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Determination of the Critical Speed of the Spindles of Ring Spinning Machines

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ABSTRACT: The article describes the method of Academician A. N. Krylov for solving a system of partial differential equations in the study of vibrations of elastic systems and Euler's mathematical method for solving partial differential equations, provides an approximate calculation and application of both methods to the study of vibration of spindles. It is noted that, in the published works, there is no information about experiments on the study of ultrahigh speeds of spindles. Therefore, an experimental setup has been developed to study the amplitude and frequency of rotation of the spindles. The results of experimental studies are presented. The coincidence of the results of theoretical and experimental studies was noted.

KEYWORDS: Speed, spindle, ring spinning machines, differential, elastic modulus.

I. INTRODUCTION

The highest critical velocities were not determined by approximate methods, therefore, it is necessary at least briefly to outline other, more accurate and more general methods for determining the frequencies of natural vibrations of spindles.

We present here a very ingenious method of Academician A. N. Krylov [1], [2] for solving a system of partial differential equations in the study of oscillations of elastic systems and Euler's mathematical method for solving partial differential equations, and we will show the application of both methods to spindle vibration research.

II. ANALYSIS OF EXISTING FILTERING MATERIALS AND RESEARCH RESULTS

Consider the vibrations of a cylindrical spindle clamped at one end if the other end is free. There is no coil or yarn on the spindle.

According to the formulas for the strength of materials, you can write:

$$EI y'' = -M \quad (1)$$

where y'' represents the second derivative of the deflection arrow along the abscissa x .

The fourth derivative gives the load intensity or load q per linear unit of spindle length:

$$EI y^{IV} = q \quad (2)$$

On the other hand, during the oscillatory movement of the spindle, the load per unit length can be expressed through the force of inertia of the mass, which consists of a segment 1 cm long. It turns out the equality: $= m_1 y''$ (.), where m_1 is the unit mass;

y'' — the second derivative of the arrow in prog and b a p about times and.

The unit mass can be represented through the cross-sectional area of the spindle, F is the specific gravity of the material and the acceleration of gravity g :

$$m_1 = \frac{F\gamma}{g} \text{ In this case, by D. Alambert } EI y^{IV} = -\frac{F\gamma}{g} \ddot{y}. \quad (3)$$

For cylindrical spindle $F = \text{constand}$ $I = \text{const.}$, therefore, where $\ddot{y} + k^2 y^{IV} = 0$,
to integrate the equation by the Euler method, one sets:

$$y = \Phi \Psi$$

Where Ψ - a function that depends only on x , but does not depend on time, while Φ , on the contrary, depends only on time and does not depend on x .

Then from the equation we obtain the equation

$$\ddot{\Phi} \Psi + k^2 \Phi \Psi^{IV} = 0 \quad (4) \text{ which splits into two: } \ddot{\Phi} + k_0^2 \Phi = 0$$

$$\text{and } \Psi^{IV} - \frac{k_0^2}{k^2} \Psi = 0 \text{ or } \Psi^{IV} - p^4 \cdot \Psi = 0, \text{ Where } p^4 = \frac{k_0^2}{k^2}$$

The equation has a general integral:

$$\Phi = L_1 \cos k_0 t + L_2 \sin k_0 t \quad (5)$$

After defining arbitrary constants L_1 and L_2 : the equation is reduced to the form of the harmonic oscillation equation

Where Φ_0 —amplitude.

However, the constant k_0 remains unknown, since it is connected not only by the condition, but also by the condition. If the constant k_0 is determined, then there is the fundamental frequency of natural oscillations and the

$$\text{critical number of revolutions per minute: } n_{kp} = \frac{30}{\pi} k_0$$

The equation is solved in different ways. For example, in circular and hyperbolic functions, its general integral

$$\text{has } \Psi = A \cos px + B \sin px + C \operatorname{ch} px + D \operatorname{sh} px. \quad (6)$$

Here - A, B, C, D — arbitrary constants;

$\operatorname{Cosp} x$ and $\operatorname{sinp} x$ — circular functions;

$\operatorname{Chp} x$ and $\operatorname{shp} x$ — hyperbolic cosine and sine.

III. EXPERIMENTAL RESULTS

The equation allows you to determine the frequencies of natural vibrations of the spindle, which is why it is called the equation of frequencies. To solve it, you need to find such values of the argument pl , in which the product $\cos pl \cdot \operatorname{chpl}$ is equal to negative one, which, obviously, is possible only for negative values $\cos$;/. Solutions can be easily found using tables of circular and hyperbolic functions. You can also look for solutions using the graphical method, for which it is necessary to build two curves by points: The point of intersection of the curves corresponds to the value of pl , for which the equation is satisfied. Infig. 1. Such a solution is shown.

$$f_1(pl) = \cos pl \text{ и } f_2(pl) = \frac{1}{\operatorname{chpl}} \quad (9)$$

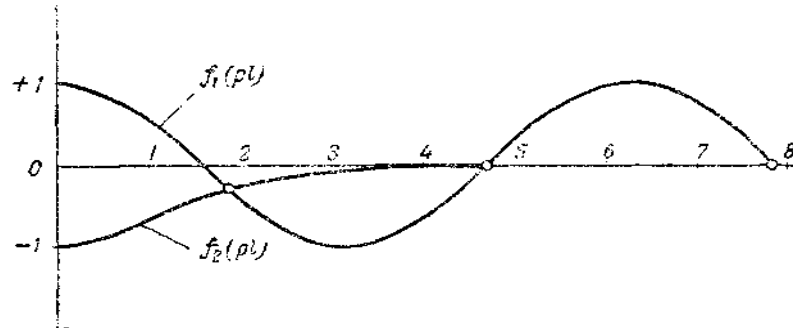


Fig. 1. Graphical solution of the frequency equation

Thus, the conditions were determined, which should be satisfied by the frequencies of natural vibrations of the spindle. For the fundamental frequency

1 = 1.875; for the second = 4.694; for the third = 7.855.

It has already been found above that $n_{kp} = \frac{30}{\pi} k_0$

Using the ratios, it is easy to find:

$$n_{kp} = \frac{30}{\pi} p^2 \sqrt{\frac{EJg}{F\gamma}}$$

Bearing for steel spindles

$$E = 2,2 \cdot 10^6 \text{ kg} \cdot \text{sm}^{-2}$$

и $\gamma = 7,5 \text{ g} / \text{sm}^3$, we get $n_{kp} = 1285 \cdot 10^3 \frac{d}{l^2} \cdot \varphi^2$ Where $\varphi = pl$.

The formula can be used to calculate the vibrations of cylindrical spindles, in which the base can be considered pinched.

If the spindle rotates in a long bearing, then it can be considered clamped on a large base. In this case, to determine the first critical speed, you can apply the Mononba formula for the schemes shown in (Fig.2.1.):

$$\omega_{\text{ед}} = \sqrt{\frac{3 \cdot E \cdot J}{m_{np} \cdot l \cdot b^2}} \quad (2.15)$$

Where l — truncated cone height;

J — equatorial moment of inertia of the cross-section of the largest base of the cone;

E — elastic modulus;

b — spindle cantilever distance.

m_{np} — reduced mass at the end of the spindles.

Let us consider the approximate method proposed by us for determining the first critical speed of the spindles of ring-spinning and ring-spinning spindles (Fig. 2)

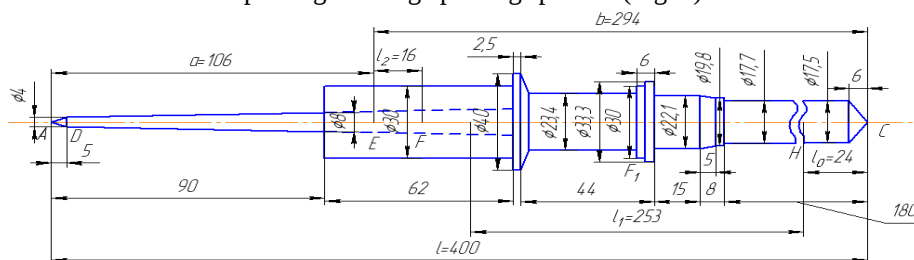


Fig. 2. Design diagram of the spindle spindle.

The values of the quantities included in the formula are clear from Figure 2.3. With the Rayleigh method, the formula for determining m_{np} would have turned out somewhat different. The critical spindle speed of the spindle can be determined by the formula. To determine the critical speed of the spindle of the spindle shown in Fig. 2.3., We measure the dimensions of the spindle, and the density and the MODULE of elasticity of the material $\rho = 2800 \text{ kg/m}^3$, $E = 0,7 \cdot 10^{11} \text{ N/m}^2$.

Using the formula, we determine the reduced mass

$$m_{np1} = 24 \cdot 10^{-3} \text{ kg}; m_{np2} = 31 \cdot 10^{-3} \text{ kg}; m_{np3} = 6.6 \cdot 10^{-3} \text{ kg};$$

Determine the critical speed of the spindle spindle by the formula: $\omega_{1kp} = 550.8 \text{ rad/s}$;

$$\omega_{2kp} = 640.6 \text{ rad/s}; \omega_{3kp} = 591.6 \text{ rad/s};$$

According to calculations, the first critical speed of the given one is about 610 rad / sec; according to experimental data, the first critical speed of these spindles is in the range 575-622 rad / sec. The working speed of these spindles is 1000-1200 rad / sec.

The study of the dynamics of spindles is devoted to works in which theoretical and experimental studies of spindles of different types and sizes are given. But they do not provide data on experimental studies of ultra-high critical speeds of the spindles of spinning machines. Also, there is no data on the method of measuring the parameters of the dynamic parameters of the spindles of spinning machines. It should also be noted that the measurement accuracy did not allow such studies to be carried out. Based on the analysis of existing measurement methods, we were faced with the task of developing a methodology and a bench for researching the dynamics of spindles at high speeds.

To study the dynamic characteristics of the spindles, we have developed and manufactured an experimental setup with laser sensors for monitoring the vibration amplitude and rotation frequency of the spindles.

Figure 3 shows a general view and a diagram of an experimental setup for studying the vibration of the spindles of spinning machines. A controllable electric motor 2 is installed on the bar 1, the frequency of rotation of which is regulated by the LATR current 7 and is fixed on the scale 8.

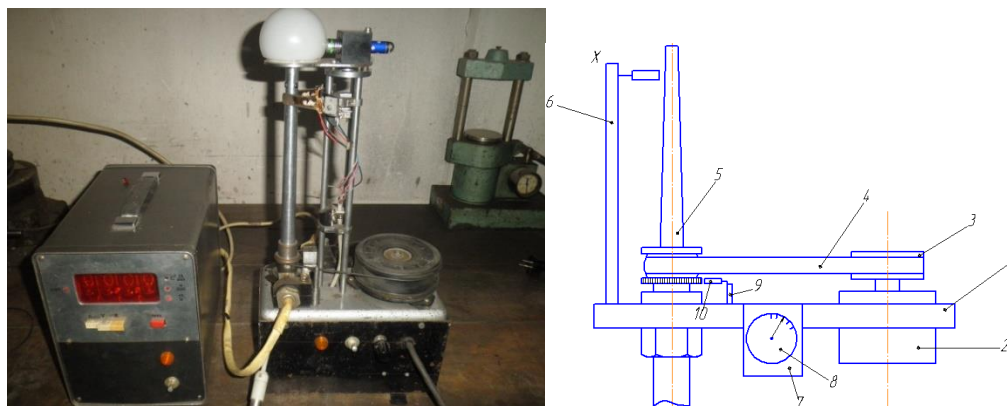


Fig. 3. General view and diagram of the experimental setup for the study of spindles.

A pulley is installed on the engine, 3 from which, by means of a tape transmission 4, the rotational movement is transmitted to the spindle 5. To control the spindle speed, the installation uses sensors 9 with a pulse imitation sector 10, which were monitored using a F3433 frequency meter. To register the amplitude of vibrations of the spindles on the rack 6, strain gauge sensitive elements of movement along two coordinates X and Y are installed.

Figure 4. an electrical circuit for measuring the vibration of the spindles in the operating modes of the spindles is shown, where the signal received from the strain gauges is amplified by the UT4-1 amplifier and visually monitored on the screen of the I-6 oscilloscope, on the screen of which, according to a pre-calibrated scale, the amplitude of the oscillations is determined.

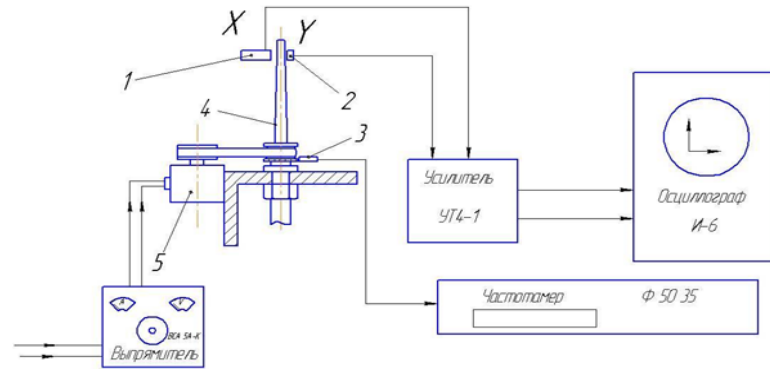


Fig. 4. Electrical diagram for measuring the vibration of various types of spinning spindles.



Fig. 5. General view of the laser head for measuring the vibration amplitude of the spindle tip.

Experimental studies were carried out for two versions of spinning machine spindles BHT-28 and BH-32 at working speeds and at extreme operating modes of the spindles. During the experiment, research was carried out on the vibration of spindles with and without attachments.

Experiments were carried out with repetitions up to 8 times each, for accuracy. The obtained results were processed by the statistical method.

Figure 6 shows the graphical dependences of the change in the vibration amplitude of the spindles on the rotation frequency for two types. From the analysis of the results obtained, it can be seen that with free rotation of the spindles, the vibration amplitude in mm, curve 1, has the smallest value and at frequencies of 6000 rpm of the spindle $A = 0.5$ mm for spindles BHT -28 and for the spindles, BH-32 $A = 0,2$ mm.

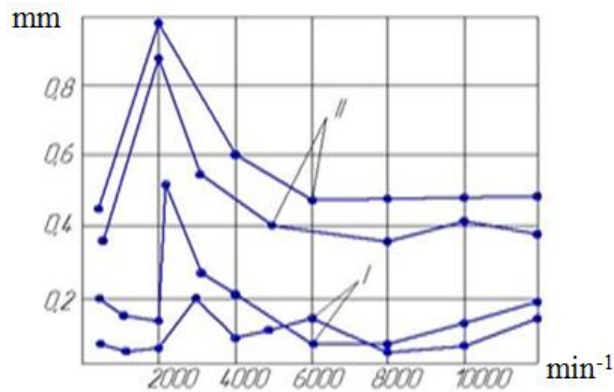


Fig. 6. Graphs of the dependence of the spindle vibration amplitude on the spindle rotation frequency. Curve 1 for spindles without chuck. Curve 2 for spindles with attachments (holder).

These zones of increased vibration amplitude are below the operating speeds and are not subjected to large loads during the spindle transition. To compare the effect of the cartridge on the magnitude of the vibration amplitude, we carried out research in the presence of the cartridge on the surface of the spindle. Figure 6 shows the dependences of the change in the amplitude of oscillations with cartridges, curve 2, where it can be seen that the values of the amplitude of oscillations are three times higher than in the case of the cartridgeless version. Apparently this is due to the method of fitting the cartridges on the spindle. The data presented show that the reactions in the spindle bearings significantly depend on the quality of the cartridges used in the production. The spindle vibration amplitudes, which also depend on the degree of package imbalance, have a similar picture.

IV. CONCLUSION AND FUTURE WORK

1. A method is proposed for calculating the critical speeds of the spindles of spinning machines.
2. The calculation of the highest frequencies of critical speeds and vibrations of the spindle is presented.
3. The installation and the method of investigation of the critical speeds of the spindles of spinning machines are proposed.
4. The critical speeds of the spindles, determined on the developed stand, confirm the calculated ones.

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