Combined finish machining of nonrigid parts by the brush electrode

V P Smolentsev, O N Kirillov, O N Fedonin and A Yu Ryazantsev

Voronezh State Technical University, 14 Moscow Ave., 394026, Voronezh, Russia

E-mail: ryazantsev86@mail.ru

Annotation. The capacities of extensive use of technology and a combined machining tool by an unshaped brush electrode are discovered. This type of machining occurs during dimensional finish formation of composite parts of small rigidity (including the parts made of difficult-to-machine materials). This process takes place provided that there is required pressure of wire beams in the brush electrode and a combination of electrical modes of the process with tool parameters. The ways of maintaining the process stability, increasing technological parameters, which allows extending the application field of universal high-productive finish machining by an electrode, are presented. This problem has been solved for the first time, and its results make it possible to create items of new generations, which is actual for machine building.

1. Introduction
With the complication of the shape of constituent elements of modern high technology production in machine building along with the increase of the unit load on the construction under the influence of operating loads and hereditary phenomena, we can observe the changes in the part shape. In addition, errors, which are capable of intervening failures in the whole article, arise. This is particularly apparent during production of parts for aircrafts, where openwork parts with small rigidity are applied to reduce the weight of the construction. New tools that have been recently produced with universal working section, which is unshaped and changeable during the machining process, allowed performing finish machining of nonrigid parts having a composite profile by a single tool. The metal brush electrode [1–3] is the tool, which is successfully used for dimensional machining of composite surfaces with any rigidity of a semi-finished product. The creation of the process control system, taking into account rigidity [2, 3] of the machined part section, has been required for the subsequent use of the promising combined technological process, which will be viewed further in this article.

2. The mechanism of interaction of the brush electrode with a machined object of limited rigidity
Nonrigid parts in respect to machining of metal parts by the brush electrode are parts that contain sections, which under the influence of tool pressure force and discharge activity, deviate by the value that exceeds the available dimension change of the finished part and the dimension of brush electrode pressure for finish machining [3, 4].

The scheme of interaction of the brush electrode with the machined nonrigid part section is presented in Figure 1.
Figure 1. The scheme of combined machining of a nonrigid part by the brush electrode: 1 – the base surface, 2 – the nonrigid part element, 3 – the control unit of mode parameters, 4 – the nozzle for supply of working fluid, 5 – the brush electrode, 6 – the weak electrolyte based on neutral salts, 7 – the source of low voltage current.

The mechanism of finished machining of nonrigid parts [3] and calculation methodology of the rush electrode [5, 6] are viewed. It is necessary to set sections with minimum rigidity practically in every item, for which the tool should be created. Thus, the relations among the properties of nonrigid machined objects, parameters of brush electrode and modes of machining are formalized.

A key parameter in the brush electrode is a material and a wire diameter combined in beams. It is known that for finished machining, it is necessary to apply brass, and the wire diameter, used in the case under consideration during high velocity machining, amounts to 0.1 up to 0.3 mm.

Machining by the brush electrode includes several types of action, such as:
1. The power from discharge pulse at the moment of beam coming to the machining area (Figure 2).

Figure 2. The start machining process by the wire beam in working liquid 4: 1 – base, $S_0$ – the tolerance between electrodes at the moment of wire 3 running on semi-finished product 2 and the start of discharge, $F_1$ – the power arising at the moment of discharge.

The limitation of this stage is a beam size and a step between beams, where it is necessary that the first beam leaves the machining area completely before the next beam contacts a semi-finished product. In this case, the cross-sectional size (diameter) of the beam should be minimum.

2. Cleaning the machining area by wire ends (Figure 3), where the contact is provided by approaching the wire ends to a semi-finished product by such value as minimum guaranteed pressure $P_{RG}$. This stage allows preparing the surface for the anode removal of the tolerance after the beam has left the machining area.
Figure 3. Cleaning of console section 2 of the semi-finished product surface, fixed on base 1, by the mechanical influence by wire ends 3: a – the scheme of cleaning, b – removal of pollutants, 4 – oxides, slivers and other materials on the surface of the machined part.

Technological recommendations on the choice of pressure (not less than $P_{rG}$, but not more than one contact by the side surface of the curved wire of the machined surface). As a rule, the pressure for the calculated tool is $P_{rG} = 0.2 \pm 0.6$ mm.

3. Tolerance $Z$ (Figure 4) is removed owing to material anode dissolution

Figure 4. The scheme of nonrigid part machining: $r$ – the radius of a nonrigid part bend owing to pulse actions with power $F_1$.

The magnitude of the bend depends on the installation scheme of the section of a semi-finished product: in the presence of support, it will be a maximum deflection when the tool is located in the middle of the section ($l/2$).

The tolerance, removable per single revolution of the brush electrode ($Z_0$), can be calculated according to the following formula:

$$Z_0 = k_0 Z_1 n_0,$$

where $k_0$ – the coefficient taking into account the portion of tolerance removal due to anode dissolution at the moment of the beam approach to a semi-finished product ($k_0 = 1.5 \pm 1.6$); $Z_1$ – the material removal due to electroerosion tolerance removal by a single beam; $n_0$ – the quantity of beams in the brush electrode.

A nonrigid semi-finished product (or its sections) (Figure 4) can initiate a bend of the wire and the whole beam with radius $r$ under the influence of discharge power, which can exceed the pressure value, initiate autovibrations and break the machining process by the brush electrode.

3. Designing of the technological process

Combined machining by an unshaped brush electrode represents a combination of three processes: electroerosion, mechanical and anode dissolution of the metal [2, 8]. Processes influence each other mutually, which is evaluated by the coefficient of mutual influence. During designing of the
technological process of finished combined machining by the brush electrode, it is necessary to combine and to enhance the advantages of influence constituents: high accuracy of electroerosion machining, high production and a low height of microroughnesses of electrochemical machining, intensification of the process by mechanical action of brush electrode beams and a high surface quality, determined by geometrical, physical and mechanical parameters of the surface layer. Owing to the mechanical action of the beams of the tool working part, there is an opportunity of removal of nonmetallic inclusions and oxides from the machined surface, which allows intensifying the machining process and enhancing technological capabilities.

The technology of high-velocity machining by the brush electrode includes several independent stages.

1. At the first stage, the type and the sizes of the electrode tool [5, 6] are chosen, at which it is necessary to consider:
   - rigidity, elasticity, electrotechnical properties and other parameters of the brush electrode, which allow finding the value of beams pressure to a semi-finished product at any tolerance value;
   - the packing density of brush electrode beams must provide the movement trajectory of electrodes for the completion of the pulse after leaving the machining area by the side of the tool;
   - justification of the choice of the brush electrode wire material: the copper and brass wire of small diameter is chosen during finish machining of current conducting items of composite geometrical shape with limited rigidity for production of the tool working part.

2. The choice of the working medium. Parameters of the surface layer, productivity, accuracy depend on properties of the working medium during high-velocity combined machining. At this, anode dissolution increases the quality of the surface layer and the velocity of metal removal from the surface of a semi-finished product. In works [7, 8 and others], a possibility of using low conducting lubricating-cooling liquids as working media, sometimes with additives (usually up to 3%) of neutral salts (for example NaCl), is presented. It allowed establishing the maximum rate of tool rotation, which is necessary during the work with high peripheral velocities of the brush electrode.

3. Special or modernized for machining brush electrode machines [9] that permanently provide a set value of beams pressing to the spot of part machining are required for high-velocity machining.

4. Electric field strength for high-velocity dimensional machining is chosen by taking into account the required roughness and wear of the brush electrode.

Optimum machining modes of nonrigid parts are given in the table below.

| Parameter name                        | Value                |
|---------------------------------------|----------------------|
| Voltage, V                            | 4–6                  |
| Size of brush electrode pressing to semi-finished product, mm | 0.1–0.3              |
| Brush electrode annular velocity, m/s | More than 30         |
| Electrode tool diameter, mm (is selected taking into account the equipment technological characteristics) | 100–300              |
| Wire diameter in beams *, mm           | 0.1–0.3              |

5. The time of high-velocity finish machining by the brush electrode depends on sizes and configurations of a machined item, predetermined technological parameters and machining modes.

4. Conclusion

The control mechanism of the contact process of finish machining and brush electrode calculation methodology for machining nonrigid composite shape parts are developed. They are developed as a technological system along with supporting the position of the machining section relatively the tool and stabilization of the pressure value. This allowed machining nonrigid composite shape parts with
high accuracy and quality of the surface per one brush electrode transfer, which increases technological capacities of the process.

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