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D. Yu Pimenov, V.I. Guzeev, G. Krolczyk, Mozammel Mia, S. Wojciechowski

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Modeling flatness deviation in face milling considering angular movement of the machine tool system components and tool flank wear

D. Yu. Pimenov[1,a*], V. I. Guzeev[1,b], G. Krolczyk[2,c], Mozammel Mia[3,d], S. Wojciechowski[4, e]

[1]Department of Automated Mechanical Engineering, South Ural State University, Lenin Prosp. 76, Chelyabinsk, 454080 Russia
[2]Faculty of Mechanical Engineering, Opole University of Technology, 76 Proszkowska St., Opole, Poland
[3]Mechanical and Production Engineering, Ahsanullah University of Science and Technology, Dhaka 1208, Bangladesh
[4]Faculty of Mechanical Engineering and Management, Poznan University of Technology, 3 Piotrowo St., 60-965 Poznan, Poland

a – danil_u@rambler.ru https://orcid.org/0000-0002-5568-8928; b – gvi174@yandex.ru; c – g.krolczyk@po.opole.pl https://orcid.org/0000-0002-2967-1719; d – mozammelmiaipe@gmail.com; mozammel.mpe@aust.edu https://orcid.org/0000-0002-8351-1871; e – sjwojciechowski@o2.pl

ABSTRACT: The torsional angle, χ_{YDeg}, of a machine tool-device-spindle unit is formulated in a face-milling operation. As there is no angular compliance in the technical specifications for the machine tool, a novel method is proposed for the determination of the angular compliance values of a GF2171S5 machine milling system. Deviation from flatness, Δ_{Zfl}, is therefore also modelled in this paper, for the first time, by considering the parameters of milling and tool wear. The proposed model performs an acceptable evaluation of various types of flatness deviation for different flank wear values. The face milling and tool-wear parameters and their influence on the torsional angle of the tool-device-spindle unit are calculated. Besides, the effects of different settings on the machining process and the material-cutting speed v_c and depth a_p, cutting-edge angles k_r, and tool slenderness- l_o/D in combination with various depths of flank wear V_B on the torsional angle of the mill χ_{YDeg} and flatness deviation Δ_{Zfl} are investigated. This method of determining the angular torsional values can be applied to other milling machines. Moreover, the model can be used to compensate the torsional angle of the mill face, thereby minimizing the flatness deviation.

Keywords: face milling; torsional angle; flatness deviation; tool wear.

NOMENCLATURE

a_p : Depth of cut (mm)
B : Width of cut (mm)
D : Diameter of the mill (mm)
f_z : Feed per tooth (feed rate) (mm/tooth)
v_c : Cutting speed (m/min)
n : Rotation speed (rpm)
V_B : Tool flank wear (mm)
$\Delta_{z\Sigma}$: The sum of angular displacement of the machining system towards the Z axis (μm)
$C_{z\Sigma}$: Subsystem: "workpiece – device – machine table", subsystem: "tool - device - spindle unit" cumulative yield towards the Z axis (μm/N)
C_{z0}; C_{z1} : Compliance of subsystems; towards Z axis (μm/N)
P_{xt}^{Σ}; P_{zt}^{Σ} : Cutting force components; towards X and Y axes (N)
P_{xys}; P_{zs} : Cutting force components induced by strain in the shear area (N)
AO : Shear plane
P_{xyV_B}; P_{zV_B} : Cutting force components induced by plowing mechanisms on the flank face (plowing forces) (N)