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ABSTRACT

The qualification paper topic: "Development of the ring ZhYTsD 712442.021 production process including the study of ring workpieces turning process." Student of group IMTm-63 of Ternopil Ivan Puluj National Technical University Elkenani Moustafa Mohamed Mahmoud Hassan.

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Keywords: mechanical engineering, technological process, operation, drilling, turning, ring.

The aim of the work is to develop technological processes and highly effective methods of location and means of rings clamping on the basis of theoretical and experimental studies, providing increase of accuracy and productivity of turning, reduction of metal consumption during rings manufacturing.

To achieve this goal, the following tasks are solved.

In the first part the analysis of existing technological processes of rings turning is made. Turning of rings from set and single workpieces is considered. It is defined that the choice of locating elements on the first operation significantly affects the design of the turning technological process. The choice of technological locating elements for the first operation is determined in each case, taking into account the specifics of the used turning equipment and technological fixtures, the accuracy of the locating surfaces of the workpieces and other factors.

In the second part the expediency of the workpiece locating on the first operation on the external or internal surface in terms of metal saving, taking into account the errors of installation of workpieces in the chucks is considered. The results of experimental studies of the ring cylindrical surface radial runout after turning are presented.

In the third part the design features, application, technical requirements, manufacturability of the ring ZhYTsD 712442.021 are analysed. The type of production is determined, the best option for the workpiece production – low pressure

casting. The synthesis of the technological route of part machining is realized, the allowances and operational dimensions are determined. Cutting tools, technological equipment and fixtures are selected. Calculations of cutting conditions are made. The design of the special fixture to perform 005 turning on CNC machine operation, on which the external cylindrical surface is turned to dimensions $\varnothing 129.8_{-0.25}$; l=28 for thread M130×2 is presented, its accuracy and power parameters are calculated.

In the fourth part the questions of safety measures are considered.

Relevant conclusions and a list of references are presented.

In the appendix the technological process for the ring ZhYTsD 712442.021 manufacturing and specifications for the drawings are presented.

CONTENTS

INTRODUCTION

The specifics of the rings production, characterized by a great variety of structural forms, requirements for precision, dimensional and geometric accuracy, necessitate the allocation of rings in an independent class of machine parts and a special approach to solving problems aimed at improving their manufacturing processes.

The emergence of advanced methods of workpieces production allows the new rethinking of the purpose of certain surfaces of the rings as technological locating elements, especially in the conditions of automated production.

The issues of increasing the efficiency of rings turning from single workpieces on the basis of development of optimal methods of location and designs of clamping chucks are also considered. At the same time, special attention is paid to the improvement of technological processes of rings turning from workpieces produced by precise methods.

Various schemes of new technological processes of rings turning with use of new methods of location and rational designs of clamping chucks are offered.

The novelty of the proposed technical solutions is that the conical surface of the ring is used as the main technological locating element. This allows to increase the efficiency of turning, reduce the complexity of further grinding operations, reduce the consumption of metal for the rings manufacturing.

1 ANALYTICAL PART

1.1. Analysis of existing technological processes of rings turning

Almost all workpieces of rings are exposed to turning. However, depending on the methods of workpieces production that determine the accuracy of their size, shape, relative position of surfaces and depth of the defective surface layer, the structure of the machining process, the volume removed when cutting metal and methods of rings locating may be different.

The main technological processes of rings turning are considered.

1.1.1. Turning of rings from set workpieces

One of the effective methods of rings turning is their processing from set workpieces. Obtaining in one workpiece rings of the same or different sizes allows to reduce the cost of metal and machining a set of the rings surfaces, using a single locating element, which increases the accuracy and productivity of machining.

The technological processes of rings turning from set workpieces have become widespread and are used by such well-known manufacturing firms as "Ametek" (France) [28], "Minganti" (Italy) [29], "Gildemeister" (Germany) [30].

Despite the wide variety of adjustments schemes used, it is possible to allocate the following basic moments peculiar to this or that method of rings turning from set workpieces.

Rings from set workpieces are machined in two operations on multi-spindle automatic machines using a complete set of carbide cutting tools (mainly with mechanical fastening) at a cutting speed of 100 ... 140 m / min.

As a rule, the outer surface and the end face of the ring is taken as a rough locating elements. The choice of locating elements on the first operation significantly affects the design of the turning technological process.

Thus, when located on the first operation on the external surface and the end face of the first ring (Fig. 1.1b), it is possible to completely machine and cut off one ring in this operation, on the second - only the second ring is finally machined.

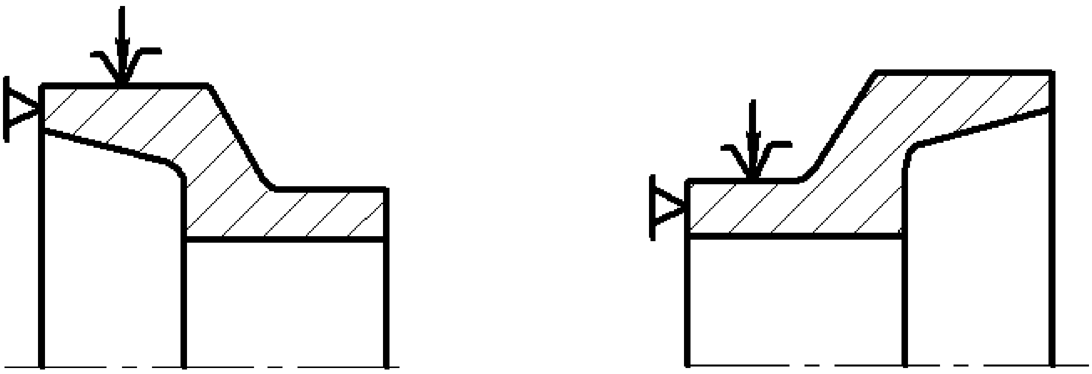


Figure 1.1 - The existing schemes of set workpieces location in the first operation a) on the external surface and end face of the first ring b) on the external surface and end face of the second ring [26]

If in the first operation the location is made on the external surface of the first ring (Fig. 1.1a), then the final machining and cut off of the first ring is possible only in the second operation. The choice of technological locating elements for the first operation is determined in each case, taking into account the specifics of the used turning equipment and technological fixtures, the accuracy of the locating surfaces of the workpieces and other factors.

Along with certain advantages of this method of setting are inherent disadvantages. Thus, step punches that form the inner surfaces of the first and second rings, work in difficult conditions and have reduced tool life, turning settings are difficult. Additional clamping devices are used to clamp the cut off ring and remove it from the machining area, which further complicates the machining process. Cutting tools are in unfavorable cutting conditions, which is reflected in their tool life, due to large differences in the diametrical dimensions of the hole of the second ring and the outer surface of the first ring virtually eliminates the choice of optimal cutting speeds. In addition, the large amount of chips formed during the removal of metal from both rings, makes it very difficult to automate turning operations.

In order to eliminate these disadvantages, work was carried out on the setting of workpieces in relation only to the first rings. At the same time, rings of different sizes were selected, the workpieces of which were combined into an axisymmetric stepped package with the providing of a common rectilinear inner conical surface generating with a given cone angle.

The scheme of the turning technological process of such workpieces on the eight-spindle semiautomatic machine with double indexing is presented in fig. 1.2. The workpiece is located on the internal conical surface with the support on the wide end face of the smaller size ring in a three-jaw chuck with self-aligning clamping elements.

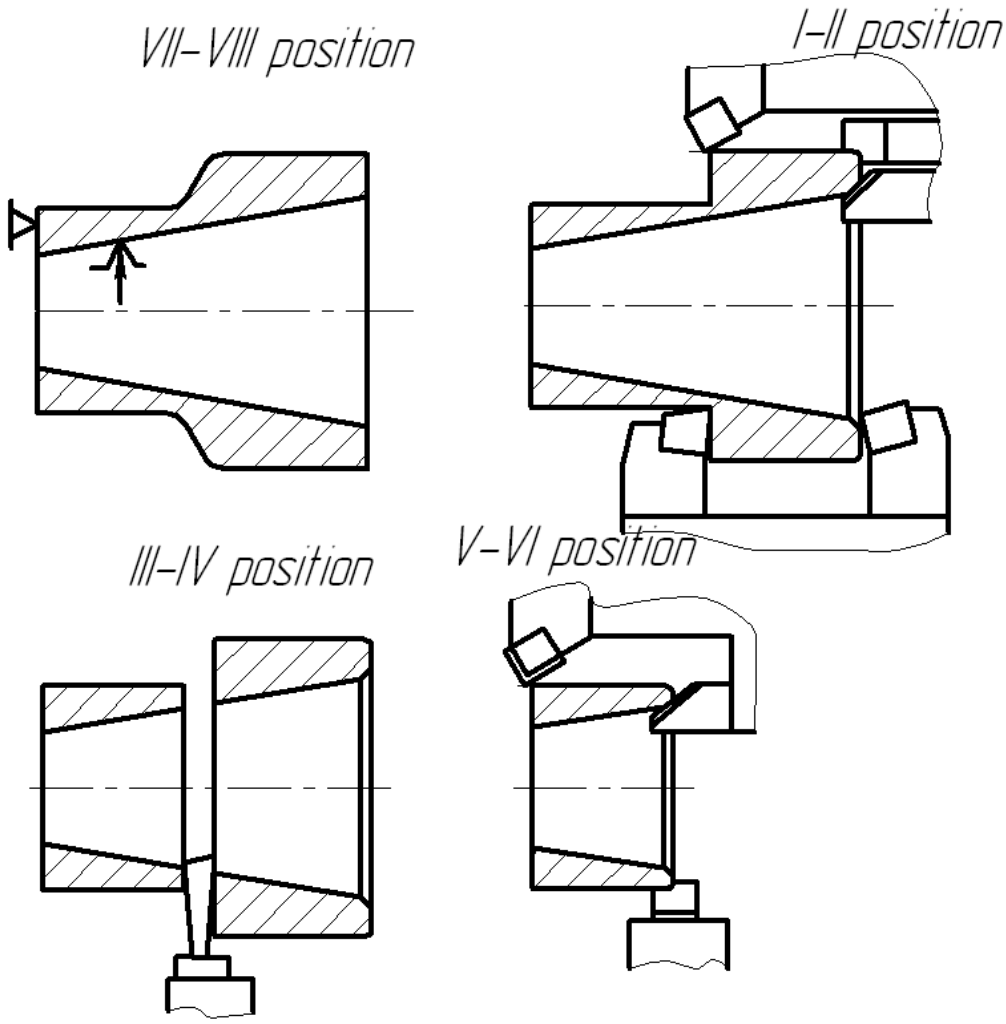


Figure 1.2 – The scheme of the technological process of rings turning from set workpieces [26]

After separating the rings, the latter are machined on a six-spindle semiautomatic machine with double indexing, where the rolling tracks are turned, wide ends are cut and chamfers are formed from wide ends. With this method of the workpieces setting, the accuracy of rings turning can be significantly increased with the use of new advanced methods of installation and design of chucks.

In recent years, in connection with the further development and improvement of forging and stamping production, a more economical way of rings production from set workpiesec is becoming more widespread. The essence of the new technology is that the separation of the first and second rings is carried out in the process of pressing on a forging and stamping press. Further turning is made separately for the first and second rings on multi-spindle semiautomatic machines.

The use of such technologies allows to obtain, according to the company "Gildemeister" additional savings of metal by 5...6% and eliminates the main disadvantages inherent in the methods of simultaneous machining of both rings.

1.1.2 Turning of rings from single workpieces

Despite the variety of technological processes used for turning of rings from single workpieces, a generalized systematic analysis of such processes is virtually absent. Based on this, the systematization of the main existing schemes for turning of such rings is proposed.

Given the fact that the order of technological processes of rings turning design is largely determined by the method of their location on the first turning operation, in the basis of systematization as a determining factor was adopted the principle of technological locating elements selection of on the first turning operation. With existing locating methods, such locating elements are either the external cylindrical surface (N_3) and the end face - wide (N_2) or narrow (N_4), or the cylindrical (N_0) or conical (N_1) surface and one of the end faces - (N_2) or (N_4).

The location of rings on the first operation on an external surface can be made with an support in a wide or a narrow end face.

The schemes of turning of rings technological processes at application in the form of locating element on the first operation of an external surface and a wide end face are presented in fig. 1.3 (variants 1-5).

In the first case the locating and clamping of the rings on the second operation is made on a conical surface with the support on the narrow end face.

This method of location in the second operation allows at first glance to carry out simultaneous machining of the external surface and the wide end face and to ensure high accuracy of their mutual location, which corresponds to the basic requirements.

However, it should be taken into account that the clamping of the rings on the inner conical surface is not reliable enough.

Calculations and processing practice show that this method of clamping does not exclude the possibility of relative displacement of the rings under the action of external forces, in connection with which the method of clamping rings on the internal conical surface with the support on the narrow end face is not widespread in factories.

In order to ensure the processing conditions when locating the rings on the first operation on the external surface with support on the wide end, it was proposed to design a further process in this way (Fig. 1.3 variant 2).

The main disadvantage of this machining scheme is the significant increase in the complexity of manufacturing, due to the need to add additional operation for machining of the external surface. In order to exclude additional turning operation for machining of the external surface, the company "Pittler" (Germany) recommends the following scheme of the turning technological process (Fig. 1.3 variant 3). However, this locating scheme leads to the formation of a step on the turned external surface and reduces the accuracy of the relative position of the surfaces.

Preliminary grinding of the initial workpieces external surface is provided at plants to exclude turning of the external surface and then turning by the scheme (fig. 1.3 c, d) is made.

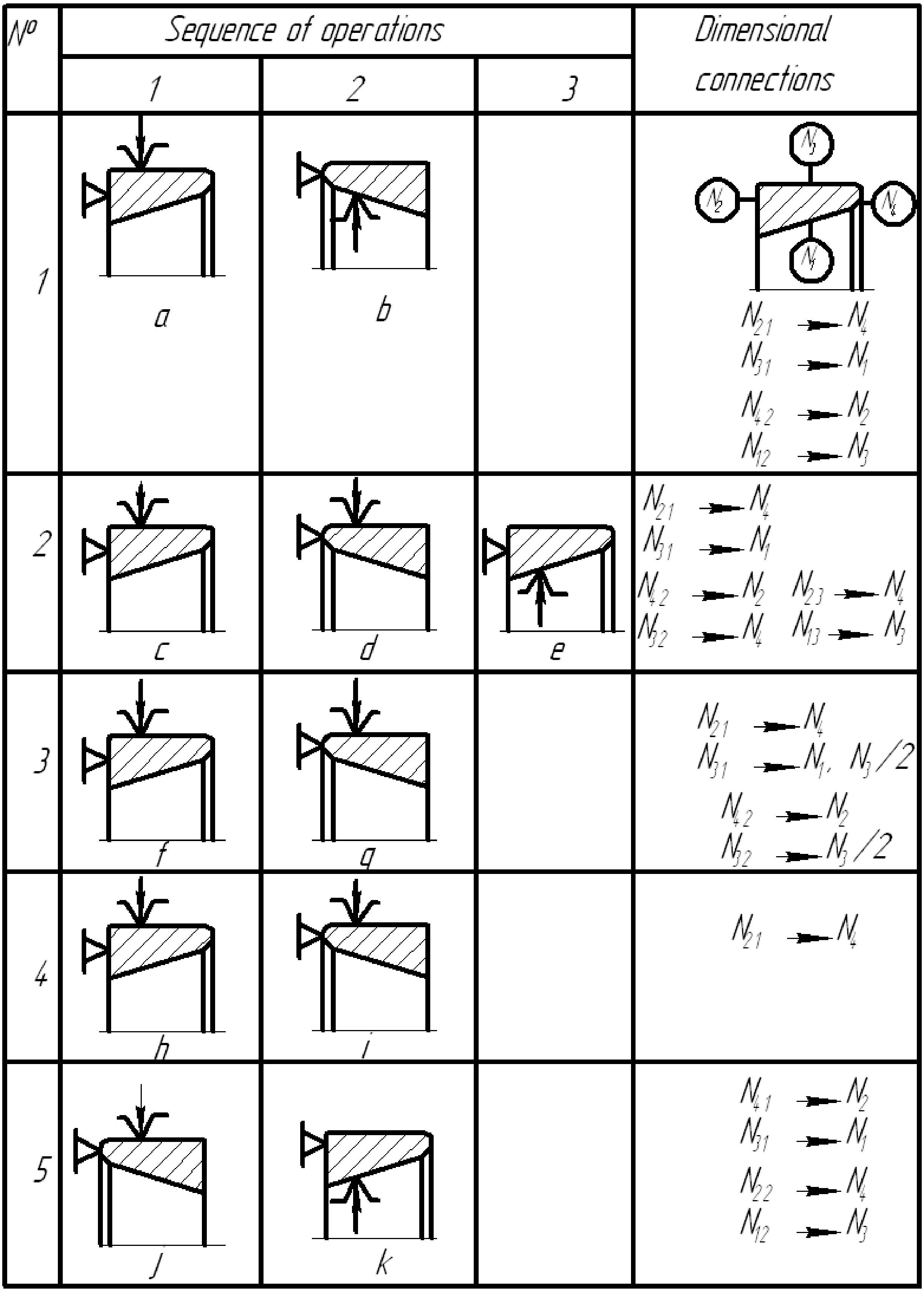


Figure 1.3 - Schemes of rings turning technological processes when the external surface and end face are used as a locating elements for the first operation

However, it also does not reduce the complexity of rings manufacturing due to the presence of an additional operation – rough grinding of the external surface.

Currently, the location of the rings on the first operation on the external surface with support on the wide end face is used only in the machining of the workpieces of rings from low-carbon cemented steels produced by cold stamping. In this case, the role of turning is limited to cutting the narrow end face to ensure the width size of the ring and turning the chamfers from the narrow end face. In the second operation, only the chamfers of the wide end face are turned (Fig. 1.5 variant 4). The remaining surfaces are made with an allowance for grinding and not subjected to turning.

The scheme of technological process of turning with the use of an external surface and a narrow end face as locating element on the first operation is presented in fig. 1.5 variant 5. This machining scheme is used, for example, in the plants of the company "Pittler" (Germany).

The main disadvantage of this process is the following. During rings production by pressure forming, the excess metal, which occurs due to the displacement of the stamped semi-finished products, changes in temperature and other factors, passes to the narrow end face. Therefore, the narrow end face, in contrast to the wide, is poorly formed and is as a plane only conditionally.

It is determined that when locating the rings on the external surface with support on the narrow end face, the amount of increase in width within the tolerance on the workpiece after stamping causes the need to increase the allowance for processing the cone surface. The magnitude of the increase in allowance for the diameter of the cone surface Δ is determined by:

$$\Delta = 2\Delta C tg\alpha, \qquad (1.1)$$

where ΔC - the tolerance on the width of the workpiece.

The value of ΔC for rings with a diameter of 50 to 180 mm, depending on the method of the workpiece production is in the range: ΔC = 1.5 ... 3.5 mm. Therefore, for rings with angle $\alpha = 10..\ 30^0$ the value of Δ = 0.53 ... 4.04 mm.

It should be taken in account that the locating of the ring on such end face leads to the decrease in the accuracy of the rings orientation during location and, as a consequence, to the appointment of the increased allowances for machining of the external surface and end face.

Schemes of rings turning technological processes at use of a conical surface as locating element on the first operation and one of end faces are presented in fig. 1.4.

The locating scheme on the internal conical surface with support on the narrow end face (Fig. 1.4 variant 1) is similar to the scheme (Fig. 1.1 b). Its main disadvantage is the unreliability of the clamping, which does not allow the use of this scheme for turning of the rings.

Difficulties associated with clamping of the rings on the internal conical surface with support on the narrow end face, necessitated the introduction solely for technological reasons, the internal cylindrical collar from the wide end face, which serves as an artificial technological locating element on which the rings were installed (Fig. 1.4 c, d).

Well-known designs of three-jaw self-centering chucks of wedge or lever type of a design with replaceable jaws were used for clamping of rings.

At the same time on multi-spindle machines turning was made according to the scheme (Fig. 1.4 variant 2), and on single-spindle machines according to the scheme (Fig. 1.4 variant 3).

The obvious disadvantages of this technology are: low utilization of metal due to the introduction of a cylindrical collar, significant radial runout of the clamping elements due to the multi-link dimensional chain of the chuck mechanism, their limited radial movement and low stiffness of the clamping due to the cantilever arrangement of the clamping elements caused the search for more efficient locating methods.

The technological process was designed in which the clamping of the rings on the first turning operations was made on the internal conical surface with the support on the wide end face (Fig. 1.4 variant 4).

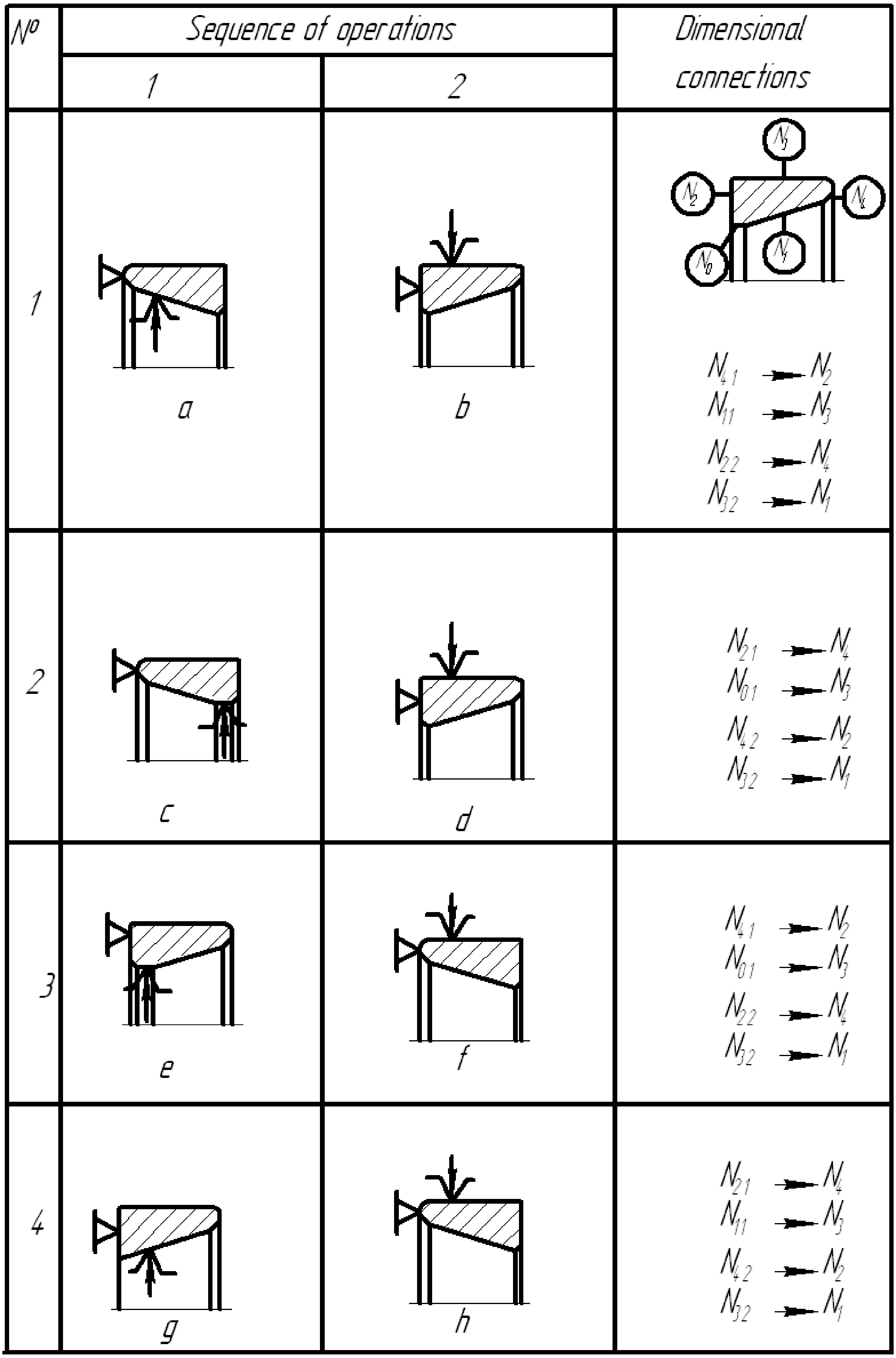


Figure 1.4 – The schemes of rings turning technological processes when the conical surface and end face are used as the locating elements for the first operation

[26]

Chucks of new design are used as a means of clamping, fundamentally different from the chucks of previous designs. One of the distinctive features of these chucks is the ability to self-install the clamping elements due to the difference in the radii of the contact surfaces of the rod and jaws, as well as the presence of gaps in the slots for jaws.

Self-installation of the clamping elements helped to increase the accuracy and reliability of the location, which together with increasing the stiffness of the clamping and increasing the radial stroke of the clamping elements eliminated the artificial technological locating element in the form of an internal cylindrical collar and thus reduce metal costs for rings production.

With the use of jaw chucks in the first operation is turning the external surface, cutting the narrow end face and turning chamfers from the narrow end face (Fig. 1.4. g). In the second operation, the ring is clamped in the collet chuck on the external surface with support on the narrow end face. At the same time the cone surface is bored, the wide end face is cut and chamfers from the wide end face are formed (fig. 1.6 h).

The scheme of turning technological process is considered, at which clamping of rings on the first operation is made in jaw chucks on the cone surface with the support on the wide end face, and on the second operation - in the collet chucks on the external surface with the support on the narrow end face, has received the widest distribution at factories.

However, this technological process also has significant disadvantages, which result in increased metal costs for the manufacture of rings, reducing the accuracy of turning, increasing the complexity of subsequent grinding operations.

1.2. Conclusions and tasks for the qualification work of the master

The specifics of the rings production, characterized by a great variety of structural forms, requirements for precision, dimensional and geometric accuracy, necessitate the allocation of rings in an independent class of machine parts and a special approach to solving problems aimed at improving their manufacturing processes.

The emergence of advanced methods of workpieces production allows the new rethinking of the purpose of certain surfaces of the rings as technological locating elements, especially in the conditions of automated production.

The issues of increasing the efficiency of rings turning from single workpieces on the basis of development of optimal methods of location and designs of clamping chucks are also considered. At the same time, special attention is paid to the improvement of technological processes of rings turning from workpieces produced by precise methods.

Various schemes of new technological processes of rings turning with use of new methods of location and rational designs of clamping chucks are offered.

The novelty of the proposed technical solutions is that the conical surface of the ring is used as the main technological locating element. This allows to increase the efficiency of turning, reduce the complexity of further grinding operations, reduce the consumption of metal for the rings manufacturing.

The aim of the work is to develop technological processes and highly effective methods of location and means of rings clamping on the basis of theoretical and experimental studies, providing increase of accuracy and productivity of turning, reduction of metal consumption during rings manufacturing.

It is also necessary to improve the existing technological process of the ring ZhYTsD 712442.021 production.

2 SCIENTIFIC AND RESEARCH PART

2.1. The influence of the locating element choice on the volume of metal removed

Technological locating element in the first operation can be both external and internal surface, depending on the adopted locating scheme when machining single workpieces. The workpiece is supported on the end face to fix its position in the axial direction.

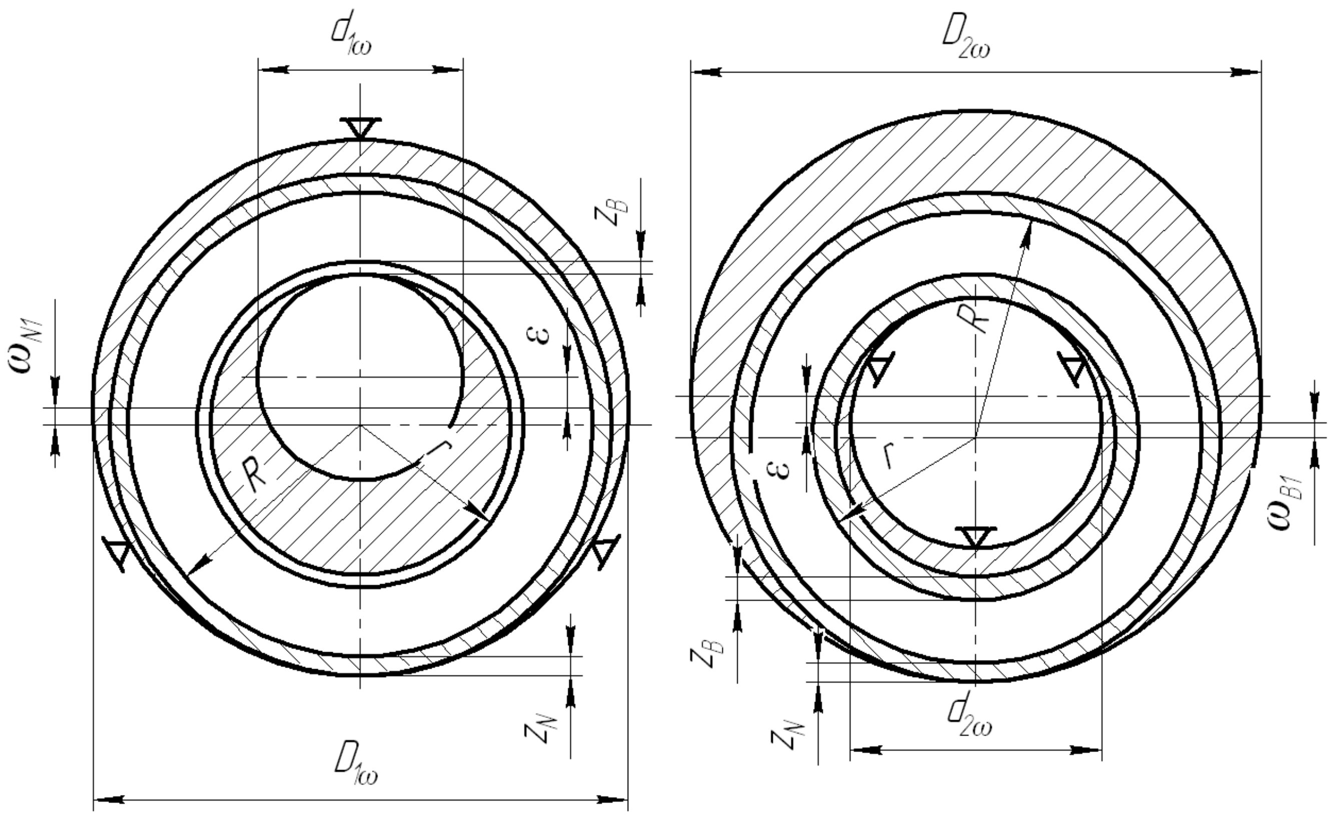
From the economy of metal point of view under all other equal conditions it is more favorable on the first operation to locate the workpiece on an external surface. This statement, which at first glance has no doubt, becomes widespread in the technical literature.

It should be noted, however, that this conclusion was made on the assumption that the clamping fixtures in which the workpieces are located and fixed, provide absolutely accurate centering, ie the installation error in both cases is 0. In real production conditions, as a rule, always has place of installation error, which is usually not taken into account when choosing a more economical method of locating.

The accuracy of the workpieces centering is affected by a set of geometric parameters, such as the shape error of the workpieces locating surfaces, the distance from the clamping elements of the chuck to its axis, inaccurate installation and mounting of the chuck, etc., and dynamic, manifested in the form of elastic deformations in the parts of fixtures and joints between them, as well as the workpiece deformation under the action of clamping and cutting forces.

The combination of these factors leads to the fact that the center 0 of the locating surface of the workpiece is displaced relative to the axis of rotation of the chuck by ω (Fig. 2.1). It is necessary to increase the estimated allowance by the 2ω to compensate this offset.

The largest installation error occurs, as a rule, when locating and clamping of the parts on not machined locating surfaces. Consequently, the allowance, depending on the accuracy of the installation in the first operation can be a decisive factor, especially in the development of the machining technological process of workpieces obtained by precise methods, in which turning is minimized.



a) b)

Figure 2.1 – The scheme for determining the volume of cut metal, taking into account the error of the rings installation in the first operation: a) on the external surface, b) on the internal surface [26]

Taking into account this important circumstance, it becomes clear the need to define clear criteria that can justify in terms of metal saving the choice of main technological locating elements in the first turning operation, taking into account the presence of installation error on the not machined surface.

The schemes of the workpieces location which are presented in Fig. 2.1. are considered in order to determine the required dependence. Thus the error of installation on the machined surface in the second operation is insignificant and is not considered.

It should be noted that in the general case, the total error caused by spatial deviations and installation error is the vector sum of these values. The separate, most favorable case of vector summation of these errors, which may occur during the installation process and which must be taken into account when determining the allowances for machining is shown in fig. 2.1.

In the fig. 2.1, a the external surface is used as the locating element for the first operation, and in the fig. 2.1, b the internal surface is used. From the first scheme it is received:

$$d_{1\omega} = 2(r - z_B - \varepsilon - \omega_{N1});$$

$$D_{1\omega} = 2(R + z_N + \omega_{N1});$$

From the second scheme

$$d_{2\omega} = 2(r - z_B - \omega_{B1});$$

$$D_{2\omega} = 2(R + z_N + \varepsilon + \omega_{B1}),$$

where $D_{1\omega}$, $D_{2\omega}$, $d_{1\omega}$, $d_{2\omega}$ - the minimal diameters of the external surface and maximal diameters of the internal surface of the workpiece, determined from the locating conditions on the first operation , taking into account the error of installation; ω_{N1}, ω_{N2} - the maximal errors of installation arising at the workpiece location on the first operation on external and internal surfaces accordingly.

The difference in the volume of cut metal will be affected by the amount of eccentric allowance cut. However, if there is an installation error, the eccentric allowance will be cut from both surfaces.

The volume of the eccentric allowance according to the scheme in the fig. 2.1, a is equal to:

$$V_{\varepsilon N} = 2\pi c\left(\frac{\varepsilon^2}{2} + r\varepsilon + r\omega_{N1} - z_B\varepsilon - z_B\omega_{N1} - \varepsilon\omega_{N1} + R\omega_{N1} + z_N\omega_{N1}\right), \qquad (2.1)$$

according to the scheme in the fig. 2.1, b:

$$V_{\varepsilon B}=2\pi c\left(\frac{\varepsilon^2}{2}+R\varepsilon+R\omega_{B1}+z_N\varepsilon+z_N\omega_{B1}+\varepsilon\omega_{B1}+r\omega_{B1}-z_B\omega_{B1}\right). \qquad (2.2)$$

From the analysis of equations (2.1) and (2.2) the conclusion can be made that if the condition $\omega_{B1}\geq\omega_{N1}$ is real, the lower metal consumption is provided when the external surface is used as the locating element on the first operation.

If $\omega_{B1}<\omega_{N1}$, then it is impossible to unambiguously solve the problem, as there are three possible cases that determine the feasibility of the workpiece locating on the first operation on the external or internal surface in terms of the metal saving:

It is more profitable to locate on the external surface. In this case $V_{\varepsilon N}<V_{\varepsilon B}$.

2. It does not matter which of the surfaces (external or internal) is accepted as the locating element. In this case $V_{\varepsilon N}=V_{\varepsilon B}$.

It is more profitable to locate on the internal surface. In this case $V_{\varepsilon N}>V_{\varepsilon B}$.

The critical for evaluating the choice of locating element is the second case, for which it is necessary to

$$\omega_{N1}=A\omega_{B1}+B, \qquad (2.3)$$

where

$$A=\frac{R+r+z_N-z_B+\varepsilon}{R+r+z_N-z_B-\varepsilon}; \qquad (2.4)$$

$$B=\frac{\varepsilon^2+\varepsilon\left(R-r+z_N+z_B\right)}{R+r+z_N-z_B-\varepsilon}. \qquad (2.5)$$

Taking into account that $2r=d$, $2R=D$, $R-r=S_{\max}$ and that, as a rule $z_N=z_B=z_k$ equations for coefficients A i B can be converted to the following view:

$$A=\frac{D+d+2\varepsilon}{D+d-2\varepsilon}; \qquad (2.6)$$

$$B=\frac{2\left(\varepsilon^2+\varepsilon\left(S_{\max}+2z_k\right)\right)}{D+d-2\varepsilon}, \qquad (2.7)$$

where D i d - respectively, the maximal outer and the minimal inner diameter of the part after turning according to the operational drawing,

$S_{\max}$ - the maximal wall thickness of the part after turning.

If $\omega_{N1} > A\omega_{B1} + B$, then less metal consumption is provided during location on the first operation from the inside, if $\omega_{N1} < A\omega_{B1} + B$, then from the outside.

From equations (2.6 and 2.7) it follows that for most dimensional and geometric parameters of the rings the value $A \approx 1$, and the main influence on the value of the coefficient B with constant parameters of the part has the value ε.

The graph in fig. 2.2 showing the impact ε on the feasibility of the locating on the first operation of a particular ring with R=50mm, r=40mm, z_B= z_N=0.5mm, ε=0.5 mm and ε=1.0mm.

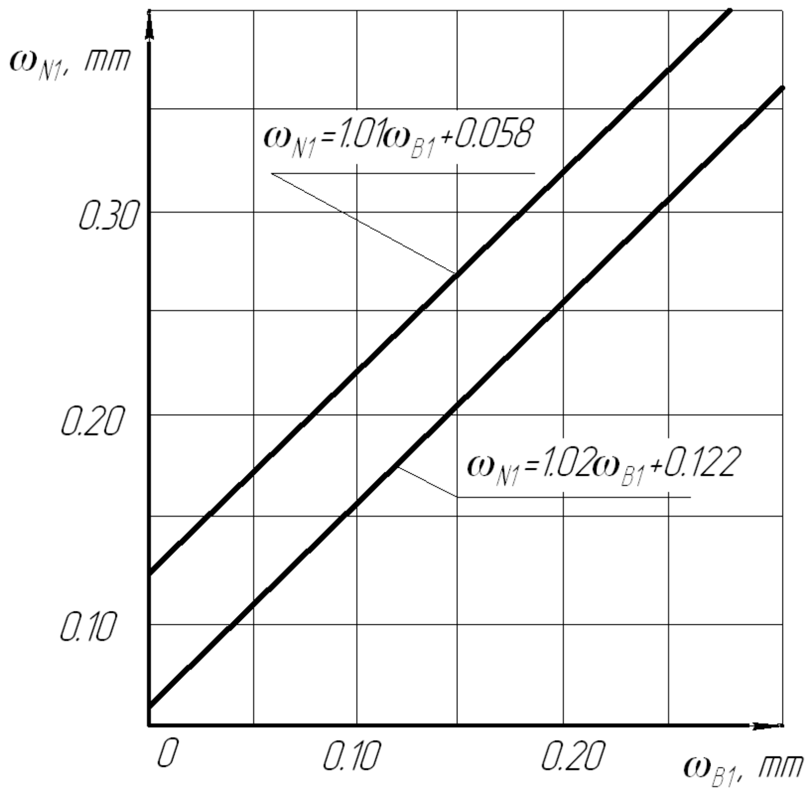


Figure 2.2 – The graph, which determines the feasibility of locating element choosing for the first turning operation [26]

These values of z_B, z_N, ε are the most characteristic for the workpieces of the rings to be turned on the main surfaces.

In the graph, the range of installation error ω_{N1} that is above the line with ε corresponds to the condition of more economical consumption of metal during it location in the first operation on the internal surface, and below the line - on the external surface.

For example, if at ε=0.5 mm the installation error is $\omega_{B1} = 0.20$ mm, it is more advantageous to locate in the first operation on the internal surface in the case when the installation error is $\omega_{N1} > 0.26$ mm. If $\omega_{N1} < 0.26$ it is more expedient to locate on the external surface.

2.2. Experimental studies of the ring cylindrical surface radial runout after turning

The experimental studies of the ring cylindrical surface radial runout after turning included the following stages:

1. Selection of equipment, workpieces and cutters for turning the ring surface.
2. Realization of experimental researches on the chosen equipment for establishment and the subsequent forecasting of the radial runout dimension of the ring cylindrical surface after turning of workpieces from steel 45 depending on change of three main factors: depth of cut by one cutter, feed rate of the cutter and cutting speed.

Standard carbide cutters were used for turning. The rings were clamped in the expansion jaw chuck. The values of the radial runout of the ring cylindrical surface were measured after turning by clock-type indicator with part location on the internal cylindrical surface and rotation in the special control device. The measurement results were subjected to statistical processing.

To determine the influence of cutting conditions (independent factors x_i) on the values of radial runout (optimization parameter δR) of the ring cylindrical surface after turning, full-factor experiments were performed, ie establishing the value of radial runout of cylindrical surfaces from three main variables: depth of cut t, feed rate *S* and cutting speed *V*, ie $\delta R = f(t, S, V)$.

The experiment with the same factors was repeated three times to determine the dispersion of the obtained data.

The response function, ie the radial runout magnitude of the ring cylindrical surface after turning δR = f(*t,S,V*), determined experimentally, is represented as a quadratic polynomial. Table 2.1 presents the results of independent factors coding.

Variable factors of the experiment were adopted:

- the depth of cut by one cutter *t*, which is encoded by the index x_1;
- the feed rate of the cutter *S*, which is encoded by the index x_2;
- the cutting speed V, which is encoded by the index x_3.

During the experiments, significant random errors in the research were eliminated, followed by statistical processing of the experimental results using a package of applications.

In table 2.2. numerical values of regression coefficients determined after statistical data processing according to known algorithms are presented.

Table 2.1 - The results of factors coding in the study of the radial runout magnitude of the ring cylindrical surface the after turning

Variable factors	Appellation		Interval variation	Levels of variation, natural (coded)		
	natural	Cod.				
Depth of cut by one cutter	*t*, mm	x_1	0.4	0.2 (-1)	0.6 (0)	1.0 (+1)
Feed rate of the cutter *S*	*S*, mm/rev	x_2	0.2	0.1 (-1)	0.3 (0)	0.5 (+1)
Cutting speed	*V*, m/min	x_3	20	70 (-1)	90 (0)	110 (+1)

Table 2.2 - Values of the established coefficients of the regression equation

Coeff.	b_0	b_1	b_2	b_3	b_{12}	b_{13}	b_{23}	b_{11}	b_{22}	b_{33}
Steel 45	0.03	0.0065	0.0059	$-8.4\cdot10^{-4}$	0.0014	-0.00019	-0.00019	-0.0017	-0.00054	0.000094

The general form of the regression equation of the radial runout of the ring cylindrical surface after turning depending on the change: the depth of cut by one cutter t, the feed rate of the cutter S and the cutting speed V, ie the results of experiments in coded values is:

- when turning rings from steel 45:

$$\delta_{(x_1,x_2,x_3)} = 0.03 + 6.5\cdot 10^{-3} x_1 + 5.9\cdot 10^{-3} x_2 - 8.4\cdot 10^{-4} x_3 + 0.0014 x_1 x_2 - \\ -1.9\cdot 10^{-4} x_1 x_3 - 1.9\cdot 10^{-4} x_2 x_3 - 1.7\cdot 10^{-3} x_1^2 - 5.4\cdot 10^{-4} x_2^2 + 9.4\cdot 10^{-5} x_3^2. \quad (2.8)$$

where x_1 - the coded value of the depth of cut by one cutter; x_2 - the coded value of the feed rate of the cutter; x_3 - the coded value of cutting speed.

The coefficient of the regression equation (2.16) b_{33} is insignificant.

In natural values, the regression equation (2.16) is presented as follows:

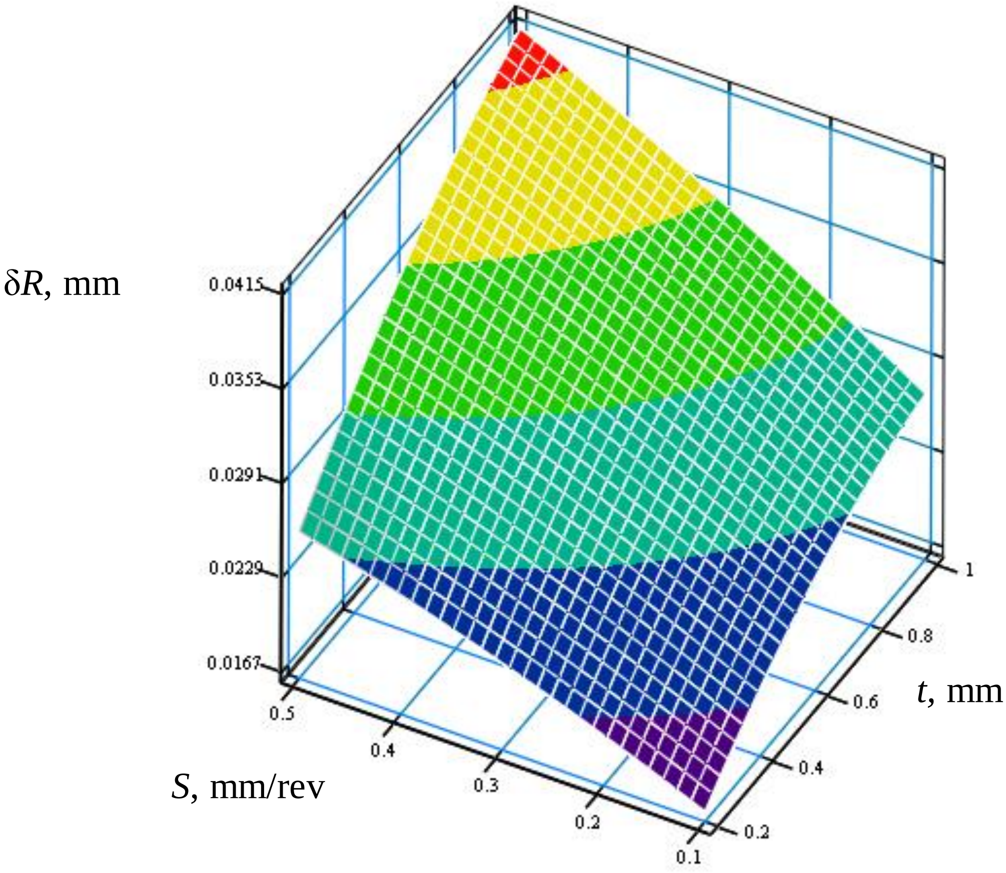
- when turning rings from steel 45:

$$\delta_{(t,s,V)} = 0.011 + 0.026t + 0.032s - 1.35\cdot 10^{-5} V + 0.018ts - \\ -2.38\cdot 10^{-5} tV - 4.75\cdot 10^{-5} sV - 0.011t^2 - 0.014s^2. \quad (2.9)$$

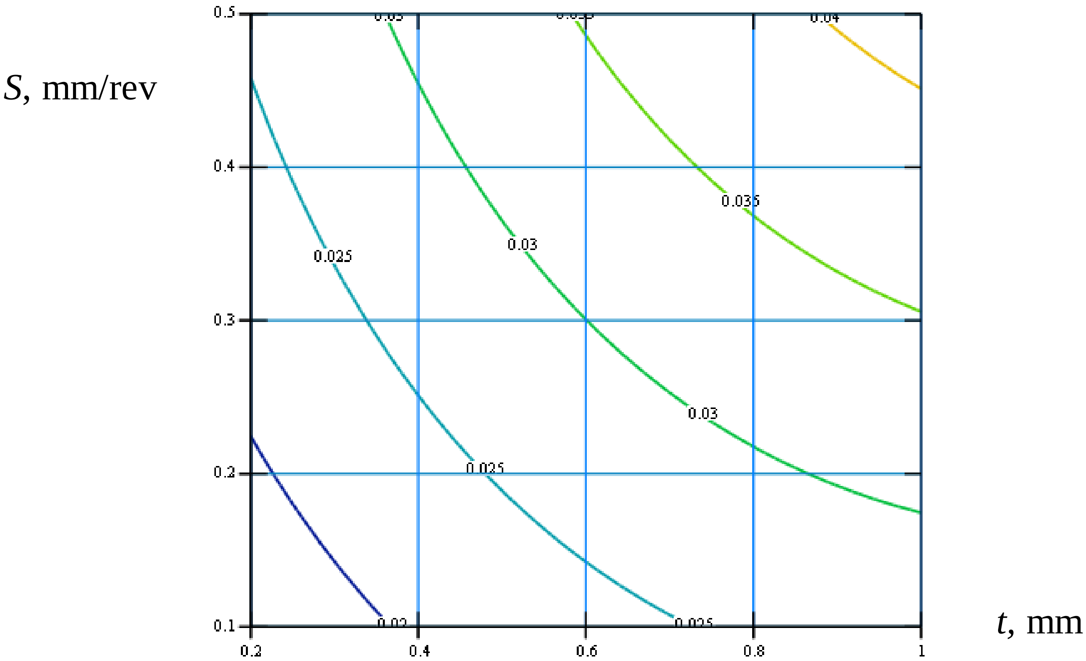
The obtained regression equations (2.16) and (2.17) can be used to predict the magnitude of the radial runout of the ring cylindrical surface after turning depending on the depth of cut by one cutter t, the feed rate of the cutter S and the cutting speed V within the following variable initial factors:

$0.1 \le t \le 0.8$ (mm); $0.1 \le S \le 0.4$ (mm/rev); $100 \le V \le 200$ (m/min).

Graphical results of the radial runout δR value of the ring cylindrical surface after turning, obtained using a package of applications, are presented in Figures 2.4 - 2.8.

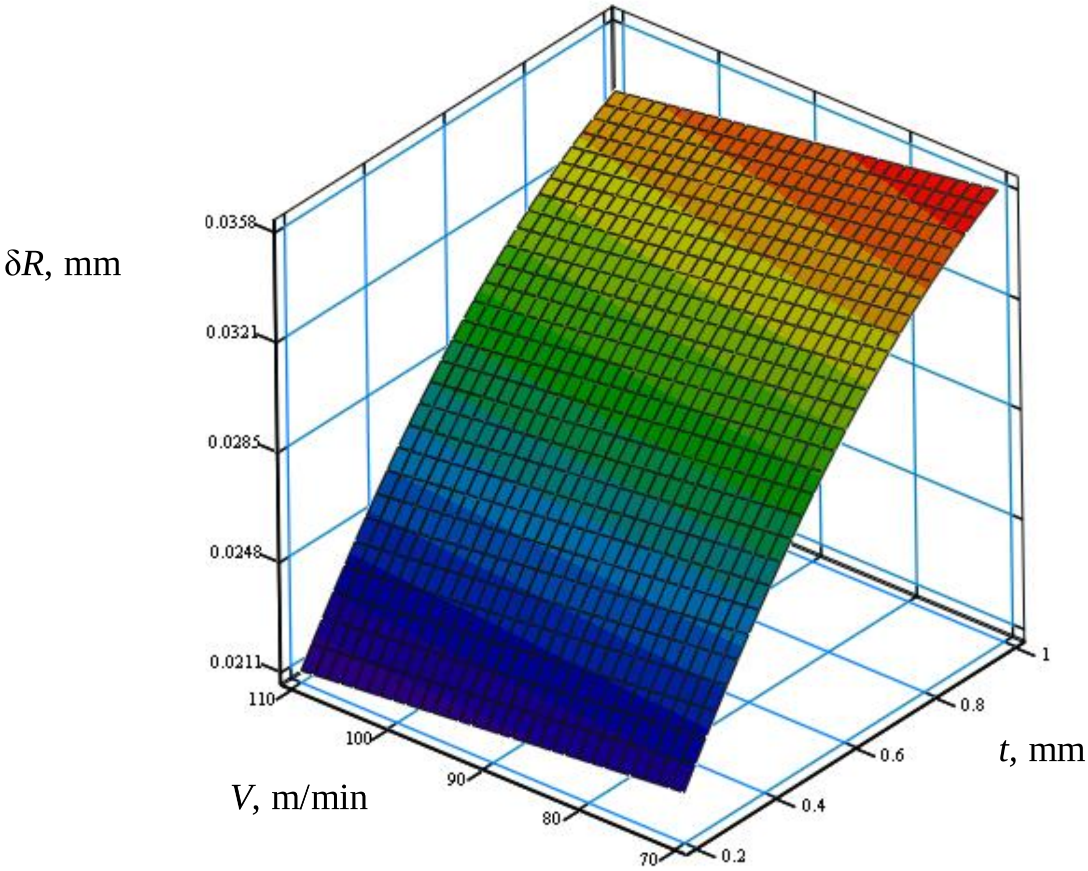


a)

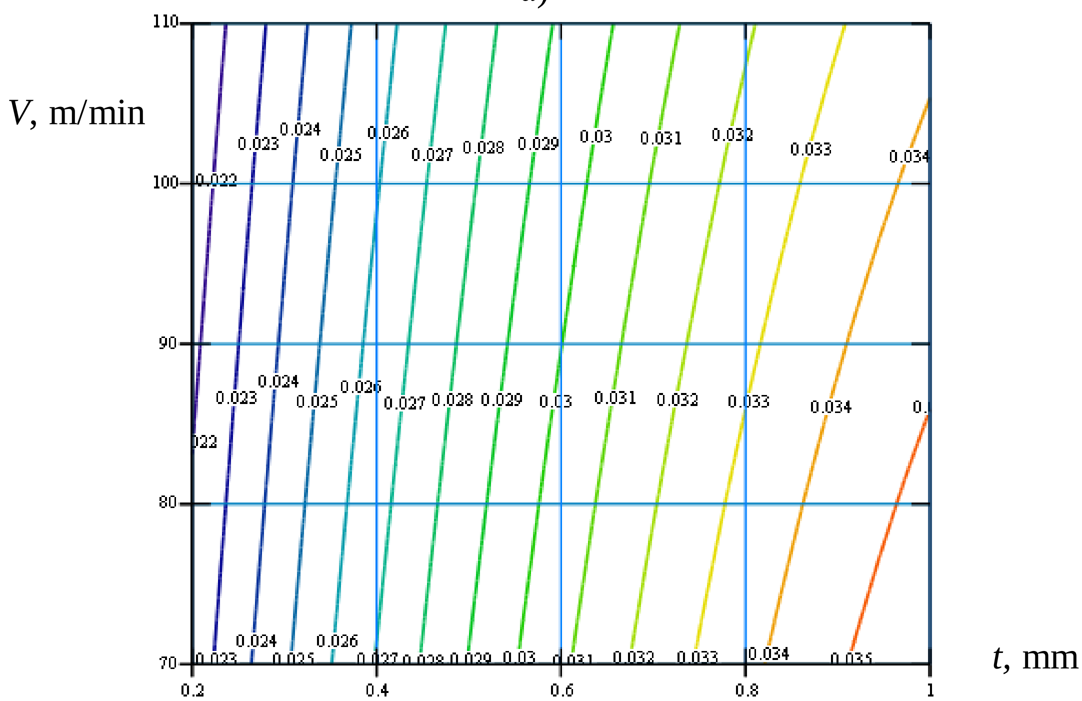


b)

Figure 2.4 – The response surface (a) and two-dimensional cross-section of the response surface (b) dependence of the radial ranout value δR of the ring cylindrical surface after turning from the depth of cut by one cutter *t* and the feed rate of the cutter *S* (*V* = 90 m/min)

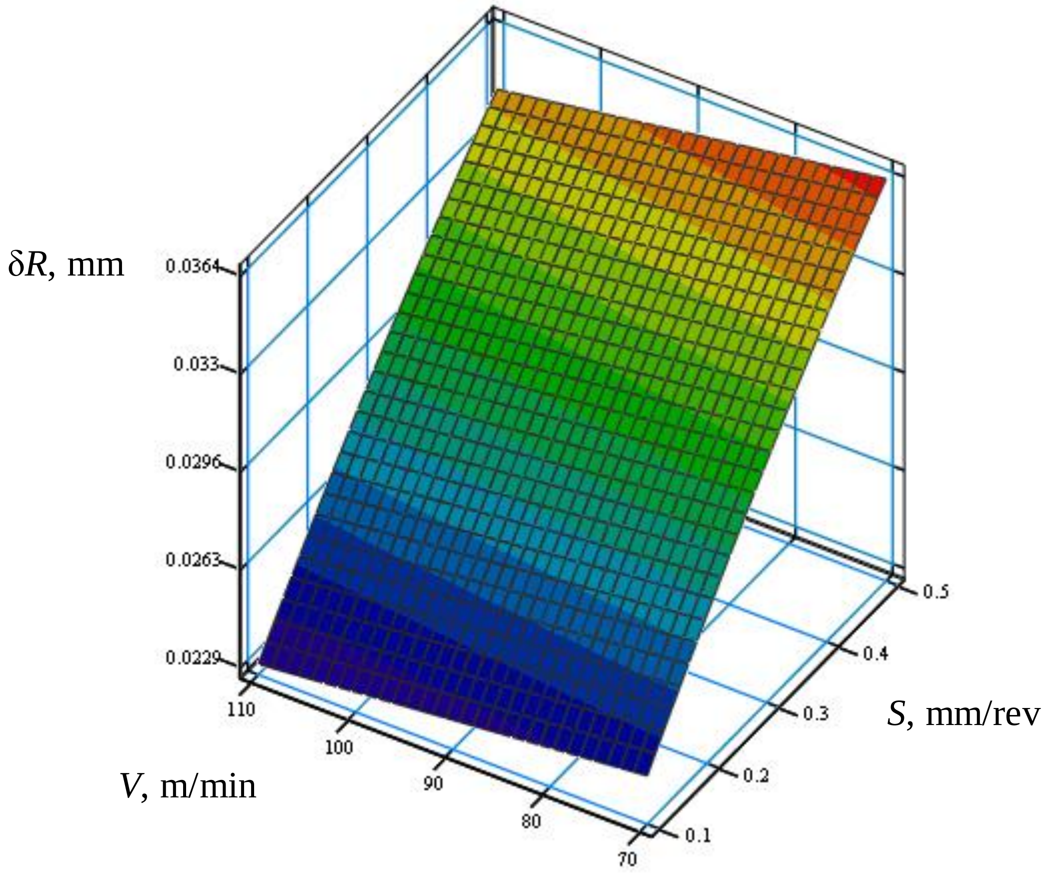


a)

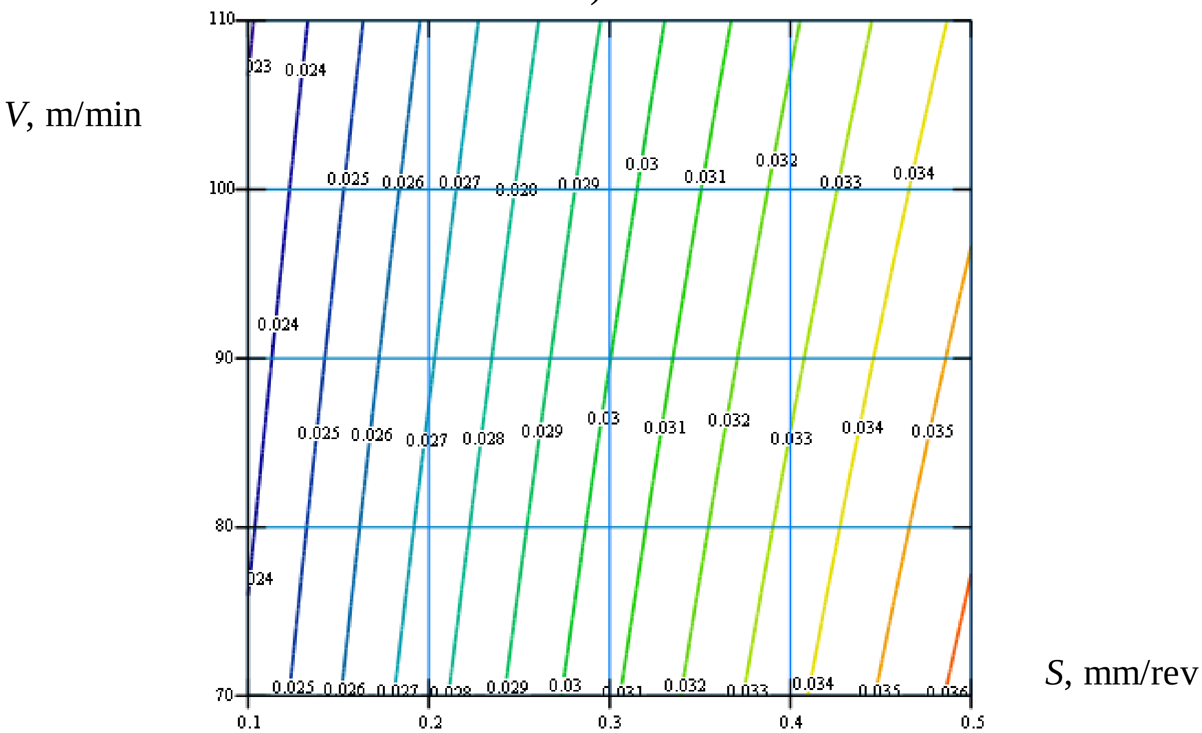


b)

Figure 2.5 – The response surface (a) and two-dimensional cross-section of the response surface (b) dependence of the radial ranout value δR of the ring cylindrical surface after turning from the depth of cut by one cutter *t* and the cutting speed *V* (*S* =0.25 mm/rev)



a)



b)

Figure 2.6 – The response surface (a) and two-dimensional cross-section of the response surface (b) dependence of the radial ranout value δR of the ring cylindrical surface after turning from the feed rate of the cutter *S* and the cutting speed *V* (*t* =0.45 mm)

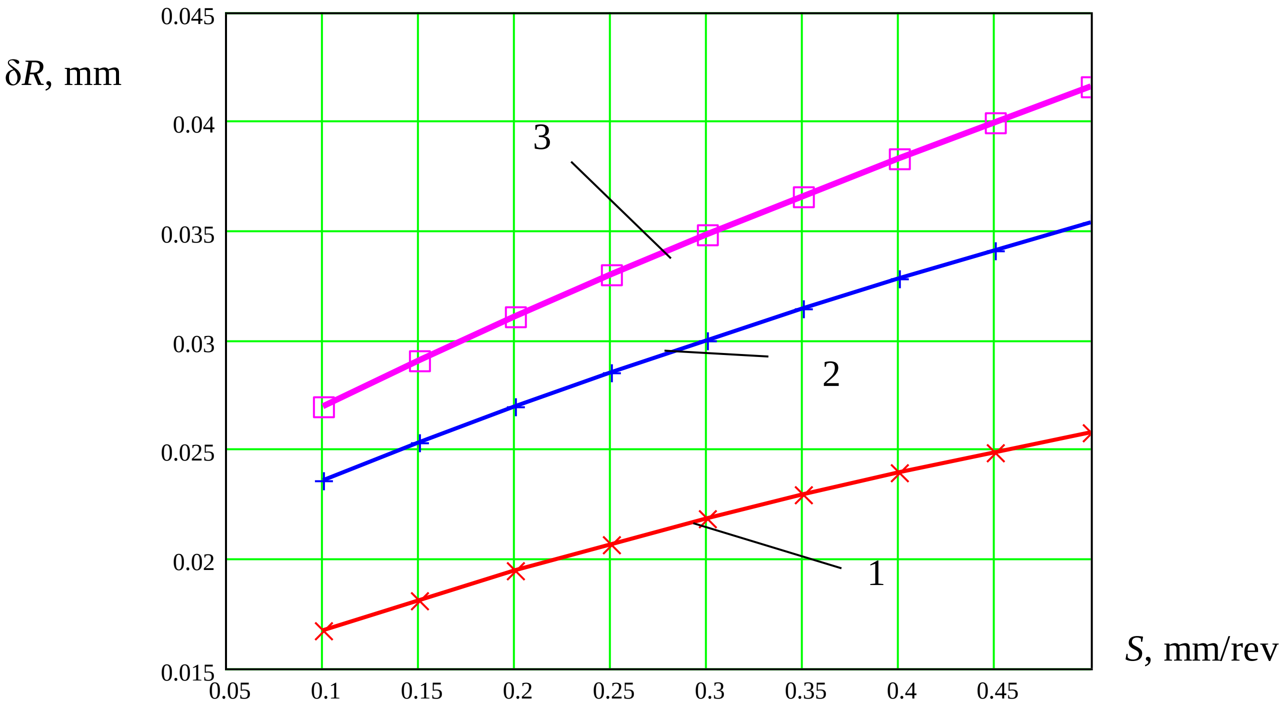


Figure 2.7 - Graphs of the radial runout δR of the ring cylindrical surface after turning from the feed rate of the cutter *S*, *V*=90 m/min:

1) *t*=0.2 mm; 2) *t*=0.6 mm; 3) *t*=1.0 mm

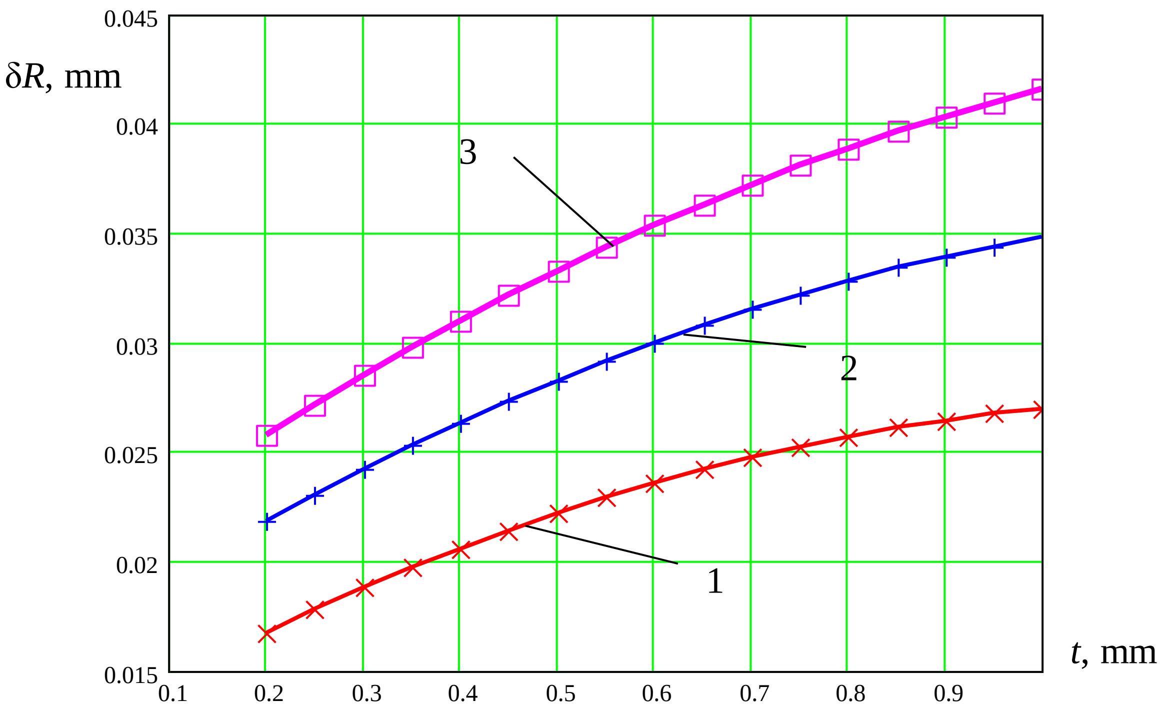


Figure 2.8 - Graphs of the radial runout δR of the ring cylindrical surface after turning from the depth of cut by one cutter *t*, *V*=90 m/min:

1) *S*=0.1 mm/rev; 2) *S*=0.3 mm/rev; 3) *S*=0.5 mm/rev

From Figures 2.4 - 2.8, and on the basis of regression equation (2.17) it is found that with increasing of the depth of cut by one cutter *t* value, feed rate of the cutter *S* value, the value of radial runout δR of the cylindrical surface of the ring increases after turning, and with increasing cutting speed *V* - decreases.

The maximum value of the radial runout δR of the ring cylindrical surface from steel 45 is 0.115 mm, and the minimum is 0.025 mm. Increasing of the depth of cut by a one cutter *t* from 0.2 mm to 1.0 mm leads to the increasing of the radial runout of the cylindrical surface by 1.7 times.

Also, increasing of the feed rate of the cutter *S* from 0.1 mm/rev to 0.5 mm/rev increases the radial runout of the cylindrical surface by 1.5 times, and increasing of the cutting speed *V* from 70 to 110 m/min reduces the radial runout of the cylindrical surface by 1.08 times.

Therefore, to ensure lower radial runout, the surface of the ring must be turned at smaller depths of cut and feed rates.

2.3. Conclusions

The expediency of the workpiece locating on the first operation on the external or internal surface in terms of metal saving, taking into account the errors of installation of workpieces in the chucks is considered.

During experimental research it is found that with increasing of the depth of cut by one cutter *t* value, feed rate of the cutter *S* value, the value of radial runout δR of the cylindrical surface of the ring increases after turning, and with increasing cutting speed *V* - decreases.

The maximum value of the radial runout δR of the ring cylindrical surface from steel 45 is 0.115 mm, and the minimum is 0.025 mm. Increasing the depth of cut by a one cutter *t* from 0.2 mm to 1.0 mm leads to an increasing in the radial runout of the cylindrical surface by 1.7 times.

Also, increasing of the feed rate of the cutter *S* from 0.1 mm/rev to 0.5 mm/rev increases the radial runout of the cylindrical surface by 1.5 times, and increasing of the cutting speed *V* from 70 to 110 m/min reduces the radial runout of the cylindrical surface by 1.08 times.

Therefore, to ensure lower radial runout, the surface of the ring must be turned at smaller depths of cut and feed rates.

3 TECHNOLOGICAL AND DESIGN PART

3.1. Official purpose of the part

The part “Ring” ZhYTsD 712442.021 is a part of the explosion-proof lamp intended for the general lighting of explosive zones in rooms and external installations of oil refining, gas, chemical, and other industries.

The part “Ring” ZhYTsD 712442.021 is used for connection of a glass diffuser and fastening to the lamp case, in which the electric elements of the lamp are placed.

The main surfaces of the part that are important in its application include the following surfaces: internal cylindrical surface $\varnothing 188H9(^{+0.115})$; Ra2.4, which is designed to install a glass diffuser; end face $70h14(_{-0.74})$; Ra12.4 is designed for precise positioning with housing and diffuser; end face 28 ± 0.2; Ra12.4 is designed for precise positioning with the case; external threaded surface M130×2-8g; Ra6.3 - for fastening of the case; threaded hole M6-7H; Ra6.3 - to attach the lock that connects the case to the ring.

The remaining surfaces are considered as auxiliary and secondary.

The part “Ring” ZhYTsD 712442.021 is made from aluminum alloy AK12 (according to the data taken from the drawing of the part).

The chemical composition, mechanical properties of the aluminum alloy AK12 are presented in the following tables [3].

Table 3.1 - Chemical composition of aluminum alloy AK12, %

Aluminium	Silicon	Calcium	Titan	Copper	Zinc	Magne-sium	Zirconium
		not more					
The main	10-13	0.08	0.1	0.6	0.3	0.1	0.1

Table 3.2 - Mechanical properties of alloy AK12

Casting method	Thermal treatment	Density, ρ, g/sm^3	σ_p, MPa	Relative lengthening, %	Hardness, HB
in metal molds	–	2.55-2.6	157	2.0	50
die casting	–		157	1.0	50
in metal molds	Annealing		147	3.0	50
die casting	Annealing		147	2.0	50

3.2. The analysis of technical requirements for the part

After a detailed study of the drawing of the part, dimensional accuracy, surface roughness, their relative position and shape accuracy, each of the surfaces is assigned serial numbers and analysis of technical requirements set by the designer, which is presented in the table 3.3.

Table 3.3 - Analysis of technical requirements

Surface number	Surface name	Surface finish	Surfaces roughness
1	2	3	4
1, 11	End face 70h14($_{-0.74}$)	14	Ra12.4
2	Internal chamfer 3×45°	14	Ra12.4
3	Internal cylindrical surface ∅117H14($^{+0,87}$)	14	Ra12.4
4	External cylindrical surface ∅127h14($_{-1.0}$)	14	Ra12.4
5	External thread M130×2-8g	12	Ra6.3
6	External groove 5$^{+0.3;}$ 45°; ∅127h14($_{-1.0}$)	14	Ra12.4
7	End face 28±0.2	14	Ra12.4
8	Hole ∅4.95$^{+0.3}$ for thread M6-7H	14	Ra12.4
9	Internal chamfer 1×45°	14	Ra12.4
10	Internal thread M6-7H; 10 min	12	Ra6.3
12	Internal cylindrical surface ∅188H9($^{+0,115}$)	9	Ra2.4
13	Internal end face 6±0.1	14	Ra6.3

Continuation of table 3.3

1	2	3	4
14	Internal chamfer $\varnothing 132H14(^{+1.0})$; 45°	14	Ra12.4
15...18	Four holes $\varnothing 6H14(^{+0.3})$; $\varnothing 176 \pm 0.1$	14	Ra12.4
19	Hole $\varnothing 5H14(^{+0.3})$	14	Ra12.4
20	External cylindrical surface $\varnothing 129.8h11(_{-0.25})$ for thread M130×2-8g	11	Ra6.3

3.3. The type of production determining

The type of production is determined on the basis of the task, the annual program of production N = 20000 pcs. and part's "Ring" ZhYTsD 712442.021 mass m = 0.66 kg from standard tables, and on the basis of these data the type of production is the middle lot production.

The type of production is determined by the coefficient of operations assignment [1]:

$$K_{з.о.} = \frac{\sum O}{\sum P}, \tag{3.1}$$

where ΣO – the total number of operations on the shop department;

ΣP – the total number of working stations on the shop department.

The data of the basic technological process are recorded in the table 3.4.

Table 3.4– Staff time of the basic technological process

Operation	Tp (Tcal) min.	Operation	Tp (Tcal) min.
005 Turret turning	1.44	025 Vertical drilling	0.33
010 Turret turning	1.82	030 Vertical drilling	0.58
015 Vertical drilling	0.38	035 Threading	0.42
020 Vertical drilling	0.36		

The number of machines for each operation according to [1] is determined:

$$m_p = \frac{N \cdot T_p}{60 \cdot F_д \cdot \eta_{зн}}, \tag{3.2}$$

where N – annual program of production, pcs. N = 20000 pcs., $F_д$=3979 hours for two shifts, $\eta_{з.н.}$=0.75 for lot type of production.

After determining the number of machines for each operation m_p, the number of workplaces P as integers is determined

$$m_{p005} = \frac{20000 \cdot 1.44}{60 \cdot 3979 \cdot 0.75} = 0.16.\ P_{005} = 1 \text{ machine tool.}$$

$$m_{p010} = \frac{20000 \cdot 1.82}{60 \cdot 3979 \cdot 0.75} = 0.2.\ P_{010} = 1 \text{ machine tool.}$$

$$m_{p015} = \frac{20000 \cdot 0.38}{60 \cdot 3979 \cdot 0.75} = 0.04.\ P_{015} = 1 \text{ machine tool.}$$

$$m_{p020} = \frac{20000 \cdot 0.36}{60 \cdot 3979 \cdot 0.75} = 0.04.\ P_{020} = 1 \text{ machine tool.}$$

$$m_{p025} = \frac{20000 \cdot 0.33}{60 \cdot 3979 \cdot 0.75} = 0.036.\ P_{025} = 1 \text{ machine tool.}$$

$$m_{p030} = \frac{20000 \cdot 0.58}{60 \cdot 3979 \cdot 0.75} = 0.06.\ P_{030} = 1 \text{ machine tool.}$$

$$m_{p035} = \frac{20000 \cdot 0.42}{60 \cdot 3979 \cdot 0.75} = 0.047.\ P_{035} = 1 \text{ machine tool.}$$

The actual load factor of the workplace is calculated [1]:

$$\eta_{з.ф.} = \frac{m_P}{P}, \tag{3.3}$$

$$\eta_{з.ф.005} = \frac{0.16}{1} = 0.16.$$

$$\eta_{з.ф.010} = \frac{0.2}{1} = 0.2.$$

$$\eta_{з.ф.015} = \frac{0.04}{1} = 0.04.$$

$$\eta_{з.ф.020} = \frac{0.04}{1} = 0.04.$$

$$\eta_{з.ф.025} = \frac{0.036}{1} = 0.036.$$

$$\eta_{з.ф.030} = \frac{0.06}{1} = 0.06.$$

$$\eta_{з.ф.035} = \frac{0.047}{1} = 0.047.$$

The number of operations in the workplace, rounding to an integer is calculated [1]:

$$O = \frac{\eta_{з.н.}}{\eta_{з.ф.}}, \qquad (3.4)$$

$O_{005} = \frac{0.75}{0.16} = 4.7$. O_{005} = 6 operations.

$O_{010} = \frac{0.75}{0.2} = 3.75$. O_{010} = 5 operations.

$O_{015} = \frac{0.75}{0.04} = 18.75$. O_{015} = 25 operations.

$O_{020} = \frac{0.75}{0.04} = 18.75$. O_{020} = 25 operations.

$O_{025} = \frac{0.75}{0.036} = 20.8$. O_{025} = 27 operations.

$O_{030} = \frac{0.75}{0.06} = 12.5$. O_{030} = 16 operations.

$O_{035} = \frac{0.75}{0.047} = 15.96$. O_{035} = 21 operations.

The coefficient of operations assignment $K_{з.о.}$ is calculated by formula (3.1):

$$К_{з.о.} = \frac{\sum О}{\sum Р} = \frac{125}{7} = 17.86.$$

Thus, based on the calculation-analytical method, the type of production is the middle lot production.

Release rate $t_В$ [1]:

$$t_в = \frac{60 \cdot F_Д}{N}, \tag{3.5}$$

$$t_в = \frac{60 \cdot 3979}{20000} = 12 \text{ min.}$$

The size of the optimal batch of parts

$$n = \frac{N \cdot a}{F}, \tag{3.6}$$

$$n = \frac{20000 \cdot 5}{257} = 389 \text{ pcs.}$$

3.4. Selection of the workpiece production method

The comparison of two methods was made for the workpiece production of the part “Ring” ZhYTsD 712442.021:

The first method is the casting in sand molds.

The second method is low pressure casting.

According to the appendix in [1] we established for these two methods of workpiece production classes of accuracy of the sizes and masses, series of allowances for castings machining.

Estimated total tabular allowances are presented in the table 3.5.

The mass of the workpiece was determined by the formula:

$$Q = q + m_{пр}, \tag{3.7}$$

The mass of the allowance was determined by the formula:

$$m_{пр} = V_{пр} \cdot \rho . \quad (3.8)$$

Table 3.5 - General allowances

Machined surface, its dimension, accuracy	Surface roughness, μm	Workpiece tolerance, mm	General allowance, mm	Workpiece dimension with deviations
1) casting in sand molds				
End face 70h14($_{-0.74}$)	Ra12.4	4.4	5.0 × 2 = 10.0	80±2.2
Hole ∅117H14($^{+0.87}$)	Ra12.4	5.0	5.0 × 2 = 10.0	∅107±2.5
External cylindrical surface ∅129.8h11($_{-0.25}$) for thread M130×2-8g	Ra6.3	5.0	5.0 × 2 = 10.0	∅139.8±2.5
Hole ∅188H9($^{+0.115}$)	Ra2.4	5.6	8.0 × 2 = 16.0	∅172±2.8
Internal end face 6±0.1	Ra6.3	2.2	3.2	9.2±1.1
2) low pressure casting				
End face 70h14($_{-0.74}$)	Ra12.4	1.1	1.2 × 2 = 2.4	72.4±0.55
Hole ∅117H14($^{+0.87}$)	Ra12.4	1.2	1.2 × 2 = 2.4	∅114.6±0.6
External cylindrical surface ∅129.8h11($_{-0.25}$) for thread M130×2-8g	Ra6.3	1.2	1.6 × 2 = 3.2	∅133±0.6
Hole ∅188H9($^{+0.115}$)	Ra2.4	1.4	2.4 × 2 = 4.8	∅183.2±0.7
Internal end face 6±0.1	Ra6.3	0.56	0.9	6.9±0.28
End face 28±0.2	Ra12.4	0.9	1.1	26.9±0.45 (on the drawing 28.1±0.45)

The volume of cylindrical parts was determined by the formula:

$$V_{пр} = \frac{\pi \cdot D^2 \cdot H}{4} . \quad (3.9)$$

Elementary volumes of the allowance:

– casting in sand molds:

$$V_{пр1} = \frac{\pi \cdot (139.8^2 - 130^2) \cdot 28}{4} = 59346 \, mm^3.$$

$$V_{пр2} = \frac{\pi \cdot (139.8^2 - 107^2) \cdot 5}{4} = 31392{,}7 \, mm^3.$$

$$V_{пр3} = \frac{\pi \cdot (117^2 - 107^2) \cdot 35}{4} = 61544 \, mm^3.$$

$$V_{пр4} = \frac{\pi \cdot (200^2 - 172^2) \cdot 5}{4} = 40882.8 \, mm^3.$$

$$V_{пр5} = \frac{\pi \cdot (188^2 - 172^2) \cdot 2.8}{4} = 12660.5 \, mm^3.$$

$$V_{пр6} = \frac{\pi \cdot (172^2 - 127^2) \cdot 3.2}{4} = 33799.0 \, mm^3.$$

$$V_{пр7} = \frac{\pi \cdot 5^2 \cdot 14}{4} = 274.75 \, mm^3.$$

$$V_{пр8} = \frac{\pi \cdot 6^2 \cdot 6}{4} \cdot 4 = 169.56 \, mm^3$$

$$V_{пр} = \sum V_{пр_i};$$

$$V_{пр} = 240069.3 \, mm^3 = 240.07 \, sm^3.$$

– low pressure casting:

$$V_{пр1} = \frac{\pi \cdot (133^2 - 130^2) \cdot 28}{4} = 18512.44 \, mm^3.$$

$$V_{пр2} = \frac{\pi \cdot (133^2 - 114.6^2) \cdot 0.9}{4} = 3256.32 \, mm^3.$$

$$V_{пр3} = \frac{\pi \cdot (117^2 - 114.6^2) \cdot 35}{4} = 15271.7 \, mm^3.$$

$$V_{пр4} = \frac{\pi \cdot (200^2 - 183.2^2) \cdot 0.9}{4} = 4548.3 \, mm^3.$$

$$V_{пр5} = \frac{\pi \cdot (188^2 - 183.2^2) \cdot 5.1}{4} = 7133.3 \, mm^3.$$

$$V_{пр6} = \frac{\pi \cdot (183.2^2 - 127^2) \cdot 0.9}{4} = 12316.6 \text{ mm}^3.$$

$$V_{пр7} = \frac{\pi \cdot 5^2 \cdot 14}{4} = 274.75 \text{ mm}^3.$$

$$V_{пр8} = \frac{\pi \cdot 6^2 \cdot 6}{4} \cdot 4 = 169.56 \text{ mm}^3$$

$$V_{пр} = \sum V_{пр_i};$$

$$V_{пр} = 61483 \text{ mm}^3 = 61.5 \text{ sm}^3.$$

The masses of the allawances for the two methods were determined

– casting in sand molds:

$$m_{пр1} = 240.07 \cdot 2.6 = 624.2 \text{ g} = 0.624 \text{ kg}.$$

– low pressure casting:

$$m_{пр2} = 61.5 \cdot 2.6 = 159.9 \text{ g} = 0.16 \text{ kg}.$$

The masses of the workpieces for the two methods were determined

– casting in sand molds:

$$Q_1 = 0.66 + 0.624 = 1.284 \text{ kg}.$$

– low pressure casting:

$$Q_2 = 0.66 + 0.16 = 0.82 \text{ kg}.$$

The materials utilization rates

$$K_{в.м.} = \frac{q}{Q}, \tag{3.10}$$

– casting in sand molds:

$$K_{в.м.1} = \frac{0.66}{1.284} = 0.51.$$

– low pressure casting:

$$K_{в.м.2} = \frac{0.66}{0.82} = 0.8.$$

The method of the workpiece production by low pressure casting was chosen for the designing of the technological process of ring manufacturing due to the higher materials utilization rate.

3.6. Design of the technological route of the part machining

The rational technological route of the part machining was selected by comparing two methods from table 3.7.

Table 3.7 – Methods of part machining

№ surface	Type of surface	Initial parameters of the part		Variants of methods and routes of surfaces machining	
		Surface finish	Roughness, μm	1	2
1	2	3	4	5	6
1, 11	End face 70h14($_{-0.74}$)	14	Ra12.4	Semifinish form turning with transverse feed	–
2	Internal chamfer 3×45°	14	Ra12.4	Semifinish boring	–
3	Internal cylindrical surface ∅117H14($^{+0.87}$)	14	Ra12.4	Semifinish boring	–
4	External cylindrical surface ∅127h14($_{-1.0}$)	14	Ra12.4	Semifinish turning	–
5	External thread M130×2-8g	12	Ra6.3	Thread forming by cutter	Thread forming by milling

Continuation of table 3.7

1	2	3	4	5	6
6	External groove $5^{+0.3}$; 45°; ∅127h14($_{-1.0}$)	14	Ra12.4	Semifinish form turning with transverse feed	–
7	End face $28_{-0.52}$	14	Ra12.4	Semifinish form turning with transverse feed	–
8	Hole ∅$4.95^{+0.3}$ for thread M6-7H	14	Ra12.4	1. Centering 2. Drilling	Drilling on the jig
9	Internal chamfer 1×45°	14	Ra12.4	Countersinking	Forming during centering
10	Internal thread M6-7H; 10 min	12	Ra6.3	Threading by tap	–
12	Internal cylindrical surface ∅188H9($^{+0.115}$)	9	Ra2.4	1) Semifinish boring 2) Finish boring	–
13	Internal end face 6±0.1	14	Ra6.3	Semifinish form turning with transverse feed	–
14	Internal chamfer ∅132H14($^{+1.0}$); 45°	14	Ra12.4	Semifinish boring	–
15... 18	Four holes ∅6H14($^{+0.3}$); ∅176±0.1	14	Ra12.4	Drilling on radial drilling machine tool	Drilling on the jig or Drilling on CNC machine
19	Hole ∅5H14($^{+0.3}$)	14	Ra12.4	Drilling on radial drilling machine tool	Drilling on the jig or Drilling on CNC machine
20	External cylindrical surface ∅129.8h11($_{-0.25}$) під різь M130×2-8g	11	Ra6.3	1) Semifinish turning 2) Finish turning	–

In the project version of technological process, it was proposed to replace turning operations 005 and 010 which are performed on universal lathes, with CNC equipment, and drilling of four holes is proposed to make simultaneously on the vertical drilling machine instead of sequential drilling on the radial drilling machine.

Operation 005 Turning on CNC machine

2. Form turning of the end face 1, to the dimension $71.2_{–0.74}$.

3. Finish boring of the internal chamfer 2, finish boring of the hole 3 successively according to the program to the dimensions $\varnothing 117^{+0.87}$; 3×45°.

4. Rough turning of the external cylindrical surface 20 with finish cutting of the end face 7, to the dimensions $\varnothing 131_{–1.0}$; 28±0.2.

5. Turning of the external groove 6 to the dimensions $5.5^{+0.3;}$ 45°; $\varnothing 127_{–1.0}$.

6. Finish turning of the external cylindrical surfaces 4, 20 to the dimensions $\varnothing 127_{–1.0}$; $\varnothing 129.8_{–0.25.}$

7. Cutting of the thread 5 to the dimension M130×2-8g.

8. Control dimensions: $71.2_{–0.74}$; $\varnothing 117^{+0.87}$; 3×45°; 28±0.2; $5^{+0.3;}$ 45°; $\varnothing 127_{–1.0}$; M130×2-8g. Control 30%.

Operation 010 Turning on CNC machine

2. Form turning of the end face 11, to the dimension $70_{–0.74}$.

3. Rough boring of the internal cylindrical surface 12 with rough cutting of the end face 13, boring of the internal chamfer 14 successively according to the program to the dimensions $\varnothing 187.81^{+0.29}$; 5.6±0.1; $\varnothing 132.8^{+1.0}$; 2.9×45°.

4. Finish boring of the internal cylindrical surface 12 with finish cutting of the end face 13 successively according to the program to the dimensions $\varnothing 188^{+0.115}$; 6±0.1.

6. Control dimensions: $70_{–0.74}$; $\varnothing 188^{+0.115}$; 6±0.1; $\varnothing 132^{+1.0}$; 2.5×45°. Control 30%.

Operation 015 Vertical drilling

Operation element 2. Drilling of the hole 8 with forming of the chamfer 9, to the dimensions $\varnothing 4.95^{+0.12}$; 1×45°.

Control dimensions: $\varnothing 4.95^{+0.12}$; 1×45°. Control 30%.

Operation 020 Vertical drilling

Operation element 2. Drilling of the hole 19, to the dimension $\varnothing 5^{+0.3}$.

Control dimension: $\varnothing 5^{+0.3}$. Control 30%.

Operation 025 Threading

Operation element 2. Tapping of the internal thread 10 in the hole 8, to the dimensions M6-7H; 10±0.29.

Control dimensions: M6-7H; 10±0.29. Control 30%.

Operation 030 Vertical drilling

Drilling of four holes 15-18 using jig to dimensions $\varnothing 6^{+0.3}$; ∅176±0.1 simultaneously

Control dimensions: $\varnothing 6^{+0.3}$; ∅176±0.1. Control 30%.

Operation 035 Control.

3.7. Determination of allowances for machining

The results of the allowances calculation for surfaces machining of the part "Ring" ZhYTsD 712442.021 are presented in table 3.8.

The graphic layout chart of allowances for the surface $\varnothing 188H9(^{+0.115})$ is drawn in fig. 3.3.

Table 3.8 –Calculated allowances for machining

Technological operations and operation elements	Surface finish	Surfaces roughness, μm	Tole-rance, mm	Allowance, mm	Operational dimensions with deviations
1	2	3	4	5	6
External cylindrical surface $\varnothing 129.8h11(_{-0.25})$ for thread M130×2-8g					
Semifinish turning	11	Ra6.3	0.25	0.6 × 2 = 1.2	$\varnothing 129.8_{-0.25}$
Rough turning	14	Ra12.4	1.0	1.0 × 2 = 2.0	$\varnothing 131_{-1.0}$
Workpiece	7-th class	R_z50	1.2	1.6 × 2 = 3.2	∅133±0.6
End face $70h14(_{-0.74})$					
Semifinish turning	14	Ra12.4	0.74	1.2	$70_{-0.74}$
Semifinish turning	14	Ra12.4	0.74	1.2	$71.2_{-0.74}$
Workpiece	7-th class	R_z50	1.1	1.2 × 2 = 2.4	72.4±0.55

End face 28±0.2; Ra12.4					
Semifinish turning	14	Ra12.4	0.4	1.1	28±0.2
Workpiece	7-th class	R_z50	0.9	–	26.9±0.45
Internal end face 6±0.1					
Semifinish turning	14	Ra6.3	0.2	0.4	6±0.1
Rough turning	14	Ra12.4	0.2	0.5	5.6±0.1
Workpiece	7-th class	R_z50	0.56	0.9	5.1±0.28
Hole ∅117H14($^{+0,87}$)					
Semifinish turning	14	Ra12.4	0.2	1.2 × 2 = 2.4	∅$117^{+0,87}$
Workpiece	7-th class	R_z50	1.2	–	∅114.6±0.6

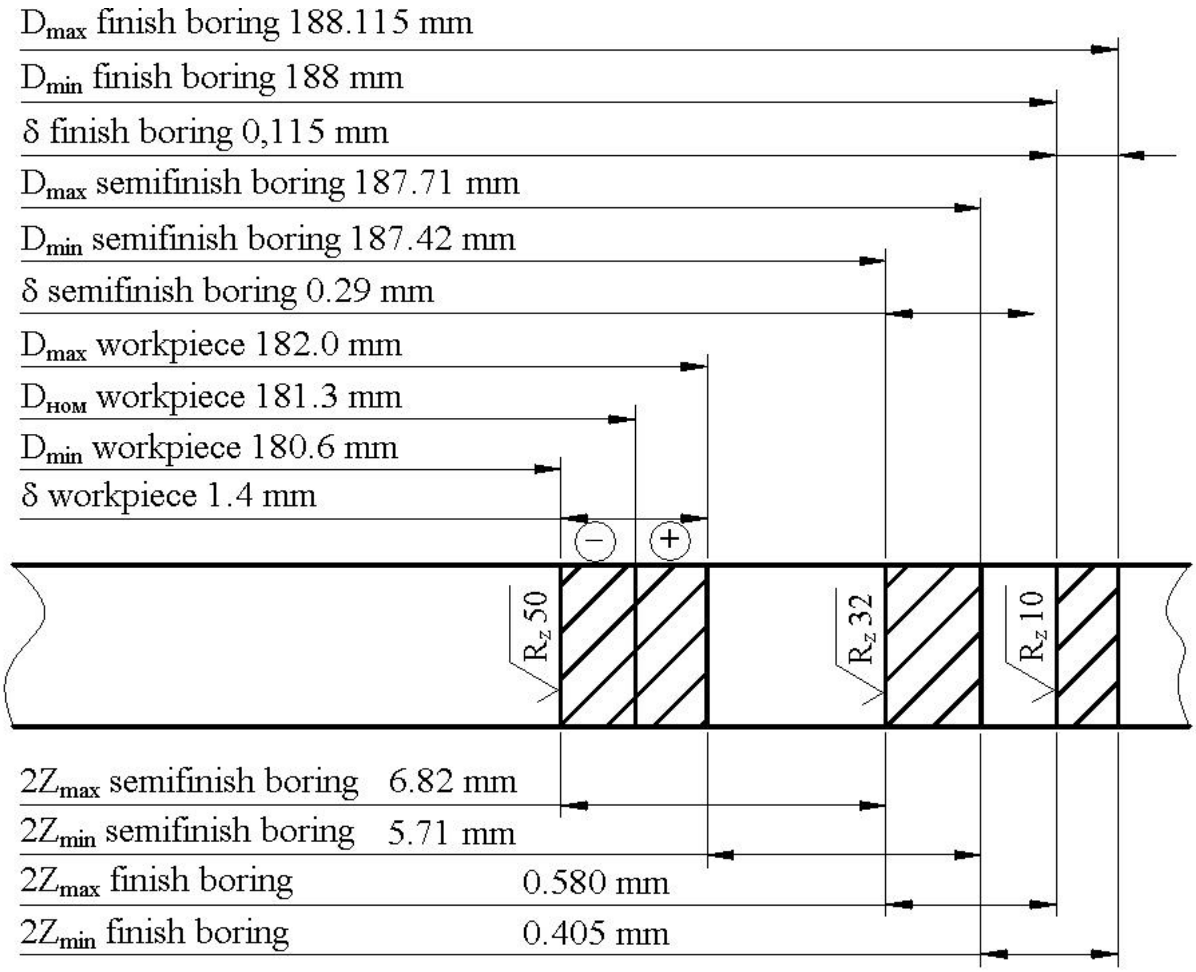


Figure 3.3 – The graphic layout chart of allowances and tolerances for the surface ∅188H9($^{+0,115}$)

3.8. Determination of cutting conditions and technical norms of time

Cutting conditions for part “Ring” ZhYTsD 712442.021 machining are presented in table 3.9.

Table 3.9 – Cutting conditions

Number, name of operation and operation element	t, mm	L, mm	i	T_m, min	S, mm/rew	n, rew/min	V, m/min	S_m, mm/min	T_o, min	N, kW
1	2	3	4	5	6	7	8	9	10	11
005 Turning on CNC machine										
Operation element 2 Form turning of the end face 1, to the dimension $71.2_{-0.74}$.	1.2	13.3	1	62	0.78	452	189	352	0.04	5.9
Operation element 3 Finish boring of the internal chamfer 2, finish boring of the hole 3 successively according to the program to the dimensions $\varnothing 117^{+0.87}$; 3×45°.	1.2 3.45	38	1	62	0.6	712	262	428	0.09	6.2
Operation element 4 Rough turning of the external cylindrical surface 20 with finish cutting of the end face 7, to the dimensions $\varnothing 131_{-1.0}$; 28±0.2.	1.0 1.1	33.8	1	62	0.78	712	294	553.9	0.061	4.8
Operation element 5 Turning of the external groove 6 to the dimensions $5.5^{+0.3;}$ 45°; $\varnothing 127_{-1.0}$.	2	5	1	62	0.08	452	172	37	0.14	3.65
Operation element 6 Finish turning of the external cylindrical surfaces 4, 20 to the dimensions $\varnothing 127_{-1.0}$; $\varnothing 129.8_{-0.25.}$	0.6	28	1	62	0.3	992	405	298	0.094	2.87
Operation element 7 Cutting of the thread 5 to the dimension M130×2-8g.	1.08	27.5	5	62	2	452	183.7	902	0.153	0.86

Continuation of table 3.9

1	2	3	4	5	6	7	8	9	10	11
010 Turning on CNC machine										
Operation element 2 Form turning of the end face 11, to the dimension $70_{-0.74}$.	1.2	13.35	1	62	0.78	353	189	275.35	0.048	5.9
Operation element 3										
Rough boring of the internal cylindrical surface 12 with rough cutting of the end face 13, boring of the internal chamfer 14 successively according to the program to the dimensions $\varnothing 187.81^{+0.29}$; 5.6±0.1; $\varnothing 132.8^{+1.0}$; 2.9×45°.	3.06 0.5	38	1	62	0.6	452	265.4	272	0.14	7.2
Operation element 4 Finish boring of the internal cylindrical surface 12 with finish cutting of the end face 13 successively according to the program to the dimensions $\varnothing 188^{+0.115}$; 6±0.1.	0.29 0.4	39	1	62	0.08	992	584	79.4	0.49	0.17
015 Vertical drilling										
Drilling of the hole 8 with forming of the chamfer 9, to the dimensions $\varnothing 4.95^{+0.12}$; 1×45°.	2.5	17	1	22	0.15	1502	23.57	227	0.08	0.85
020 Vertical drilling										
Drilling of the hole 19, to the dimension $\varnothing 5^{+0.3}$.	2.5	6	1	22	0.15	1402	22	212	0.02	0.8
025 Threading										
Tapping of the internal thread 10 in the hole 8, to the dimensions M6-7H; 10±0.29.	0.54	30	1	22	1.0	562	10.58	562	0.054	0.06

Continuation of table 3.9

1	2	3	4	5	6	7	8	9	10	11
030 Vertical drilling										
Drilling of four holes 15-18 using jig to dimensions $\varnothing 6^{+0.3}$; $\varnothing 176\pm0.1$ simultaneously	3	9	1	22	0.1	1402	26.6	142	0.064	1.02

Technical norms of time are collected on table 3.10.

Table 3.10 – Technical norms of time

Number, name of operation	$T_о$, min	Additional time, $T_д$ min			$T_{оп}$, min	Service time, $T_{об}$, min			$T_{шт}$, min.	$T_{п.з.}$, min.	n, pcs	$T_{шт.к.}$, mim
		$T_{у.}$	$T_{пер.}$	$T_{вим.}$		$T_{тех.об.}$	$T_{орг.об.}$	$T_{відп.}$				
005 Turning on CNC machine	0.44	0.2	0.5	0.48	2.112	0.148			2.43	28.65	610	2.48
010 Turning on CNC machine	0.678	–	–	–	–	–	–	–	–	–		1.7
015 Vertical-drilling	0.08	–	–	–	–	–	–	–	–	–		0.24
020 Vertical-drilling	0.02											0.18
025 Threading	0.054											0.42
030 Vertical-drilling	0.064											0.224

3.9. Calculation of the fixture error

Loading error of the part “Ring” ZhYTsD 712442.021 in the fixture [9]:

$$\Delta\varepsilon_{\text{у}} = \sqrt{\Delta\varepsilon_{\text{б}}^2 + \Delta\varepsilon_{\text{з}}^2 + \Delta\varepsilon_{\text{пр}}^2}\,, \qquad (3.11)$$

where $\Delta\varepsilon_{\text{б}}$ – error that occurs when locating the workpiece in the fixture;

$\Delta\varepsilon_{\text{з}}$ – the error of workpiece fixing by clamping elements of the fixture;

$\Delta\varepsilon_{\text{пр}}$ – fixture manufacturing error.

On the 005 turning on CNC machine operation, the external cylindrical surface is turned to dimensions $\varnothing 129.8_{-0.25}$; l=28 for thread M130×2.

The scheme to calculate the installation error on the turning operation 010 with a gap on the inner hole of the chuck is presented.

The locating error is calculated by the formula defined in [12]

$$\Delta\varepsilon_{б.} = S_{max}, \tag{3.12}$$

where $S_{max.}$ – the maximum guaranteed clearance.

The maximum guaranteed clearance:

$$S_{max} = D_{max.p.} - d_{min.p.}, \tag{3.13}$$

whwre $D_{max.p.}$ – the maximum dimension of the locating surface of the part (hole of the part), mm;

$d_{min.p.}$ – the minimum dimension of the locating surface of the fixture (base), mm

The locating hole of the part is made with a deviation $\varnothing 127H14(^{+1})$.

The locating external diameter of the base is $\varnothing 127h7(_{-0.040})$.

The maximum clearance is determined

$$D_{max.p.} = 127 + 1 = 128 \text{ mm.}$$

$$d_{min.p} = 127 + (-0.04) = 126.96 \text{ mm.}$$

$$S_{max.} = 128 - 126.96 = 1.04 \text{ mm.}$$

Then, the locating error is:

$$\Delta\varepsilon_{бр.} = 1.04 \text{ mm.}$$

The fitting on existing prototypes of parts with a gap of 0.1..0.2 mm is performed during the manufacture of the chuck. Therefore, the locating error is $\Delta\varepsilon_{б.} = 0,2$ mm.

Clamping error [12]: $\varepsilon_з$ = 70 μm when loading the part on the mandrel with clamping on the surface that was subjected to machining.

The fixture error of normal accuracy in engineering calculations $\varepsilon_{пр}$ = 120 μm.

Thus the error of the part "Ring" ZhYTsD 712442.021 loading in the fixture:

$$\Delta\varepsilon_у = \sqrt{200^2 + 70^2 + 120^2} = 244\ \mu m. = 0.244\ mm.$$

The allowable loading error $\Delta\varepsilon_{у.доп.}$ during turning to dimension $\varnothing 129_{-0.25}$ is determined

$$\Delta\varepsilon_{\ у.доп.} = \delta, \tag{3.14}$$

where δ – the tolerance for dimension $\varnothing 129_{-0.25}$, δ =0.25 mm.

Thus, $\Delta\varepsilon_у$ = 0.244 mm < $\Delta\varepsilon_{у.доп.}$ = 0.25 mm., respectively turning of the cylindrical surface $\varnothing 129_{-0.25}$ in the part "Ring" ZhYTsD 712442.021 in the fixture is possible with the definite accuracy.

3.10. Calculation of the fixture drive

The design scheme was developed in order to calculate the required forces for the "Ring" ZhYTsD 712442.021 clamping on 005 turning on CNC machine operation, during rough boring of the hole $\varnothing 117^{+0.87}$.

The sum of the friction moments $M_{тр}$ must be greater than cutting torque $M_{різ}$ when clamping the workpiece in order to ensure the stability of the plains milling process:

$$KM_{різ} = \sum M_{тр}, \tag{3.15}$$

where K - safety coefficient.

The cutting torque during milling is calculated:

$$M_{різ}=P_z \cdot r, \qquad (3.16)$$

where P_z – cutting force, N;

$r=58.5$ mm – the radius of cutting.

The friction moment is calculated:

$$\sum M_{тр}=Q \cdot R \cdot f_1+\frac{2Qf_2 \cdot \left(R_2^3-R_1^3\right)}{3\left(R_2^2-R_1^2\right)} \qquad (3.17)$$

де Q – the clamping force, N;

$f_1=0.2$ – the friction coefficient between part and strap clamp;

$f_2=0.2$ – the friction coefficient between part and base;

$R_1=63.5$ mm – smaller radius of the ring base;

$R_2=93$ mm – larger radius of the ring base;

$R=90$ mm – the clamping radius of the workpiece.

The clamping force:

$$Q=\frac{K \cdot P_z \cdot r}{f_1 \cdot R+2f_2 \cdot \frac{R_2^3-R_1^3}{3(R_2^3-R_1^3)}}. \qquad (3.18)$$

Safety coefficient [6]:

$$K = K_0 \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot K_6, \qquad (3.19)$$

$$K = 1.5 \cdot 1.2 \cdot 1.15 \cdot 1.2 \cdot 1.05 \cdot 1.0 \cdot 1.0 = 2.6.$$

The cutting force during turning [20]:

$$P_z = 10 \cdot C_p \cdot t^x \cdot S^y \cdot V^n \cdot K_p, \qquad (3.20)$$

where Cp = 40; x = 1.0; y = 0.75; n = 0 ;

$t = 1.2$ mm; $S = 0.6$ mm/rev; $V = 260$ m/min ; $K_p = 1$.

$$P_z = 10 \cdot 40 \cdot 1.2^{1.0} \cdot 0.6^{0.75} \cdot 400^0 \cdot 1 = 327.2 \text{ N}.$$

Substituting the data into formula (3.14), we obtain:

$$Q = \frac{2.6 \cdot 327.2 \cdot 58.5}{0.2 \cdot 90 + 2 \cdot 0.2 \cdot \frac{93^3 - 63.5^3}{3 \cdot \left(93^2 - 63.5^2\right)}} = 1470.9 \text{ N}.$$

The condition of reliability clamping was verified:

$$Q \leq W \cdot i. \qquad (3.21)$$

A single-acting pneumatic chamber is selected for the workpiece clamping. For such pneumatic chambers, the pulling force on the rod is determined by the formula [22]:

$$W = 0{,}785 \cdot (D_1^2 - d_2^2) \cdot p \cdot \eta, \qquad (3.22)$$

where $D_1 = 0.1$ m; $d_2 = 0.022$ m;

p – air pressure in the system [14] ; $p = 0.4 \cdot 10^6$ Pa;

η – efficiency factor of the pneumatic drive [14]; $\eta = 0.9$.

Then $W = 0{,}785 \cdot (0.1^2 - 0.022^2) \cdot 0.4 \cdot 10^6 \cdot 0.9 = 2689.2$ N.

The condition of the workpiece reliability clamping

$$W > Q.$$

It is established based on the calculations, that $W = 2689.2$ N $>$ $Q = 1470.9$ N.

Conclusion: the part “Ring” ZhYTsD 712442.021 will be securely clamped during turning on 005 turning on CNC machine operation.

4 SAFETY MEASURES

4.1. Methods of safeguarding machinery

There are many ways of safeguarding machinery. The type of operation, the size or shape of material being worked, the method of handling, the physical layout of the work area, and the type of material and production requirements or other limitations, all need to be considered in order to determine the appropriate safeguarding method for the individual machinery or integrated manufacturing system. Machine designers and manufacturers and safety professionals should choose the most effective and practical safeguard available. All information in this chapter is taken from [26].

Stop functions initiated by safeguards, such as interlocking devices or presence-sensing devices, are the safety function. The greater the dependence of risk reduction on the safety function, the higher the required integrity of the safety-related parts of control systems, including software, to resist faults and reliably perform safety functions. The appropriate design measures of control system and the proper selection of components used should therefore be applied to achieve a sufficient level of fault tolerance and risk reduction.

There are many types of guard. Barrier guards are usually the first safeguarding method considered for machines. When a guard is used as the primary safeguarding method, it should be designed, constructed, adjusted and maintained so that a person cannot reach around, under, through or over the guard. A guard opening scale is a valuable tool to use during the design, installation and inspection of guards, in accordance with national law and practice. The following are representative examples of guards.

A fixed guard is a permanent part of the machinery and is not dependent on moving parts to perform its intended function. It should be constructed of sheet metal, screen, wire mesh, bars, plastic or any other material that is substantial enough to withstand whatever impact it may receive and to endure prolonged use. Fixed guards are usually preferable to all other types because of their relative simplicity and permanence. It should not be possible to remove them without the use of a tool.

When interlocking guards are opened or removed, the switch or interlock automatically stops the hazardous motion or power source or disconnects the drive power, and the machinery cannot cycle or be started until the interlocking guard is back in place. Replacing the interlocking guard should not, however, automatically restart the machinery. Interlocking guards may use electrical, mechanical, hydraulic or pneumatic power, or any combination of these. Interlocks should not prevent “inching” (gradual progressive movements) for a specific area if additional controls are in place, such as hold-to-run buttons. Consideration should be given to the position and selection of the interlocking guard, its characteristics (response time) and those of the machinery to which it is fitted (time needed to stop) to make sure that it is sufficient to ensure safety.

In situations where an interlocking guard can be opened and the time needed to stop the hazardous operation is not sufficient to prevent unsafe access, interlocking guards with guard locking should be used. The locking system keeps the guard closed and locked until the risk of injury from hazardous machinery functions has ceased.

Manually adjustable guards are guards whose opening can be adjusted and then fixed to suit the size of material being introduced into the point of operation. Adjustable guards offer varying degrees of protection.

The openings of self-adjusting guards are determined by the movement of the material. As the operator moves the material into the danger area, the guard is pushed away, providing an opening sufficiently large to admit only the material. After the material is removed, the guard returns to the rest position. This guard protects the operator by placing a barrier between the danger area and the operator. The guards may be constructed of plastic, metal or other substantial material. Self-adjusting guards offer varying degrees of protection.

Protective devices may stop the functions of machinery if any part of the body is inadvertently placed in the hazard zone, or may require the removal of the operator from the danger area before a cycle is started. They may provide a virtual barrier in accordance with the operating cycle of the machinery in order to prevent access to the danger area during the hazardous part of the cycle, or may require the worker operating the machinery to use both hands on machinery controls simultaneously (thus keeping both hands and body out of danger).

It should be noted that since protective devices are not physical barriers, they are not appropriate where protection is required against hazards such as extremes of temperature, noise emissions, dust, fumes, etc.

In order to ensure that the hazard zone cannot be reached before the hazardous function of machinery has ceased when a protective device initiates a stop function, an appropriate minimum distance, based on the response time of the stop function, needs to be provided between the positions of the protective device and the hazard zone.

In addition, any machinery fitted with a protective device should be fitted with a device such as a brake or other reliable means for stopping the machinery before the hazard zone can be reached. In this case, it is important that the brake performs consistently (for example, brake pad wear needs to be considered in the case of mechanical brakes). Where the deterioration of that performance is critical to intended risk reduction, stopping performance should be monitored by any suitable mechanisms or control systems so that if the stopping time exceeds an allowed level, further start-up can be prevented.

Safety trip controls such as pressure bars, trip rods and tripwires are manual controls which provide a quick means of deactivating the machinery in an emergency situation. Pressure-sensitive body bars, trip rods and tripwires, when activated, will stop the machinery if the operator or anyone trips, loses balance or is drawn toward the machinery. The positioning of the bar, trip rod or tripwire is critical, as it needs to stop the machinery before a part of the body reaches the danger area. Trip rods deactivate the machinery when pressed by hand. Since they have to be actuated by the worker operating machinery during an emergency situation, correct positioning is critical. Tripwire cables are located around the perimeter or in the vicinity of the danger area. The operator should be able to reach the cable with either hand to stop the machinery.

An emergency stop is not a substitute for other safeguarding measures but is intended to stop the machine in a safe and reliable way. It should not be used instead of isolation measures when maintenance is carried out. An emergency stop is: initiated by a single human action; manually reset prior to restarting of the machinery; and available and operational at all times, regardless of the operating mode.

4.2. Basic types of protective devices

Three types of sensing devices which stop machinery or interrupt the work cycle or operation if a worker is within the danger zone are described below. All information in this chapter is taken from [26].

Photoelectric or optical presence-sensing devices use a system of light sources and controls which can interrupt the machinery’s operating cycle. If the light field is broken, the machine stops and will not cycle. Such devices should be used only on machines which can be stopped before workers reach the danger area. The device may be swung up or down to accommodate different production requirements.

Vision systems use a system of cameras linked to a complex logic unit that can monitor the presence of persons and adjust the area which will lead to a signal or stopping of the machine, depending on the machine operation going on at any given time. The system normally warns persons against approaching the danger areas and will stop the machine if the danger area is reached. At present, this is new technology and standards are currently under preparation.

Pressure-sensitive mats, when depressed, will deactivate the machinery. They can be used to prevent a machine from starting when a worker is in a hazard zone and stop the machinery if a person moves into that zone. The positioning of the mat is critical, as it needs to stop the machinery before a part of the body reaches the hazard zone.

4.3. Machinery guarding and protection against hazards

Where machinery has an electricity supply, it should be designed, constructed and equipped in such a way that all hazards of an electrical nature are or can be prevented, in accordance with national law and practice. All information in this chapter is taken from [26].

Machinery should be designed and constructed to prevent or limit the build-up of potentially dangerous electrostatic charges and be fitted with a discharging system.

Where machinery is powered by sources of energy other than electricity, it should be so designed, constructed and equipped as to prevent all potential risks associated with such sources of energy.

Errors likely to be made when fitting or refitting certain parts which could be a source of risk should be precluded by the design and construction of the parts or, failing this, information explaining how to fit them correctly should be provided on the parts themselves and their housings. The same information should be provided on moving parts and their housings where the direction of movement needs to be known in order to prevent a risk.

Where a faulty connection can be a source of risk, the design should make it impossible to connect parts incorrectly; failing this, information should be provided on the items to be connected and, where appropriate, on the means of connection.

Steps should be taken to eliminate any risk of injury arising from contact with, or proximity to, machinery parts or materials at very high or very low temperatures.

The necessary steps should also be taken to avoid or protect against the risk of very hot or very cold material being ejected.

When machinery is used in very high ambient temperatures and/or humidity (such as in tropical or subtropical regions) or in very low ambient temperatures, consideration in the design of machinery should be given to the following aspects: the effect of extreme heat, cold and humidity on machinery; the effect of high and low ambient temperatures on workers in terms of fatigue; the effect of high levels of sunlight; the effect of climate on the stability of chemical substances used for operating machinery; and the effect of climate on equipment operation and maintenance.

Machinery should be designed and constructed in such a way as to prevent any risk of fire or overheating posed by the machinery itself or by gases, liquids, dust, vapours or other substances produced or used by the machinery.

Machinery should be designed and constructed in such a way as to prevent any risk of explosion posed by the machinery itself or by gases, liquids, dust, vapours or other substances produced or used by the machinery.

Where machinery is intended for use in a potentially explosive atmosphere, it should be designed and manufactured to exclude or minimize ignition sources and comply with any national laws and standards applicable to explosive atmospheres.

Machinery should be designed and constructed in such a way that risks resulting from the emission of airborne noise are eliminated or reduced to the lowest possible level, taking account of technical progress and the availability of means of reducing noise, in particular at source.

Where applicable, information should be supplied with the machinery on noise emissions, as required by national laws and standards, and on any additional safety precautions required. If this advice is incomplete, the employer should seek further information from the supplier, and if necessary arrange for competent persons to undertake measurements in accordance with nationally and internationally recognized standards.

The level of noise to which workers are exposed should not exceed the limits established by the competent authority or under internationally recognized standards. Noise measurements should be used to quantify the level of exposure of workers and compared to nationally or internationally agreed exposure limits.

As regards noise reduction, employers should give consideration to the following, normally referred to as a hearing conservation programme: the appropriate choice of machinery which emits the least amount of noise, taking account of the work to be done; noise reduction by technical means: reducing airborne noise, for example with shields, enclosures or soundabsorbent coverings; reducing structureborne noise, for example with damping or isolation; alternative working methods that require less exposure to noise; the design and layout of workplaces and workstations; organization of work to reduce noise: limitation of duration and intensity of exposure; and appropriate work schedules with adequate rest periods; appropriate maintenance programmes for machinery, the workplace and workplace systems; adequate information and training to instruct workers in the use and maintenance of machinery to minimize noise emission. Workers who may be exposed to noise levels above agreed levels should receive regular audiometric testing, in accordance with national laws and practice, and employers should ensure that workers in noisy environments are informed of the results of the testing.

CONCLUSIONS

In the master's qualification paper the analysis of technical requirements of the part "Ring" ZhYTsD 712442.021 and its official purpose is made. The type of production definite after the calculations is the middle lot production. A rational method of workpiece production is low pressure casting. The technological process of the ring manufacturing is developed.

In the project version of technological process, it was proposed to replace turning operations 005 and 010 which are performed on universal lathes, with CNC equipment, and drilling of four holes is proposed to make simultaneously on the vertical drilling machine instead of sequential drilling on the radial drilling machine.

Also calculations of intermediate allowances, cutting conditions and norms of time are carried out.

The reduction of the machining time was obtained as a result of the changes in the technological process, of the CNC turning machines and multi-tool settings use, as well as the introduction into the technological process of a rational method of the workpiece production - low pressure casting.

The expediency of the workpiece locating on the first operation on the external or internal surface in terms of metal saving, taking into account the errors of installation of workpieces in the chucks is considered.

During experimental research it is found that with increasing of the depth of cut by one cutter *t* value, feed rate of the cutter *S* value, the value of radial runout δR of the cylindrical surface of the ring increases after turning, and with increasing cutting speed *V* - decreases.

The maximum value of the radial runout δR of the ring cylindrical surface from steel 45 is 0.115 mm, and the minimum is 0.025 mm. Increasing the depth of cut by a one cutter *t* from 0.2 mm to 1.0 mm leads to an increasing in the radial runout of the cylindrical surface by 1.7 times.

Also, increasing of the feed rate of the cutter *S* from 0.1 mm/rev to 0.5 mm/rev increases the radial runout of the cylindrical surface by 1.5 times, and increasing of the cutting speed *V* from 70 to 110 m/min reduces the radial runout of the cylindrical surface by 1.08 times.

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