engineering, Department of Technological equipment, mechanical engineering and standardization, Karaganda, Kazakhstan

Nurgul Smakova
Karaganda State Technical University, Faculty of Mechanical Engineering, Department of Technological equipment, mechanical engineering and standardization, Karaganda, Kazakhstan

Khasan Akhmedov
Navoi State Mining Institute, Department of mechanical engineering, Navoi, Uzbekistan

Yernat Imanbaev
Karaganda State Technical University, Faculty of Mechanical Engineering, Department of Technological equipment, mechanical engineering and standardization, Karaganda, Kazakhstan

Key words: *rolling method, gear, shaver-roller, chips, hindered layer*
doi:10.5937/jaes18-23794

Cite article:
Sherov, K., Mardonov, B., Zharkevich, O., Mirgorodskiy, S., Gabdyssalyk, R., Tussupova, S., Smakova, N., Akhmedov, K., & Imanbaev. Y. [2020]. Studying the process of tooling cylindrical gears. *Journal of Applied Engineering Science*, 18(3) 327 - 332.

Online aceess *of full paper is available at:* www.engineeringscience.rs/browse-issues

Istrazivanja i projektovanja za privredu
Journal of Applied Engineering Science

Original Scientific Paper

doi:10.5937/jaes18-23794 Paper number: 18(2020)3, 696, 327 - 332

STUDYING THE PROCESS OF TOOLING CYLINDRICAL GEARS

Karibek Sherov[1], Bakhtiyor Mardonov[2], Olga Zharkevich[1], Sergey Mirgorodskiy[3], Riza Gabdyssalyk[3], Sayagul Tussupova[1], Nurgul Smakova[1], Khasan Akhmedov[2], Yernat Imanbaev[1]*

[1]Karaganda State Technical University, Faculty of Mechanical Engineering, Department of Technological equipment, mechanical engineering and standardization, Karaganda, Kazakhstan
[2]Navoi State Mining Institute, Department of mechanical engineering, Navoi, Uzbekistan
[3]D.Serikbayev East Kazakhstan State Technical University, Department of mechanical engineering, Ust-Kamenogorsk, Kazakhstan

The studies of the state of gears production show that there is a problem of ensuring the accuracy and quality of teeth tooling in finishing operations. To solve this problem, there has been developed a method of finishing the teeth of gears and a design of a special reeling tool for its implementation. A feature of the proposed method is its implementation on universal lathes.

This article presents the results of an experimental study of the proposed method of tooling and studying the chip formation process. The research methodology is based on the scientific principles of engineering technology, the theory of chip formation, the theory of metal cutting and gear tooling. The metallographic method of research has also been used and the experiment has been planned.

The results of experimental studies confirm the possibility of applying the proposed method for finishing side surfaces of the cylindrical gear teeth, at this there has been achieved roughness R_a = 1.25 ÷ 0.32 μm.

The results of studying chip formation show that the tooling of the "shaver- squeegee" ensures high-quality crushing of chips, it somewhat weakens the structure of the chips and improves the working conditions of the tool and improves the quality of the finishing tooling of gear teeth.

Key words: rolling method, gear, shaver-roller, chips, hindered layer

INTRODUCTION

Improving the efficiency of machine-building production can be achieved through the use of advanced equipment and tools that enable large-scale implementation of high-performance resource-saving technologies. These paths have the greatest relevance in the production of complex parts that include gears. This is caused by specific features, both of the gear design and the technology of their manufacturing [1].

The current state of the engineering industry, in particular the production of gears, dictates the need to develop and implement advanced technological equipment, cutting tools and high-performance, resource-saving machining technologies.

Despite the continuous improvement of technological processes for manufacturing gears, the laboriousness of gear formation operations remains very high and makes up 50-60 % of the total labor intensity of gear tooling [2, 3].

Gears are characterized not only by the geometric shape complexity, but also by the interdependence of dimensional parameters that must be performed with high accuracy even for non-critical gears. Therefore, the most time-consuming and responsible specific operation in their manufacturing is the process of shaping the teeth. When shaping the gear teeth, the main role is played by the methods of final finishing.

The analysis of the main trends of improving the quality of gear manufacturing shows that despite a large amount of basic research [4, 5, 6] and the important results obtained, the issues of ensuring the accuracy and quality of the working surfaces of gears, in particular, when shaping the teeth in finishing operations, remain a problem.

The results of the studies carried out show that the existing methods and ways of finishing the gear teeth [7, 8, 9], in particular spur gears [10, 11], are not always acceptable for the conditions of modern domestic engineering industries. Their main disadvantages are as follows: low accuracy, low productivity, complexity of design and commissioning, high cost, etc. The studies carried out at domestic enterprises of machine-building profile revealed a shortage of technological equipment for finishing gear teeth, in particular gear-grinding and gear-shaving machine tools. There have also been identified the problems associated with the complexity of the adjustment works of the gear grinding machine, when machining gears with different numbers of teeth and with different modules. This issue is even more complicated with a large range of machined gears and a relatively small number of them, which is typical of domestic engineering industries.

The current state of the issue dictates the need to develop a new method and design of the tool for finishing the teeth of cylindrical spur gears.

In this regard, the research and development of a re-

*shkt1965@mail.ru

source-saving method and tool design for final tooling of the teeth of cylindrical spur gears is an urgent task.

EXPERIMENTAL RESEARCH AND DISCUSSION OF THE RESULTS

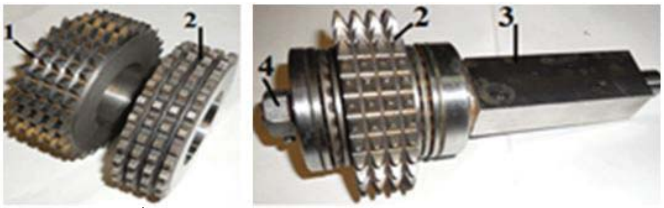
The research methodology is based on the scientific statements of such sciences as fundamentals of engineering technology, engineering technology, theory of cutting metals and gear tooling, theory of chip formation, technology of metals, materials science. In studying chips there has been used the metallographic method of research. An experimental study of machining gears with the shaver-roller reeling tool was carried out on the NT250I lathe. Figure 1 is a photograph of the shaver-roller tool.

The experiment has been planned according to the procedure of [12]. For planning the experiment, the following factors have been used: cutting speed (V), feed (S) and depth of cut (t).

The measurements are carried out with variation of the three parameters at two levels of the recommended range, as indicated in Table 1.

Table 1: Cutting parameters and their levels

Factors	Levels		Variation interval
	+1	-1	
Cutting speed (V) [rev/min]	200	400	100
Feed (S) [mm/rev]	0.07	0.15	0.03
Depth of cut (t) [mm]	0.015	0.035	0.010



a) b)

Figure 1: Photograph of the shaver-roller tool: a) shaver-roller; b) tool assembly; 1 – shaver-roller R6M5; 2 – shaver-roller ShH15; 3 - holder; 4 – clamping nut for a,b respectively

There has been carried out the experiment of the 23 type, where the number of factorsk=3, the number of levels p=2, the number of experiments N=8, the number of repeated experiments n=5.

A special mandrel has been made to mount the blank (Figure 2b). Gear 2 is engaged in backlash-free engagement with shaver-roller 3.

The analysis of the results obtained has determined the effect of the spindle speed on roughness of the machined side surfaces. Figure 3 shows a graph of roughness of the side surfaces of the gear teeth on the spindle speed.

Modes are S=0.1 mm/rev; t =0.025 mm (Figure 3). In the graph it can be seen that when machining with both shaver-rollers, an increase in the spindle rotation speed favorably affects the machined side surfaces roughness of the spur gears teeth. At values of the spindle rotation frequency n = 200 ÷ 400 rpm, there has been ensured roughness Ra = 1.25 ÷ 0.32 μm of the machined side surfaces of the teeth of the cylindrical gears.

Based on the obtained results, the optimal cutting conditions have been established when machining with a “shaver-roller” made of steel ShH15: S = 0.2 mm/rev; n = 400 rpm.

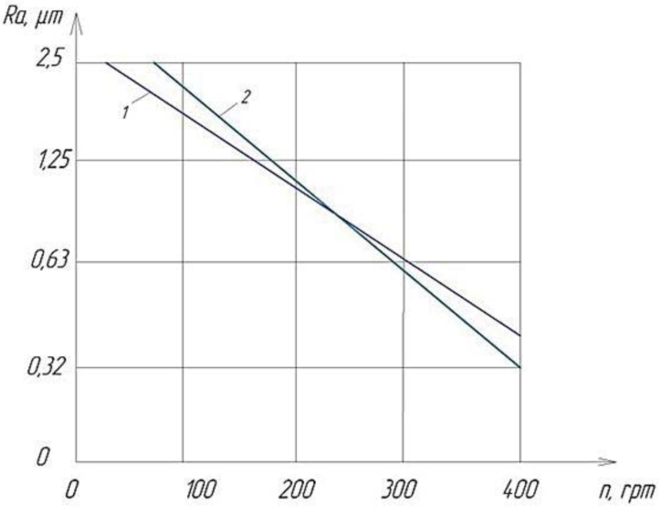


Figure 3: Side surfaces roughness of gear teeth dependence on the spindle rotation frequency: 1 - tooling with a shaver-roller made of R6M5 steel; 2 - tooling with a shaver-roller made of ShH15 steel

a) b) c)

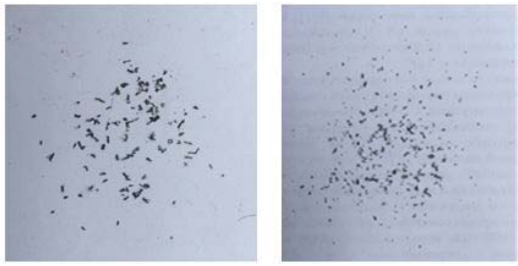
Figure 2: Tooling process, special mandrel and machined gears (respectively in a,b, c): 1) mandrel for mounting the blank; 2) blank; 3) shaver-roller ShH15; 4) gear machined in modes: n = 200 rpm; S = 0.1 mm/rev; t = 0.025 mm; 5) gear machined in modes: n = 400 rpm; S = 0.1 mm/rev; t = 0,025 mm

The obtained data show the possibility of applying the proposed method of machining the teeth of cylindrical gears, using reeling tools made of steel R6M5 and ShH15. As a result of experimental studies, it has been found that the use of rolling tools in machining cylindrical gears has a high (at 2…3 degrees of accuracy according to GOST 1643-81) correcting ability. This confirmed the feasibility of using the rolling tool (shaver-roller) for finishing cylindrical gears.

In the mechanics of the process of cutting metals great attention is paid to chip formation. More than 90 % of the force and work of cutting is spent for the chip formation process, respectively, the main part of heat is generated during chip formation. The thermal mode and contact loads on the working surfaces of the tool, and hence the intensity and nature of their wear, depend on this process. The quality of the surface layer and the accuracy of machining a part are directly related to the chip formation process. Thus, almost all the characteristics of the cutting process and its practical results depend on the chip formation process. The course of this process is mainly determined by the deformed state of the chip formation zone [13].

Contact phenomena occurring during chip formation are accompanied by intense friction on the front and rear surfaces of the tool, which has a significant impact on a number of important characteristics of the cutting process, in particular, on the nature and intensity of wear, the quality of the machined surface, cutting force, accuracy of machining, etc.

It is known [14, 15, 16] that during traditional gear cutting, chip separation is accompanied by its sliding on the front surface under conditions of either boundary friction without significant secondary plastic deformations of the contact layer, or with full seizure of the contact surfaces with intense plastic deformation of this layer. In this case, the discontinuity of the cutting process is mainly caused by the natural alternation of the cutting edges of the tool. When machining with the "shaver-roller", the mechanism of individual elements of the cut layer transformation into chips changes. These changes mainly concern the basic physical processes of chip formation: plastic deformation and destruction of the material being machined, as well as friction on the contacting surfaces, which undoubtedly should also affect the formation mechanism of individual chip elements.



a) b)

Figure 4: Chips obtained when machining with the shaver-roller under the cutting conditions n=200 rpm; S=0.1 mm/rev; t=0.025 mm andchips obtained under the cutting conditions: n=400 rpm; S=0.1 mm/rev; t=0.025 mm. (respectively in Figure 4 a, b)

Figure 4 shows the chips obtained by machining with a "shaver-roller" made of ShH15 steel. When carrying out experimental studies, the cutting speed has been varied in the range of n = 100 ÷ 400 rpm.

At low cutting speeds large fracture chips have been obtained (Figure 4a). With increasing the cutting speed, there has been observed decreasing the size of the fracture chips and better crushing. To study the texture of the obtained chips, a universal metallographic microscope Altami MET 5T has been used.

Figure 5 presents microphotographs of chips obtained

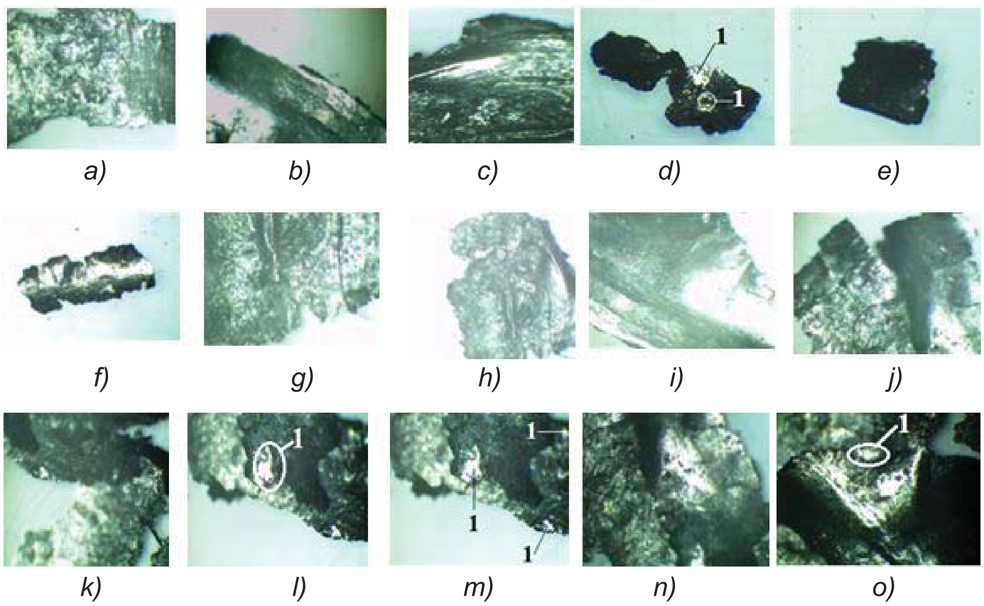


Figure 5: Microphotographs of chips (×100) obtained when machining cylindrical gear teeth with the shaver-roller made of ShH15 steel: 1 - build-up

when machining cylindrical gear teeth with saver-squeegees made of ShH15 steel.

When machining with a shaver-roller, the surface of the chips turned out smooth. In the microphotographs (Figure 5) it can be seen that some chips have parallel textures (microphotographs of Figure 5 *b, c, m*). In the microphotographs with magnification x100, build-ups are clearly visible (Figure 5 *g, m, n, o*). The studies have shown that at first there are mainly formed small build-ups, the number of which fluctuates sharply, quickly increasing in size and turning into a large build-up.

It is known [17] that increasing the size of build-ups and their transformation into a large build-up is associated with the conditions of friction in the contact between the tool and the blank. To prevent the formation of build-up during cutting, it is necessary to soften the machined layer of the blank to the ductile state. It can be achieved by increasing deformation in the layer of the blank being machined, thereby increasing the amount of heat released due to plastic deformation and temperature, as well as by increasing the friction force in the contact zone “shaver-roller and gear” by selecting the optimum values of cutting conditions that helps to achieve softening the layer of the blank being machined. The results of the study show that with increasing the cutting speed and feed, the size of the build-up decreases or it disappears altogether.

The microphotographs presented also show that some chips have an uneven shape in length (Figure 5 *g, j, k*). According to the findings of [15, 18], as well as to the results of this study, it can be assumed that this is the result of the appearance of a hindered layer. It should be noted that this phenomenon is characteristic of the combined treatment methods [15, 18]. In this case, it is assumed that the mechanism of machining with the “shaver-roller” made of ShH15 steel contributes to the appearance of this phenomenon. The results of the study show that with increasing the machining modes, the size of the build-up decreases or it disappears altogether. The appearance of the hindered layer was detected in works [15, 18, 19] carried out to study the process of the chips formation. It is known [20, 21] that this phenomenon usually appears when treating plastic materials. Its formation when machining 40H steel, especially heat-treated steel, is a feature of the cutting mechanism of the “shaver-roller” made of ShH15 steel. Figure 6 shows the chip pattern when machining with a shaver-roller made of ShH15 steel.

It is known that the cut layer is subjected to compression when machining with a cutting tool [17]. The cutting edge of the tool contributes to the appearance in front of him, in the limited area, at the initial moment of time, a complex elastic-stress state caused by pressure.

This process, as a result of the working movement of the tool, transforms into deformation and propagates in the zone bounded by the surfaces located at a certain angle β_1 (Figure 6). When machining brittle and highly sticking metals, shear and chip formation occur precisely in this zone. In the cutting zone of the metal, according to some researchers, the elementary volumes of the layers under shear are subject to uniform all-round compression with simultaneous impact of tangential stresses [22, 23]. Coincidence of the acting forces direction and the direction of the plane of possible shear has a strong impact on the ease of deformation, especially in case when the shear force is parallel to its plane. The shear plane is usually located perpendicular to the spatial diagonal of the cube.

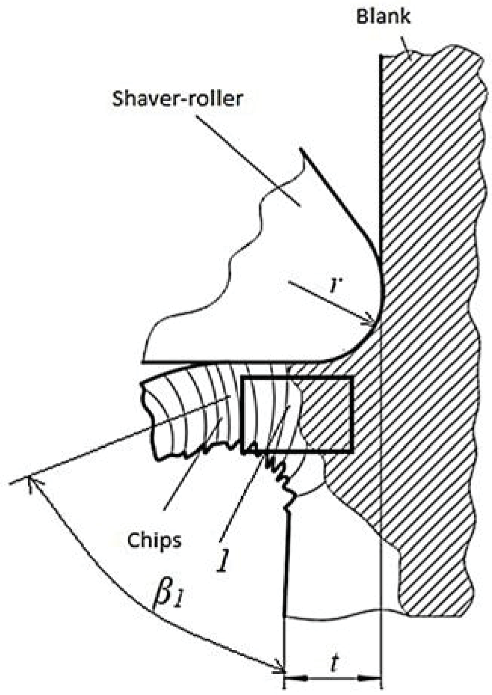


Figure 6: Chip formation pattern when machining with a shaver-roller made of ShH15 steel: β_1) shear angle; 1) more plastic section in the chip formation; r – radius af the shaver-roller; t - allowance

A number of researchers believe that the shear angle β_1 is of great importance for the cutting process, because its value determines the shrinkage of the chips, i.e. deformation of the removed layer with all the ensuing consequences [24, 25]. It is assumed that implementation of cutting in the process of machining with a shaver-roller" (made of ShH15) is based on friction in the tool-blank contact. Intensive deformation of grains is performed in the zone indicated by square 1 (Figure 6).

This section 1 is more plastic, and its dimensions and deformations of the grains of materials in this section are determined by the friction intensity on the front surface of the shaver-roller.

It can also be concluded that machining with a shaver-roller made of ShH15 steel ensures high-quality crushing of chips, the structure of the chips is weakened and the working conditions of the tool are improved, so the quality of the finishing of the spur gear teeth is improved.

CONCLUSIONS

It has been established that the use of the reeling tool in machining cylindrical gears has a high (at 2...3 degree of accuracy according to GOST 1643-81 correcting ability).

It should be noted that studying the process of chip formation when implementing the new method and design of the cutting tool, is an urgent task, since all the characteristics of the cutting process and its practical results depend on the chip formation process.

Studying the chips shows that at the beginning of treatment with a “shaver-roller” made of ShH15 steel, mostly small build-ups are formed, the number of which fluctuates sharply, quickly increases in size and turns into a large build-up, and with increasing cutting speed and feed, the size of the build-up is reduced or it completely disappears.

The formation of a hindered layer has been established, which is not typical for steel 40H; this can be attributed to the features of the cutting mechanism of a “shaver-roller” made of ShKh15 steel.

It is assumed that implementation of the cutting process when tooling with the "shaver-roller" made of ShH15 steel is based on friction in the contact between the tool and the blank. In this case, intensive deformation of the grains occurs in section 1 (Figure 6). This section 1 is more plastic, and its size and grain deformation of materials are determined by the friction intensity on the front surface of the tool.

A comprehensive study of the process of chip formation shows that machining with the “shaver-roller” made of ShH15 steel provides high-quality crushing chips, somewhat weakens the structure of chips, and improves the working conditions of the tool, as well as improves the quality of the final machining of gear teeth.

REFERENCES

1. Filippov, K.V. (2003).Technological capabilities of cylindrical gear cutting processes. PhD Thesis, Tula, 124 p.
2. Kalashnikov, S.N., Kalashnikov, A.S. (1986). The production of gears. Higher School, 287 p.
3. Pechenkin, M.V. (2016). Multi-coordinate shaping by milling the teeth of double curvature hyperboloid gears, PhD Thesis Kazan, 132 p.
4. Fradkin, E.I., (1993). Improving the accuracy of gear milling and gear grinding, STIN, 1, P. 9-11.
5. Valikov, E.N., Timofeev, Yu.S., Zhurina, A.S. (2013). Finishing gearing with the use of cutting properties of surfaces after EDM processing, News of Tula State University. Technical science, №12-1.
6. Kalashnikov, A.S., (2004).Technology for manufacturing gears. Mashinostroenie, 408 p.
7. Mardonov, B.T. (2017). The investigation of precision-of installation pieces of cylindrical gears in the process of rolling gear shaving. International Journal of Scientific & Engineering Research, 8 (5), P. 1205-1207. https://www.ijser.org/researchpaper/The-investigation-of-precisionof-installation-pieces-of-cylindrical-gears-in-the-process-of-rolling-gear-shaving.pdf
8. Mardonov, B.T. (2018). Determination of the accuracy of the gear wheels of technological factors. International Journal of Advanced Research in Science, Engineering and Technology, 5 (5).P. 5757-5761. http://www.ijarset.com/upload/2018/may/11-IJARSET-Oybek-mardonov.pdf
9. Mardonov, B.T. (2018). Investigation of the accuracy of cylindrical gears machined with various installations of the rolling tool (shever-roller) Scientific and Technical Journal FerPI., (3), P. 103-107.https://uzjournals.edu.uz/capmse/vol3/iss3/2/
10. Alikulov, D.E., Mardonov, B.T., and Shokulov, B.K. (2005). The Choice of Parameters and Processing Modes of Spur Gears. Proc. Fourth International Conference “Resource Reproductive, Low-waste and Environmental Protection Technologies for Subsoil Development”, Moscow-Navoi. Part3, P.239-241.
11. Mardonov, B.T. (2018). Ways to improve the accuracy of the installation of gear cogwheels for the operation of round-trip sheaving, Gorny Vestnik of Uzbekistan, (3), P. 66-67.
12. Spiridonov, A.A.(1991).Planning an experiment in the study of technological processes. Mashinostroenie, 184 p.
13. Zaitsev, V.E., Violin, E.A., Voronin, A.V. (2014). Study of the influence of the main parameters of cutting on the process of chip formation during face milling of aluminum alloy 6082 T6. Collection of scientific papers Discovery of information and computer integrated technologies, (65), P.42-48.
14. Skribanov, E.V., Enin, V.N., Markov, I.E. (1990). Precision control of kinematic chains of gear-cutting machines and gears. Bulletin of mechanical engineering, (9), P. 49-51.
15. Sherov, K.T., Rakishev, A.K., Donenbaev, B.S., Ainabekova, S.S. (2018). Chip formation and deformed state of the layer being cut off during XPS of internal and external cylindrical surfaces. University proceedings, 3 (72), P. 49 - 58.
16. Zorokhovich, A.A., Island, N.M. (1968).Production of high-speed gear wheels of medium modules. Engineering, 228 p.
17. Sherov, K.T., Sikhimbayev, M.R., Donenbaev B.S., Sagitov, A.A., Ainabekova, S.S. (2017). Experimental Research of Rotational-and-Frictional Boring of Big Holes in Large Parts,Journal of Theoretical and Applied Mechanics, 47 (4), P. 23-36. https://doi.org/10.1515/jtam-2017-0018

18. Musaev, M.M. (2017). Research and development of a comprehensive method of processing high-strength materials. PhD Thesis. Karaganda State technical university, Kazakhstan, 152 p.
19. Sherov, K.T., Alikulov, D.E. (2012). Control ruler for angles between planes of V-shaped guides. Measurement Technique, 55 (4), P. 397-399. https://doi.org/10.1007/s11018-012-9971-5.
20. Lizarditsyn, P.I., Eremenko, M.L., Feldstein, E.E. (1990).Cutting theory. Physical and thermal processes in technological systems: Proc. for universities, Your. school., 512 p.
21. Sherov, K.T., Musaev, M.M. (2016). Calculation of chip shrinkage when processing steel 30HGSA milling. Mechanics and technology, 3, P.36 - 42.
22. Kushnazarov, I.K., Yakubov, F.Ya., Khodzibergenov, D.T. (1995). Features of the process of chip formation at MRO. Proc. Scientific and Technical conference "ISTIQLOL-4", Navoi. Part 2. P.453-455.
23. Odintsov, P.G., Dzegylenok, V.N. (1990). The main directions of improving the methods of surface plastic deformation. Mashinostroenie, 263 p.
24. Vilner, G.S. (2000). To the question of determining the shear angle when cutting metals. News of universities. Engineering, 5-6, P. 95-100.
25. Vilner, G.S. (2001). The mechanism of formation of a hardened surface layer during metal cutting. Engineering technology VINITI, 6, P.6-11.

Paper submitted: 29.10.2019.
Paper accepted: 03.07.2020.