EFFECTIVE FINISHING APERTURES USING ROUGHNESS CRITERION RA = 0.2 µM

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Abstract

Increasing demands for reducing the surface roughness of components impose high requirements for finishing operations. As a result, it creates a space for the application of new progressive methods for the surface finishing of components. The experimental activity referred to in this paper aims at comparing the conventional method of surface finishing (surface grinding followed by polishing) and a progressive finishing operation - forming with a diamond tip. The experiment was designed for the Wotan RJN 44 grinder and the Wagner WDR 1000 lathe. As the material to be machined, was chosen X17CrNi16-2. Forming with a diamond tip was made using a tool from Baublies, DDW type. The aim of this experiment was to compare the two finishing operations with the criterion for evaluating surface roughness Ra = 0.2 µm.

Keywords: Diamond tool polishing, grinding, finishing holes

1. INTRODUCTION

Increasing service life of pressure parts, particularly hydraulic cylinders, valves and fittings, imposes increased requirements on service life of sealing elements. Replacement of these sealing elements results in high costs of the machine repair and shut-down. In the case of underwater extraction, for instance, the costs of such repairs are considerable. To prevent abrasive wear of sealing elements, the modern trend of designing complex parts aims to achieve the highest possible quality of sealed surfaces (surface roughness, in particular). With regard to the design features of newly manufactured sealing elements, increased stress is no longer laid on geometric accuracy of contact surfaces. Dimensionally, the new sealing elements are able to adapt to geometric inaccuracies of manufacture. The design parameters specified by the manufacturers of sealing elements enable production on common CNC machine tools. The only required parameter which cannot be achieved on common CNC machine tools is surface roughness. Consequently, new finishing operations are necessary to enable the roughness of Ra = 0.2 µm to be achieved on the common CNC machine tools. One of the possible variants consists in application of forming with a diamond tool. This experiment aimed to compare the conventional method of finishing the internal surface (by grinding and polishing) with the new technology applicable on the CNC lathe (diamond tool forming). In particular, the main parameters to compare included surface roughness, manufacturing and inter-operation times. [1, 2, 3]

2. EXPERIMENT DESCRIPTION

This experiment aimed to suggest a finishing machining method enabling the minimum surface roughness of Ra = 0.2 µm to be achieved with a hole of the diameter of (ø220 ±0.1) mm, length of 255 mm, with the shortest possible manufacturing and operation times. The finished hole had been pre-treated on the universal centre lath WDR-1000x4000. After boring of the hole, the roughness of Ra = 1.5 µm was achieved. Detailed technological conditions of boring are indicated in **Table 1**. **Figure 1** shows a drawing of the manufactured part. [1, 2, 4]

Table 1 Hole boring - technological conditions

Cutting speed ***v***	115 m·min^{-1}
Feed ***f***	0.15 mm
Cutting depth a_p	0.5 mm
Achieved surface roughness ***Ra***	1.5 µm

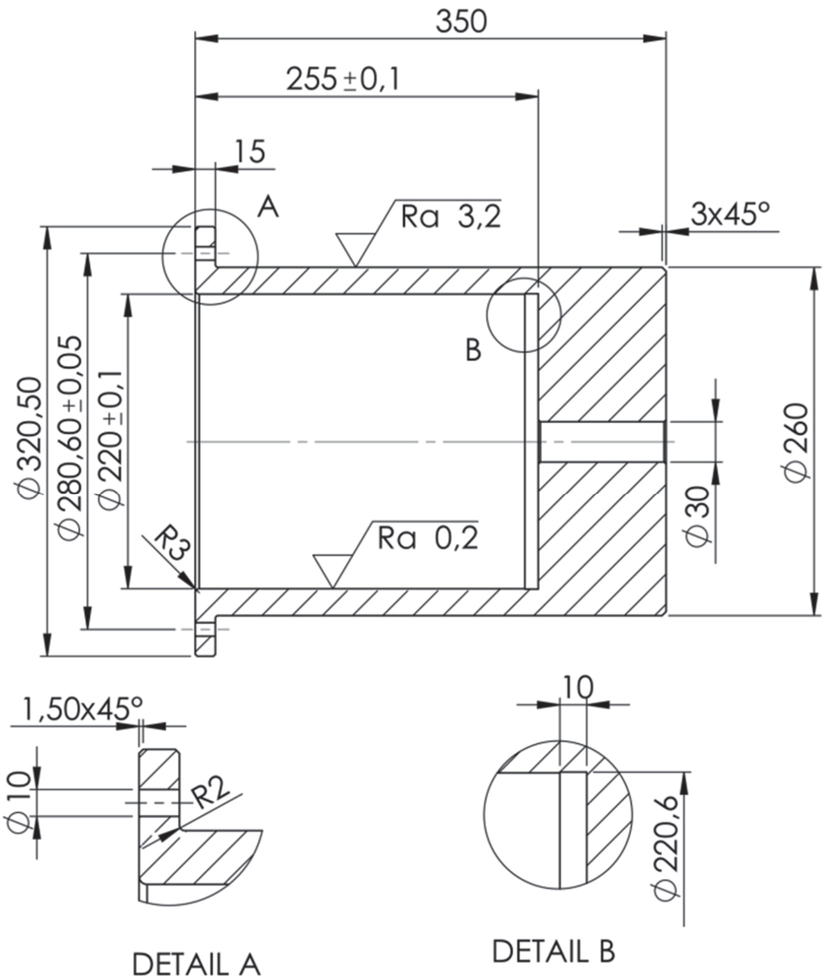

Figure 1 Manufactured part drawing

2.1. Grinding with subsequent gradual repolishing

The first sample experiment was conducted on a hole grinding machine of the RJN 44 type, manufactured by Wotan. Detailed parameters of the machine are indicated in **Table 3**. According to the previous experiments, 3 finishing operations have been selected as the most suitable conditions. Firstly, grinding was executed with a technological allowance of 0.02 mm per wall; subsequently, repolishing was done with a wheel from woven grinding fleece. Then the final polishing was executed by means of a felt wheel. With regard to the surface roughness criterion, the best manufacturing times were achieved at maintaining invariable cutting conditions for the individual operations. The detailed technological conditions are indicated in **Table 2**. [5, 6, 7, 8]

Table 2 Description of the grinding operation with subsequent final polishing

Operation	Tool	Cutting conditions
A - Grinding	Corundum wheel with one-side recess D150 x 63 x d51 1A/d80x38	Tool cutting speed: v_c = 30 m·s^{-1} Feed speed: v_f = 15 m·min^{-1} Process medium: AQUAL3010, 10% emulsion.
B - First polishing stage	SCOTCH BRITE D150 / d25 x 50mm wheel quality Grade 9S - 3M	
C - Second polishing stage	Felt wheel D150 / d25.4 x 40mm K3V-0.65	

Table 3 Technical parameters of machine RJN 44 - Wotan

Machine type	RJN 44 - Wotan
Manufacturer	Wotan - NSR
Range of diameters of ground holes	200 - 300 mm
Accuracy grade /Worked surface quality	IT 6 / 0.8
Grinding spindle speed	12000 min^{-1}
Working spindle speed	120 - 1000 min^{-1}

2.2. Forming with diamond tool

Essentially, forming with a diamond tool consists in the force action of a diamond ball on the workpiece surface. The pressure exerted by the tool action on the workpiece surface causes plastic deformations which induce volume and geometric change of the workpiece surface. During the forming process, microscopic unevenness is simultaneously planed; further, metallurgical surface structure is changed. Further, the forming operations are also supplemented with the phenomenon of the surface consolidation, which depends on the material and its crystalline structure. These changes in the workpiece surface result in reduced notch toughness, ductility, increased strength and hardness. Disadvantageously, this method necessitates high quality of the surface created by the previous chip machining. The quality of this pre-operation has a crucial effect on geometric accuracy of the final product. [1, 6, 9, 10, 11]

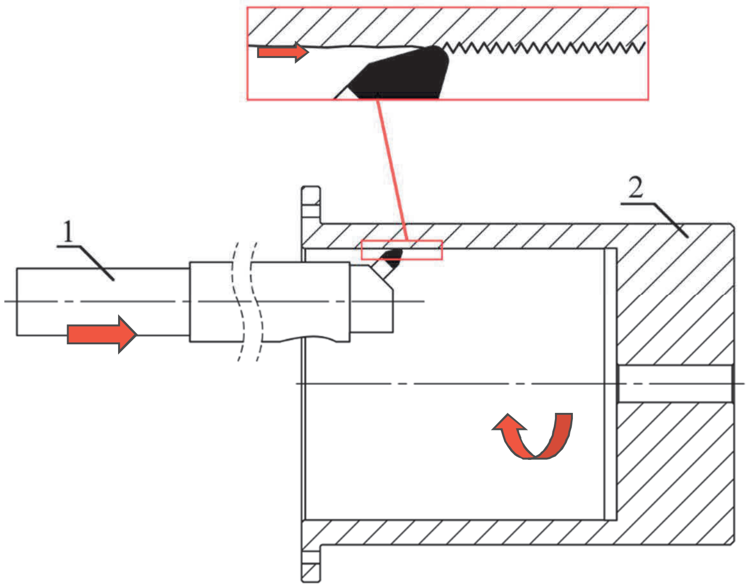

Figure 2 Diagram of diamond tool forming; 1 - forming tool, 2 - workpiece

Table 4 Description of the operation of polishing with a diamond tool

Operation	Tool	Cutting conditions
Diamond point forming - 1st pass	Baublies type DDW-I-IK 88-397-00 Ød 65 x 270 mm	Tool cutting speed: v_c = 120 m·min^{-1} Feed: f = 0.05 mm Impression depth: 0.3 mm Spring force: 50 - 120 N Process medium: AQUAL3010, 10 % emulsion.
Diamond point forming - 2nd pass	Baublies type DDW-I-IK 88-397-00 Ød 65 x 270 mm	Tool cutting speed: v_c = 120 m·min^{-1} Feed: f = 0.05 mm Impression depth: 0.3 mm Spring force: 50 - 120 N Process medium: AQUAL3010, 10 % emulsion.

3. MEASURING RESULTS

During the experiment, both of the selected methods proved to be suitable for finishing of holes with the roughness criterion of *Ra* = 0.2 µm. The grinding operation had to be divided into 3 separate stages so that the required surface roughness could be achieved. This division increased manufacturing and handling times. The total time of grinding and subsequent repolishing was calculated as 198 min / piece. Detailed description of the manufacturing and inter-operation times is indicated in **Table 5**.

Table 5 Experiment results - grinding with subsequent surface repolishing

Operation	Surface roughness achieved	Manufacturing time
A - Grinding	*Ra* = 0.6 µm	80 min
B - First polishing stage	*Ra* = 0.3 µm	90 min
C - Second polishing stage	*Ra* = 0.2 µm	
Handling times		28 min
Total product time		198 min / piece

Similarly to the previous turning operation, the forming with the diamond point was executed on the universal centre lathe WDR - 1000 x 4000. This resulted in substantial decrease in handling times for clamping and adjustment of the workpiece. After the first pass of the diamond tool, the required surface roughness criterion was already achieved. The experiment also included a test whether the second pass of the tool enables even a lower roughness degree to be achieved. This roughness reduction, however, did not occur. The second pass of the tool did not result in a change in the surface roughness. The probable cause was that plastic deformation of the material had been exhausted by the first pass. Therefore, to achieve the required accuracy, it is possible to take one pass into account only; that is, the total time of 21.5 min / piece. **Table 6** contains a detailed schedule of the times.

Table 6 Experiment results - forming with a diamond point

Operation	Surface roughness achieved	Manufacturing time
Diamond point forming - 1st pass	*Ra* = 0.18 µm	17.5 min
Diamond point forming - 2nd pass	*Ra* = 0.18 µm	17.5 min
Handling times		4 min
Total product time		21.5 min / piece

4. CONCLUSION

The experiment enabled a suitable finishing operation to be found, verified and compared - the technology of forming with a diamond tool, which achieves a higher productivity than conventional grinding. It was this that the experiment aimed at. It was possible to reduce the total manufacturing time by up to 89 %; at the same time, the required surface roughness criterion of *Ra* = 0.2 µm was achieved. The diamond tool forming can be applied as the finishing operation wherever stress is laid on minimum surface roughness without simultaneous demand on high geometric accuracy. The geometric accuracy of the formed surface is given by the previous surface treatment. To achieve a quality surface, the pre-treatment of the surface is crucial before forming with a diamond tool. During machining, it is necessary to attend to uniform processing without any defects, scratches and build-up marks as well as geometric inaccuracies of the surface caused, for instance, by vibrations of the tool. Further, this finishing operation can only be executed on surfaces treated by turning.

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