

# Recommendations on Diagnostics of Support Condition of High-Speed Spindle Units

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**Abstract.** In the course of the study, amplitude-frequency characteristics of the responses of vibrational acceleration of the spindle unit were obtained experimentally with a short-term impact of a force directly on its spindle. By analyzing the frequency composition of amplitude spectra, the peaks of natural frequencies of the spindle unit were determined at various values of the preload, and, accordingly, the operating modes of the spindle unit were selected, which would reduce its vibration activity and increase processing accuracy.

With the current trend in the design of high-speed spindle units, when a spindle is taken as an absolutely rigid shaft on elastic supports, the dynamic quality of spindle units will be completely determined by the elastic damping characteristics of its supports, which in 90-95% of cases for spindle units of metalworking machines consist of rolling bearings. Elastic-damping characteristics of spindle units largely depend on the choice of the optimal preload of bearing arrangements, and its practical implementation is one of the most difficult tasks in the design and manufacture of spindle units [1-3].

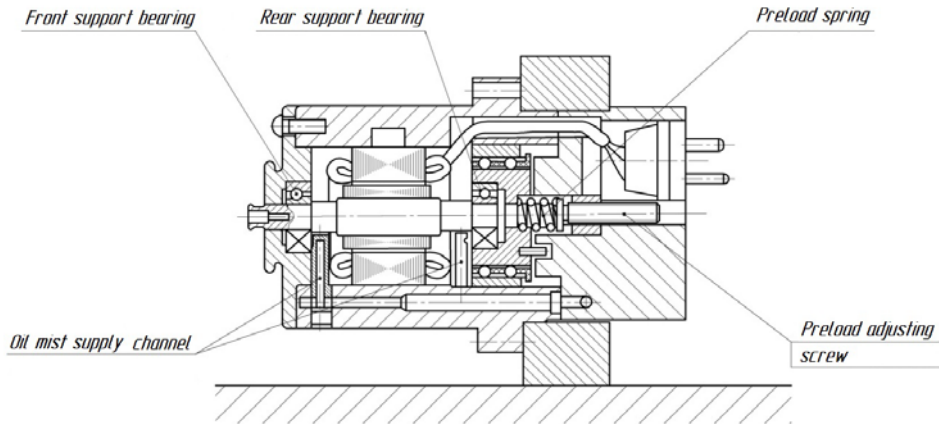
Thus, the preload forces determine the dynamic quality of spindle units, and the task of developing methods for assessing it, especially without disassembling them, is urgent. In this regard, a number of recommendations is given to ensure the dynamic quality of spindle units.

At the stage of installation and repair work, as well as in the case of organizing control over the state of the spindle units and during breaks in their operation, it is necessary to diagnose the condition of the spindle supports and determine the value of their preload. Diagnostics must be carried out by the method of test diagnostics by applying impulse influences along the front end of the spindle. When using impulse action, it is necessary to ensure that the response signal amplitude does not exceed the dynamic range of the vibration acceleration sensor used and does not leave residual deformations on the elements of the spindle unit [4, 5].

If a short-term impulse action along the front end of the spindle is not possible, then the point on the body on the front spindle bearing should be selected as the second control point of action. The test point must be free of paint or unpainted and damping the impulse. In this case, it is necessary to ensure that the direction of the impulse force action and the working axis of the vibration acceleration sensor are in the same plane.

The analysis of the received signals must be carried out by the spectral analysis method. Based on the amplitude spectrum or the power spectrum, one determines the resonant frequency ranges for the entire range of preload values of the rolling bearings used in the diagnosed spindle for which dynamic quality is maintained or enhanced. In this case, a

qualitative determination of resonant frequencies is possible only by the spectrum of signals obtained by impulse action on the front end of the spindle. The spindle speed must be selected in such a way that the spindle speed and, if possible, other frequencies of the main forced oscillations of the supports do not fall into the resonance zones of the spindle unit. For example, for an internal grinding high-speed spindle with 2-76101E rolling bearing (Fig. 1), which was used in the experimental stand [6-9], the manufacturer stated the range of operating spindle speeds from 60,000 to 100,000 rpm.

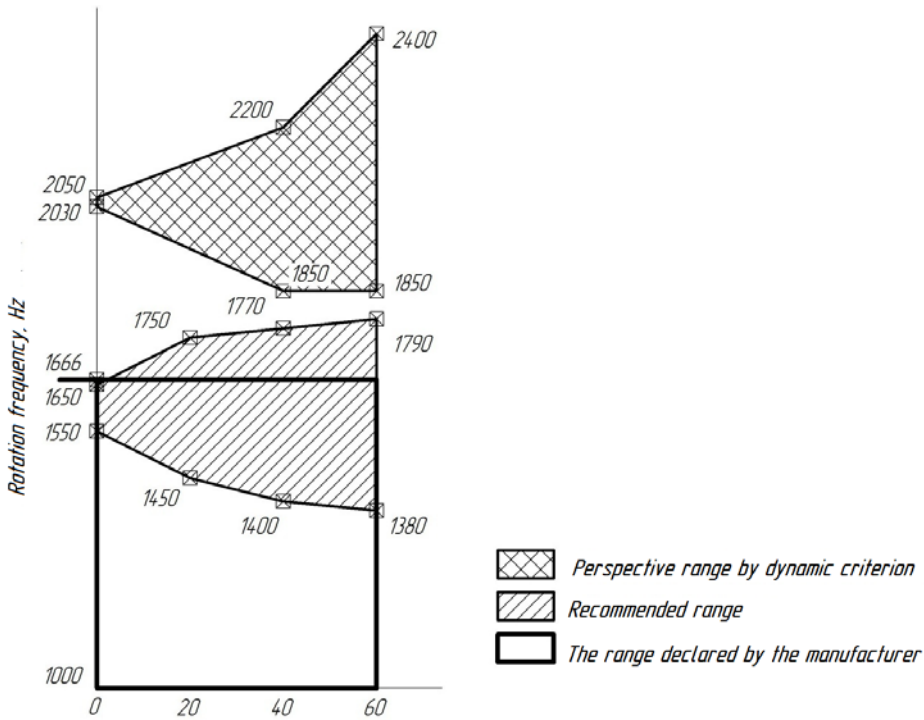


**Fig. 1.** Grinding spindle design

By analyzing the amplitude-frequency response, for this spindle unit, operating modes are selected that will not only ensure the dynamic quality of the unit, but also increase the dynamic quality by reducing vibration activity. The results of the dependence of the spindle speed on the preload value for the experimental spindle unit are shown in the form of Table 1.

**Table 1.** Dependences of revolutions of the tested grinding spindle on the preload value

Preload $P_n$ , N	0+	20+	40+	60+
Recommended spindle speed, t/ Rpm	93-99	87-105	84 - 106.2	82.8-107.4
	121.8 - 123		111 - 132	111 - 144
The spindle speed interval declared by the manufacturer, t/ Rpm	60 - 100	60 - 100	60 - 100	60 - 100

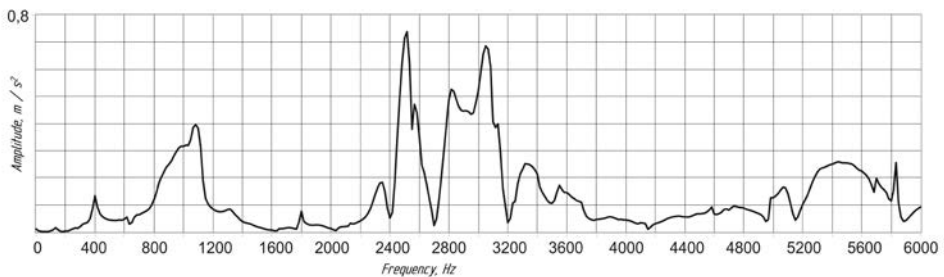


**Fig. 2.** Dependencies of the grinding spindle speed on the preload value

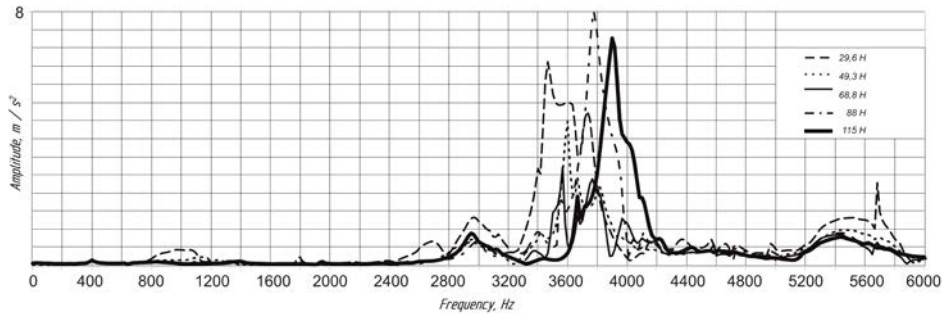
In Table 2, in the line of recommended spindle revolutions, the second line indicates the intervals of revolutions that can be the working revolutions of the spindle of the spindle under study, provided that the problems of outputting increased heat emissions from the supports and their lubrication, as well as cooling the stator windings, are solved.

The use of these intervals of spindle revolutions with appropriate preload values in the future will significantly improve its performance, while maintaining the dynamic quality of the spindle [10].

The table shows that with an increase in preload, the range of recommended spindle speeds increases. For the full range of preload values, the upper and lower limits of the recommended RPM ranges are higher along the frequency axis of the corresponding manufacturer-specified spindle RPM limits. To ensure the dynamic quality of the spindle, it is recommended to exclude the range of revolutions from 60,000 to 75,000 rpm from the spindle operating speed range declared by the manufacturer from 60,000 to 100,000 rpm since it is in the area of the spindle natural resonance frequencies (Fig. 3, 4) in the range from 850 to 1250 Hz.



**Fig. 3.** Frequency response of the spindle at a preload force of 0.92 N



**Fig. 4.** Frequency response of the spindle at different values of the preload force

The use of the spindle unit at speeds from 51,000 to 75,000 rpm leads to an increase in the vibration activity of the unit and, as a consequence, to a decrease in its dynamic qualities. This statement, as well as the fact that the values of the resonant frequencies are critical rotational frequencies and are valid during the operation of the spindle, were experimentally confirmed in [10, 11] when diagnosing and determining the values of the preload of the spindle supports using the methods of functional diagnostics.

To select a rational spindle speed in order to ensure and improve the dynamic quality of spindle units, it is necessary to determine the value of the preload of the unit supports. For this, it is necessary to calculate the relative frequency of the peak, calculated as the abscissa of the center of gravity of the corresponding resonance intervals of the signal spectrum. To ensure dynamic quality and organize an automated process without collapsible control of the preload value of the supports of the same type of spindle units, it is necessary to create a base of reference values of the relative peak frequency and the corresponding preload values in advance.

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