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Method of Mathematical Model Development to Study Vibration Resistance of Non-Rigid Shaft Linear Turning

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Abstract

This article is devoted to the mathematical modeling of vibration resistance of non-rigid shaft linear turning. The relevance of the study is based on the occurrence of vibration in machining non-rigid shafts, which are so intense that they force to significantly reduce the cutting mode, and to resort to multi-pass processing; they lead to premature cutting tool wear and, as a consequence, reduce the productivity of the part machining on metal-cutting machine-tools. In this regard, the purpose of this article is the establishment of appropriate mathematical models which describe the vibrations of the machine-tool elastic system under the influence of dynamic cutting forces generated during machining. The article presents methods of constructing a mathematical model closed to the process of non-free machine-tool dynamic system cutting at turning non-rigid shafts. The model takes different ways of mounting the workpiece on the machine-tool into account including the use of the damper. The basic theoretical principles to build a generalized mathematical model closed to the process on non-free machine-tool dynamic system cutting are substantiated herein. The regions of stability border for different types of technological equipment are revealed by the mathematical model developed. These mathematical models give an opportunity to reflect the complex processes that occur in a closed lathe dynamic system objectively to a greater degree. The article may be useful for engineers, scientists and students of engineering courses.

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Keywords: non-rigid shaft; block diagram; dynamical system; mathematical model; cutting process.

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1. Introduction

Among the large variety of machine parts more than 30% are the details in the form of bodies of revolution. The most time-consuming of them in manufacture are the parts having low rigidity: a variety of axle, torsion bars, shafts, rods, guide cylinders, non-rigid shafts, etc.

Non-rigid shaft are commonly considered those having a ratio of length L to the diameter D as of more than 12 (L/D> 12). Due to the low rigidity of the treated non-rigid shaft the machine-tool-appliance-tool-workpiece technology system is compliant to the action of the external lateral forces and dynamic factors accompanying the process of cutting [1].

In this regard, the machining of such parts is associated with significant difficulties which arise from the deformation of the workpiece under the influence of cutting forces, as well as the occurrence of part vibration in the machining (Fig. 1), which can be so intense, that in practice they force to significantly reduce the cutting mode, to resort multiple-pass machining and result in reduced durability and longevity of the cutting tool [2-7]. The vibration emergence is highly undesirable in finishing when cutting is made at shallow depths and the violation of vibration-free movement of parts and cutter in the cutting zone can lead to part rejection.

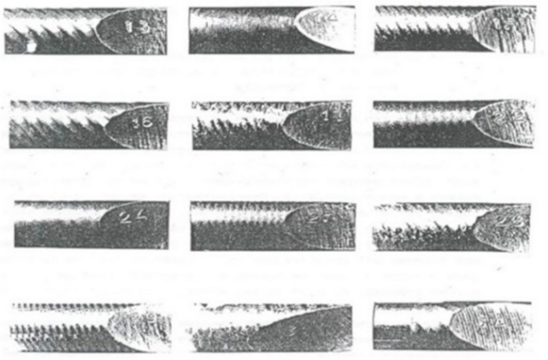

Fig. 1. Traces of vibrations on the workpiece surface treated with d = 16 mm, L = 480mm, L/d = 30, obtained at different machining modes.

The problem of vibration occurrence is relevant in the metal working on CNC machine-tools since apart from reducing the machining precision the vibrations in the cutting zone can lead to accelerated wear of the machine equipment.

In addition, uncontrolled mechanical oscillations with a relatively large amplitude are a limiting factor in increasing the productivity of the cutting process [8-10]. At the same time the oscillation occurrence is due to the presence and the mutual influence of technological cutting conditions, external perturbing forces and parameters of the lathe elastic system. Therefore, improving the machining efficiency of non-rigid shafts mainly depends on the sustainability of their treatment.

2. The design diagram and equations of oscillation movements, the dominant elements of the machine-tool elastic system

The design diagram (Figure 2) shows the two most common kinds of machined shaft fastening: in the chuck with the close-end rear center and in the centers. The equivalent elastic system of the machine-tool (EES) is represented as a set of related elastic-damping elements.

In the adopted idealization the fluctuations in the two dominant elements of the machine-tool elastic system are taken into consideration: the machined shaft and the rams.

The equivalent mechanical model which describes oscillations of this node includes the mass m_3, the moment of inertia J_3 relative to the central axis of inertia x'', the coefficients of stiffness λ_{3j} and damping, $\overline{\lambda_{3j}}$, j= 1,4 joints as well as stiffness and damping of support holder-vibration damper contact elements $\lambda_{3.5}$, $\lambda_{3.6}$, $\overline{\lambda_{3.5j}}$, $\overline{\lambda_{3.6j}}$.