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Multidimensional Model of Surface Waviness Treated by Shaping Cutter

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Abstract

The article observes the regression model of waviness of the treated profile surface resulting from the planning and implementation of multidimensional experiment. The analytical dependences linking waviness of the treated surface with elements of the profile milling mode and design parameters of the shaping cutting tool were determined. Based on multidimensional model managing of the profile milling process in order to achieve the desired waviness of the treated surfaces at the highest possible performance of technological operations is performed. It was found that the dominant factors of the process of the profile milling with shaping cutter are the feed, the rate speed, the number of teeth of the cutting tool and the cutting depth. As a result of statistical processing of the experimental data was obtained the multidimensional models, the 3D XYZ surface graphics, 2D contour graphics.

Keywords: profile milling; treated surface; waviness; shaping cutter; multidimensional model.

1. Introduction

Waviness of the products' treated surfaces, along with the roughness and shape accuracy has a large influence on their service reliability. In this regard, high requirements are applied to such surfaces, that are not only for the micro and macro geometry, but the waviness [1-6] because it affects, for example, on the level of vibration in the work of rolling bearing assembly, magnitude of predetermined interference, and, consequently, the permissible workload on the knots etc. Waviness occupies an intermediate position between the macro and microgeometry of treated

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surfaces, because its altitude parameters are close to the parameters of roughness, and stepwise values - to the values typical for macrogeometry.

Process of profile milling of the treated surfaces with shaping cutter has been neglected in scientific and technical literature, despite the fact that this type of treatment is characterized by high performance and low cost technology of product [7-12]. The use of shaping cutter allows to improve the utilization of the material, to reduce the waste occurring during milling of products widely used in various industries, including in woodworking. In some industries, for example in wood working the recycling is an actual economic problem [13-19].

The most important and comprehensive scientific information on the process of profile milling with shaping cutter can be obtained on the basis of multidimensional experimental studies, as a result of which an adequate multifactorial response function is determined, which specifies the value of optimization parameter on the output of the technological system.

Process of milling the profile surfaces with shaping cutters is multidimensional and multivariable [20-24], so at the beginning the single-factor experiments were conducted, based on that the non-resonant work conditions of the "machine - tool - instrument - workpiece" system were determined and the processing was in a stable zone at minimal level of vibration of the spindle unit with the set shaping cutter [25-27].

In addition, the profile milling with shaping is different at kinematics and dynamics of the cylinder [28-30], so for the analysis of the geometric accuracy of the treated surfaces it is necessary to have mathematical models linking the indicators of surface's geometry with dominant factors of the process: the elements of cutting mode, and the parameters of the cutting tool [31-41].

Conducted one-factor experiments confirmed the validity of the choice of the counter circuit of profile milling with pressing the spindle unit to the male wedge slide, as this scheme provides the greatest stability of the product treating process and minimal vibration level of technological system's elements. Based on one-factor experiment it was determined that the minimal geometrical errors of treated surface provides a counter-milling, that is why the multidimensional experiment was performed for this milling circuit.

The verification of independent factors of shaping cutter milling process, the calculation of their levels and varying intervals, were the basis for the choice of multidimansional experiment plan. Waviness of profile surfaces subjected to milling with shaping cutter was chosen as the optimization parameter. As a result of statistical processing of the experimental data the multidimensional model of waviness was obtained.

2. Methods of research

The independent factors were chosen: cutting depth t, mm (code name x_1), workpiece feed v_s, m/min (x_2) rate speed the n, min^{-1} of the spindle unit with a shaping cutter (x_3) and the number of cutter teeth Z, pieces (x_4). The full factorial experiment $N = 2^4 = 16$ was performed. As previously noted, as the optimization parameter waviness H_B (coded Y_i) was selected.

A priori postulated mathematical model linking the parameter optimization process with factors of profile milling process with shaping cutter, was identified in the form of:

$$Y_i = b_0 + \Sigma_{2\le i\le k} b_i x_i + \Sigma_{2\le i\le j\le k} b_{ij} x_i x_j \quad (1)$$

where Y_i – the parameter of optimization; b_0, b_i, b_{ij}, – regression coefficients; x_i – independent factors; $x_i x_j$ – interaction effects.

In expanded form, expression (1) is provided:

$$Y_i = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{14}x_1x_4 + b_{23}x_2x_3 + b_{24}x_2x_4 + b_{34}x_3x_4 \quad (2)$$

In the process of multidimensional experiment planning matrix is implemented:

$$abcd\ \ bcd\ \ acd\ \ cd\ \ abd\ \ bd\ \ ad\ \ d\ \ abc\ \ bc\ \ ac\ \ c\ \ ab\ \ b\ \ \ a\ \left(-1\right) \quad (3)$$