Improving the accuracy of deep hole machining by diamond honing process in 41Cr4 steel parts

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Abstract. This study presents the results of accuracy parameters during the machining of deep holes by diamond honing process in 41Cr4 steel parts. It was clarified that the use of diamond honing stones in the developed tool design helps to correct the geometric parameters of the hole obtained in the preliminary machining operations. The experiments showed that diamond honing is a productive process and provides high accuracy for the formation of roundness and straightness of deep holes in comparison with the internal grinding.

1. Problem statement
Reliabilities of machine tools and equipment are ensured by meeting the increased requirements for accuracy and quality. To solve these problems, it is necessary to develop technological methods.

Obtaining holes of increased accuracy, especially deep ones, are laborious processes. One of the widespread methods of processing such surfaces is diamond honing. The main purpose of honing operations involves improving the accuracy of shape and size, as well as reducing the height of the microroughness of the machined surfaces through the holes produced by preliminary machining operations. To fulfill these requirements, a tool having resistance and high cutting properties is required. The use of synthetic diamonds for finishing deep and precise holes is most effective during honing.

The improvement of new tool design increases the rigidity and opens up new possibilities for the effectiveness of its application.

2. Literature review
As is known, finishing process of deep holes is a complex process. One of the well-known method for post-processing of deep holes is internal grinding that does not provide accuracy and surface quality at desired level. The presence of vibrations and elastic deformations generating from the grinding wheel and the mounted cantilever due to high speeds and temperature in the cutting zone leads to the appearance of an error in the shape of the hole. Honing deep holes by using diamond bars is a high-performance process that many works have been performed.

Huang et al. [1] analyzed the numerical results and researchers’ study showed that the fixing of the shape error was mostly influenced by the rigidity of fixing the hone bars to the mandrel and the constant component of the contact pressure. In the other studies [2, 3], simulation models of the honing process were developed. Based on these studies, a new method allowed controlling the
Peripheral speed of the bars when they move along the axis of the hole being machined. Pawlus et al. [4] carried out some experimental studies in order to determine the influence of the trajectory of the working movement of the tool on the main indicators of the honing process. Zhao et al. [5] investigated the honing process to correct the geometric deviations in the longitudinal section by varying the intensity of removal of the stock layer when changing the frequency of axial oscillations per unit length of the machined hole.

Based on the studies in literature, it can be concluded that the machining of deep holes using diamond honing is insufficiently studied and requires improvement.

3. Method and materials
The experiments were carried out on a 2K522 radial drilling machine tool. For the stepless reciprocating movement of the spindle of the drill head in automatic mode, the machine tool was modernized, which consists the installation of a crank mechanism as seen in Figure 1.

A specially designed and developed honing head was used as the cutting tool to machine precise deep holes with a diameter of 21-25 mm as seen in Figure 2. This special honing head is equipped with three diamond bars, grade ACB 100/80-M1-100%, which move along the beveled base of the groove. Adjusting the bars to the required size and performing rigid fastening are carried out by bushings and locknuts. The required diameter was set using the reference bushings.

![Figure 1. Modernized radial drilling machine tool](image)

The test objects were samples of bushings with a nominal diameter of 21.4 mm and length of 100 mm. The workpiece material was 41Cr4 steel having hardness of 48-53 HRC.

Honing operations were carried out at the constant peripheral speed ($V_p$) of 0.73 m/s, reciprocating motion speed ($V_{rm}$) of 0.05 m/s and radial feed of bars ($\Delta r$) of 0.08 mm/double stroke. And a mixture of kerosene and 15% Shell Morlina S2 B 32 oil was used as a cutting fluid.

The measurements of the main geometric parameters of the deep holes were carried out using a special measuring device, seen in Figure 3, to characterize the accuracy. The main geometric parameters of the deep holes were straightness of the generatrix and deviation from roundness. During measurements, a digital internal dial gauge with a graduation of 0.001 mm in four cross and six longitudinal sections was used (Figure 4).
4. Results

According to the measurement results of 20 parts after countersinking as a preliminary operation and honing, circular diagrams in various sections and profiles along the generatrix of the deep hole in various directions were obtained as given in Figures 5 and 6. As seen in Figures 5 and 6, the deviation of the hole shape decreased and the shape deviation tolerance was obtained as 0.016 mm after honing process while the initial shape deviation tolerance was obtained as 0.04 mm after countersinking process.

These experimental results showed that the absolutely rigid fixing of the bars and their high durability caused the intensive correction of the initial shape errors, deviations from roundness and straightness of the generatrix at the selected machining conditions.

**Figure 3.** Deep hole geometry parameters measuring device:
1. digital indicator head, 2. screw, 3. setting screw, 4. measuring rod, 5. workpiece, 6. magnetic plate, 7. switch, 8. movement mechanism, 9. handle, 10. rack, 11. rod

**Figure 4.** Scheme for measuring the straightness of the generatrix and the deviation from the roundness of deep holes:
A - A, B - B, C - C, E - E measured cross sections of the hole; 1 - 1, 2 - 2, 3 - 3, 4 - 4, 5 - 5, 6 - 6 measured longitudinal sections of the hole
Figure 5. Circular diagrams of the average diameter values of the original surface in various sections and the profile of the longitudinal section in various directions after countersinking.
Figure 6. Circular diagrams of the average diameter values of the original surface in various sections and the profile of the longitudinal section in different directions after honing

5. Conclusion
This study indicated that the cutting modes adopted by authors, the use of a tool design with increased rigidity for diamond honing of precise deep holes and the high durability of the bars caused intensive correction of the initial shape errors as deviations from the roundness and straightness of the generatrix.

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