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Vibroacoustic processes of grinding fibrous semi-finished products in the knife refiners

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Vibroacoustic processes of grinding fibrous semi-finished products in the knife refiners

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Abstract. Vibroacoustic processes during refining in knife refiners are investigated. When the rotor blades move relative to the stator knives, pressure pulses occur that act on the fibrous semi-finished product, causing it to refine, and on the rotor and stator, causing them to vibrate. A technique has been developed for calculating the sliding speed of the rotor knives on the stator knives. The sliding speed of the knives depends on the headset pattern and the rotor speed and can reach the speed of sound in the metal. The necessity of taking into account the Doppler effect during vibration diagnostics and controlling the functioning of mills is shown. The error in calculating headset frequencies without taking into account the above effect can reach more than 40%, taking into account up to 8%.

1. Introduction

Knife refining machines are the main technological equipment for refining fibrous semi-finished products in the pulp and paper industry. When refining fibrous materials in mills, the basic properties of the products are laid [1,2]. The relevance of the study of processes in knife refiners has been confirmed by many publications analyzing various aspects in the field of properties of fibrous semi-finished products [3-7] and factors affecting the course of refining [8-14]. When the rotor knives move relative to the stator knives, pressure pulses arise that act on the fibrous semi-finished product, causing it to refine [3,6], and on the rotor and stator, causing their vibration [13,15,16]. The amplitude and frequency of the pressure pulses depends on the operational and operational factors of the refining process. Vibration diagnostics and control of the functioning of mills were studied in [15-19].

The interaction of the rotor and stator of the knife refiners is considered as a “moving load” between movable and fixed knives. There are a large number of works devoted to the problem of "moving loads." In these works, various models are described that describe the interaction of a moving object and an elastic system. Especially worth noting the work of A.I. Vesnitsky, his students and followers [20,21]. In relation to the type of elastic system, these works can be divided into two groups. The first group is an analysis of structures of infinite length, the second - of finite length. This article belongs to the second group of works. The purpose of the work is the study of vibroacoustic processes during grinding in knife refining machines.

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2. Methods and materials

When grinding, the rotor knives slide over the stator knives. Between the knives there is milled fibrous material. Let us consider a model of interaction between rotor and stator knives having a certain angle of inclination to the headset radius α (figure 1). The rotor rotates at a constant frequency ω. During dt, the rotor headset will rotate at an angle ωdt, and the rotor knife will move from position I to II.

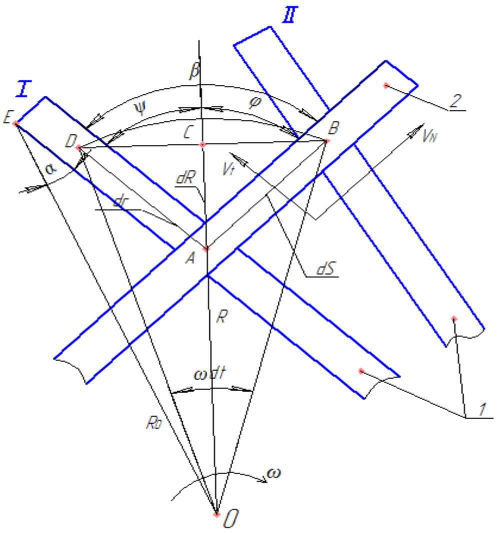

Figure 1. Model of interaction of rotor and stator knives: 1 - rotor knife; 2 - stator knife.

A formula is obtained for determining the sliding speed of knives

$$V = (V_N^2 + V_t^2)^{1/2} = \left\{\{[\omega R(1-\sin^2\alpha)^{1/2}]/\sin\beta\}^2 + \{[\omega R\cos(\beta-\alpha)]/\sin\beta\}^2\right\}^{1/2}, \qquad (1)$$

where V_N, V_t are normal and tangential velocity components, R is headset outer radius, β is the angle of intersection of the rotor and stator knives.

3. Experimental part and results

The headset of the mills has a variety of patterns, depending on the milled semi-finished product, the design of the mills, operating and technological factors of refining. The dependence of the sliding speed of the knives on the rotor speed, inclination and crossing of the knives is shown in figure 2.

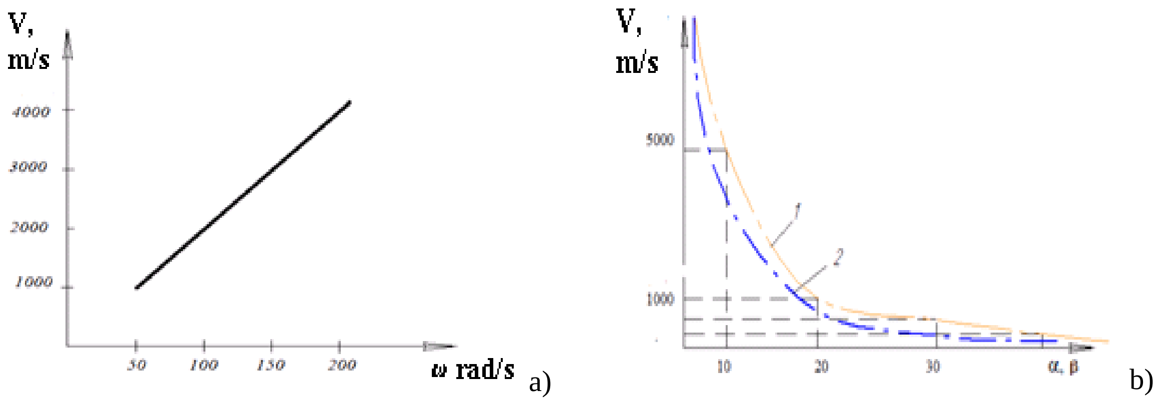

Figure 2. Dependence of the sliding speed of the headset knives: a) - on the rotor speed; b) - the angle of inclination of the knives to the radius α (1) and the angle of intersection β (2).

The sliding speed of the headset knives increases with an increase in the rotor speed and a decrease in the angle of inclination to the radius and crossing.

The vibration frequency caused by the interaction of the rotor and stator knives is called by the author the headset frequency [11]. The headset frequency *fri* on the *i*-th knife belt is defined as [22]

$$fri = (nz_i/60)\cos\beta_i\,, \tag{2}$$

where n is rotor speed, min^{-1}, z_i, β_i are the number and angle of crossing knives on the *i*-th knife belt.

As studies have shown, the sliding speed of knives can reach 5000 m/s or more, which is comparable to the speed of sound waves in a metal. When vibration diagnostics and control the operation of mills based on the analysis of headset frequencies, it is necessary to take into account the Doppler effect [20], the frequencies recorded by a stationary vibration transducer on the stator of a knife grinding machine should be calculated by the formula

$$f^*ri = fri/(1 \pm V/C), \tag{3}$$

where *fri* is headset frequency on the *i*-th knife belt according to the formula (2), V is the sliding speed of the rotor knives on the stator knives according to the formula (1), C is speed of sound waves in the stator material.

In equation (3), the “+” sign - if the sliding speed of the knives is directed to the vibration transducer and the “-” sign - from the vibration transducer. The vibration frequencies recorded by the vibration transducer depend on the place of its fastening, i.e. some headset frequencies will be identified with a “+” sign, others with a “-”. The received wavelength is defined as $\lambda = (C-V)/f^*ri$.

At low sliding speeds of the rotor knives over the stator knives on the knife belts, the ratio $V/C<<1$, and equation (3) can be written as $f^*ri \approx fri$, and the Doppler effect in this case can be neglected. However, at high speeds, when $V \approx C$, the discrepancy between *fri* and *f*ri* increases. In this case, the above effect must be taken into account.

Set frequencies were studied on peripheral knife belts according to formula (2) without taking into account and formula (3) taking into account the Doppler effect. Experimental studies of vibration of mills at the enterprises of the industry. Figure 2 shows an example of the vibration spectrum of the stator of the mill RT-70 ZAO Turinsky TsBZ (headset D-1000.02, rotor speed 1000 rpm).

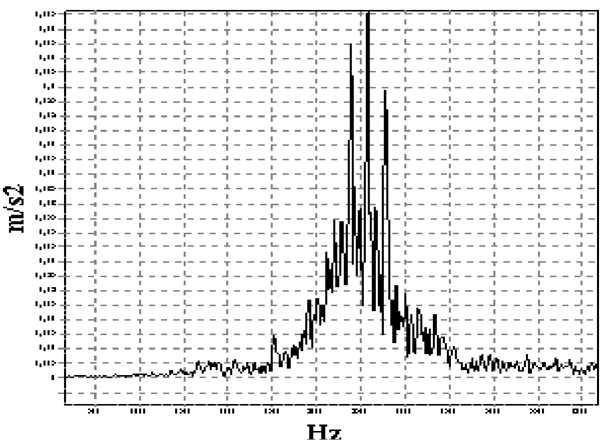

Figure 3. RT-70 mill stator vibration spectrum.

Headset frequencies research results are presented in the table 1.

Table 1. Knife slip speed and headset frequencies on the peripheral belts of the headset.

Mill brand / headset brand	Knives sliding speed, m / s	Headset frequency excluding the Doppler effect, kHz / error,%	Headset frequency taking into account the Doppler effect, kHz / error,%	Headset frequency determined experimentally, Hz
RT70/ Д.1000.002	216	4.53/ 6	4.34/ 2	4.26
MD-5Sh1A/XTM1-00-11	253	7.07/ 7	7.68/ 1	7.58
MD-5Sh1A/ XTM1-00-17	8028	7.51/ 40	12.40/ 3	12.75
MD-5Sh1A/ XTM1-00-18	9210	9.12/ 23	10.83/ 8	11.80
MD-31/ 1000.071	186	7.20/ 5	7.32/ 4	7.54
MD-31/ D56.01	442	6.67/ 7	6.13/ 1	6.12
MD-3Sh7/ 1000.71	448	9.60/ 9	9.88/ 6	10.52
MD-14/ R-630.002	164	3.30/ 7	2.95/ 3	3.07

The error in determining headset frequencies without taking into account the Doppler effect reaches 40%, taking into account the above effect - up to 8%. When vibration diagnostics and control the operation of mills by vibration parameters, the Doppler effect should be taken into account.

4. Conclusion

The sliding speed of the knives depends on the headset pattern and rotor speed and can reach 5000 m/s or more, which is comparable to the speed of sound waves in a metal.

When vibration diagnostics and control the operation of mills, based on the analysis of headset frequencies, it is necessary to take into account the Doppler effect.

The error in determining headset frequencies without taking into account the Doppler effect can reach 40%, taking into account up to 8%.

To calculate the headset frequencies, the above methodology is recommended.

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