Investigation of dynamic characteristics of spindle units of CNC lathes batch

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Abstract. Studies of the dynamic characteristics of a batch of CNC lathes of the same model, in particular, the frequency response of spindle units, which are obtained experimentally by pulsed excitation of an elastic system, are considered.

Keywords: spindle unit, stiffness, amplitude-frequency characteristics.

1. Introduction

Technological characteristics of lathes change during their operation process. One of these characteristics is the spindle unit stiffness, which affects such quality indicators of manufactured parts as shape accuracy, roughness and undulation of the processed surface. Spindle unit stiffness in addition to wearing depends on the quality of the unit assembly and adjustment of the spindle bearing supports.

2. Experiment

In this paper, an attempt to assess the state of the spindle unit by experimentally obtained dynamic characteristics of a CNC lathes batch operated at the same industrial enterprise has been made. Five lathes of the same model operated in the same conditions during the year have been studied.

The study involved measuring the amplitude-frequency characteristics by impulse input of a dynamometer hammer on the mandrel fixed in the chuck of a lathe and measuring the absolute oscillations of the reaction to this action near the point of impact and on the headstock (Figure 1). The initial signals are vibration acceleration signals.
3. Experimental data processing

Signal processing was performed according to the methods and using the Recorder software [1, 2] developed at MSTU STANKIN. The software provides the following characteristics (Figure 2):

- "Spectrum 1" — averaged over several implementations of the spectrum of pulse action;
- "Spectrum 2" — averaged spectrum of reaction to force action;
- "AFC" — amplitude-frequency characteristics;
- "Phase" — phase-frequency characteristics;
- "Coh" — coherence function, showing the linearity of the connection between the input and output and serving as a measure of the reliability of the frequency characteristics (0 — no reliability, 1 — high reliability). For example, the natural frequencies 407.2 Hz, 430.9 Hz and 473.2 Hz have a coherence function close to 1, i.e. have high reliability. The frequency of 49.8 Hz has low reliability, it is the frequency of the network, the interference in the vibration measurement channel.

![Figure 2. Recorder software interface and frequency characteristics obtained with its help](image)
Figure 3 presents the AFC of the five lathes studied. It can be seen that the AFC of different lathes differ significantly. One lathe has a natural frequency of 450 Hz, the other has two natural frequencies of 400 and 500 Hz, some lathes have three distinguished natural frequencies. Modelling of the spindle unit using the software complex SpinDyna [3-6] can help to identify the causes of such a difference in AFC.

The SpinDyna software is developed at MSTU "Stankin" and designed for automated calculation of static and dynamic characteristics of axisymmetric elastic systems, which allows you to model the lathes spindle units on various supports (rolling-contact bearing, aero, hydrostatic and others) in the presence of parameters characterizing their stiffness and damping properties.

4. Modelling

According to the drawings of the spindle unit, a geometric model is developed (Figure 4), in which the final elements in the form of cylinders describe the spindle body, the concentrated masses are represented by gears, a three-jaw chuck, springs (support) describe the bearings. The geometric model is then converted to a mathematical model. Further, the frequency characteristics are calculated by the finite element method.

![Figure 3. Spindle units AFC of five CNC lathes](image)

![Figure 4. Modelling the spindle unit in the SpinDyna software](image)
5. Conclusion
An example of the AFC of the lathe spindle unit with catalogued data of bearing stiffness is shown in Figure 5 (red graph). As a result of changing the model parameters, namely reducing the stiffness of the front and rear radial bearings with two short cylindrical rollers on average by 55%, results close to the experimental data of one of the lathes (blue graph) were obtained. It was not possible to make the calculated AFC have two natural frequencies in the range of 400-500 Hz by varying the stiffness of the bearings. Further research involves clarifying the identification of model parameters using experimental AFC, as well as changing the structure of the model itself. Hopefully, the variation of the model structure, stiffness and inertial parameters will reveal the reasons for the difference in frequency characteristics of different instances of the lathe as well as assess the actual stiffness of the bearings and predict the residual life of spindle units on this basis [7-9].

Figure 5. Design AFC of a spindle unit in the SpinDyna software

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