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Stability analysis of multipoint tool equipped with metal cutting ceramics

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Abstract. The article highlights the issues of determining the stability of the cutting process by a multipoint cutting tool equipped with cutting ceramics. There were some recommendations offered on the choice of parameters of replaceable cutting ceramic plates for milling based of the conducted researches. Ceramic plates for milling are proposed to be selected on the basis of value of their electrical volume resistivity.

1. Introduction

In the modern production conditions, special attention is attracted to the search for a new method of ensuring dynamic stabilization of the cutting process in multipoint machining, which would allow not only to ensure stability during cutting, but also to improve the quality of processing.

This problem is especially actual in case of using material applied for finishing as the replaceable plates of oxide-carbide ceramics, which differs with its relatively high brittleness, for which the absence of dynamic stabilization quickly leads to its destruction and loss of processing quality. Ceramics as an instrumental material has a high hardness even at high temperatures and the greatest durability at maximum cutting speed. These valuable qualities of cutting ceramics determine the peculiar areas of the most effective operating conditions for instrumental materials.

Ceramic cutting tools are expedient to operate in high speeds cutting mode (more than 500 m/min) and with insignificant cutting depths and feeds, for finishing or semi-finishing operations.

Using ceramics on these operations makes it possible to increase the processing capacity and the quality of the machined surfaces in the automated production conditions, and in some cases, to refuse subsequent finishing operations. Nevertheless, with all the advantages of cutting ceramics, there is a serious drawback - high brittleness, especially in conditions of intermittent cutting and breaking of dynamic stabilization [1, 5, 8, 10, 11].

The following methods are usually used to solve the problem of providing dynamic stabilization during milling and improving the quality of machining [2, 3, 6, 7]:

- increasing the stiffness of fixing the workpiece or cutting tool on the machine;
- application of dampers and dynamic absorbers;
- increasing the rigidity of the technological machining system;
- optimum cutting mode selection;
- changing the loading value of the technological system by cutting forces;
- changing the geometry of the cutting tool part.

These methods of ensuring dynamic stabilization have a number of disadvantages that limit their use. For example, the measures laid down during the design of the machine are often practically inefficient due to the large number of milling processing methods.

Overhead and recessed dampers and mechanical absorbers have a narrow range of vibration damping and require adjustment or replacement for each particular job.

Increasing of the diameter of the tool or the installation of an additional flywheel on the mandrel is not always possible because of the machine's adjustment. Increasing the stiffness of the tool attachment leads to changing the loading scheme of the technological system by cutting forces.

Changing the geometry of the cutting tool often leads to its premature wear and reduced quality of the machined surface, and changing the cutting modes can highly decrease the processing capacity. Changing number of teeth of the tool or the angular distance between them requires the design and manufacture of a new tool for each type of operations and the material being processed [3].

Based on this, it can be concluded that none of the above methods is suitable for dynamically stabilizing the milling process when using replaceable plates of cutting ceramics.

It is required to find a new way of stabilizing the milling process with the use of cutting ceramics, which will ensure the stability of the processing and stabilize its quality.

2. Materials and methods

As a way of dynamically stabilizing the milling process using mills equipped with replaceable plates of cutting ceramics, a method that is more versatile and efficient is proposed; it is based on the selection of cutting ceramic plates with the same performance parameters for equipping one tool.

The performance of ceramic plates is proposed to evaluate through the parameters of their electrical volume resistivity [1].

It is known that the plates with the highest values of electrical volume resistance (close to $R = 100\ \Omega$), have better microstructure parameters affecting their performance - they have the smallest diameter of carbide grains and a smaller porosity [1, 4].

Two identical end mills were chosen for a comparative analysis of the performance of a cutting multipoint tool equipped with ceramic plates (Fig. 1). Each of the mills was equipped with six same-type replaceable multifaceted plates of oxide-carbide cutting ceramics type VOK-63.

Figure 1. End mill equipped with plates of cutting ceramics.

The first tool was equipped with ceramic plates with electrical volume resistivity parameters having a similar value (in the range R = 75 ... 100 Ω).

This range of the electrical volume resistivity parameters of ceramic plates allowed them to be in the same group in terms of their microstructural parameters, and therefore in terms of the performance parameters (Fig. 2).

The second tool was equipped with ceramic plates with electrical volume resistivity parameters having a similar value (in the range R = 75 ... 100 Ω), except for one position which was equipped with the ceramic plate with the sharply distinguished from the representatives of the group parameter of the electrical volume resistivity (Fig. 3).

Each of the plates was marked with its own color to exclude the mistake in determining their operability.

This range of electrical volume resistivity parameters of the ceramic plates allowed five of them to be in the same group in terms of their microstructural parameters, and therefore in terms of the performance parameters, and the sixth plate had a specific electrical volume resistance value equal to R = 10 Ω. Its predicted performance was significantly less than the performance of the rest of the plates.

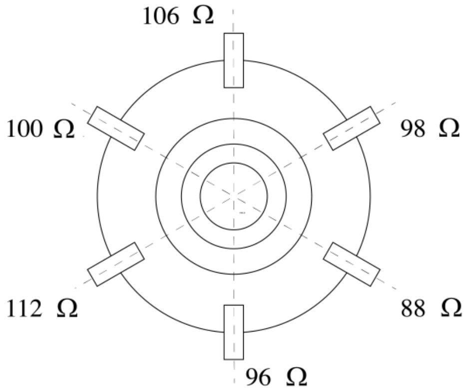

Figure 2. The layout scheme of plates with similar electrical resistivity parameters on the milling cutter

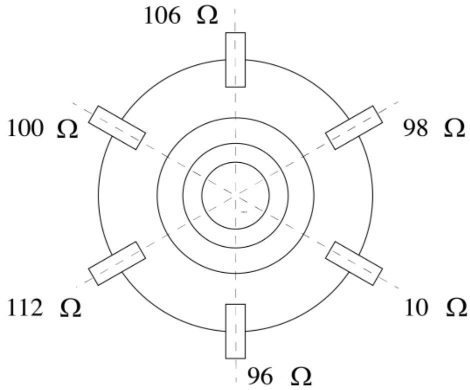

Figure 3. The layout scheme of plates with different electrical resistivity parameters on the milling cutter

Identical parameters were chosen for testing each of the mills equipped with ceramics: one model of the machine (EMCO Concept Mill 250), the identical workpiece elements, the same finishing cutting parameters (cutting speed v = 900 m/min, feed S = 0.01 mm/rev, depth t = 0.1 mm). Not only the working ability of the whole instrument was tested, but also the quality of the machined workpiece surface (precision grade *IT*7, surface roughness Ra = 0.63 μm).

3. Results and Discussion

The main reliability measure of the cutting tool is the period of its durability - the time of operation before its failure, that is, the time to reach the critical value of the tool wear, which depends on the accepted failure criterion.

The failure of a standard oxide-carbide ceramic cutting tool, as a rule, occurs suddenly and at an arbitrary time, without having a pronounced dependence on the tool's operating time for failure. In particular, defective zones with a depth of up to 0.5 μm can appear at the cutting edge of the ceramic plate with flank wear values of the replaceable plate just 0.1 mm (in condition of intermittent cutting), which indicates the initial stage of the tool failure. These zones are a source of intensive formation of microcracks, which lead to the destruction of bonds between grains and to their intensive separation from the cutting plate. When the first chips of the cutting edge appear during milling, the roughness of the machined surface sharply increases and the probability of a complete failure of the tool also increases. Since a loss of shape stability of the ceramic tool occurs immediately after the cutting-in of the tool due to the resulting stress peak, there is a sharp increase in the crack and cleavage of the cutting edge at the apex, which is the main reason for the roughness deterioration of the machined surface and the loss of processing quality.

As a rule, the failure of the tool is accompanied by a sharp deterioration in the quality of the machining that includes deterioration of the roughness and exceeding the tolerance range of the machined element. Proceeding from this, the performance of a tool equipped with ceramic plates was evaluated according to the path it had passed before failure.

The mill equipped with ceramic plates with similar electrical volume resistivity parameters (a group of "high-resistance" plates with R = 75 ... 100 Ω) showed the following results of steadiness of the milling process:

- the path passed by the tool without loss of processing quality was l = 32 m, after which there was a sharp deterioration in the roughness of the processed surface and exceeding the tolerance limit of the processed element,
- the actual period of tool life, when it could work without loss of quality, was T = 35.6 min.

After the completion of the processing, each of the plates was examined in order to determine its excessive wear.

The most worn out (right up to the destruction) were the plates with the minimum values of the resistivity R = 75 Ω and R = 82 Ω, respectively.

The mill equipped with ceramic plates with different electrical resistivity parameters (a group of "high-resistance" plates with R = 75 ... 100 Ω and one plate with R = 10 Ω) showed the following results of steadiness of the milling process:

- the path passed by the tool without loss of processing quality was l = 20.5 m, after which there was a sharp deterioration in the roughness of the processed surface and exceeding the tolerance limit of the processed element,
- the actual period of tool life, when it could work without loss of quality, was T = 22.7 min.

After the completion of the processing, each of the plates was examined in order to determine its excessive wear.

The most worn out (ruined) was a plate with a minimum value of the volume resistivity R = 10 Ω.

It should be noted that the wear and subsequent destruction of the most "low-resistance" ceramic plate led to an intensification of wear and destruction of plates with large values of electrical volume resistivity (and, therefore, high values of performance).

4. Conclusion

Thus, it can be concluded that equipping the cutter with the replaceable ceramic plates with the same range of values of electrical volume resistivity can not only stabilize the milling process, but also significantly improve the tool's performance by increasing the period of its durability, which will ensure the required quality of processed surfaces of component billets of machine parts.

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