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Dynamics of Stock Removal in Profile Milling Process by Shaped Tool

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Abstract

The article describes the mechanism of the stock removal during the milling of cylindrical and shaping cutters, the cutting of the latter is outlined around. It is shown that during the processing with concaved shaping cutter the contact angle of the cutter with the workpiece changes in the height of the tool because of curved cutting teeth. The current contact angle increases from the end to the transverse mirror plane of the cutter, causing the shift in end of operation time of elementary cutting blades, considered in small neighbourhood of diametral plane of tool. It is found that for the convex surface to be treated a minimum value of the current contact angle is typical for the surface of each cutter and the maximum value - for the transverse diametral plane of the cutter. The results obtained reveal the dynamics of the stock removal in the profile milling of shaping cutter and are necessary for high-quality project of efficient processes for profile milling of mechanical engineering products, wood working and other industries. When the counter circuit of profile milling with the cutter tool the contacting of the tool with a workpiece starts at zero point of cut layer thickness and ends its maximum value at the end of a single cut which causes an increase in the cutting force.

Keywords: profile milling; treated surface; shaping cutter; dynamic impact; cutting speed; stock; cutting force.

1. Introduction

Technological operations for milling of materials are discrete and are characterized by a relatively high dynamic activity system "machine-instrument-tool-workpiece" [1-5], is the appearance in the course of stock removal of high vibration level, deflection of the trajectory of the cutting periphery of the cutter blade from trajectory, given to the

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setting of the machine, and others [6-9]. Increased dynamic of technological system activity has a negative impact on the quality indicators of treated surface and performance of the treatment process [10-13].

In the analysis of the process of mechanical surface treatments with the position to ensure their high geometric accuracy is necessary to analyze not only the kinematics of [14], but also the dynamics of the process [15,16]. Improving the accuracy and productivity of profile milling is possible on the basis of the study results of contact mechanism of the cutting tool and workpiece. Moreover, these problems can be solved both analytically, and with the use of modern software, allowing to model and calculate the voltage directly on the contact surface of workpiece tool [17,18]. Within each single cutting tooth of cylindrical cutter start and end of material removal in planes perpendicular to the tool axis of rotation, takes place without any time shift that leads to hard hitting of the cutting teeth on the machined surface of the workpiece and dynamic job of processing system [19-22].

The use of shaping cutting tool can improve the utilization of the material [23,24], to reduce the waste occurring during milling products distributed in various industries, including woodworking [25,26]. In some industries, industrial production, for example, wood, recycling is an actual economic problem [27-30]. Reduction of vibration levels is possible by stabilization of the external dynamic effects on technological system and, above all, the cutting force, which is determined by the dynamics of stock removal by single tooth cutter [31-37].

2. Time of dynamic effect of a single shaping cutter tooth on the workpiece

During oncoming milling of workpiece by cylindrical cutters with rectilinear cutting teeth extending parallel to the axis of rotation, the contact between tool and workpiece begins with cut thickness equal to zero, and terminates at its maximum value $a_{\max}$. This situation is typical for any cross-section of the cutting tool, that is why during single tooth cylindrical milling the workload increasing from zero to a maximum value occurs, after which the rest of the system occurs and the load becomes zero until the next elementary cut.

Bursts of cutting force from zero to a maximum value at the work of each cutter tooth causing a dynamic effect on the technological system that reacts to these disturbances by elastic displacements of the tool and the workpiece, defining the level of vibration of its elements and geometric precision of treated surfaces. Time dynamic effect of the tool on the workpiece by rotating a cylindrical cutter to the corner tooth pitch in the circumferential position is determined by the formula:

$$\tau_1 = \frac{\varepsilon}{\omega} \tag{1}$$

where ε – the angle of contact of the cutting tooth with the workpiece, which when removing the permanent stock of spur cutter is constant; ω – the angular velocity of the cutter.

Running time of cutter per tooth:

$$\tau_z = \frac{2\pi}{\omega Z} \tag{2}$$

where Z – number of cutter teeth.

Time for rest, that is, lack of cutting within a "cutting-rest" single cycle is equal to:

$$\tau_0 = \tau_z - \tau_1 \tag{3}$$

In the expression (3) the values τ_z, τ_1 for a specific tool and cutting mode are constant and characterize the temporal component of the dynamic force action of the cylindrical cutter on the workpiece within a single cycle of "cutting-rest."

Fundamentally different situation is indicative for the process of the profile milling with cutter when changing the current radius R_i of the cutter on height B entails a change in current contact angle ε_i, under consideration in the