Multiflute Drill-Broach for Precision Machining of Holes

Nikolay Dudak¹, Galiya Itybaeva², Asylbek Kasenov³, Zhanara Mussina⁴, Aizhan Taskarina⁵, Kairatolla Abishev⁶

¹Mechanical Engineering and Standardization Department at S.Toraighyrovy Pavlodar State University (Lomov Street 64, Pavlodar, Kazakhstan); nikolaydns@mail.ru

²Mechanical Engineering and Standardization Department at S.Toraighyrovy Pavlodar State University (Lomov Street 64, Pavlodar, Kazakhstan); gali-ityibaeva@mail.ru

³Corresponding author: Mechanical Engineering and Standardization Department at S.Toraighyrovy Pavlodar State University (Lomov Street 64, Pavlodar, Kazakhstan); 8-777-435-06-35; Asylbek_Kasenov@outlook.com

⁴Mechanical Engineering and Standardization Department at S.Toraighyrovy Pavlodar State University (Lomov Street 64, Pavlodar, Kazakhstan); mussina_zhanara@mail.ru

⁵Metallurgy Department at S.Toraighyrovy Pavlodar State University (Lomov Street 64, Pavlodar, Kazakhstan); aya_taskarina@mail.ru

⁶Transport Equipment and Logistic at S.Toraighyrovy Pavlodar State University (Lomov Street 64, Pavlodar, Kazakhstan); a.kairatolla@mail.ru

Abstract

This paper deals with hole-enlarging multiflute drill processing. The analysis of existing structures, their advantages and disadvantages is carried out. Cutting conditions during hole-enlarging multiflute drill processing are shown. A new design of hole-enlarging multiflute drill as a hole-enlarging multiflute drill-broaching tool from broaching-speed steel with carbide plates, as well as a new way of handling the new tools is offered. Hole-enlarging multiflute drill-broaching combines the features of hole-enlarging multiflute drill (in cross section) and the features of broaching tool (in longitudinal section). In this way, it was
possible to increase the quality of hole making (size variance, surface roughness), to facilitate the cutting conditions and to increase the durability. The results of prototypes testing are presented.

**Keywords:** multiflute drill processing, the quality of hole making, hole enlarging, hole surface microstructure.

1. **Introduction**

The main objective for the development of machinery is the continuous improvement of products quality [1-2]. One of the ways for product improvement is to increase the accuracy of surface treatment, which directly affects the functional quality of the product.

Optimization process of broaching and reaming tools are continuous and uninterrupted, as an example of the relevance of the problem, one can see a few recent publications: [3] a paper dedicated to geometrical optimization of broaching tool [4-6], articles dedicated to the analysis of the distribution of forces in the process of holes machining; U.S. Patent of new broaching tool, there are many new patent every year concerning new design of tools, and this particular patent – only example of such continuous process [7,8]. Articles dedicated to the analysis of the relationship of the cutting forces with the resulting surface quality.

As one can see holes machining is the branch in which the search and optimization of existing approaches continues and does not cease.

In the design of machine parts one of the basic elements are holes [9-11]. Depending on the requirements the holes get drilling, reaming, unfolding, etc.

When reaming cutting work is concentrated in a relatively small (15 mm) length of the cutting part (Figure 1). The cutting part is often perceives high mechanical and thermal stresses, which lead to increased wear, low resistance of hole-enlarging multiflute drill, and consequently a low machining accuracy and surface roughness of the hole [12-14].
There are various hole-machining methods – honing operation, laser processing, electrochemical machining. Operation with these methods requires the purchase of expensive equipment. Hole-machining operation with multiflute drill-broach is carried out on a universal vertically oriented drilling machine, which does not require equipment costs. It is available in any machine-building enterprise.

The main advantage of the hole-enlarging multiflute drill is the ability to correct the hole axis and its shape.

[Fig 1 here]

Hole-enlarging multiflute drills have a number of disadvantages: a high degree of concentration of cutting edges at the hole-enlarging multiflute drill provides cutting a large mass of metal [15–17]. This, in turn, increases the concentration of forces and temperature of cutting on the tool body, that deteriorates the conditions of its work. The growth of forces leads to increased roughness of the surface, and sometimes to the damage of the instrument. The growth in temperature increases the wear of the tool.

In the terms of eccentric compression all the core tools for holes machining work, including the hole-enlarging multiflute drills. At the core tools the shank is located behind the instrument [18-19]. The work of core tools is based on pushing through the holes, that leads to additional radial forces and to the breakdown of the processing holes diameter under the action of axial cutting force (Figures 2).

[Fig 2 here]

For the illustration of this situation a scheme of complex diagrams of acting specific forces (Figure 3) arising from the action of axial cutting forces on the taper shank is shown.

[Fig 3 here]
\[ y = \frac{P_{axis}}{i}, \]  

(1)

Where: \( i \) – number of selected points on the cone surface, which varies from \( n_1 \) to \( n_2 \).

\[ P_{axis} = \sum_{i=n_i}^{n_2} P_{oy} \cdot i, \]  

(2)

Where: \( P_{oy} \) – specific axial force acting at selected points;

\( P_{axis} \) – axial force acting at the shank end.

Off-center compression and axis bending give rise to additional radial forces and to the breakdown of machined holes diameter. These effects also lead to the reduction of processing quality.

A cutting force arises when the broach teeth interact with the process material. It is divided into one acting along the direction of broach movement and into one perpendicular to such a direction.

In broaching, the round broach is under the stretching forces. The stretching force \( P_z \) is opposite to the broach movement; stretching force \( P_y \) is perpendicular to the broach movement (Figure 4). These forces \( P_z \) and \( P_y \) depend on the process material, cut thickness, cut length, the number of chip grooves on a tooth, front and back angles.

[Fig 4 here]

The total force \( P_z \) is composed of the specific forces \( P_{zi} \), mutually equilibrated in action on the broach.

Based on the \( P_z \) component, necessary stretching force and the strength of broach elements (neck, cross-section along the first tooth) are determined. \( P_y \) component squeezes the broach from the workpiece and affects the accuracy in its size after broaching.

In broaching holes with round broaches, cutting force changes abruptly due to a variable number of simultaneously operating teeth, which pitch is usually not a multiple of a workpiece length. After the time \( t \) equal to the ratio of cutting speed and teeth pitch \( t = \frac{V}{p} \), the
number of simultaneously operating teeth decreases by one tooth, cutting force decreases and the tooth, leaving the surface of a workpiece, stops (in our case, this is the tooth No. 1). After the latter happens, the next tooth, engaging with the surface of a workpiece (in our case, this is the tooth No. 5), comes into operation (Figure 5).

[Fig 5 here]

After the tooth No. 1 leaves the surface of the workpiece, broaching force is reduced by $\frac{P}{\tau_i}$.

As a result, stress-strain state of a technological system is constantly changing. In addition, there are oscillations reducing the surface quality (roughness and deviation from the specified geometric shape of a hole); broach resistance ability is reduced.

To eliminate the above-mentioned drawbacks, we have developed and proposed a new metal-cutting tool for machining holes - hole-enlarging multiflute drill broaching. The proposed tool combines the advantages of a drill - self-centering and alignment correction holes complex profile and broach - a favorable distribution of the forces in the body of the tool eliminates the beating, and contributes to the high accuracy of the resulting hole. It provides improved cutting conditions, self-centring by dragging the tool through the hole, with fixing shank front location, as well as the stability of the process.

Broach reamer is recommended to machine cylindrical holes up to 40 mm in diameter and two diameters in length with accuracy rate about 6-7 points for the rough surface $Ra=0.08...0.16 \, \mu m$ and with allowance equal to the allowance for processing with reamers [20]

Hole-enlarging multiflute drill-broach is recommended to machine cylindrical holes over 40 mm in diameter and up to two diameters in length in materials subjected to hardening with accuracy rate about 7-8 points for rough surface $Ra=0.16...0.32 \, \mu m$ and with an increased allowance up to 0.8 - 1.0 mm.

Hole-enlarging multiflute drill-broach is designed to remove more allowance in comparison
with the broach reamer $\phi_1 \angle \phi_2$, where: $\phi_1$ – cone angle of a broach reamer; $\phi_2$ – cone angle of a hole-enlarging multiflute drill.

2. Method

Methodological bases of research are the methodology of dialectical and subject-activity approaches, methods of epistemological explication, conceptualization, methodological analysis, modeling, idealization and structural-functional analysis.

To achieve this goal, we used methods of mathematical statistics and statistical modeling. The experience of domestic and foreign scholars on the subject was summarized.

To verify obtained results, an experiment was conducted, in which objects under study were delivered in a special, controlled and managed conditions. It gave an opportunity to consider the object of study and to obtain its full characterization.

Studies in this area began in 2008 and continue to date.

2.1. Scheme of the hole-enlarging multiflute drill-broach operating and description of the design

New cutting tool for machining holes is based on the combination of several types of operations in one, i.e. drilling and broaching. The use of new designs of reamers, called hole-enlarging multiflute drills-broaches, eliminates negative factors of machining holes with existing hole-enlarging multiflute drills and improves the quality and accuracy of holes machining, as well as tool life.

Hole-enlarging multiflute drill-broach, in which hole-enlarging multiflute drill and broach properties combined in a single tool, is designed to handle details such as sleeves, plugs, rings, etc. in the standard, large-scale and mass production by 7 to 8 of IT Grade. Preliminary patents of the Republic of Kazakhstan have been received [10, 21, 22].

Hole-enlarging multiflute drill-broach is constructively built on the following principle: in
axial section it has structural features corresponding to the broach: front shank, neck, front and rear alignment, cutting and calibrated parts (they have helical teeth, and the cutting part has a conical shape and the calibrating one has a cylindrical and extends through the hole as a broach) and in cross-sectional part it has hole-enlarging multiflute drill features: the shape and number of teeth, the geometry of the cutting part (Figure 6) and proposed tool is rotated during processing as the hole-enlarging multiflute drill. So, new tool is named hole-enlarging multiflute drill-broach.

[Fig 6 here]
Figure 7 shows the cross-sectional profile and the shape of hole-enlarging multiflute drill-broach teeth in the normal cross-sectional profile of cutting portion (versions 1, 2, 3) and of sizing part - version 4. In the cross-section the profile of hole-enlarging multiflute drill-broach helical teeth can be of the following versions: standard profile of teeth (versions 2 and 3), and fixed width profile of teeth (version 1). Application of fixed width profile of teeth will increase the resistance of hole-enlarging multiflute drill-broach, the number of regrinding and, consequently, increase the service life due to regrinding flank surface, as opposed to the hole-enlarging multiflute drill-broach with a round tooth, by analogy with hole-enlarging multiflute drill with a wire screw tooth and recreate the state of the rear surface after regrinding to the state of a new instrument that will lead to higher quality of treatment. All the versions (1, 2, 3 and 4) can be refaced on the flank surface.

[Fig 7 here]
As a material for cutting part of hole-enlarging multiflute drill-broach can be as high speed steel R6M5, R18, so soldered carbide plates. Cross-sectional profile is presented in Figure 8.

[Fig 8 here]
Hole-enlarging multiflute drill-broach concludes in its design elements of a hole-enlarging multiflute drill and a broach, which combination creates more favorable conditions for
cutting. Work on cutting is distributed over long cutting part, as at the hole-enlarging multiflute drill-broach with a screw tooth, teeth shape in the cross-section with a clearance groove profile, and the working movements (a combination of rotational and translational movements) – as at the hole-enlarging multiflute drill. The design of hole-enlarging multiflute drill-broach has such advantages of the broach as a relatively low cutting speed, processing quality (dimensional accuracy, surface roughness, the reduction of abrasion), while the number of grooves as at the hole-enlarging multiflute drill from 2 to 6 depending on the diameter of the treatment.

Machinery parts holes processing by the hole-enlarging multiflute drill-broach is performed on a lathe in the following ways: fixing hole-enlarging multiflute drill-broach in the cartridge or on the support of the lathe to the left or right direction of depending on the direction of spindle rotation with the cutting tool.

In the design of the hole-enlarging multiflute drill-broach the shank is located at the front and the tool is pulled through the hole, eliminating breakdown of holes, followed by treatment with pushing the tool through the hole (Figure 9).

Thus, good centring of hole-enlarging multiflute drill-broach and improving the quality of hole machining is achieved. In view of the above the scheme of cylindrical holes processing was developed. In the front of the tool the shank is located, which eliminates the eccentric bending, because the hole-enlarging multiflute drill-broach pulled through the hole.

[Fig 9 here]

In the process of pulling with the hole-enlarging multiflute drill-broach through the hole this tool is centered, its bending and axis withdrawal is excluded, that improves the quality of holes processing. When machining by the proposed method the tool is given a relative longitudinal movement as when pulling or the workpiece is given a longitudinal movement that relatively corresponds to pulling. Either hole-enlarging multiflute drill-broach or
workpiece is given a rotary motion inherent to the hole-enlarging multiflute drill. That corresponds to reaming.

When processing with the hole-enlarging multiflute drill-broach the following movements are used simultaneously: a longitudinal movement along the axis (of workpiece or tool), which is inherent in broaching - the main cutting motion, we denote it Drп, and rotational motion inherent to reaming. We denote it Drз (Figure 10).

When developing a new way, the synthesis of two processing methods has been performed: reaming with the main cutting motion Dr by the rotation of hole-enlarging multiflute drill or a part and axial feed of hole-enlarging multiflute drill or a part Ds; and broaching with the main movement of cutting Dr - translational motion of the tool and constructive feed Sz. At the same time, in view of the constructive filing for hole-enlarging multiflute drill-broach, feed movement of hole-enlarging multiflute drill has become one of the main components of the resultant cutting motion. Constructive feed of hole-enlarging multiflute drill-broach is done at the expense of the conical shape of working part with spiral teeth. With this arrangement, the supply is carried out continuously.

When processing with the hole-enlarging multiflute drill-broach the feed motion of the tool is not available, it is replaced by constructive feed for stock removal in the radial direction, as when broaching.

The teeth direction of the hole-enlarging multiflute drill-broach, as well as a hole-enlarging multiflute drill, always coincides with the cutting direction and varies depending on the direction of rotation of the workpiece or tool during machining.

The combination of direct (right) rotational motion of the workpiece and translational motion of the hole-enlarging multiflute drill-broach creates working conditions and the relative
motion of the hole-enlarging multiflute drill-broach and the workpiece, as during reaming holes and provides the uniformity of teeth direction.

When machining by the proposed new method the instrument is given a longitudinal movement or the workpiece is given a longitudinal displacement, that corresponds to the broaching process. Rotary motion inherent in hole-enlarging multiflute drill, is given to hole-enlarging multiflute drill-broach or to the workpiece, that corresponds to reaming. The combination of rotational and translational motion is such that the tool always approaches to the workpiece with on the screw thread “ram” tooth from the obtuse angle between the cutting edges of the teeth and the axis of the hole-enlarging multiflute drill-broach and for the tool the conditions for work of the hole-enlarging multiflute drill and the hole-enlarging multiflute drill-broach are enabled. The direction of helical teeth is similar to the cutting direction; a sectional shape of the chip groove (teeth) coincides with the shape of chip grooves of the hole-enlarging multiflute drills; the number of teeth - in accordance with the requirements of the standard (Figure 1).

[Fig 1 here]

Fig 1. Hole-enlarging multiflute drill-broach.

The axial broaching force value of hole-enlarging multiflute drill is constant \( P = \text{const} \). The cutting process is accompanied by a rotational movement \( M_k \) depending on the machining technique; bending moment \( M_u \) appears due to drill axis bending

Differential equation for hole machining with a hole-enlarging multiflute drill-broach will be

\[
m \frac{\partial^2 x}{\partial t^2} + \mu \frac{\partial x}{\partial t} = cx + \frac{2(M_k + M_u)}{d} = F
\]

The constant broaching force is an advantage of hole machining with helical broaches based on helical teeth \( P=\text{const} \). Consequently, force developed by operating cylinder is also constant, \( F = \text{const} \).

Then, differential equation (3) will be as \( F > P = cx \)
\[ m \frac{\partial^2 x}{\partial t^2} + \mu \frac{\partial x}{\partial t} + cx = F \]  \hspace{1cm} (4)

Equation of motion of a point on the cutting edge of a broach with helical teeth shows that there must be tangential and additional axial forces because of helical teeth. Thus, a rotational moment takes place.

Then, differential equation (4) will be the following:

\[ m \frac{\partial^2 x}{\partial t^2} + \mu \frac{\partial x}{\partial t} + cx + 2 \frac{M_k}{d} = F \]  \hspace{1cm} (5)

Where: \( d \) – diameter of a broach;

\( M_k \) – rotational moment

\( M_k \) has an additional effect on the broached workpiece.

In hole machining with a hole-enlarging multflute drill-broach, axial force is equal to Poc. It is lower than the force acting on the trip spindle of the lathe F, \( F > P \).

The force \( P_{oc} \) is an additional axial force, acting thanks to helical teeth of a hole-enlarging multflute drill-broach.

If we take into account the rotational moment caused by helical teeth of a hole-enlarging multflute drill-broach, differential equation for machining with a hole-enlarging multflute drill-broach countersink-broach will be:

\[ m \frac{\partial^2 x}{\partial t^2} + \mu \frac{\partial x}{\partial t} + cx = F - P_{oc} \]  \hspace{1cm} (6)

We will transform the differential equation, introducing the following notations \( T_k = \sqrt{\frac{m}{c}} \),

\( T_g = \frac{\mu}{c} \); \( K = \frac{1}{c} \); then

\[ T_k^2 \frac{\partial^2 x}{\partial t^2} + T_g \frac{\partial x}{\partial t} + x = K \cdot (F - P_{oc}) \]  \hspace{1cm} (7)

Machining involves all the conditions for broaching holes with a helical broach.

To find the transient process for the case when \( T_g \geq 2T_k \), let us form a characteristic equation

\[ T_k^p^2 + T_g p + 1 = 0 \]  \hspace{1cm} (8)
Its solution is the following:

\[ P_{1,2} = \frac{-T_g \pm \sqrt{T_g^2 - 4T_k^2}}{2T_k^2} \]  

(9)

The general integral for \( T_g > 2T_k \) is

\[ x_n = c_1 e^{-p_1 t} + c_2 e^{-p_2 t} \]  

(10)

The steady-state value is \( x_y = K(F - P_{oc}) \), because \( \frac{\partial x}{\partial t} = 0 \), and \( \frac{\partial^2 x}{\partial t^2} = 0 \).

The complete solution of differential equation:

\[ x = x_n + x_y = C_1 e^{-p_1 t} + K(F - P_{oc}) \]  

(11)

The integration constants \( C1 \) and \( C2 \) are determined in a conventional manner from initial conditions when \( t = 0 \):

\[ x = 0; \frac{\partial x}{\partial t} = 0. \]

The graph of transient process consists of two exponents with a flex point \( n \) (Figure 12).

[Fig 12 here]

The nature of transient processes and their duration depends on the values \( T_k \) and \( T_g \) that include the system parameters.

Unlike the hole enlarging with a standard drill, the same process with a hole-enlarging multiflute drill-broach is more stable, because a drill is self-aligning in the hole during the "broaching". Equation solution shows that the system is stable, as can be seen from the graphs of transient process.

The developed mathematical model, describing the process of hole machining with a hole-enlarging multiflute drill-broach, allows calculating the system parameters to solve the problems of mechanical design and machining technologies.

2.2. Experimental studies on hole-enlarging multiflute drill-broach processing
Hole machining was carried out on the screw-cutting lathe of model STANKO 1A616, geometric accuracy assessment was carried out in accordance with the GOST standart 18097-93 by the Euro-Asian Council for Standardization, Metrology and Certification (EASC). For the experiments samples of parts were prepared. The samples were drilled with a diameter equal to the diameter of the front rail of the hole-enlarging multiflute drill-broach (Figures 13-14).

Processing with hole-enlarging multiflute drill-broach was done using cooling lubricants. When processing the steel a 10% solution of the emulsion was used as a lubricating and cooling liquid, in the treatment of bronze and iron a 10% solution of the emulsion and kerosene was used. Adding kerosene is a common practice used in drilling. It provides high drilling rates and reduction in differential sticking.

Conducting experiments is related to the definition of the minimum required, but a sufficient number of experiments. To solve this problem we apply the mathematical apparatus of full factorial experiment by type 23 [23].

The procedure for conducting experiments has been selected so as to be able to estimate the random error of the experiment and to avoid the effect of possible systematic errors. Identifying accidentally interfering factors, which effect may be systematic, allowed the principle of randomization, which is used in the implementation of the matrix for experimental design.

To assess the reproducibility of the experiment G. Cochran’s C test was used [24]. The experiment is reproducible, as $G_{max} = 0.537 < G_{tab} = 0.7679$

The experimental data were processed with the Excel program.
The adequacy assessment of the obtained regression equations were performed using Fisher’s exact test \(F - 1.441 < F_T = 5.32\).

By transforming the regression equation empirical relationships were derived

1) the surface roughness
\[ R_a = 0.1487 + 0.0004n - 0.109S \]

2) the depth of the surface defect layer
\[ h = 1.15 + 0.032n - 11.364S \]

3) surface hardness
\[ HB = 126.3 + 0.099n - 60S \]

4) the diameter deviation
\[ \delta = 19.793 + 0.000186n - 0.0455S \]

---

3. Results and Discussions

The main characteristic of the multiflute drill-broach is a compound of the multiflute drill and the broach features in one tool. This factor improves cutting conditions.

The results of the samples testing treated with the new cutting tool - hole-enlarging multiflute drill-broach and a new way of processing:

- the accuracy of the diametrical size of the holes is 0.018-0.033mm (7-8 IT Grade);
- the surface roughness of the holes is in the range \(Ra = 0.16 ... 0.32\)mkm, which corresponds to 9 and 10 grades of roughness.

Analysis of the results shows that the precision of holes diametric sizes after the treatment with hole-enlarging multiflute drill-broach increased by 1, 2 IT Grade as compared with the quality of cylindrical hole-enlarging multiflute drill; roughness decreased by 2, 3 grade. In this case, feed per tooth if necessary, can be reduced, and total allowance for processing hole-enlarging multiflute drill-broach is reduced.
According to the results of the data the graphs for speed effect and feed on the breakdown of the holes diameter with hole-enlarging multiflute drill-broach. Figures 15 - 16 are graphs of the precision of diametric dimensions of speed and feed to handle openings Ø19,8 mm.

As can be seen from the graphs, the diametrical size deviation increases with rotation frequency and decreases with increasing feed. This is due to the fact that the processing holes with the multiflute drill-broach close to broaching process.

The surface roughness of holes was measured on a profilometer 259 by the contact method. Figures 17 - 18 are graphs of the roughness dependence on rotation frequency of feed for the treatment of holes Ø19,8 mm.

The proposed approach makes it possible to radically solve the many problems of tool wear because the geometry of the proposed instrument and, consequently, forces and cutting forces contribute to less intense conditions of instrument operating. In other words, the tool geometry will allow on the basis of already known and proven structural materials provide greater tool life time. Moreover, due to better distribution of forces in the tool, and drastically reduces beats result becomes quality improvement treatment material, reduced roughness, improving alignment holes complex profile grows processing quality in general.

After machining with a hole-enlarging multiflute drill-broach, the hole surface microstructure was determined according to the procedure. The polished section was studied with a OLYMPUS BX2M metallographic microscope for surface microstructures (Figure 19-20).
Microstructure analysis of samples, machined with a hole-enlarging multiflute drill-broach, showed that inner surface has areas with a deformed layer, which maximum depth is 25 μm. This is a ferrite-pearlite microstructure.

4. Conclusion

The quality and the productivity of the holes machining process heavily depend on the tool design which defines the cutting conditions. A procedure is described for optimal design of the new multiflute drill-broach tool.

To sum up, experimental studies show that the processing of holes with the multiflute drill-broach provides a higher quality of holes surface, decreases roughness, depth of the defect layer, a breakdown of the holes. This is due to benign cutting conditions in comparison with standard multiflute drill. Due to the taper cutting part of the multiflute drill-broach a constant pulling force, elimination of the cutting process continuity influence, reducing the overall length of the simultaneous cutting edges of the teeth are provided and, as a consequence, the tool life has been increased by 2-3 times compared to a standard multiflute drill.

Analysis of the results shows that the diametrical size accuracy of holes after the treatment with the multiflute drill-broach has been increased by 1, 2 quality grade compared to broaching; roughness has been decreased by 1, 2 grade.

Analysis of the above made graphs enables the optimal choice of processing modes for getting high precision parts. The accuracy of the geometric sizes, the lowest roughness is provided at relatively low speeds of rotation and high feed, and depth of the defect layer grows with increasing rotation frequency and decreases with the growth of tool feed.

Microstructure analysis of samples, machined with a hole-enlarging multiflute drill-broach, showed that inner surface has areas with a deformed layer, which maximum depth is 25 μm.
This is a ferrite-pearlite microstructure.

Acknowledgements

This study is a part of a grant under the Young Scientist program of the S. Toraighyrov Pavlodar State University on topic No. C1 "Determination and designation of cutting modes for machining holes with new cutting tools" Order No. 1-02-07/683 dated 11/23/2009. Research continue to date within the initiative-search topic "Research and development of resource-energy-saving metal-cutting tools" from its own funds, which is registered in the National Center of Science and Technology Evaluation JSC (Kazakhstan) registration number 0117PKU0382, 2017.

References


[16] Bulat, P., Volkov, K., Ilyina, T. "Interaction of a Shock Wave with a Cloud of


**Nikolay S. Dudak**
He is Candidate of Engineering Sciences. Now he is Professor at Mechanical Engineering and Standardization Department in S.Toraighyrov Pavlodar State University. His main works was “TRUE LIC N.K. REERH”, which was printed in. Pavlodar, S.Toraighyrov. Also, in co-authorship with Janushkin, AS in 2011, he wrote next work “METHOD AND CUTTER HEAD FOR HIGH-PERFORMANCE FACE PERFORMANCE OF HOLES”. Besides, he gas three self-written works “Cosmic morality, the cosmic knowledge of unity and brotherhood”, “A true world view is the epistemological basis of secular education of morality” and “Thin-energy-information Basis and Beauty of Life and Evolution”.

**Galiya T. Itybaeva**
She is Candidate of Engineering Sciences. Now she is Associate Professor at Mechanical Engineering and Standardization Department in S.Toraighyrov Pavlodar State University.
Her main works was written in co-authorship and called “Processing of holes with a reamer-broach” (2014) and “Hole machining based on using an incisive built-up reamer” (in 2017).

**Asylbek Z. Kasenov**  
He is Candidate of Engineering Sciences. Now he is Associate Professor at Mechanical Engineering and Standardization Department in S.Toraighyrov Pavlodar State University. His main works was written in co-authorship and called “Control holes with calibers” (in 2013); “Review and analysis of the capabilities of application programs” (in 2017); “Processing of holes with a reamer-broach” (in 2014); “AN ISSUE OF INTELLIGENT ROAD TRANSPORT IN KAZAKHSTAN” (in 2017) and “Hole machining based on using an incisive built-up reamer” (also in 2017).

**Zhanara K. Mussina**  
She is Candidate of Engineering Sciences. Now she is Associate Professor at Mechanical Engineering and Standardization Department in S.Toraighyrov Pavlodar State University. Her main works was written in co-authorship and called “The use of magnetic phenomena in non-destructive control” and “Hole machining based on using an incisive built-up reamer”.

**Aizhan Z. Taskarina**  
She is PhD and work as Associate Professor at Metallurgy Department in S.Toraighyrov Pavlodar State University. Her main works was written in co-authorship and called “Physical phenomena in the tool zone during the hole-making operations of the tool slide built-up reamer” (in 2014); “The method of finishing turning billets with an inclined axis through a continuous saber cutter” (in 2014); “The design of broaching profile profile cutting with screw-like equal teeth” (in 2014); “International scientific conference of young scientists, undergraduates, students and schoolchildren ”XV Satpayev readings” (in 2015) and “Materials of the X international scientific and practical conference «CONDUCT OF MODERN SCIENCE -2014» (in 2014).  

**Kairatolla K. Abishev**  
He is Candidate of Engineering Sciences. Now he is Associate Professor at Transport Equipment and Logistic Department in S.Toraighyrov Pavlodar State University. Now he doesn’t his own works.
Figure captions

Fig 1. Elements of cutting at hole enlarging.
1 – hole-enlarging multiflute drill; 2 - blank; φ - the main angle in the plan; a – thickness of cut; b - width of cut; t - depth of cutting; D - diameter of the hole; Do – diameter of pilot hole; L - length of treatment; S - axis feed; Sz - feed per tooth; V – speed of cutting

Fig 2. Scheme of axial force distribution on the cylinder of a standard hole-enlarging multiflute drill.

Fig 3. Scheme of acting specific forces complex diagrams.

Fig 4. Scheme of forces acting in broaching.
Di – broach teeth diameter; L – length of broaching; A – allowance; Sz – Advance per tooth; b – cutting edge width; p – tooth pitch; P – broaching force; Pyi. Pzi – forces acting in broaching.

Fig 5. Scheme of broach teeth operation.
L – length of broaching, P0 – tooth pitch; ΔP0 – distance between the workpiece and the next tooth No. 5.

Fig 6. Structural elements of hole-enlarging multiflute drill-broach
dfr.sh., dre.sh. – diameter of the front and rear shank; dfr.pil.– diameter of the front pilot; dsiz.part – the diameter of the sizing part; dre.pil. – the diameter of the rear pilot; ℓfr.sh., ℓre.sh. – the length of the front and rear shank; ℓneck – neck length; ℓfr.pil., ℓre.pil. – the length of the front and rear pilot; ℓann.groove. – the length of the annular groove; ℓcut.port. – the length of the cutting portion; ℓsiz.part. – the length of sizing part; L – the length of hole-enlarging multiflute drill-broach, ω – the angle of spiral leads, ω direction like cutting direction; to – axial step of hole-enlarging multiflute drill-broach; 1 – front shank; 2 – neck; 3 – front pilot; 4 – an annular groove; 5 – cutting portion; 6 – chip-breaking groove; 7 – clearance groove; 8 – sizing part of hole-enlarging multiflute drill-broach; 9 – rear pilot; 10 –
rear shank.

Fig 7. Ross-sectional profile of hole-enlarging multiflute drill-broach.

\( \gamma \) – front corner; \( \alpha \) – back angle; \( \eta \) – the angle of the tooth back \((\eta=\gamma)\)

Fig 8. Cross-sectional profile of hole-enlarging multiflute drill-broach with hard alloy plates

1 – hard alloy plate; \( \gamma \) – front corner; \( \alpha \) – back angle; \( \eta \) – the angle on the tooth back \((\eta=\gamma)\)

Fig 9. Distribution of forces by the holes processing with hole-enlarging multiflute drill-broach.

Fig. 10. Scheme of the main cutting motions.

1- hole-enlarging multiflute drill-broach; 2 - workpiece; 3 - rotational motion in the designated point A gives the cutting motion inherent to reaming; 4 - the progressive movement of the workpiece, causing the cutting force along the axis of the hole-enlarging multiflute drill-broach and propelling the cutting inherent in broaching; \( S_z \) - feed per tooth; \( t_o \) - axial spacing between the teeth.

Fig 11. Hole-enlarging multiflute drill-broach.

Fig 12. Graph of transient process.

Fig 13. Free position of a hole-enlarging multiflute drill-broach.

Fig 14. Terminal position of a hole-enlarging multiflute drill-broach.

Fig 15. Graph of diametrical size accuracy dependence on the rotation frequency for processing \( \varnothing 19.8 \) mm.

Fig 16. Graph of diametrical size accuracy dependence on the feed for processing \( \varnothing 19.8 \) mm.

Fig 17. Graph of the roughness dependence on the speed machining of holes \( \varnothing 19.8 \) mm.

Fig 18. Graph of the roughness dependence on the feed in the processing holes \( \varnothing 19.8 \) mm.

Fig 29. Microstructure of a sample No. 4, machined with a hole-enlarging multiflute drill-broach \( \times 200 \).

Fig 20. Microstructure of a sample No. 4, machined with a hole-enlarging multiflute drill-
broach x100.
Fig. 2
Fig. 9
Fig. 10
Fig. 12

$T_y < 2T_x$ - oscillation process

$T_y > 2T_x$
Fig. 15

Graph showing the effect of rotation frequency on the wear depth (Sd) for different materials:
- **Cost-iron GG 15-32**
- **Bronze CuAMn 9-2**
- **Stabilized steel 3**

Material details:
- **Diameter**: 19.8 mm
- **Depth of cut (S)**: 0.2 mm/rev

The graph plots Sd (wear depth) against rotation frequency (rot/min) from 120 to 300 rotations per minute.
Fig. 17

- Stabilized steel 3
- Cast iron GG 15-32
- Bronze CuAMn 9-2

$\varnothing 19.8\ mm$
$S=0.2\ mm/rev$
Fig. 18

- Cobalt alloy GG 15-32
- Bronze CuAMn 9-2
- Stabilized steel 3

Rotation frequency:
- Diameter: 19.8 mm
- Rotation frequency: 210 rot/min

Horizontal axis: s, mm/rev
Vertical axis: Ro, MKM
