Processing of holes with a reamer-broach

Nickolai S. Dudak[1], Asylbek Zh. Kasenov[1], Zhanar K. Musina[1], Galiya T. Itybaeva[1], Aizhan Zh. Taskarina[2]

[1]Pavlodar State University named after S.Toraigyrov, Pavlodar city, Republic of Kazakhstan
[2]Kazakh National Technical University named after K.I Satpaev, Almaty city, Republic of Kazakhstan

Abstract. This article considers issues of processing of holes with reamers. The analysis of present constructions, of their advantages and disadvantages, has been carried out. The conditions of cutting during processing of holes with reamers have been shown. A new construction of a reamer – a reamer-broach from high-speed steel and with hard alloy plates which was patented in the Republic of Kazakhstan, has been proposed. The reamer-broach combines in itself the features of a reamer (in cross-section) and a broach (in longitudinal section). This enables to enhance the quality of processing of holes (dimensional deviation, surface roughness), to simplify the cutting conditions and enhance the resistance. The results of productive tests of pilot models have been presented.
[Dudak N.S., Kasenov A.Z., Musina Z.K., Itybaeva G.T., Taskarina A.Z. **Processing of holes with a reamer-broach.** *Life Sci J* 2014;11(10s):282-288] (ISSN:1097-8135). http://www.lifesciencesite.com. 50

Keywords: productivity, hole, reamer, broach, resistance, resource, accuracy, quality, roughness

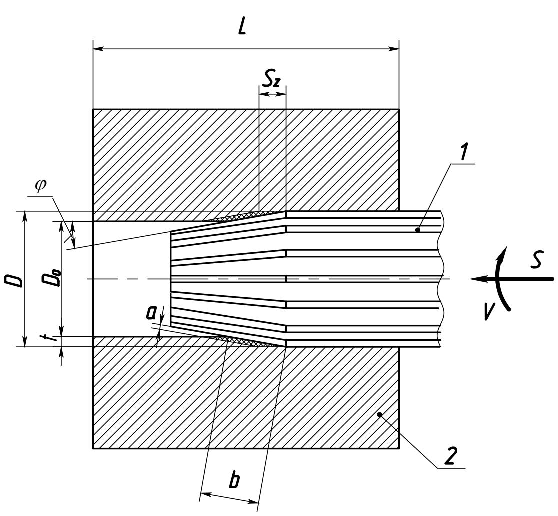
Introduction

In modern mechanical engineering, the big list of various on the purpose and on the construction, metal-cutting tools for processing of exterior, interior and flat surfaces, is used. At the same time, processing of holes with axial tools involves a number of difficulties caused by the reduced tool hardness coming from the processing pattern.

One of the directions that should be developed in mechanical engineering is processing of holes that should meet high requirements on dimensional accuracy, configuration and location. Processing of holes is mostly carried out with bar measuring tools: a drill, a rose bit, a reamer and a broach, a boring cutter, blocks and boring heads. The appropriate tools are used depending on requirements to holes accuracy. In this regard, the reaming operations have a significant meaning. Drilling and countersinking are preliminary operations. Reaming and broaching are the finishing operations.

Axial (bar) tools have a number of disadvantages: cutting operation is concentrated at comparatively short cutting part (Figure 1), unfavourable cutting conditions cause increased mechanical load on the blade area which separates chip from material base layer and its deformation accompanied with significant heat emission as well as mechanical and thermal stresses lead to comparatively low resistance of cutting tools.

Pushing of the cutting tool through the hole (broaching) causes the curving moment. Its impact on the deflection amount of the tool axis is increased with the diameter reduction, i.e with reduction of tool hardness that leads to the splitting of the processing hole and to its axis carrying off. The specified circumstances make necessary to reduce cutting conditions and integrate additional operations into the technological process.

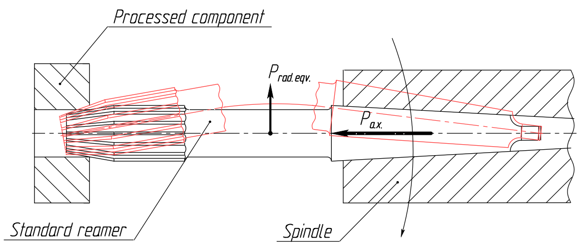


1 – reamer; *2* – billet; *φ* – major angle in the plan; a – thickness of shear; *b* – width of shear; *t* – cutting depth; *D* – hole diameter; D_o – preparatory hole diameter; *L* – processing length; *S* – axial feed; S_z – feed per cog; *V* – cutting speed

Figure 1. Cutting elements in reaming

Every bar cutting tool for processing holes: drills, rose bits, reamers – pushed through holes, is operated in the conditions of out-of-centre compression. The shank is placed at the back of the tool and this leads to additional radial forces and breakdown of the processed holes diameter under the effect of cutting axial force (Figure 2).

The unfavourable cutting conditions cause increased mechanical load on the blade area where chip is separating from the material base layer and its deformation takes place, accompanied with significant heat emission even if it is less than in case of countersinking. Mechanical and thermal stresses lead to comparatively low resistance of cutting tools [1-9].



$P_{rad.eqv.}$ – radial equivalent force arisen from impact of $P_{a.x.}$;
$P_{a.x.}$ – force effecting on the axis
Figure 2. Scheme of processing of holes with a standard reamer and effecting forces

Processing of holes with axial tools is more common among other tools and has the significant meaning in the technological process of machine components manufacturing, 80% of which have holes of different types. Processing with axial tools is a more economical way of holes making. Issues of raising of productivity, accuracy and reliability of processing of holes have always been and remain topical and important for metalworking, to which this article is also dedicated.

Problem statement

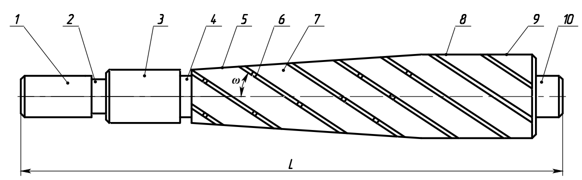
The analysis of methods and ways of processing of holes, parameters of the cut layer during cutting, of geometry and of constructions of present metal-cutting tools (reamers, broaches, combined tools) has led to the development of a new metal-cutting tool – a reamer-broach. It should be noted that in the processing of holes the reamer-broach operates more stable since it is being dragged (broached) through the processing hole instead of being pushed. The cutting conditions in the new construction of the metal-cutting tool, have been improved and the impact of specified unfavourable factors accompanying the cutting process, has been reduced to a minimum [9-12].

The theoretical research has been carried out using the general regulations of mechanical-engineering technology, cutting theory, tooling and mechanics design.

During the conduct of experimental researches, methods of experiment planning, mathematical statistics and parameter optimization theory, have been used. The analysis of the experimental results and the required calculations have been made with the help of computer programmes for construction of mathematical dependence diagrams and experimental data approximation.

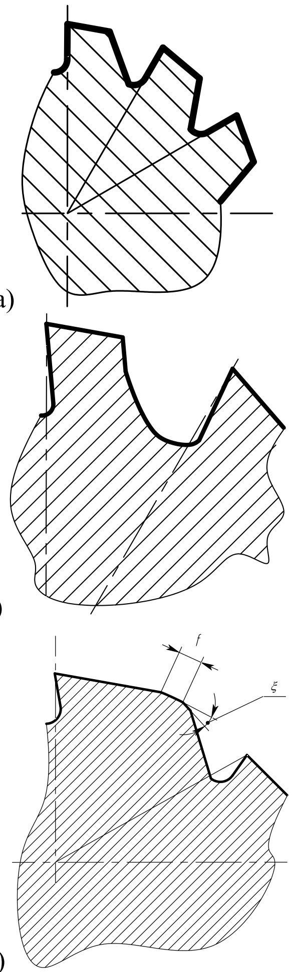
Results

The reamer-broach is constructively made under the following principle: it has design features in the axial section which matches to a broach: front shank, neck, front and tail directings, cutting and calibrating parts (during the operation, it is being broached through the hole as the broach) and it matches to a reamer in the cross-section: shape and number of cogs, cutting part geometry (Figure 3) and it is rotated as a reamer during the operation.



1 – front shank; *2* – neck; *3* – front directing; *4* – annular slot; *5* – cutting (conical) part; *6* – chip separatory slot; *7* – chip slot; *8* – calibrating part (cylindrical); *9* – tail directing; *10* – tail shank; *L* – reamer-broach length, *ω* – angle of spiral chip slots, direction *ω* is opposite to the cutting direction
Figure 3. Constitutive elements of reamer-broach

The contour of spiral cogs of the reamer-broach in the cross-section can be as follows: standard contour of the reamer cogs (Figure 4, a), equal wide cog contour (Figure 4, b) as the reamer with a spiral equal wide cog [11], cutting-deforming (Figure 4, c). Using the equal wide contour of cogs enables to increase resistance of the reamer-broach and the number of sharpenings. Due to sharpening across the back surface as distinct from the broach with circular cogs, the resistance is increased and the back surface is reconstructed after the sharpening to a condition of a new tool and it provides the increasing of processing quality. Using the cutting-deforming contour enables to implement the cutting process and surface plastic deformation. Processed cylinder surface is formed with burnishing tape *f*. At the same time; the sudden transition from deformed to nondeformable condition may cause processed surface deterioration. To exclude this, an angle $\xi \leq 10°$ providing the smooth transition from deformed to nondeformable condition of processed surface, has been input after the tape in order to increase its quality.



a)

b)

c)

Figure 4. Contour of reamer-broach in cross-section

In the developed construction of the reamer-broach the shank is located in front and the tool is pulled through the hole and it excludes the hole breakdown accompanying the processing with pushing the tool through the hole. Even though, the hole breakdown with the reamer is less due to out-of-centre compression and bend than under operation of the rose bit, but using the reamer-broach excludes the additional radial force and increases the accuracy of the hole axis position and its size.

Thus, a better centering of the reamer-broach and quality increasing of processing of holes are provided. Considering the above listed, the method of processing of cylindrical holes has been developed with a tool in which the shank is located in front that excludes the out-of-centre bend as the reamer-broach is being broached through the hole (Figure 5).

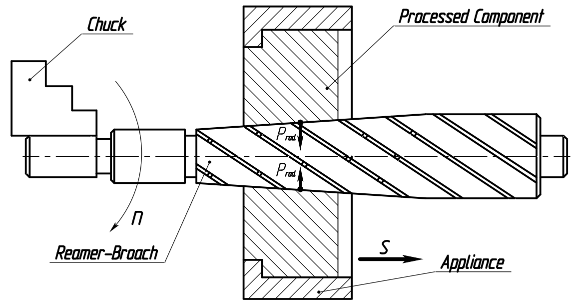


Figure 5. Method and scheme of processing of holes with reamer-broach

Processing of holes of machine components with the reamer-broach is performed at the lathe with the following methods: the reamer-broach is fixed in a chuck or lathe head [12].

Pilot models of the reamer-broach were manufactured at the Mechanical Engineering Enterprise "Format Mach Company" Ltd (the former Tool Plant) in Pavlodar city and were tested in training and production workshops of Metallurgy, Mechanical Engineering and Transport Faculty, "Mechanical Engineering and Standardization" Department, PSU named after S. Toraigyrov.

Production tests were conducted at the "Nonstandard Equipment Plant" Ltd by comparing the results of processing of holes made with a standard machine reamer and the reamer-broach.

The results of production tests models processed with metal cutting tools are as follows:

1) standard machine reamer: accuracy of holes diameter sizes comprises 0.018-0.033mm (7-8 accuracy workmanship); the surface roughness of holes ranges within R_a=0.16…0.32 µm that are corresponding to 9th and 10th roughness classes.

2) reamer–broach: accuracy of holes diameter sizes comprises 0.011-0.021mm (6-7 accuracy workmanship); the surface roughness of holes ranges within R_a=0.08…0.16 µm that are corresponding to10th and 11th roughness classes.

Before the conduct of the experiment the models had been turned on the outer surface and the hole had been drilled according to the diameter of the front directing of the reamer-broach, and also the shpon joint which is necessary to exclude the rotation of the component around its axis, had been milled to components.

Then the assessment of the geometrical accuracy of the screw-cutting lathe mod. 1A616 according to State Standard 18097-93 "Lathes and screw-cutting lathes. Standards of accuracy and hardness", was conducted.

The experiment conduct is connected with the definition of the minimally necessary, but enough number of the tests. To solve this problem the mathematical apparatus of fully factor experiment of type 2^2, was applied. The experiment planning suggests the function finding which defines the link between the researched parameter and effecting on it independent variables. The problem – the construction of the model, i.e. dependence with the help of which it can be defined as the value of the researched parameter.

Experimental researches were conducted according to the conditions given in Chart 1.

Chart 1. Values of technological factors during experiments

Variation levels	Factor values			
	Spindle rotation frequency		Cutting feed lengthwise	
	nat.	cod.	nat.	cod.
	n, rot/min	x_1	S, mm/rot	x_2
Basic level	210	0	0,19	0
Upper level	280	+ 1	0,3	+ 1
Lower level	140	– 1	0,08	– 1
Variation interval	70	Δx_1	0,11	Δx_2

The planning matrix 2^2 was developed for two factors. Lines in columns x_1 и x_2 of the matrix set the experiment plan, i.e. the experiment conditions realized in every possible combination of factor levels. The planning matrix is compiled as follows: the first line of the matrix is chosen so that studied factors are present at the lower levels, i.e. $x_1 = -1, x_2 = -1$.

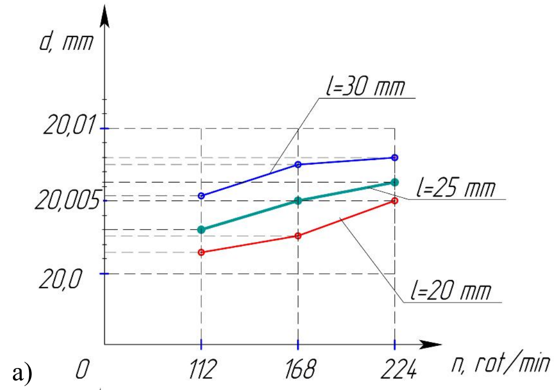
The conduct of any experiment is connected with the mistakes, the knowledge of which is necessary for the experimental results. Due to this the order of the experimental conduct was chosen so as to have the opportunity to assess an occasional mistake of the experiment and to avoid the effect of the possible systematic mistakes. The principle of randomization let to exclude the occasional disturbing factors, the action of which can have the systemic character.

Before the definition of the experimental model in the kind of a regression equation, the checking of the precision of the experiment for the researched object on Cochrane's criterion G, had been conducted. The experiment is précised as $G_{\max} = 0{,}643 < G_{chart} = 0{,}7679$.

The statistic analysis of the gotten regression equations was made which includes the checking: significance of the equation factors (Student's criterion); adequacy of the received equation or the process description (Fisher's criterion F).

The quantity of the received value of Fisher's criterion $F=4.67$ less critical value $F_{crit} =5.32$ for the number of the freedom degrees of numerator $v_{resid} = N - d = 1$ and denominator $v_{mist} = N(m-1) = 8$ and chosen theoretical frequency $P = 1 - \alpha = 0{,}95$; the experimental models (the regression equation) are recognized as acceptable and adequately describing the processing of holes with the reamer-broach.

For measuring of the quality parameters of the holes processed with the reamer-broach, the appliances were applied: tool horizontal optimeter IKG3 for measuring of the accuracy of the diametrical sizes; profilometer of model 259 for assessment of the surface roughness; hardmeter TK-2M for definition of the hardness.



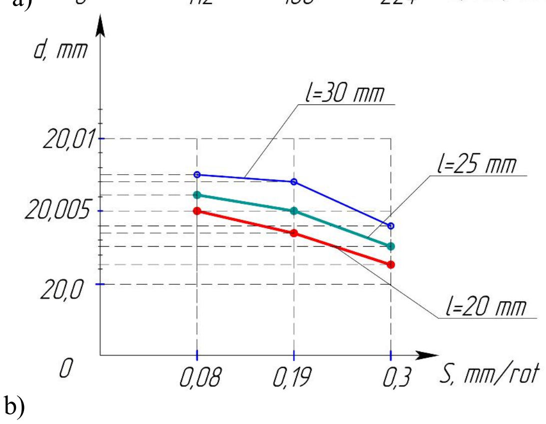
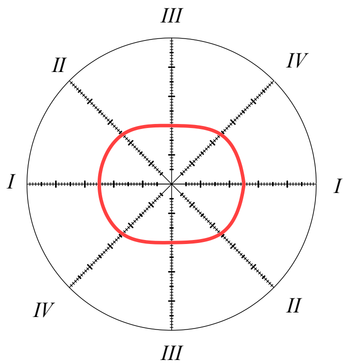


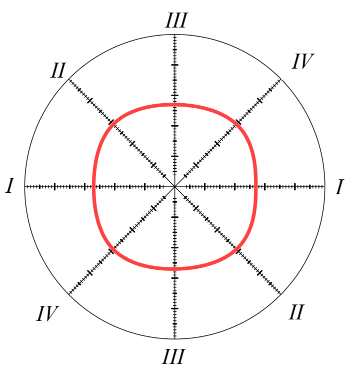
Figure 6. Diagrams showing dependences of deflections of 20 mm diameter hole from spindle rotational frequency *n* rot/min (a), from cutting feed *S* mm/rot (b)

On the basis of the obtained data of the deflections of the diametrical sizes, the diagrams showing the dependence of the accuracy of the diametrical sizes of the processed holes from the spindle rotation frequency and the cutting feed, have been constructed. The deflection of diametrical sizes is increased with the increase of the rotational frequency and is decreased with the increase of the feed. It arises from the fact that the processing of holes with the reamer-broach is closer to the broaching process and during the increase of the feed, radial forces centering the tool in the processed hole, are increased. On the increasing of the rotational frequency the breakdown of the hole The hole splitting is increased (Figure 6, a) and on the increasing of the feed the radial centering forces are increased and the breakdown of the hole is decreased (Figure 6, b).

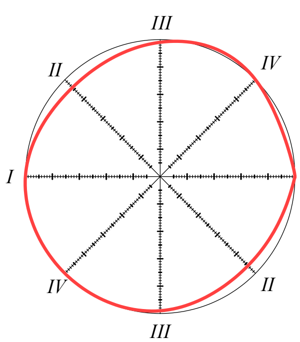
The deflection of hole shape with diameter 20 mm in the cross section of the processed holes were made using the caliper and the circle diagram designing (Figures 6,7), more distinctive from each other deflections of the hole shape, are shown.



a)



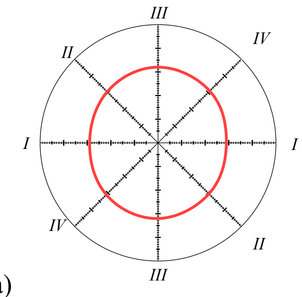
b)



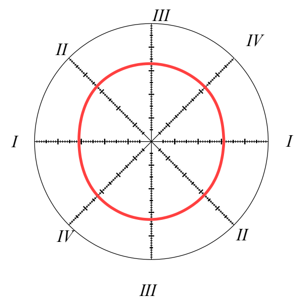
c)

a, b,c – 1,4 and 9 experiments, the deflection of which comprised 16 µm, 18 µm and 36 µm accordingly.

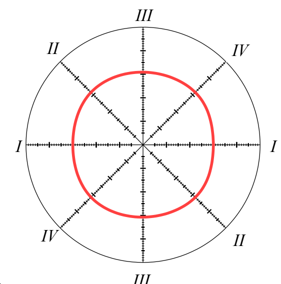
Figure 7. Deflections of hole shapes in cross-section from conditions of cutting, from spindle rotation frequency and from feed (after machine reamer)



a)



b)



c)

a,b,c – 1,4 and 9 experiments, the deflection of which comprised 6 µm, 4 µm and 10 µm accordingly.

Figure 8. Deflections of hole shapes in cross-section from conditions of cutting, from spindle rotation frequency and from feed (after reamer-broach)

During processing of holes with the reamer-broach, the deflection of the shape in the cross-section is 2 times less than with a standard reamer.

The surface roughness of holes was measured at the profilemeter with the contact method. Based on the data of the measuring results, the diagrams showing the dependence of roughness from processing factors (rotational frequency, feed) are presented in Figure 9. When the rotational frequency is increased, the hole breakdown is increased and the roughness is risen (Figure 9, a) and when the feed is increased, the centering forces are increased, the tool's position is stabilized and the roughness is decreased (Figure 9, b).

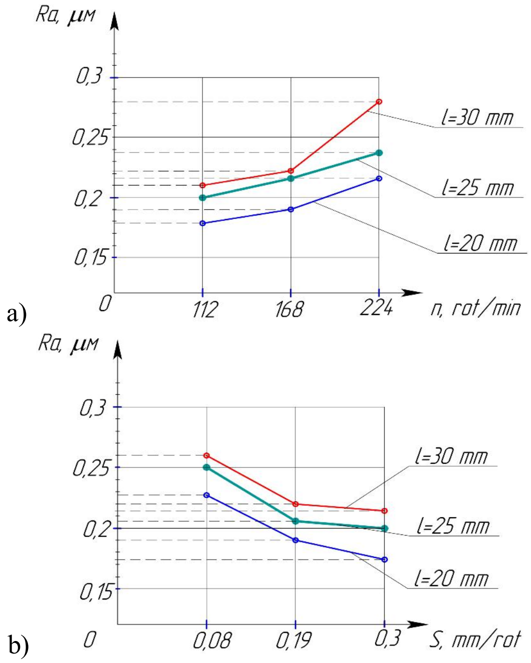


Figure 9. Diagrams showing dependences of surface roughness of 20 mm diameter holes from spindle rotational frequency *n* rot/min (a), from cutting Feed *S* mm/rot (b)

The dependence of the depth of the defective layer of the hole surface from the processing factors (rotational frequency, feed), based on the data of the measuring results, is given in Figure 10 in the form of the diagrams.

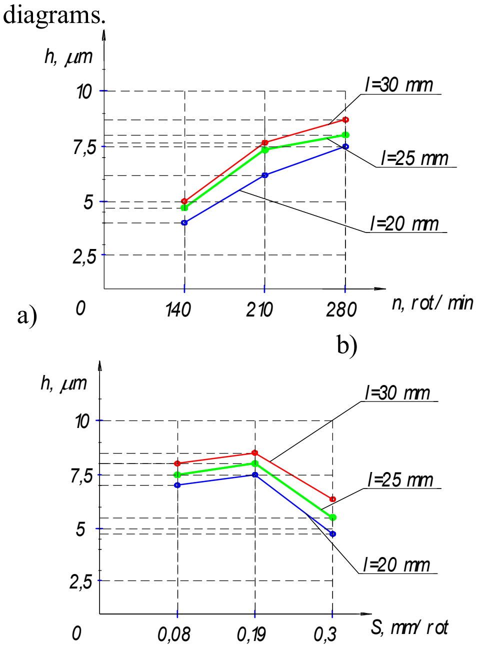


Figure 10. Diagrams of dependence of depth of defective layer of surface of 20 mm diameter holes from spindle rotational frequency *n* rot/min (a), from cutting feed *S* mm/rot (b)

When the rotational frequency is increased, the hole breakdown is increased and the depth of the defective layer is risen and when the feed is increased, the centering forces are increased, the tool's position is stabilized and the depth of the defective layer is decreased.

The dependence of the constancy of the hole surface from the processing factors (rotational frequency, feed), based on the data of the measuring results, is given in Figure 11 in the form of the diagrams.

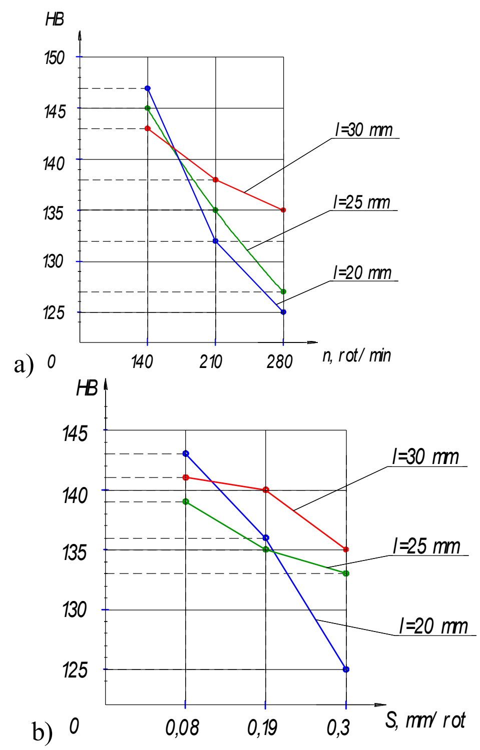


Figure 11. Diagrams of dependence of constancy of surface of 20 mm diameter holes from spindle rotational frequency *n* rot/min (a), from cutting feed *S* mm/rot (b)

When the rotational frequency is increased, the depth of the defective layer is increased and the constancy is decreased and when the feed is increased, the constancy of the hole surface is decreased. The effect of escaping of the deformated area from the deformation delivery (the decreasing of the depth of the penetration of the plastic deformation) on the component surface.

Conclusions

As a result of the theoretical and experimental researches performed to provide favorable cutting conditions in the processing of holes with the reamer-broach, the following conclusions have been made:

1. The construction of the reamer-broach was developed which integrates the features of the reamer and the broach in one tool.

2. As a result of the theoretical researches, the cutting conditions were changed due to the developed method of the processing of the cylindrical holes with the reamer-broach.

3. The accuracy of the diameter sizes in the processing of the holes with the reamer-broach corresponds to 6-7 accuracy workmanship; the surface roughness of the holes ranges within R_a=0.08…0.16µm.

4. During the processing of the holes with the reamer–broach, the shape deflection in the cross-section comprised 11…13 µm.

5. The obtained theoretical and technological results have a practical importance for finishing processing of cylindrical holes. The technique for design and calculation of constructive and geometrical parameters of the reamer-broach was developed.

6. It is recommended to use the reamer-broach for processing of cylindrical holes up to two diameters long and with *6–7* accuracy workmanship, having *Ra=0.08…0.16 µm* surface roughness and the allowance equal to the allowance for processing with reamers.

7. The developed theses can be used for improvement of present and development of new technological ways of the processing of the holes.

Corresponding Author:
Dr.Dudak Nickolai S.
Pavlodar State University named after S.Toraigyrov
Pavlodar city, Republic of Kazakhstan

References

1. Benes J. Cutting Tools Review// American Machinist, № 6, p. 18-20, 2007.
2. Byrne G. Modern State of Cutting Technologies of Various Materials and Field of Their Practice// Annals CIRP, Vol. 52, № 2, p. 483-507, 2003.
3. Sergeev S.V., Skhirtladze A.G. The Impact of Dynamic Factors on the Accuracy of Hole Dimension in the Drilling Process// Guide. Engineering journal with appendix, № 10, p. 33-39, 2010.
4. Ignatov M.N., Ignatova A.M. Metal-cutting Tool and Cutting Conditions Assignment in Turning// Perm, 2005.
5. Kirsanov S.V., Glebov V.V. Using the Methods of Electrochemical Labeling in Machine Building// Electronic processing of materials, № 5, p. 4-6, 2004.
6. Kataev Yu.P. Theoretical Determination of Cutting Force in Drawing through// Bulletin of Kazan State Technical University named after A.N Tupolev, № 2, p. 80-84, 2012.
7. Malyugin V.M., Klepikov V.V. The Analysis of Processing of Holes with the Use of Drawing through Technology// Tractors and agricultural machinery, № 2, p. 49, 2006.
8. Klepikov V.V. Combined Broaching of Splined and Plain Surfaces// Tractors and agricultural machinery, № 11, p. 53-54, 2006.
9. Preliminary patent of the Republic of Kazakhstan № 16167 of 15.06.2005 on the invention “Broaching for Processing of Cylindrical Holes with Medium and Large Diameters”. Authors: Dudak N.S., Sherniyazov M.A.
10. Mukhamadieva R.M. Quality Improvement of Processing of Holes with Combined Cutting Deforming Reamers// Abstract of Ph.D thesis in Engineering Science// OmSTU Publishing House: Omsk, 2004.
11. Preliminary patent of the Republic of Kazakhstan for an invention № 20210. Reamer-broach with Hard Alloy Plates for Processing of Cylindrical Holes./ Dudak N.S., Itybaeva G.T., Musina Zh.K., Kasenov A.Zh.; publ. 17.11.2008, Bulletin № 11, 10 p: illustrated.
12. Innovative patent of the Republic of Kazakhstan for an invention № 20811. The Way of Processing of Cylindrical Holes with Reamer-broach. Dudak N.S., Kasenov A.Zh./ publ. 16.02.2009, Bulletin № 2, 14 p: illustrated.

6/18/2014