Ways to implement hybrid finishing technology with a hand-held rotary tool

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Abstract. In some segments of mechanic engineering: instrument-making, shipbuilding, automotive, aviation, aerospace industry there is a need for finishing processing of difficult to access surfaces of complex configuration. If it is not possible to process such surfaces on the equipment, then a manual rotary tool is applied. Such tools, in particular, include drills and engravers equipped with a grinding and polishing tool. If, using a manual rotary tool, the electrochemical grinding and electrochemical polishing are consistently applied, then it is possible to synthesize a hybrid technology for the electrochemical processing of complex profile metal products combining the advantages of each type of processing. The presented work is devoted to the development and study of ways to implement hybrid technology for finishing with manual rotary tools. The work provides a schematic diagram of the device and description of its operation. Analysis of the research results allows us to conclude that the hybrid technology allows to achieve a surface roughness of an average of Ra 0.25 μm and be successfully implemented when processing difficult to access surfaces of items of complex configuration with a manual rotary tool.

The finish machining of details is applied in all industries. The goal of finish machining is both to ensure the quality parameters of products and their decorative finishing.

In some segments of mechanic engineering: instrument-making, shipbuilding, automotive, aviation, aerospace industry there is a need for finishing processing of difficult to access surfaces of complex configuration. If it is not possible to process such surfaces on the equipment, then a manual rotary tool is applied. During its operation, the main movement is made from the engine, and the auxiliary movements and control of this tool is done manually. Such tools, in particular, include drills and engravers equipped with a grinding and polishing tool.

With this treatment, the share of manual labor, monotonous, responsible and requiring the tireless attention of the worker, is quite large. It should be borne in mind that the materials from which the details are made have a different machinability spectrum: from widely used steels and aluminum alloys to hard-to-machine corrosion-resistant and heat-resistant steels and alloys based on titanium and nickel. Consider this machining on the example of processing steel 12X18H10T with a hardness of 44 ... 46 HRC.

Additional features that must be considered when manually finishing the parts are the following:
- Minimization of force pressure on the machined surfaces;
- Availability of difficult to access places for machining, projections, grooves and other structural elements of parts of a complex profile;
- Uniform machining of surfaces of different levels and locations;
- Absence of burns and minimization of heat exposure on parts.

The choice of the method and sequence of finishing, in this case, depends on the specified parameters of the surface quality, including its roughness.

1. If the required roughness parameter of the machined surface Ra shall not exceed 1.25 μm, then fine grinding is performed [1]. When processing alloys based on titanium and nickel, corundum heads and diamond heads on a ceramic binder are most often used, which do not have sufficient strength to intensify the machining process. It is possible to increase the productivity of the grinding process by applying highly efficient diamond heads on a metal bond, but they are quickly get salted and lose their cutting abilities [2].

2. With higher requirements for surface roughness (roughness parameter Ra should not exceed 0.25 μm) additional polishing is performed [1]. Polishing is carried out using silicone and rubber polishing heads, felt and flap wheels. The polishing process is also characterized by low productivity due to minimal material removal.

The reserve to enhance the performance of such processing, when a specified product surface roughness is achieved, is observed in the use of modern methods of combined mechanical and electrochemical processing. It is known that grinding performance can be improved by applying a combined electrochemical grinding process with a diamond tool on a metal bond with its continuous dressing [2, 3, 4]. To improve the performance of polishing, it is recommended to apply the process of electrochemical polishing with rotating electrodes [5]. If, using a manual rotary tool, electrochemical grinding and electrochemical polishing are consistently applied, it is possible to synthesize a hybrid technology for the electrochemical processing of complex metal products combining the advantages of each type of machining [6-13]. The presented work is aimed at identifying ways to implement the hybrid technology of finishing processing using a manual rotary tool.

We have developed a device for implementing the hybrid technology of finishing with a manual rotary tool. Figure 1 shows its schematic diagram. The device design consists of a constant current source 1 and a microcontroller programmable via computer, installed in control unit 2. It is used to control the duration and frequency of current pulses and controls four relays 7 ... 10 installed in current switching unit 3. The current switching unit has two outputs and is intended for supplying the “workpiece - electrolyte - conductive tool” currents of direct and reverse polarity to the electrical circuit. The inputs of the two relays 9 and 10 are connected to the positive pole of the current source 1, and the inputs of the other two relays 7 and 8 are connected to the negative pole of the current source 1. In this case, the outputs of the relay connected to the poles of the current source of the same name are connected to different outputs of the current switching unit 3. A conductive tool 5 is installed in the spindle of the manual rotary tool 4. Electrolyte is supplied to the contact zone of the conductive tool 5 and product 6.

The principle of the device operation for the implementation of hybrid technology finishing with manual rotary tool is as follows. A diamond abrasive head is mounted on a metal bond in the spindle of a manual rotary tool.

The control signal comes from the control unit to the relays installed in the current switching unit. The power circuits of the relay are closed. As a result, the workpiece is connected to the positive pole of the current source, and the diamond head with a negative one. There is an electrochemical impact on the detail, as a result of which the surface layer of the part is softened, which is subsequently machined with a diamond abrasive head. Then the control signals come from the control unit to other relays. As a result, the workpiece is connected to the negative pole of the current source, and the diamond head is connected to the positive pole of the current source. The electrochemical dressing of the tool takes place. After this, the cycles of electrochemical impact on the part and the diamond head are repeated. Then the diamond head is removed. A smooth tool-electrode is installed in the spindle of the manual rotary tool. The control signal comes from the control unit to the relays installed in the
current switching unit. The power circuits of the relay are closed. As a result, the workpiece is connected to the positive pole of the current source, and the smooth electrode is connected to the negative one. The electrochemical effect on the part takes place, as a result of which the process of electrochemical polishing occurs.

![Figure 1. Schematic diagram of the device for the implementation of hybrid technology finishing with manual rotary tool: 1 - DC source, 2 - control unit, 3 - current switching unit, 4 - spindle of the hand-held rotary tool, 5 - conductive tool, 6 - the workpiece, 7, 8, 9, 10 - relay](image)

Using the proposed device, a series of experiments was carried out to identify the quality of steel samples 12X18H10T after mechanical (manual) processing using the proposed hybrid technology. Sample sizes: diameter 10 mm, length 6 mm. The hardness of the original samples 44 ... 46 HRC. An engraver was used as a rotational tool for the experiments.

Sample processing was carried out sequentially by grinding and polishing. The appliance with the fixed sample and the instrument were immersed for the technology implementation in a bath with processing medium (water-based electrolyte NaNO₃ - 3%, NaNO₂ - 1%, Na₂CO₃ - 0.5%).

At electrochemical grinding there were established the following modes of combined machining: cutting speed 5.5 m \cdot s⁻¹, depth of cut 0.1 mm, longitudinal feed 5 mm / min. A cylindrical diamond head on a metal bond with a diameter of 3 mm was used as an abrasive tool. The grain size is 90/125 µm. The current is 0.1 ... 0.18 A, the voltage is 13.5 ... 14.7 V. Electrochemical polishing modes: the rotation frequency of the tool-electrode is 35000 min⁻¹, the longitudinal feed is 5 mm / min. An electrode made of brass wire with a diameter of 2.5 mm was used as a working tool. The current strength is 0.1 ... 0.18 A, the voltage is 13.5 ... 14.7 V.

After processing, measurements of the surface roughness of the samples were carried out on 130 Profilometer (Proton-MIET OJSC). In addition, the chemical composition of the sample surface was additionally investigated using a Hitachi TM4000Plus bench-top scanning electron microscope. Microhardness of samples was measured on a microhardness meter HMV-G21S.

Samples surface roughness studies have showed that:

1. The roughness of the samples machined surface after electrochemical grinding averaged Ra0.332 µm.
2. The roughness of the samples machined surface after additional electrochemical polishing averaged Ra0.243 µm.

Studies of the chemical composition and microhardness after mechanical (manual) processing using the proposed hybrid technology have confirmed the stability of the specified quality indicators of the samples machined surface [13].

Analysis of the studies results of 12X18H10T steel samples allows us to conclude that the use of the proposed hybrid processing technology, which consists in synthesizing electrochemical grinding sequentially on a single (manual) tool with a diamond head on a metal bond and subsequent
electrochemical polishing of samples with a round electrode tool, allows to achieve surface roughness on average, Ra is 0.25 µm and be successfully implemented when processing difficult to access surfaces of complex configuration using manual rotary tool.

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