Tooling Backup of Cutting and Deforming Processing of Non-rigid Shafts

E. I. Yatsun, N. P. Anikeyeva and I. S. Karnaukhov

Abstract The article presents the conditions for ensuring the quality parameters of the machining of surfaces of hydraulic cylinder rod during machining and using the methods of surface plastic deformation. Modern machines and equipment should have a good performance in various conditions of their use. Improvement of performance characteristics can be achieved both through the constructive improvement of machines, the use of new structural materials and the use of advanced technology for manufacturing parts and through the development of new tool designs and improvement of existing ones. The article analyzes the static and dynamic characteristics of the tool system for combined cutting and deforming processing, which affect the accuracy parameters of the machining quality. The processes of combined machining and surface plastic deformation of non-rigid parts of the shaft class are considered, and the results of the study of technological parameters of processing for cutting and deforming rod treatment are presented which are obtained during production tests. Traditionally, non-rigid parts are machined by turning, followed by grinding and polishing. However, turning and abrasive machining often provide the required quality parameters of these parts (JT7 … 8, Ra < 0.16 .., 0.32 micron) as unstable and have low productivity, and as a result these processes are not used for manufacturing these parts. The use of tools and tool systems for the combined cutting and deforming machining can improve the accuracy of the shape and size of the processed non-rigid part, to ensure a small amount of surface roughness and to improve the physical and mechanical properties of the surface layer of the part.

Keywords Non-rigid part · Tooling system · Roughness · Vibration · Anti-vibration holder · Dampening cutter

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1 Introduction

Purpose of work—increased productivity while ensuring the required quality parameters of machining of non-rigid parts.

Subject of research—the processes of combined machining and surface plastic deformation of non-rigid parts, as well as the study of technological parameters of processing in the tool system for cutting and deforming processing of the said parts and the influence of structural elements of the tool system on the machining error in the system.

Object of research—tool system for combined cutting and deforming treatment of non-rigid parts.

Urgency—practical value it consists in the development of the design of the tool system for cutting and deforming processing of non-rigid parts and recommendations for the selection of technological modes of cutting and deforming processing of non-rigid parts necessary to obtain the required parameters of the product.

2 Problems of Achieving Quality in the Processing of Long Shafts

Rod is a part of the hydraulic cylinder (Fig. 1).

The development of new high-performance and improvement of existing designs of tools and tool systems in the manufacture of non-rigid parts with the possibility of using them for various types of production is a task of great scientific and practical importance. The solution of the problem of stabilizing the machining process during cutting will ensure the specified resistance of the cutting too [1–18].

Rod refers to the type of long non-rigid shafts, the condition $l/d = 10 \ldots 20$ is satisfied: diameter 60d9; length 4050 mm; surface roughness Ra_{max} 0.32 microns; hard chrome coating thickness h_{min} 20 microns. Part material—Steel 45 GOST 23270-89. Hardness is HB269 in a condition of delivery.

For a tight connection with the working cylinder by means of bushings with seals it is necessary the high quality of the guide surface of the rod. The main task in

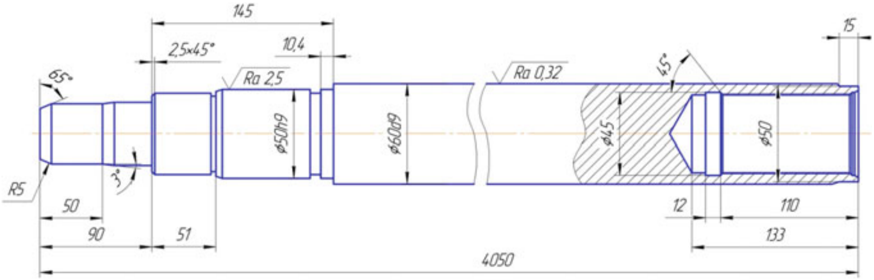

Fig. 1 Rod design

the finishing treatment of hydraulic cylinder rods is to achieve the stability in obtaining the required dimensions and surface roughness.

We analyze the processing of part "Rod" (Fig. 1). Rough Stock—Pipe 73X15-35 GOST 23270-89.

Since the outer surface of the rod works in an aggressive environment and must withstand heavy loads, then running, polishing and chroming the outer surface are used to harden the surface layer of the part, to increase its wear resistance and to provide the required surface roughness.

Problems with processing part "Rod":

(1) using a fixed steady to reduce the spinning of the rough stock during the turning leads to stop the machine and rearrange the steady;
(2) pressing leads to a barrel shape in the middle of the shaft and causes the tool to vibrate;
(3) using a soldered tool does not give a stable receipt of the roughness parameter in the finishing turning operation;
(4) after the operation of running, the fiber delamination of the surface is observed, which has to be removed with a sandpaper.

3 Tasks that Need to Be Solved to Achieve Quality in the Processing of Long Shafts

To improve the processing efficiency of the guide surfaces of the rod it is necessary to solve the following tasks:

1. To ensure the specified roughness parameter $R_{a\max}$ 2.5 microns for the finishing turning operation, it is necessary to choose a new design of the turning tool.
2. To reduce vibrations that impair the quality of processing, it is recommended to use anti-vibration cutting tool holders.
3. It is proposed to turn the turning at the turning center РЦМ8000 with a through-slide and a moving steady (Fig. 2).

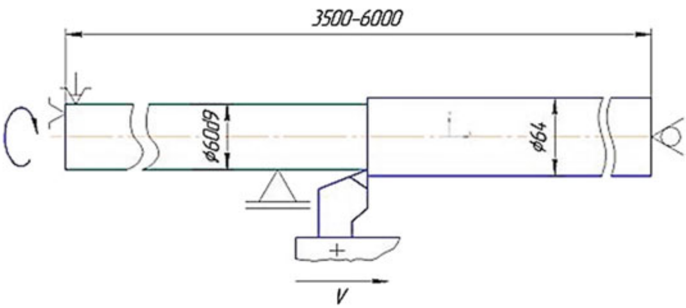

Fig. 2 The scheme of the operation

Under the action of cutting forces and its own weight, the stock bends, vibrates. Consequence: the destruction of the cutting plate of the cutter, the deterioration of the quality of processing, reduced performance. To avoid these shortcomings, the treatment with a moving rest is applied [19–24].

In the process of processing the movable lunette moves with the cutter, which allows you to place the Cams of the lunette in close proximity to the cutting zone and thus almost eliminate the deflection of the workpiece. Chips under this condition moves to the left, which is required. The lunette is exposed on the processed surface by means of a short mandrel. One end of the mandrel is fixed in the cartridge, and on the other end, pre-verified with the indicator, set the Cams of the lunette.

4 Theoretical Studies of Options to Achieve Quality in the Processing of the Shaft

The surface under the Cams should be periodically lubricated to reduce friction. Since in the process of processing the part is heated and it is necessary to weaken the compression of the rear center, it is proposed to conduct processing in the direction from the cartridge to the tailstock, that is, from left to right (Fig. 2).

Two variants of the tool are considered:

(1) Lamina STAR-LINE cutter: holder ST-SXJBL 2525 M06, carbide inserts ST-VBMT 060404L NN LT 10 and ST-DBMT 060404L NN LT 10 with a cutting angle of 55° and 35°, respectively.
(2) Mitsubishi cutter: holder CTGPL 2525 with plates TPGR 160308L NX 2525 and TPGR 160304L NX 2525, plate material is metal-ceramic NX 2525 [25].

To select a tool with the best performance, an analysis of the solid model of cutters has been carried out using the Solidworks software (Fig. 3) [26].

As a result of static analysis, the following values are obtained: stress, displacement and deformation of the composite cutter. For specified machining conditions when turning the outer surface of the Ø60 stem (−0.12; −0.18), Mitshubishi cutter (holder CTGPL2525, plate TPGR 160308L NX 2525) is recommended.

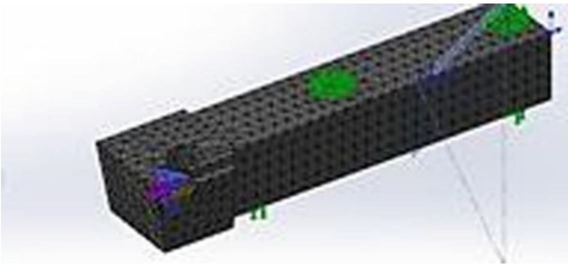

Fig. 3 Solid-state cutter model CTGPL2525 after generation of finite element mesh

Experimental industrial processing has been carried out to check the performance and stability of the resulting dimensions and surface roughness, to determine the period of resistance of the plates. The roughness of the surface of the rough stock after finishing has been measured. The full-factor experiment 2^3 has been set up. It has been revealed the dependence of the roughness value of the machined surface after finishing turning on three factors—the rotational speed of the rough stock *n*, the depth of cut *t* and the feed of the cutting tool *S*.

Following experimental processing conditions: assembly part—rod; rough stock- Trumpet 73X15-35 GOST 23270-78; number of parts—48; diameter of treated surface ∅60d9; length of the treated surface/part length,—3769/3942 mm; tolerance of the treated surface cylindrical rod along the entire length of 0.01 … 0.02 mm. The cutting modes are n = 214/250 rpm, t = 2/1.5/1.2 mm, S = 0.26/0.3/0.33 mm.

When increasing or decreasing the feed value, a decrease in the resistance period of the cutting edge of the plate has been observed. Reducing the supply leads to wear on the back surface of the tool and to reduce its durability. The increase in feed leads to higher temperatures in the cutting zone and to wear on the front surface. To prevent strong heating of the cutting plate abundant cooling of the coolant "Cimstar 536" is used.

However, the impact of the feed on tool life is disproportionately small compared to the cutting speed. Cutting speed recommended by the manufacturer is 200 … 300 m/min. Cutting speed when processing rods ∅60d9 is · 40 m/min. The vibration has not arisen during the experimental processing.

Based on the processing carried out, it has been established:

The roughness of the guide surface of the rod is ∅d60d9 Ra 9.43 … 9.47 microns; cylindrical tolerance over the entire length of 0.01 … 0.02 mm. Resistance period is T = 470 min on one cutting edge of the plate TPGR 160308L NX 2525 with a radius of the tip R = 0.8 mm, which corresponds to 8 processed parts. The plate has 3 cutting edges.

5 Experimental Studies of Options to Achieve Quality in the Processing of the Shaft

Experimental studies were carried out to determine the dependence of the roughness on the technological factors of the surface plastic deformation treatment process. For the experimental study, a special knurling with a damping element was used.

Two "Rod" parts have been tested, outer diameter ∅60d9. Surface roughness corresponds to the drawing, there is no fiber delamination.

For further theoretical substantiation of ways to reduce vibrations during cutting and the development of devices for their implementation it is required the development of effective methods for studying the processing of long non-rigid shafts and hardware. The solution of the problem of stabilization the machining process during cutting will ensure the specified resistance of the cutting tool with high productivity. We have proposed several new designs of damping cutters, qualitatively improving the processing of materials [27–33]. Experimental studies have been conducted to determine the dependence of the roughness value when machining with a dampening cutter. The results obtained suggest that when turning such tools of long non-rigid shafts, it is possible to ensure the roughness of the processed surface and increase the productivity of the process due to the cutting speed.

To prevent the appearance of fiber delamination during the running process, the design of a rolling tool with a dampening head has been developed and laboratory tests have been carried out.

We have proposed several designs of cutters that reduce vibration levels, including those associated with shock loads. A feature of the design of the cutter is the presence of grooves along the perimeter of the holder for better adhesion to the composite material on a polymer basis. The uniformity of the gaps between the tool holder and the inner walls of the glass is selected technological screws. The gaps are filled with a mixture of self-vulcanizing liquid rubber with a filler of different size fractions. Tests of cutters of standard and modified design at various modes of processing of a shaft for the purpose of identification of parameters of roughness of the processed surface and determination of value of natural frequencies of fluctuations of a turning cutter are carried out.

Experimental studies have been conducted to determine the dependence of the roughness in the treatment of a damping cutter. The roughness of the treated surface is achieved in accordance with the requirements. The productivity of the process is increased due to the cutting speed.

6 Conclusion

Experimental production and laboratory studies of turning and rolling of the guide surface of the rod were carried Ø60d9. During production tests revealed the following. In the lathe machining of the guide surface, the cutters were used:

(1) Lamina STAR-LINE cutter: holder ST-SXJBL 2525 M06, carbide inserts ST-VBMT 060404L NN LT 10 and ST-DBMT 060404L NN LT 10.
(2) Mitsubishi CTGPL 2525 with plates TPGR 160308L NX 2525 and TPGR 160304L NX 2525, plate material is metal-ceramic NX 2525.

The roughness of the workpiece surface after finishing was measured.

The full-factorial experiment 2^3 was put. The dependence of the roughness of the machined surface after the turning on three factors—the workpiece rotation frequency n, the cutting depth t, and the feed of the cutting tool is determined.

The conducted production studies have revealed that:

(1) with an increase in the feed value of the cutting tool above the interval 0,20 … 0,40 mm/rev and the cutting depth of more than 2 mm there is an increase in the roughness of the treated surface;
(2) when speed increase above 47 m/min, there was vibration of the cutter.

Resistance of the cutter №1 $T = 210$ min, which corresponds to the processing of 3 parts.
Resistance of the cutter №2 $T = 470$ min, which corresponds to the processing of 8 parts.
Resistance of the cutter №3 $T = 140$ min, which corresponds to the processing of 1–2 parts.

Recommended cutter №2 Mitsubishi CTGPL 2525 with plates TPGR 160308L NX 2525 and TPGR 160304L NX 2525, plate material is metal-ceramic NX 2525.

In the processing of surface plastic deformation applied special plastic deformation tool with a damping element. Roughness according to requirements.

Experimental laboratory studies of the turning treatment of the guide surface of the rod with a damping cutter were carried out. The roughness of the machined surface in accordance with the requirements and increase the productivity of the process due to the cutting speed.

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