Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 15th International Scientific and Practical Conference. Volume III, 158-161

Improvement of Technological Processes to Reduce Total Inaccuracy during Boring Deep Holes

Angel Lengerov
Faculty of Mechanical Engineering
Technical University of Sofia,
Plovdiv Branch
Plovdiv, Bulgaria
anlen@tu-plovdiv.bg

Silviya Salapateva
Faculty of Mechanical Engineering
Technical University of Sofia,
Plovdiv Branch
Plovdiv, Bulgaria
sisisal@tu-plovdiv.bg

Georgi Levicharov
Faculty of Mechanical Engineering
Technical University of Sofia,
Plovdiv Branch
Plovdiv, Bulgaria
glevi@tu-plovdiv.bg

***Abstract*—Ensuring accuracy of the shape of holes processed by boring is essential for increasing productivity and economy of the process. The great influence for ensuring the prescribed operational and quality indicators during boring is the stability of the technological system and in particular the total deformations. This determines the goal of the present development, namely reduction of elastic deformations and displacements of the elements of the technological system.**

Keywords— inaccuracy, facing, holes, deformations.

I. INTRODUCTION

A significant increase in the productivity and economy of machining when boring holes can be achieved by reduction of the errors, caused by the dissipation of the elastic deformations of the technological system. In the existing systems for controlling the elastic displacements during turning [1] – [14], the accuracy is increased by stabilizing the deformations of the support, which to the greatest extent determine the magnitude and character of change of the total deformation of the system. In order to determine the limiting element of the system during boring, which has a significant effect on the deformation, it is necessary to carry out studies for determining the technological system stability.

II. ANALYTICAL DETERMINATION OF ACCURACY IN THE TECHNOLOGICAL SYSTEM

A basic requirement toward the technological system for boring deep holes is to be stable under all applied operating modes. It has been proved [1] that when boring with a cantilever non-rotating boring bar by one-sided cutting, the necessary condition for stable operation is achieved when the inequalities are satisfied:

$$\left(2k-1\right)\frac{\pi}{2} \le \alpha \le k\pi, \quad (k=1,2) \text{ , when } y>0 \tag{1}$$

$$\left(k-1\right)\pi \le \alpha \le \left(2k-1\right)\frac{\pi}{2}, \quad (k=1,2) \text{ , when } y<0 \tag{2}$$

where α is the angle between the feed directions and the adjustment speed.

In addition to the angle α, stability can be influenced by the magnitude of the adjustment speed. This is illustrated in Fig. 1, in which the angle α satisfies the inequality (1).

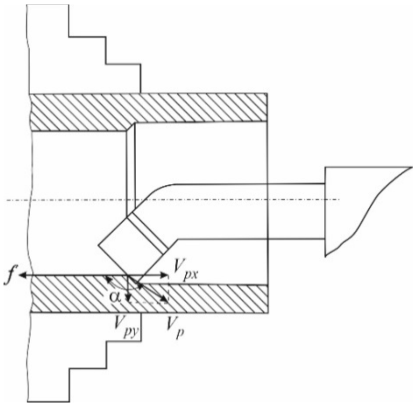

Fig. 1.

The adjustment speed can be represented by its two projections:

$$V_{px} = V_p \cos\alpha \tag{3}$$

$$V_{py} = V_p \sin\alpha \tag{4}$$

Print ISSN 1691-5402
Online ISSN 2256-070X
https://doi.org/10.17770/etr2024vol3.8127

In cases when:

$$V_p \cos\alpha > fn ,$$

the main cutting edge separates from the cutting surface. Cutting is done by means of the auxiliary cutting edge and the system strives to achieve equilibrium under abnormal operating conditions. This is the beginning of an irreversible or self-oscillating process. To avoid this, the following inequalities must be satisfied:

$$\left|V_p \cos\alpha\right| < fn \quad , \tag{5}$$

$$\frac{V_p \sin\alpha}{fn + V_p \cos\alpha} < fn \; . \tag{6}$$

From the inequality (6), an expression for determining the adjustment speed can be obtained.

$$V_p < \frac{fntg\varphi_1}{\sin\alpha - \cos\alpha tg\varphi_1} fn , \tag{7}$$

where *f* is the feed in mm/tr; *n* – the revolutions in tr/min; *φ1* – the auxiliary setting angle.

In order to analyze the mechanisms for determining the elastic deformations in the technological system during boring by a boring bar, the schematic representation of the process shown in Fig. 2 is used.

$$Y = P_y W , \tag{8}$$

where P_y is the radial component of the cutting force; W − the susceptibility of the technological system.

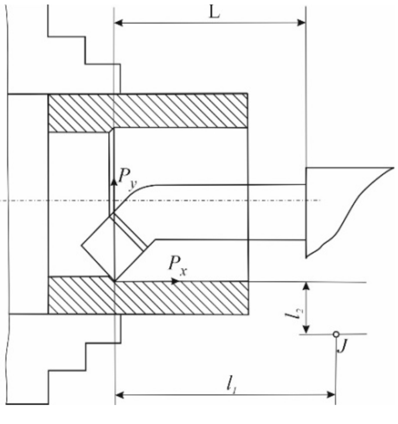

Fig. 2.

The susceptibility W of the technological system can be expressed as follows:

$$W = \frac{1}{j_{\sup}} + \frac{L\left(l_1 + C_{xy} l_2\right)}{j_{\alpha_c}} + \frac{L^3}{3EI}\left(1 - C_{xy}\frac{R}{L}\right) \tag{9}$$

where $j_{\sup}$ is the stability of the support in the direction of the radial component of the cutting force;

$j_{\alpha_c} = \dfrac{P_y l_1 + P_x l_2}{\alpha}$ − the angular stability of the support;

L − the arm (length) of the bar; *l1, l2* − the arms, respectively, of the components P_y and P_x of the cutting force and the coefficient $C_{xy} = P_x/P_y$; *E* − the modulus of elasticity of the bar material; *I* − moment of inertia of the transversal cross section of the bar; *R* − the radius of the machined surface.

When boring by means of a boring bar, established on two flexible hinge supports, according to Fig.3 the susceptibility W of the technological system will be

$$\begin{aligned} W = {} & \left(1 - \frac{x}{L}\right)^2 \left(1 - C_{xy}\frac{R}{L - x}\right) W_{fs} + \\ & + \left(\frac{x}{L}\right)^2 \left(1 + C_{xy}\frac{R}{x}\right) W_{rs} + \\ & + \frac{x^2 (L - x)^2}{3LEI}\left[1 + C_{xy}\frac{R}{x}\left(1 - \frac{x}{L - x}\right)\right] \end{aligned} \tag{10}$$

where *x* is the coordinate of the cutting area; *L* – the distance between the supports; W_{fs}; W_{rs} – susceptibility of the front and rear support, respectively.

From the expressions (8), (9) and (10) it follows that the error, and respectively the accuracy of the machined surface, obtained from the dissipation of the elastic deformation *Y*, when working with a cantilever boring bar, is mainly determined by the change of the cutting force in magnitude and direction.

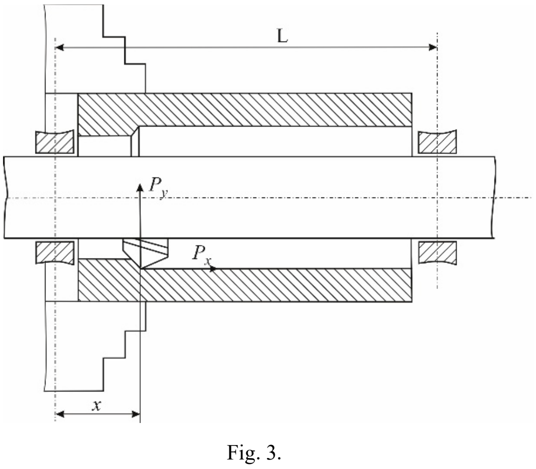

Fig. 3.

When working with a two-support bar, the change in the susceptibility *W* of the system, occurring when the coordinate of the cutting zone is changed (when a feed movement is implemented), is an additional source of error. Using formula (8), the following expression for the error from the elastic displacements can be obtained:

$$\varepsilon = Y_{\min}\left(R_p R_\omega - 1\right) , \tag{11}$$

where $Y_{\min} = P_{y\min} W_{\min}$ is the smallest deformation of the technological system; R_p – the range of variation of the radial component of the cutting force for a batch of workpieces; R_ω – the range of variation of the susceptibility of the system when processing one workpiece.

From the analysis of formula (11), it can be found that there is a possibility of increasing the accuracy by reducing $Y_{\min}$, using a lighter cutting mode. The proposed methodology will contribute to reducing the processing productivity.

The processing accuracy can also be increased by adjusting the size of dynamic tuning. A necessary condition is to maintain constancy of the elastic deformation Y of the technological system, i.e.

$$Y = P_y W = const\ . \tag{12}$$

Using the empirical dependence for P_y, the condition (12) can be written in the form

$$Y = C_{Py} a_p^{x_{Py}} f^{y_{Py}} V^{n_{Py}} \left(HB\right)^{z_{Py}} W = const\ . \tag{13}$$

From equation (13) it can be seen that the constancy of Y can be ensured by adjusting the feed f, the geometry of the tool and the susceptibility of the technological system W.

If the tool geometry and the cutting speed are kept constant when adjusting the feed, for the range of feed adjustment, we get

$$R_s = \left(R_{a_p}^{x_{Py}} R_{HB}^{z_{Py}} R_\omega\right)^{\frac{1}{y_{Py}}}\ , \tag{14}$$

where R_t is the range of variation of the depth of cut; R_{HB} –range of change in the hardness of the processed material.

When processing constructional steel by means of a carbide metal cutting tool, according to the data in [2], formula (14) takes the following specific form:

$$R_s = R_{a_p}^{1.5} R_{\sigma_B}^{2.25} R_\omega^{1.67}\ . \tag{15}$$

When adjusting the geometry, according to [2], it is most appropriate to adjust the cutting angle δ in the range from 70 to 110°. For the adjustment range Rδ it can be written:

$$R_\delta = R_{a_p}^{0.34} R_{\sigma_B}^{0.51} R_\omega^{0.38}\ . \tag{16}$$

A comparison between the expressions (15) and (16) shows that when adjusting the tool geometry, the adjustment range is significantly smaller. Besides, the variation of the cutting angle δ has a negligible effect on the roughness of the machined surface. Despite these advantages, the tool geometry adjustment is also characterized by some disadvantages, such as the complex construction of the boring tool and the need for a mechanism for small reversing displacements.

Feed adjustment is accomplished using a simple boring tool and a variable in magnitude feed rate, without reversal, which is why it is preferable. However, in order for it to be applied, it is necessary to have a sufficiently small range of adjustment.

When working with a cantilever boring bar, the susceptibility of the technological system changes slightly as a result of the wear of the cutting tool, and therefore the ranges of adjustment R_S and R_δ are mainly determined by the dispersion of the depth of cut and the hardness of the machined workpieces.

By choosing an appropriate magnitude of the smallest depth of cut, for a given workpiece size tolerance, R_{a_p} can be varied, and thus - the R_S and R_δ ranges.

The magnitude of the smallest depth of cut is determined by the expression:

$$a_{p\min} = \frac{\delta_D}{2\left(R_{a_p} - 1\right)}\ , \tag{17}$$

where δ_D is the tolerance of the hole in the workpiece.

This shows that when working with a cantilever bar, the dynamic tuning size adjustment can be successfully realized.

It should be noted that the vibration resistance of the system and the tool strength limit the possibilities regarding the depth of the processed hole.

III. CONCLUSIONS

From the obtained analytical dependences for susceptibility, mainly influencing the total inaccuracy of the technological system when boring holes by means of single- and double-support boring bars, it has been established that the process can be controlled. This can be realized by adjusting the technological parameters of the process, mainly influenced by the dynamic tuning of the technological system. The implementation of an adaptive control system for the boring process, carried out by a cantilever non-rotating boring bar, will contribute to increasing the accuracy and productivity of the machining process.

REFERENCES

[1] H. Metev, K. Krumov. Determination of inaccuracy by milling taking into account the phenomenon of technological heredity. 9TH International Scientific Conference "TechSys 2020" – Engineering, Technologies And Systems 14-16 May 2020, Plovdiv, Bulgaria. IOP Conf. Series: Materials Science and Engineering 878 (2020) 012049. doi:10.1088/1757-899X/878/1/011001.

[2] S. Sabev and P. Kasabov, The influence of feed rate and cutting speed to surface roughness during hole boring of AISI 304 with anti-vibration boring bar. AIP Conference Proceedings, (2022), 2449. 060004, DOI:10.1063/5.0091006.

[3] C. Deng, J. Chin, Hole roundness in deep-hole drilling asanalysed by Taguchi methods. Int J Adv Manuf Technol 25(5-6): 420–426, 2005.

[4] T. Aized and M. Amjad Received, Quality improvement of deep-hole drilling process of AISI D2, The International Journal of Advanced Manufacturing Technology 69(9-12), Published online: 8 August 2013 # Springer-Verlag London 2013, DOI:10.1007/s00170-013-5178-4.

[5] L. Francis, D Xavier, D. Elangovan, Effective Parameters For Improving Deep Hole Drilling Process By Conventional Method, International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 3, March - 2013 ISSN: 2278-0181.

[6] F. Zou, J. Dang, X. Cai, Q. An, W. Ming, M. Chen, Hole quality and tool wear when dry drilling of a new developed metal/composite co-cured material. Proc. Inst. Mech. Eng. Part B J. Eng. Manuf. 234, 980–992, 2020.

[7] K. Sentyakov, J. Peterka, V. Smirnov, P. Bozek, V. Sviatski, Modeling of Boring Mandrel Working Process with Vibration Damper. Materials 13, 1931, 2020.

[8] L. Lie, S. Beibei, H. Haitao, H, Nonlinear system modeling and damping implementation of a boring bar. Int. J. Adv. Manuf. Technol. 104, 921–930, 2019.

[9] L. Kon et all., Complex nonlinear behaviors of drilling shaft system in boring and trepanning association deep hole drilling. Int J Adv Manuf Technol 45(3-4):211–218, 2009.

[10] C. Deng, J. Chin, Hole roundness in deep-hole drilling as analyzed by Taguchi methods. Int J Adv Manuf Technol 25:420–426, 2005.

[11] K. Weinert, O. Webber, C. Peters, On the influence of drilling depth dependent modal damping on chatter vibration in BTA deep hole drilling. CIRP Ann Manuf Technol 54(1):363–366, 2017.

[12] E. Kilickap, M. Huseyinoglu, A. Yardimeden, Optimization of drilling parameters on surface roughness in drilling of AISI 1045 using response surface methodology and genetic algorithm. Int J Adv Manuf Technol 52:79–88, 2021.

[13] G. Chern, J. Liang JM, Study on boring and drilling with vibration cutting. Int J Mach Tool Manuf 47(1):133–140, 2007.

[14] M. Amjad M, Parametric Analysis Based Quality Improvement of Deep Hole Drilling Process of AISI D2. M.Sc. Manufacturing Engineering thesis submitted to the University of Engineering and Technology, Lahore, Pakista, 2012.