Ministry of Education and Science of Ukraine
Sumy State University

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"IMPROVEMENT OF THE TECHNOLOGICAL PROCESS OF MANUFACTURING GUIDE DEVICE 002.002.00.03-03 BY SELECTING OF RATIONAL CUTTING PARAMETERS ON CNC MILLING OPERATION"

131 Applied Mechanics

Summary
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INTRODUCTION

Guiding device 002.002.00.03-03 is part of the pump cantilever type NK 16/70, which is used in the oil and gas industries and in industries where there is work with liquid minerals and in fuel supply systems. The demand for industries in pumps of this type is relatively high. The satisfaction of existing order can be achieved by designing promising technological processes for the manufacture of parts, which consider the need to improve machining associated with the part formation and change the physical and mechanical properties of its material and cutting parameters. Promising technological processes should increase manufacturing process efficiency and ensure quality parameters of the part. One of the possible ways to increase the productivity of machining and reduce the technological cost is to increase the tool life of the cutting tool by determining the rational cutting parameters, which is an urgent engineering task.

The study aims to improve the technological process of machining guide device 002.002.00.03-03 based on rational cutting parameters selection on CNC milling operation. **These research tasks** are solved to achieve the research goal:

- to perform an analysis of the basic manufacturing process of manufacturing parts Guiding device 002.002.00.03-03;
- to develop a rational manufacturing process of machining Guiding device 002.002.00.03-03;
- to develop a dedicated fixture on CNC milling operation for machining slots;
- to implement a full-scale experiment according to the design of an experiment. Measure and proceed flank wear rate of end mill at different cutting parameters;
- Determine the area of the most rational cutting parameters for the CNC milling operation.

The object of the study the technological process of manufacturing guide device 002.002.00.03-03.

The study's subject cutting parameters and tool wear at CNC milling operation.

The scientific novelty consists in:

- as a result of experimental research, mathematical polynomial models of the cutting tool flank wear and machining time was defined for five cutting parameters when milling steel 20X13 (AISI 420). The rational cutting parameter was determined when milling slots in part guiding device 002.002.00.03-03 based on experimental results analysis.

The experimental research was conducted **for practical value** to define cutting parameters for machining slots in part guide device 002.002.00.03-03 at CNC milling operation with a carbide end mill. Implementation of the specified cutting parameter in technological process increase tool life of cutting tool and productivity of CNC milling operation.

MAIN CONTENT

The first chapter discusses the purpose of the part, assembly, and product where it is used. The analysis of surfaces of part guide device and their purpose was carried out. The technical requirements and technological task for its manufacture and material are determined. The small-batch type of the details` production was determined based on the product launch batch analysis. The basic technological process of manufacturing of part was analyzed.

During the analysis, it was necessary to choose the workpiece and its production method, which will be the most cost-effective. For increasing the production efficiency of the part machining, it was proposed to modify the basic technological process via the replacement of milling and lath machines on modern CNC turning and milling centers. Cutting tools, as well as cutting parameters of machining, was proposed to be modified. According to the production type, it is advisable to develop a dedicated fixture for CNC milling operation that will reduce the setup error and shorten fixture lead time.

The second chapter is devoted to improving the technological process of manufacturing part guide device. Rational manufacturing steps for the manufacture of part were specified. According to the calculations, it was defined that the proper manufacturing method of workpiece production should be stamping. The proposed method is more cost-effective in comparison with forging. Using the method of Prof. Kovan, allowances for the most accurate surface of the part - Ø265f7 - were calculated 020 and 035 CNC Turning operation, and 045 CNC milling operation were chosen as operations for detailed analysis.

In 020 CNC Turning operation, roughing of surfaces Ø268 mm and boring Ø235 mm was carried out, using cutters DDJNL2525M15 and S32TPDUNL15, cutting inserts - carbide DNMG150608. Based on the analytical calculation and the tables, the ranges of cutting parameters varied: v = 171 m/min, f = 0,4 mm/rev; v = 184 m/min, f = 0,8 mm/rev; v = 234 m/min, f = 0,37 mm/rev. It is proposed to carry out technical control of the machined surfaces with calipers ШЦ-I-125-0,1 and ШЦ-II-300-0,1.

In operation 035 CNC Turning operation, the groove Ø265f7 is finished, parts` two ends Ø297 / Ø275 and Ø275 / 235 mm were machined and Ø237 mm was cut, using cutters DDJNL2525M15, S32TPDUNL15 and two grooves cutters TTFPL25200-4, cutting insert TD4C450. Based on the analytical calculation and the tables, the ranges of cutting parameters varied v = 250 m / min, f = 0.05 mm/rev, v = 150 m / min, f = 0.144 mm/rev, v = 250 m/min - 438 m / min were determined. Technical control of the machined surfaces is proposed to be carried out with calipers ШЦ-I-125-0,1 and ШЦ-II-300-0,1 and micrometer MK 275-0,01.

In 045 CNC milling operation of 6 channels and drilling of 12 holes, thread machining M6 openings Ø5 mm is carried out. Two carbide cutters Ø7 LH4EM-070, drills Ø5 SHD3050 and Ø7 SHO3070, tap M6-6H 2621-1493 and countersink DIN 335 are used as a cutting tool in this operation.

Based on the analytical calculation, cutting parameters in the range from v = 15 m / min, v_f = 15 mm / min, v = 120 m / min, v_f = 450 mm / min. Technical control of the treated surfaces is proposed to be carried out with thread gauge M6-7H ПР/НЕ, calipers ШЦ-I-125-0,1 and ШЦ-II-300-0,1, micrometer MK 275-0.01, plug caliber. A dedicated fixture has been designed for the current operation, which with the help of a pneumatic chamber and three clamps, allows fixing the workpiece with minimal time and minimal locating error (Fig. 1). Clamping force of the device - 2474 N, error of locating 220 µm.

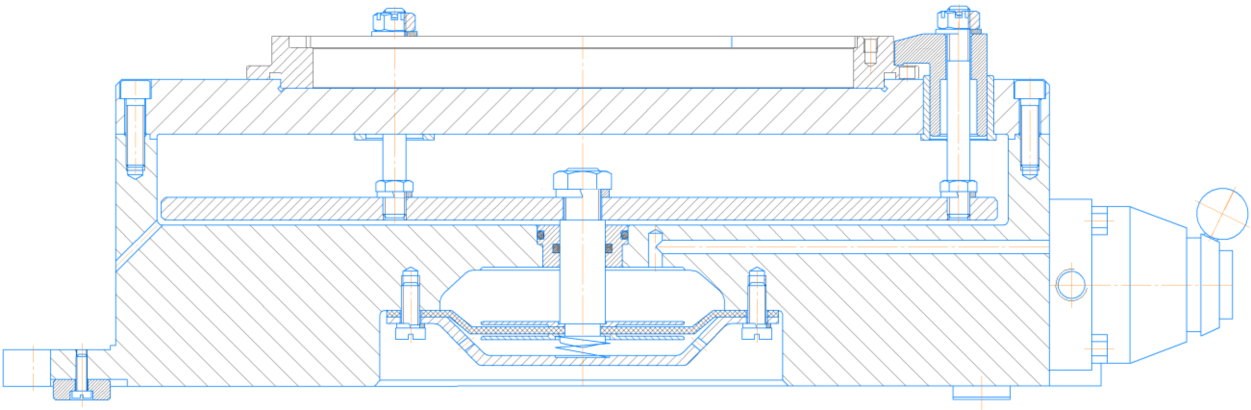


Figure 1 – Sketch of a special device

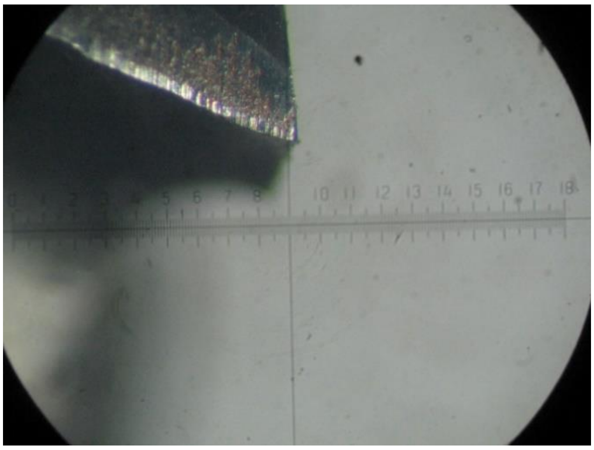
The third chapter is devoted to the experimental (full-scale) study of tool wear when milling. Based on the analysis of the basic technological process of machining the guide device, the engineering problem of low tool life of end mill when machining slots on CNC milling operations was determined, which led to further research.

As a result of end mills design analysis, it was found that end mill ⌀8 mm LH4EM is suitable for machining slots. Considering cutting parameters recommended by tool manufacture and cutting parameters defined via analytical calculations the upper and lower levels of cutting speed and feed were specified. The experiment's design consisted of two factors: cutting speed and feed, which varied on two levels. In such a way, the design of the experiment included five trials (Table 1). The end mills' tool life study was carried out on an experimental setup assembled at CNC milling center MAG FADAL VMC 4020 FX.

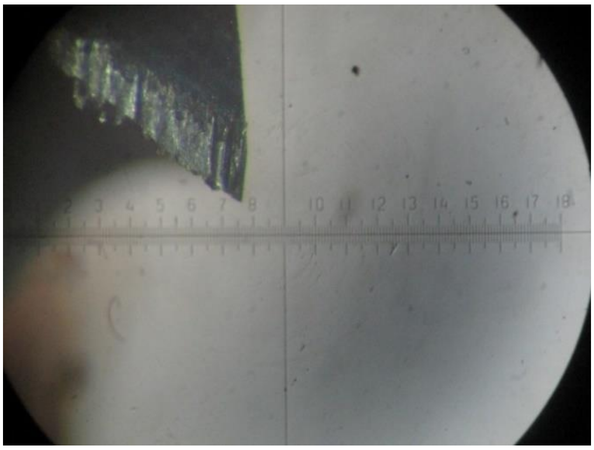
Table 1 – Design of Experiment 2^2

Coding of factors			Decoding of factors			
№ Trail	**X_1**	**X_2**	**Cutting speed *v*, (m / min)**	**Feed v_f, mm / min**	**Depth of cut, (mm) const.**	**Number of cuts**
1	-1	-1	40	180	1	3
2	+1	-1	114	180	1	3
3	-1	+1	40	225	1	3
4	+1	+1	114	225	1	3
5	0	0	77	203	1	3

During the experiment, the tool path was managed by the CNC program, which ensured the tool movement's stability with an equal cutting path (2.24 m) in each trial of the experiment. Flank wear was determined as a criterion of tool life of end mill. It was proposed to measure flank wear on the flank surface of axillary cutting edge of the end mill. Measurements were carried out on tool microscope МБС-9 with an accuracy of up to 7 μm (Fig.1). Flank wear of the end mill in each trail was measured three times after each cut. Each cut depending on cutting parameters, was equivalent to the time interval from 8 minutes 11 seconds to 12 minutes 10 seconds.



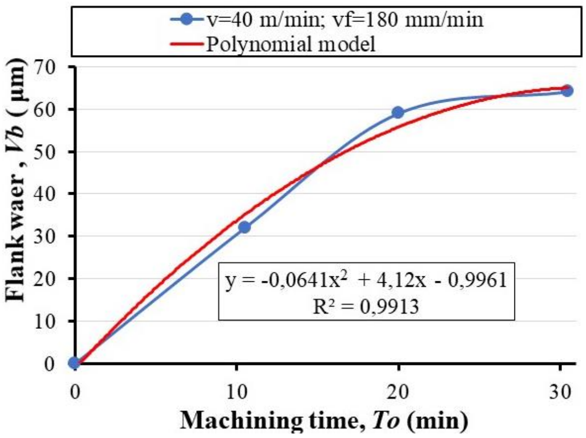
a)



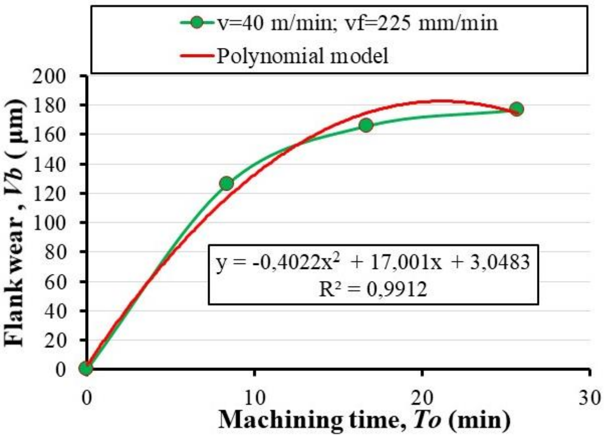
b)

Figure 1 – Measurement of cutting tool at tool microscope МБС-9: a) End mill №1 after the third cut; b) End mill №4 after the third cut

Results of flank wear measurement were summarized in graph form (Fig. 2). Excel software analytical tools were used to define the dependence between flank wear and machining time regarding cutting conditions. The polynomial model was defined as the most appropriate for an approximation of gained data.



a) Flank wear in trail №1

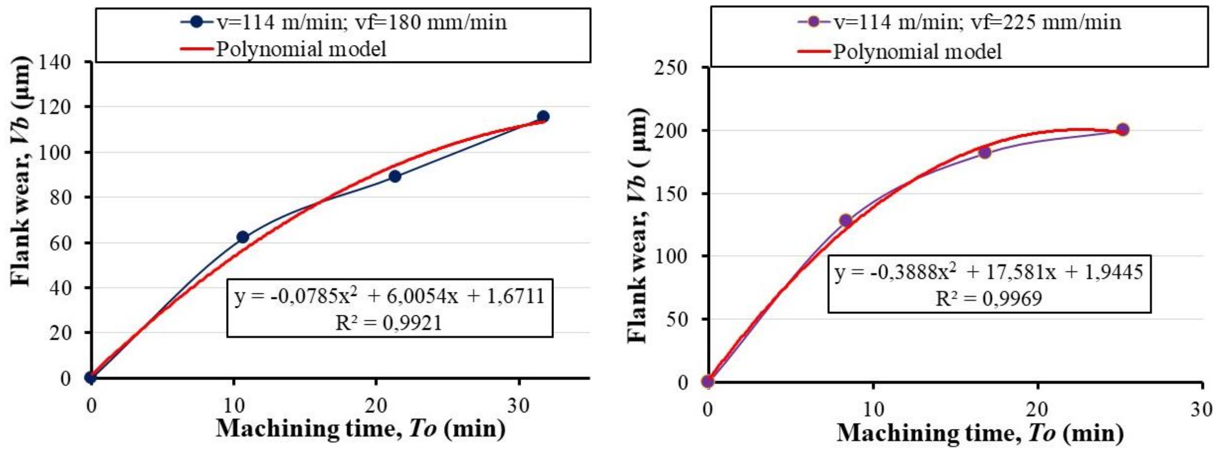


b) Flank wear in trail №2

Figure 2 – Wear rate of end under cutting speed *v*=40 m/min

From the comparison of flank wear rate depended by verifying table feed in the range from 180 to 225 mm/min, it can be concluded that increasing feed impulses more severe and rapid wear rate. In the first trail, when table feed was

180 mm/min flank wear after the third cut was 62 μm, while at 225 mm/min it reached 180 μm. It can be explained by increasing cutting force and more favorable conditions for chipping for cutting edge.



a) Flank wear in trail №3 b) Flank wear in trail №4

Figure 3 – Wear rate of end under cutting speed *v*=114 m/min

With the increasing of cutting speed up to 114 m/min, flank wear reached 120 μm, which is two times bigger in comparison to flank wear measured under 40 m/min. Increasing flank wear with increasing cutting speed is affected by increasing cutting temperature. However, under the combination of cutting parameters with high cutting speed and high table feed, cutting temperature on flank wear is not so obvious.

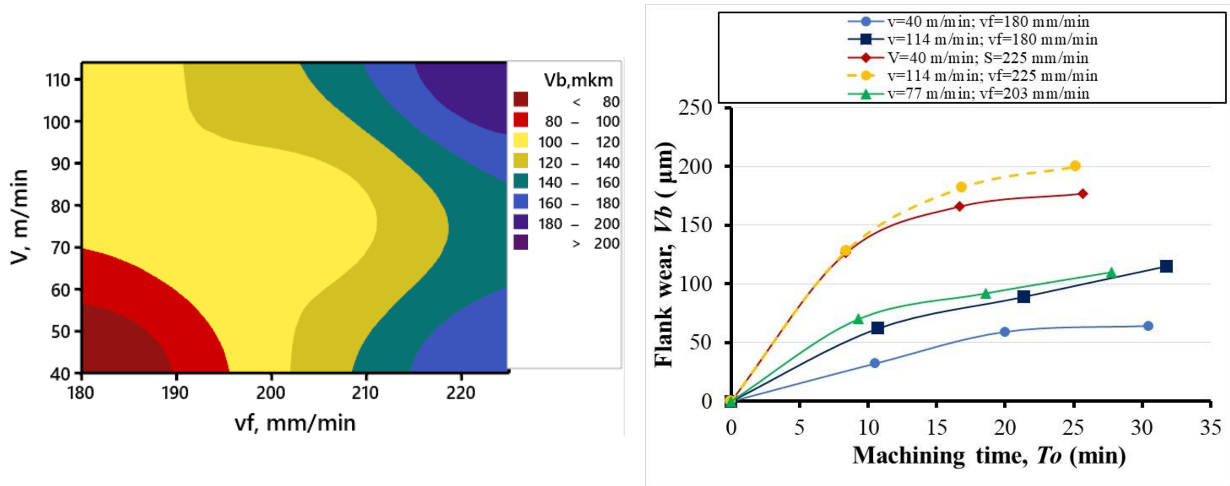


Figure 4 – Comparative graph of flank wear with respect to cutting parameters

Based on the flank wear measurement, mathematical models of the dependence of the flank wear to the machining time for each cutting parameter were determined. As the result of the analysis of mathematical models concluded that the rational cutting parameters for machining slots in guiding device 002.002.00.03-03 (part material: 20X13 AISI420) is a combination of cutting speed v = 77 m / min, and table feed v_f = 203 mm / min. The defined cutting parameter will make it possible to combine the moderate wear rate of the end mill and machining productivity.

CONCLUSIONS

1. Based on the analysis of the needs of industries in cantilever-type pumps for oil and gas, to meet demand, a promising technological process for the manufacture of the guide device of this pump, which is more cost-effective.

2. It was proposed to increase the productivity and economic feasibility of manufacturing parts by new workpieces, replacement of obsolete equipment in mechanical operations, rational selection of cutting and measuring tools. The analytical method calculated cutting modes for mechanical operations and machining allowances for the most accurate surface. For milling operation, a special machine device was developed for fixing during machining, which allowed to reduce the time for fixing and removing the workpiece.

3. The experimental setup was assembled at CNC milling center MAG FADAL VMC 4020 FX, making it possible to conduct experimental research in real production conditions.

4. It was proposed to use as the criterion of tool life, parameter of flank wear which was measured on the tool microscope МБС-9 with accuracy up to 7 μm.

5. It was found that the most rational cutting parameter form the range of cutting speed, which was varied in experimental research from 40 to 114 m/min, and table feed from 180 to 225 mm/min is cutting speed v = 77 m / min, and table feed v_f = 203 mm / min, because it ensures maximal tool life with comparison with other cutting parameters.