

Research Journal of Pharmaceutical, Biological and Chemical Sciences

The Optimum Cutting Speed and Acceptable Parameters for Tool Vibration when Turning an Inhomogeneous Material.

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ABSTRACT

This paper deals with the dynamic characteristic of cutting the inhomogeneous material structure using DC motor commutator as an example. The commutator ring consists of alternating copper and insulating plates, and cutting force during mechanical processing has periodically changing nature, which promotes the technological vibration. There is a danger of self-oscillation process when turning and a sharp degradation of quality of the surface being processed. There is a description of the law of variation of cutting force when turning the inhomogeneous structure of the commutator ring. The tool vibration parameters associated with the inhomogeneous structure of the object being processed have been determined. A criterion for the absence of self-oscillations when turning the commutators has been defined to ensure the required quality of the contact surface. The theoretical assumptions are in good agreement with experimental studies of vibrations of the blade in different turning modes due to periodically varying cutting forces.

Keywords: turning, cutting force model, cutting tool overhang, technological vibration, commutator, DC motor.

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INTRODUCTION

A number of strict requirements are imposed upon the commutator motors for the manufacturing accuracy and quality of mounts and components, for the electromagnetic characteristics, durability and heat resistance of individual mounts. Commutator is the most complex and expensive mount of the motor. When optimizing mechanical processing it is important to accurately and correctly predict the final quality of processing [1]. The assembled commutator has an intermittent surface, which consists of commutator and insulating plates overhanging at different levels, thus the component cutting forces P_z and P_y vary depending on the coordinate during machining. The cutting tool is under impact load at this moment, which is significantly higher than the estimated values calculated by the conventional continuous cut method [2,3]. Mechanical processing of the commutator working surface contacting with the brush current collectors has no sufficient theoretical justification of the purpose of modes and processing conditions at this time. Technical literature has quite little technological information and recommendations for the processing of copper materials. Existing reference data recommended for copper materials can not be considered completely acceptable to create an effective processing technology of the commutator, as they do not address specific physical and mechanical properties of copper and electrical features of the cutting process [4]. Therefore, it is very important to investigate the turning process of the commutator in order to create a theoretical framework and practical recommendations ensuring the required quality of the contact surface and the absence of harmful technological vibration [1].

MAIN BODY

The feature of the cutting process while commutator turning is that cutting has an intermittent nature, since the collector consists of alternating copper and insulating plates. Since insulation crumbles during cutting due to its fragility and relative softness, it has been assumed that the commutator surface in the process of cutting is described by a periodic function (Fig. 1).

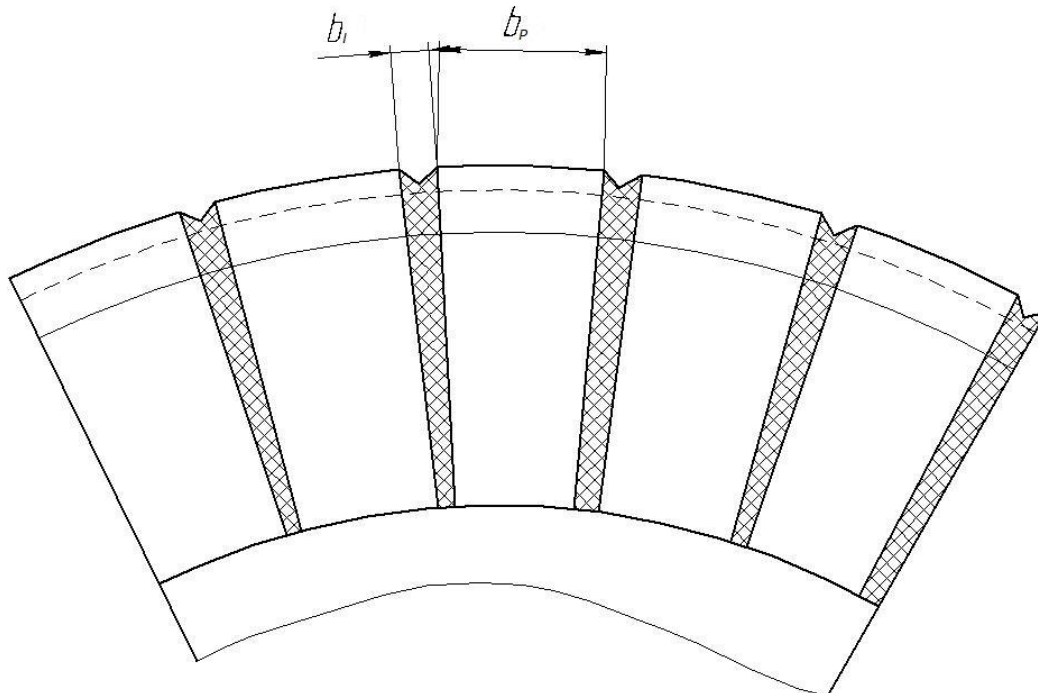


Figure 1: Commutator section fragment:

b_i – thickness of the insulating spacer; b_p – thickness of the commutator plate.

Cutting process will be characterized by an impulse change in the cutting parameters that will affect the quality of the surface being processed. The cutting tool cuts periodically into copper or isolating plate. While the cutting tool passes the commutator plate of 3-5 mm thickness, the cutting process does not reach a steady state. We shall represent an expression, describing cutting force when turning the intermittent commutator surface, as:

$$P_z(t) = \begin{cases} (1 + f) \cdot P_z \text{ npu} & 0 \leq t \leq T - \frac{b_p}{v} \\ 0 \text{ npu} & T - \frac{b_p}{v} \leq t \leq T \end{cases}, \quad (1)$$

where f – is a coefficient considering changes in the hardness of copper and random variation of the allowance; T - the period of oscillation of the cutting force, ms; b_p - commutator plate thickness, mm.

The period of oscillation of the cutting force is calculated by the formula:

$$T = \frac{b_p + b_i}{v}, \quad (2)$$

where b_i – the insulation thickness, mm; v - cutting speed, m/min.

The number of jumps (pulse repetition period) of cutting force will be equal to the number of commutator plates. Pulse repetition diagram is schematically shown in Fig. 2.

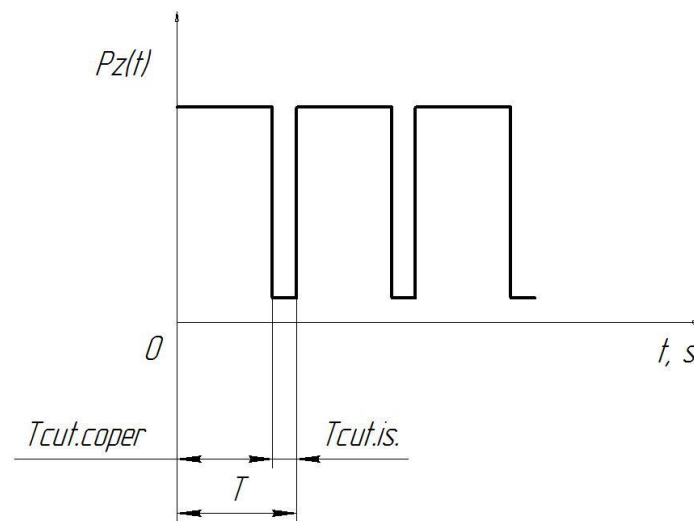


Figure 2: A schematic diagram of the repetition of cutting force pulses during turning the intermittent surface

It should be noted that pulse, actually, increases with some speed rather than abruptly when turning the intermittent surfaces.

Change frequency of the cutting force pulses depends on the spindle rotation speed and the number of commutator plates, Hz:

$$f = \frac{n \cdot m}{60}, \quad (3)$$

where n - the commutator rotation speed, rev/min; m - number of commutator plates.

When selecting a cutting tool and designing the technology by accuracy and performance criteria it is assumed that the process takes place at an acceptable level of vibration. Causes of vibration when turning the armature can be fluctuations associated with the vibrations of the equipment elements, low stiffness of the armature assembled with commutator, or fluctuations of the cutting force. An intermittent turning of the commutator may cause self-oscillation that develops when the frequency of the driving force (cutting force) coincides with the first natural bending frequency of the cutting tool.

To prevent the occurrence of self-oscillation when turning the intermittent surfaces the following condition shall be observed [6]:

$$\frac{b_p}{v} \geq (\tau_{lag} + T_{damp}), \quad (4)$$

where b_p – commutator plate thickness, m; v – commutator rotation speed, m/s; τ_{lag} – delay time, characterizing the lagging of cutting force change when cutting into another commutator plate, s; T_{damp} – dead time of cutting force, s.

Delay time can be calculated by formula [7]:

$$\tau_{lag} = 2,6 \cdot \xi - 1, \quad (5)$$

where ξ – chips shrinkage ratio.

Dead time of the system T_{damp} provided that the system comes to a standstill after reducing the vibration amplitude by 10 times [7]:

$$T_{damp} = \frac{2,3 \cdot \sqrt{4 \cdot \pi^2 + \delta^2}}{\delta \cdot \omega_0}, \quad (6)$$

where δ – logarithmic dimensionless decrement of oscillations; ω_0 - circular natural frequency of sustained oscillations of the cutting tool, 1/s.

The natural frequency of sustained oscillations is determined by the natural frequency of bending vibrations and dimensionless damping coefficient:

$$\omega_0 = \frac{2 \cdot \pi \cdot f_{nat}}{\sqrt{1 - \eta^2}}, \quad (7)$$

where f_{nat} – the natural frequency of bending vibrations, Hz; η – dimensionless damping coefficient.

A dimensionless damping coefficient is determined on the basis of dimensionless vibration decrement:

$$\eta = \frac{\delta}{\sqrt{4 \cdot \pi^2 + \delta^2}}, \quad (8)$$

where δ – dimensionless vibration decrement.

A dimensionless decrement depends on the size of the cross section of the toolholder and the length of its overhang while processing and is defined as an expression:

$$i = \frac{l_c^2}{\sqrt{\frac{I}{F}}}, \quad (9)$$

where l_c – length of cutting tool overhang, m; I – moment of inertia of toolholder section m^4 ; F – sectional area of the toolholder m^2 .

After converting the expression (5), considering the formulas (6) and (7), we shall obtain the dependence for determining the cutting speed, which may cause the self-oscillation, m/min:

$$v_{\max} = \frac{120 \cdot \delta \cdot \omega_0 \cdot b_p}{10^{-3} \cdot (2,6 \cdot \xi - 1) \cdot \delta \cdot \omega_0 + 2,3 \cdot \sqrt{4 \cdot \pi^2 + \delta^2}} \quad (10)$$

The magnitude of the cutting speed, calculated by the formula (11), represents the cutting speed threshold, the excess of which may cause additional vibration of the technological system due to the presence of self-oscillations. Additional vibration may increase roughness [8,9].

To determine the conditions of cutting tool vibration we have carried out experimental studies. During the experiments, the cutting tool vibrations were measured at different processing modes, and the amplitudes of the resultant cutting tool oscillations were recorded. Assessment of change in the resultant cutting tool oscillations depending on the cutting tool speed and feed has been performed by dynamic coefficient k , which characterizes the ratio of the average value of the amplitude of experience vibration to the average value of the amplitude of idling vibration:

$$k = \frac{A_{\text{arithmetical mean observation}}}{A_{\text{arithmetical mean free running}}} \quad (11)$$

where $A_{\text{arithmetical mean observation}}$ – the average value of the amplitude of cutting tool vibration, μm ;
 $A_{\text{arithmetical mean free running}}$ – the average amplitude of cutting tool idling vibration, μm .

Figure 3: shows the change in the dynamic coefficient characterizing the cutting tool vibration. It is seen that the coefficient is considerably higher at a rate of 390 m/min than at 155 and 310 m/min.

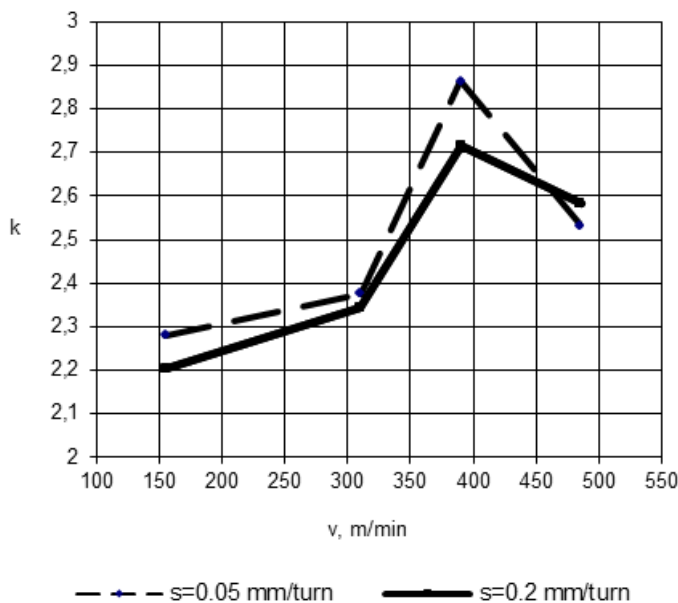


Figure 3. Variation of dynamic coefficient k depending on the cutting rate at feed of 0.05 and 0.2 mm/rev and depth of cut of 0.25 mm

CONCLUSION

Increase in cutting tool vibrations in the speed range of 310-390 m/min confirms the results of theoretical and experimental studies about the negative impact of cutting speed on the roughness, associated with intermittent cutting of commutator copper. Nomograms for determining the speed range, ensuring the absence of self-oscillations, were constructed based on the research findings (Fig. 4).

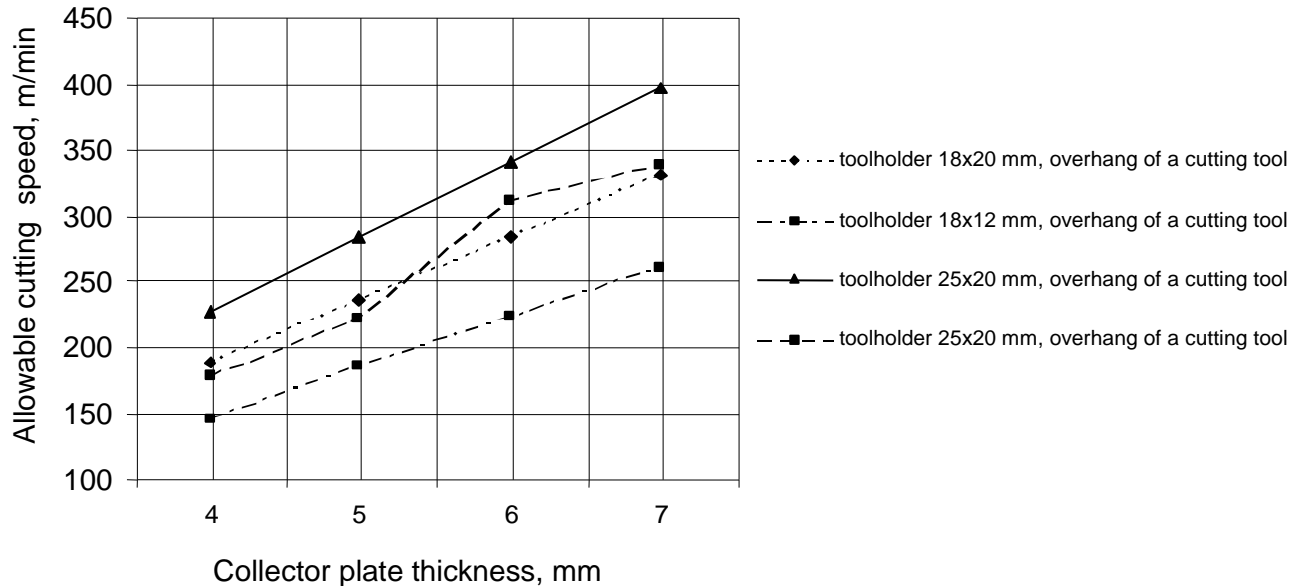


Figure 4: Nomograms for determining the allowable cutting rate, m/min depending on thickness of the commutator plate, mm

Experimental studies of the process of turning the current collecting commutator surface [10,11] confirm the theoretical assumption made about a possible increase of roughness at a specific cutting speed that promotes self-oscillation process.

SUMMARY

- Peculiarities and differences of the cutting process while turning the inhomogeneous structure of the commutator assembled from copper and insulating plates have been defined.
- Law of change of cutting force, as well as cutting force variation parameters associated with the geometry of the copper plates and cutting tools have been determined.
- Assumption has been made about the reduce in quality of the surface layer due to technological vibrations associated with the periodic law of the cutting force.
- A criterion of "vibration-free" cutting while turning the commutator has been suggested, which defines an unallowable cutting speed.
- The impact of technological regimes on the occurrence of cutting tool vibrations unacceptable from the point of view of the surface quality has been experimentally confirmed.

REFERENCES

[1] Duyun T.A., Grinek A.V., Sakharov D.V., 2013. Modelling and optimization of manufacturing processes of products using the dynamic programming approach. Bulletin of Belgorod State Technological University named after V.G. Shukhov: #3, p. 61-65.

[2] Armarego I. J. A, Brown R.H. Cutting processing of metals. Translated from English by V.A. Pastunov. M., "Mechanical Engineering", 1977, p. 325

[3] Luo X., Zhang C., Wei J., 2011. Generation and control of vibration in machining. International Conference on Consumer Electronics Communications and Networks CECNet, pp: 387-389.

[4] Wiercigroch M., 1997. Chaotic Vibration of a Simple Model of the Machine Tool-Cutting Process System. Journal of Vibration and Acoustics, 119(3): 468-474.

- [5] Stanimir A., Pascu L. C., Buzatu S., Geonea L., 2008. Chip formation and cutting force in the machining of. *Management*, 7(17): 1812–1817.
- [6] Vasin S.A. Prediction of tool vibrostability when turning and milling. Series of "Toolmaker Library" - M.: Mechanical Engineering, 2006. - p. 384: illustr.
- [7] Zharkov I.G. Vibrations in the processing with blade tool. - L.: Mechanical Engineering. 1986. – p. 179
- [8] Altintas Y., Eynian M., Onozuka H., 2008. Identification of dynamic cutting force coefficients and chatter stability with process damping. *CIRP Annals Manufacturing Technology*, 57(1): 371-374.
- [9] Shawky A M, Elbestawi M A, 1997. Enhanced dynamic model in turning including the effect of ploughing force. *Journal Of Manufacturing Science And Engineering Transactions Of The Asme*, 119(1):10-20.
- [10] Duyun T. A., Grinek A.V., 2009. Tangential Component of the Cutting Force in Turning the Contact Surface of an Electric-Motor Commutator. *Russian Engineering Research*, 29(10): 1067-1069.
- [11] Duyun T.A., Grinek A.V., 2008. Features of turning handling of DC motor commutator surface. *Engineering Technology*, #9, p. 25-26.