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Broaching As A Way Of Ensure Quality During The Recovery Of Surface Of The Pinholes In Details From High-Temperature Materials.

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ABSTRACT

Broaching as a way of improve the quality and recovery of openings small diameter in high-temperature alloys is considered. The article presents results of machining of openings of draw plate feeders for obtaining basalt fibers with using flexible broach. The problem is to improve the quality of hole surfaces draw plate feeders by reducing roughness, and correcting deviations of the form, as well as to improve production efficiency by the possibility of collecting the chips during processing. A method of recovery work surfaces of draw plate feeders for obtaining basalt fibers with using flexible broach. The correction curvilinearity of the axis of draw plate (deviation of form) is provided by a complex of construction features, such as flexible cable shaft and the linkage between the elements by means of protrusions and recesses which corresponding to each other in shape and size on end face. The simulation results have shown that the offered by authors method of recovery work surfaces of draw plate feeders for obtaining basalt fibers with using flexible broach allows to remove the desired material without damaging the tool, correcting the hole axis and provide the desired roughness. Simulation of the processing is also considered in this article.

Key words: Broaching, Mathematical model, Deform

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INTRODUCTION

When parts are manufacturing have to meet with the processing of deep pinholes in hard alloys. Achieving the desired accuracy in machining openings is more difficult than the outer surface during processing. Draw plate feeders or extruders can be attributed to this details.

Depending on official appointment it is necessary to provide openings dimensional tolerance, surface roughness [1], straightness of the hole axis and its generatrix, correct geometric shapes, alignment, concentricity with the other cylindrical surfaces and the openings, perpendicular axis of the hole - end face, the distance between the axes of the holes from the specified base [2].

Both the wear of hole's surface and destruction of the product are arise during use. For example, the hole surfaces of draw plate feeders for obtaining basalt fibers are exposed active wear because of the aggressiveness of melt basalt [3].

The result of this wear is increase the height of microroughnesses on the its surface, that leads to rupture of fibers, stopping of the installation and replacement of the draw plate as the forming tool [4].

The material the draw plate feeders for obtaining basalt fibers is an alloy based on platinum and rare earth elements, that is, it has a high cost and its replacement leads to additional costs, that eventually passed on to the cost of products [5]. The recovery of the hole surfaces in conditions of repair manufacture could decrease these costs.

The problem is to improve the quality of hole surfaces draw plate feeders by reducing roughness, and correcting deviations of the form [6], as well as to improve production efficiency by the possibility of collecting the chips during processing. The decrease of roughness is achieved by having of the deforming element, which "smooths" the remaining after cutting elements roughness in the process of drawing. The burnishing force is determined by the method described in [7]. Considering that the stock for burnishing isn't more than 0,05 μm, it is insignificant.

Also collecting chips is especially relevant, if the work piece material - an alloy of precious and rare earth elements having high cost that is the return of materials after processing is needed. This can be achieved by designing features execution of a special tool to broach the holes, for example, of the implementation of deforming element and the location chip grooves of cutting elements staggered.

A patent on a special flexible broach to receive openings is obtained by the authors [8].

MATERIALS AND METHODS

The essence of flexible broach is that it includes a flexible cable shaft with installed on it operating elements with chip grooves staggered. They connected to each other on end face by means of protrusions and recesses which corresponding to each other in shape and size. Broach provided a deforming element which placed after the last working element and designed as a ball truncated on two parallel planes. The material of the flexible cable shaft selected according cutting forces.

The problem solved by the utility model is development of the device which helps to raise the quality of the treated surface by reducing the roughness and correcting the deviation form and also to improve production efficiency due to the possibility of collecting chips while machining.

This problem is solved by the chip grooves staggered and supply of the broach with a deforming element which is placed after the last working element, and designed as a ball truncated on two parallel planes. At the same time all of working and deforming elements are connected to each other by means of protrusions and recesses which corresponding to each other in shape and size, and the material of the flexible cable shaft selected according the depending: $P_{broach} < \sigma_{add} < P_{cutting\ forces.}$

The offered broach is intended for broaching draw plate in devices for obtaining basalt fibers, which diameter ranges are 2.0 - 0.8 mm. In connection to the high hydrostatic pressure and high temperature of basalt melt, from which the fiber is obtained, device for producing basalt fibers is made of precious and rare materials such as alloy PtIrRo- 20 DS.

Initially, in the device for obtaining basalt fiber, which is a slab with draw plate (through-holes) after drilling, draw plate is treated of broaching. Then, during manufacturing of basalt fiber the shape and roughness of the inner surface of draw plat is changed, which leads quality problems of fiber.

Using the offered broach, you can restore the state of draw plate surface, its form, change the diameter of the fiber and subsequently receive the fiber of required quality and diameter. The improvement of quality of treated surface is expressed in decrease of roughness and correction of the surface shape [6]. The decrease of roughness is achieved by having of the deforming element, which "smooths" the remaining after cutting elements roughness in the process of drawing. Also, a complex of construction features, such as flexible cable shaft and the linkage between the elements by means of protrusions and recesses which corresponding to each other in shape and size on end face, provide the correction curvilinearity of the axis of draw plate (deviation of form).

As the material of the work piece is the alloy of precious and rare-earth elements having high cost, need to return the material after treatment, that is provided of construction features of the implementation of deforming element and the location chip grooves of cutting elements staggered.

The choice of the material of the flexible cable shaft is selected according the depending: $P_{broach}<\sigma_{add}<P_{cutting\ forces}$, where P_{broach} – the force of broaching cutting; σ_{add} - allowable force at break of the shaft; $P_{cutting\ forces}$- cutting force.

RESULTS

The essence of flexible broach for processing of openings of small diameter is illustrated by graphic materials.

Fig. 1 shows a flexible broach for processing of openings of small diameter, general view; Fig. 2 shows a joint of cutting elements, a note I from Fig. 1.

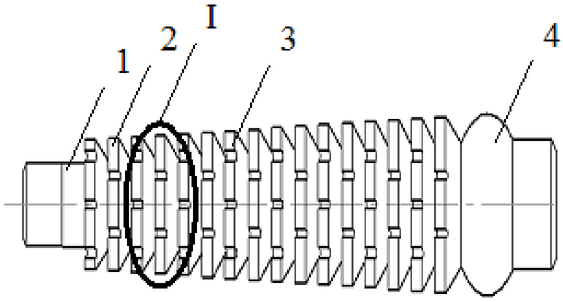

Figure 1: Flexible broach for processing of openings of small diameter, a general view

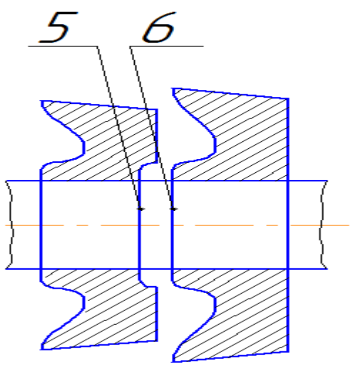

Figure 2: Joint of cutting elements, a note I from figure 1

The flexible broach for processing of openings of small diameter includes a flexible cable shaft 1 with installed on it operating elements 2 in the form of cups having chip grooves 3 staggered. The broach is provided a deforming element 4 which placed after the last working element, and designed as a ball truncated on two parallel planes. All working elements 2 and deforming element 4 are connected to each other on end face by means of protrusions 5 and recesses 6 which corresponding to each other in shape and size. The material of the flexible cable shaft selected according the depending:

$$P_{broach} < \sigma_{add} < P_{cutting\ forces}$$

where P_{broach} – the force of broaching; σ_{add} - allowable force at break of the shaft; $P_{cutting\ forces}$- cutting force. This makes it possible to get the optimum value σ_{add} and select the material of cable shaft.

The flexible broach for processing of openings of small diameter is installed and works as follows:

Previously the material of the flexible cable shaft selected according the depending:

$$P_{broach}<\sigma_{add}<P_{cutting\ forces.}$$

At the end of cable shaft 1 rigidly installed the deforming element 4 which is designed as a ball truncated on two parallel planes. Then on cable shaft the cutting elements 2 in the form of cups with diameters in the descending order are mounted. The number of cutting elements 2 depends on the necessary quality of processing. The spherical protrusions 5 and recesses 6 are made on the end face of the cutting elements 2 to ensure the angular displacement for the purpose of location of chip grooves 3 staggered (Fig. 2). In the previously drilled draw plate the free end of the cable shaft is introduced, and the first cutting element is fed to a processed surface. Then the attractive force is included and the processing begins. Each next operating elements 2 begins to increase the diameter of the opening. The last cutting element 2 has the required diameter. This serial removal of the stock with the flexible cable shaft 1 allows to obtain or restore the required precision shape of draw plate. The chip grooves 3 are arranged staggered for removal cut material to the side of each following cutting element 2. The deforming element 4 serves for final smoothing of surface roughness and collecting the cut material, and the space between the final cutting element 2 and deforming element 4 serves to collect the cut material and its removal from draw plate.

In general, the mathematical model for determining cutting forces of broaching process has the following limitations [7].

Restriction 1. The cutting force when broaching is determined from the value of the length of simultaneously working cutting edges of broach teeth [9]:

$$P_z = P_p * Z_{pZ}$$

where P_z- cutting force on 1 mm of the length of cutting edge of broach teeth;

P_p – perimeter of the treated surface;

Z_{pz} – the number of simultaneously working teeth.

Restriction 2. The cutting force is divided into two components acting along the direction of motion of broach and perpendicular to it. The first component determines the required broaching force, which the applied equipment should ensure, and also the necessary strength of structural elements of broach. The second component, which separates the broach from the work piece determines the dimensional accuracy of the detail after broaching. And therefore it should be considered for external and internal asymmetric broaching [10].

Restriction 3. Let us assume, that each millimeter of the length of front surface of the tooth blade is loaded by force ΔPx, which parallel directed to the velocity V. And the part of the same length of back surface of the blade is loaded by force ΔPy, which perpendicular directed to the force ΔPx. Then the force acting on each tooth of broach, is [10]:

$$P_x = bz * \Delta Px$$

$$P_y = bz * \Delta Py$$

where bz – the total width of layer which cut off one tooth, mm.

Restriction 4. The values of specific forces ΔPx and ΔPy depend on the thickness of the shear layer - t, cutting speed V, front angle γand rear angleα, and k - the number of chip grooves on the blade of each tooth.

Thus we obtain a mathematical model of the process of broaching expressed by the system of equations:

$$P_X = 1{,}15bz\,(C_1 a_Z^x + C_2 k - C_3 V - C_4 \gamma - C_5 \alpha)$$
$$P_Y = 1{,}15bz\,(C_6 a_Z^x + C_7 V - C_8 \gamma - C_9 \alpha)$$

As a geometric model is used the model of obtain in a medium of solid modeling KOMPAS V13 (Fig. 3), and as a package of finite element analysis is DEFORM.

As a material model is assigned platinum having a density - 21,45 g/m^3, Poisson's ratio – E=5*10^{11} N/m^2;Young's modulus - μ=0,32.The model was devoid of all six degrees of freedom, that is rigidly fixed. As a material of the cutting part is accepted a carbide - T6K5, Poisson's ratio – E=1,5*10^{11} N/m^2;Young's modulus - μ=0,28 [10,11].

We specify the conditions for subsequent modeling of broaching.

As a fracture criterion used adopted in the system DEFORM default normalized Cockcroft - Leytem's criterion, which indicates the destruction of metals and alloys during a monotone deformation with reasonable accuracy.

$$D = \int_1^{\bar{\varepsilon}} \frac{\sigma^*}{\bar{\sigma}}\, d\bar{\varepsilon} D = \int_1^{\bar{\varepsilon}} \frac{\sigma^*}{\bar{\sigma}} d\bar{\varepsilon}$$

where $\bar{\varepsilon}$– the accumulated equivalent deformation;

σ^*- the maximum principal stress;

$\bar{\sigma}$ - the Mises equivalent stress.

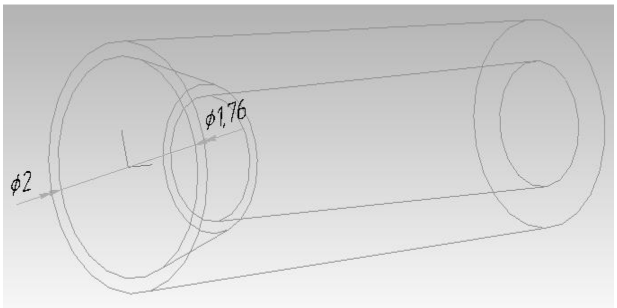

Figure 3: Geometrical model of the opening

This criterion is the most simple and is based on a calculation of potential energy of the plastic deformation. This criterion can evaluate the possibility destruction of solids with reasonable accuracy in plastic deformation with a simple movement trajectory.

The critical value of the criterion is received 0.28 [12].

The results of modeling of broaching openings are shown in Fig. 4. It shows that the greatest cutting force for one cup is 650-700 MPa. As the stock varies evenly and all the cups are equally loaded, then it is 700 MPa for 10 cups, which is quite acceptable when using the declared in patent cable of broach.

The burnishing force is determined by the method described in [7]. Considering that the stock for burnishing isn't more than 0,05 μm, it is insignificant.

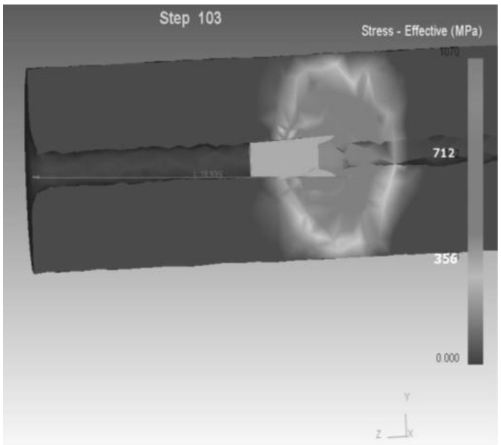

Figure 4: Simulation of process of drawing

DISCUSSION

Analysis of the results of the mathematical model of the process of shaping shows that it is possible to find the forces, generated by the cutting edges of the teeth [13].The broaching openings of small diameter in materials having considerable hardness and plasticity, is quite difficult. The authors already have experience in processing of nickel alloys, and also experience in simulation of the machining [9].

This task is complicated by the fact that experiments on broaching deep openings in the articles of precious and rare earth elements associated with additional costs of materials, but the above described tool allows to collect the cut material of stock.

In the analysis of this problem is necessary to determine the arising cutting forces, also check the possibility of using the flexible cable shaft in the construction of broach as the carrier of cutting cups, and also the possibility of correcting shape of the opening.

CONCLUSION

The simulation results have shown that the offered by authors method of recovery work surfaces of draw plate feeder obtaining basalt fibers with using flexible broach allows to remove the desired material without damaging the tool, correcting the hole axis and provide the desired roughness.

The area of using the results of this work is limited by industrial objects that use structural elements containing pinholes. The implementation of this method for holes which diameters are greater than 5 mm is associated with an increase of the broach's size, and most importantly, with the advent of considerable cutting forces. During the research, the authors estimated the possibility of the recovery of the hole surfaces in the alloy PtIrRo- 20 DS. As the spectrum of the alloy of draw plate used in the glass industry is considerable, that the authors plan to get recommendations to recovery the geometry of the holes in other materials in the long term, and also the development of the device to control of roughness on the surface of the hole [11].

The practical implementation of the results of the research is introduced by authors in Joint Stock Company "Ivotsteklo" in installations for obtaining basalt fibers. The mechanisms to recovery of rigging for obtaining glass fibers and minerals with minimal costs are also required in companies engaged in production of soundproof materials and heat insulating materials.

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