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Engineering of the knife grinding machine milling process

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Abstract. The paper investigates milling process in knife grinding machines. Engineering process of these machines involves determining a degree of knife garniture wear as well as rotor and stator misalignment without the stop of the machines. To find these parameters a series of experimental researches were conducted at the enterprises of the industry. Vibrating diagnostics methods are the most informative ones for exploiting engineering of the knife grinding machine milling process. Methods of determining a degree of knife garniture wear and rotor and stator misalignment without the stop of the machines are protected by patents of the Russian Federation. Use of the developed methods and means by support and diagnostic team specialists at the enterprises increased the efficiency of the engineering process of knife grinding machine milling. Proposed methods can be used in other businesses, for example, in mining and steel industries.

1. Introduction

Knife grinding machines are the main technological equipment for grinding fibrous materials in the pulp and paper industry. When grinding fibrous materials in mills, the main properties of the products are included [1-2]. These machines belong to the most energy-intensive equipment in the production of paper, cardboard and wood boards [2-5]. The relevance of the operational engineering investigation of the grinding process of knife milling machines is confirmed by a number of publications [6-9].

The diameter of the mill disc reaches 1,600 mm and above. The accuracy of the grinding unit manufacture should be the same for all types of mills. This is due to the fact that the effective impact on the semi-finished product is possible with a gap not exceeding a few tenths of a millimetre [9]. Hence, strict requirements for admission to the gap between the rotor and the stator follow. The gap depends on the mass concentration, the circumferential velocity of the rotor, the deformation of the mill elements under the influence of the additive force, backlashes in bearings [10-11].

The reasons for the rotor and the stator misalignment are divided into static, dynamic and technological ones [12]. The statistical reasons are the end run-out of the rotor without mass and the wrong stator setting. Dynamic causes include insufficient rigidity of the mill design, uneven temperature distribution on the body and grinding chamber. Technological reasons consist of steam release irregularity on backlash periphery between disks at a grinding of chips and weight of high concentration. To reduce technological reasons, it was proposed to feed raw materials to a mill from two sides [13]. The way of excluding influence of the temperature distribution on the disk misalignment is proposed in [14]. However, the developed tools do not respond to the static and technological causes of misalignment.

The publication [15] proposes a device for supporting the parallelism of grinding disks. For this purpose, the axial forces acting on the stator disk during the grinding process are measured at three



points. The deviation of force reveals violation of the disk parallelism. The axial thrust acting on the machine discs is maximal at collateral discs [9]. The parallelism of the discs is maintained automatically by changing the length of the stator bolt fastening. However, this device has low accuracy and high inertia.

There are known methods of determining the garniture wear coefficient by the quality gain change of a semi-finished product [16] and by metallic inclusions in a semi-finished product at the mill outlet [17]. The lack of these methods is low accuracy and labour intensity. There is also a method for determining the degree of garniture wear by changing the idling power [11].

Diagnosis of metal contact piece of rotor and stator is possible with the help of the timbered vibrator inventor on stator [6]. At overflow of level signal from the vibrator inventor of a set value it is possible to judge metal contact piece of rotor and stator. Overall systems of monitoring of mill operation, including powering up spacing sensor, the device monitoring metal contact piece, common availability index of product by the level of vibration [6] are known.

The aim of the research is operational engineering of these machines in order to develop methods and means of knife grinding machine garniture diagnosis.

2. Experimental researches and results

As it is known [9] when plug knives pass shell knives there can occur pulses of pressure which affect fibrous by-product. Amplitudes of pressure pulses will depend on fibrous interlayer properties and on spacing between rotor and stator. Pressure pulses affect fibre, thus call its milling [18], and stator and rotor, calling their vibration. Influence of garniture on fibrous material is of high-frequency which is up to 30 kHz. Therefore, vibration acceleration is chosen as a measured parameter of stator vibration as it is mostly sensitive to high frequencies [19].

Frequency spectrum vibration acceleration stators of various mill brands have been investigated. It is found out, that the most informative direction of vibration stator measurement is the one along the shaft. The basic source of high-frequency stator vibration includes the pressure pulses occurring at crossing of plug knives and stator. On the spectra obtained, characteristic peaks corresponding to different belts of the garniture crossed knives are clearly visible. Central frequencies of these peaks are plates [19].

Moreover, the knife belt on periphery of the disc with the most number of knives corresponds to the peak with maximal plate frequency [19]. At plates frequencies measurement it is necessary to take into account Doppler effect arising at plug knife movement and fixed vibrator inventor [20].

When the garniture wears out, the geometrical sizes of its grinding elements and, as a rule, this wear changes unevenly [17], which aggravates reduction ability of garniture [9] and reduces dynamic influence of the product and, hence, reduces the vibration level of stator at stationary values and other factors of milling.

To prove the relationship between the vibration level of the stator and the wear coefficient of the garniture studies were carried out in the grinding of sulphite spruce cellulose in mills under production conditions. The mass concentration during grinding was $6 \pm 1\%$, the productivity was 50 ± 5 tons per day. The stator vibration was measured periodically during garniture exploiting at a constant engine power of 0.35 MW. The results of experiments are shown in figure 1.

Also, studies have been carried out in the grinding of waste from sorting spruce wood pulp. Pulp density at milling is $16 \pm 5\%$, productivity is 76 ± 30 t/day. During researches engine capacity of 0.75 MW was supported. The stator vibration was measured periodically during garniture exploiting. As mill productivity changes over wide range, the ratio of root-mean-square meaning of amplitude vibration acceleration to productivity was analysed. This ratio during serviceable life of garniture decreases.

Amplitude of the stator vibration acceleration (or its ratio to productivity) during serviceable life of garniture decreases at permanent output of the mill engine. It occurs because of the garniture wear. It is recommended to use the amplitude of the stator vibration acceleration (or its ratio to the mill productivity) as a diagnostic characteristic of the garniture wear.

Irregularity of the mill stator vibration field is investigated at different sag magnitudes of garniture casing. Received results are introduced in the table 1.

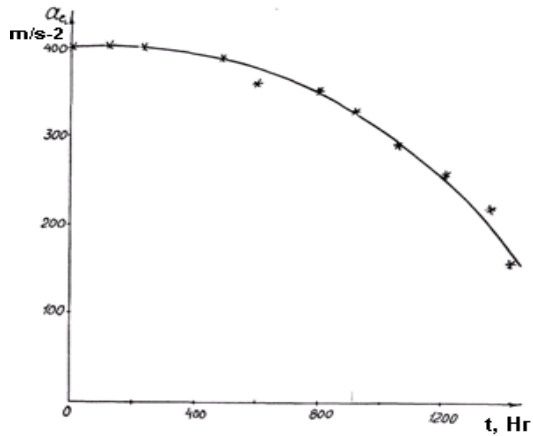


Figure 1. Amplitude of stator vibration during serviceable life of garniture.

3. Operational diagnosis of the garniture technical conditions

The method of defining mill garniture wear letting to measure vibration amplitude of casing at permanent output of the engine [21] is offered. Wear coefficient is defined by following formula:

$$K_{wear} = (a_{e0} - a_e) / (a_{e0} - a_k), \tag{1}$$

where a_{e0}, a_k = vibration amplitude of a casing in the beginning and at the end of garniture exploitation accordingly (m/s²), a_e = vibration amplitude of casing at the present time (m/s²).

The way is implemented as follows. From the field experience of an analogous garniture the vibration amplitude in the beginning and at the end of serviceable life at permanent output of the engine is known. At the same engine capacity the vibration level in the present time is found out and, having substituted the meanings of these parameters into the formula (1), one can currently define the coefficient of garniture wear. In case of need the garniture can be substituted.

Table 1. Vibration parameters of mill casing MD-3SH7 at different magnitudes of stator garniture sag.

Vibration measurement points (figure 4)	Vibration amplitude, m/s ²		
	Rotor and stator are parallel (parallel garniture)		
A	380		
B	375		
C	380		
	0.1 mm sag in a point		
	A	B	C
A	330	275	280
B	285	325	270
C	280	215	335
	0.2 mm sag in a point		
	A	B	C
A	270	205	205
B	210	280	210
C	215	215	275
	0.25 mm sag in a point		

	A	B	C
A	230	190	175
B	180	220	185
C	190	175	235

At major oscillations of mill productivity, the ratio of casing vibration amplitude to productivity, i.e. garniture wear coefficient is defined by the following formula:

$$K_w = (a_{c0}/Q_0 - a_c/Q) / (a_{c0}/Q_0 - a_k/Q_k), \quad (2)$$

where Q_0 , Q_k , Q = mill productivity at the beginning, at the end and at the current moment of exploitation accordingly.

Definition of garniture wear coefficient can be executed by means of graphs in figures 2 and 3.

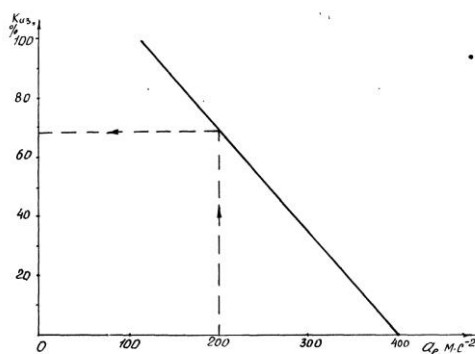


Figure 2. Definition of garniture wear coefficient by the amplitude of stator vibration.

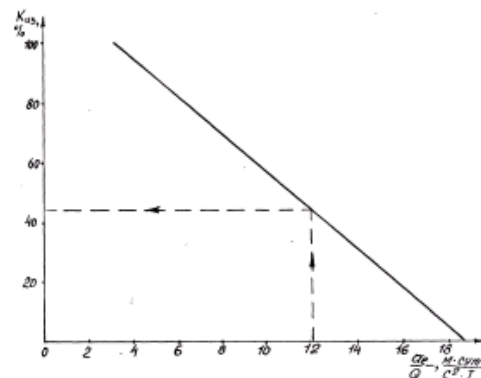


Figure 3. Definition of garniture wear coefficient by the ratio of stator vibration level to productivity.

Compared to known way [11] of the garniture wear defining, offered method is less labour consuming, since it does not require mill jiggling at the moment of measurement, and its "lockout" from production line during measurement.

The control mode of rotor and stator garniture parallelism [22], which can be implemented by means of the device in figure 4, is offered.

Device contains vibrator inventors (1), timbered with the help of wave-guides (2). Vibrator inventors (1) and wave-guides (2) are located on equal radius and equal distances from each other from the back side on the garniture periphery (3) of the stator (4) containing also the rotor (5) with garniture (6).

Final control devices are anchored near vibrator inventor. Vibrator inventors (1) are paired to relevant inputs of the comparator (8) through the intensifier (7) consisting of uniform channels (A), (B) and (C). Output of the comparator is bound to an input of the control assembly (9) consisting of changeover valves and governor valves. Feeding system of oil, for example, hydroelectric station (10) is bound to operating mechanisms which are hardly anchored on the cover (11) of the plate chambers through the control assembly. An operating mechanism of the bound contains the chamber (12) connected to the hydraulic-circuit system inside which the relative frame wall (13) is installed, with rod (14). The rod (14) is fixed on the cover (11) and is bound by the loose extremity to stator (4).

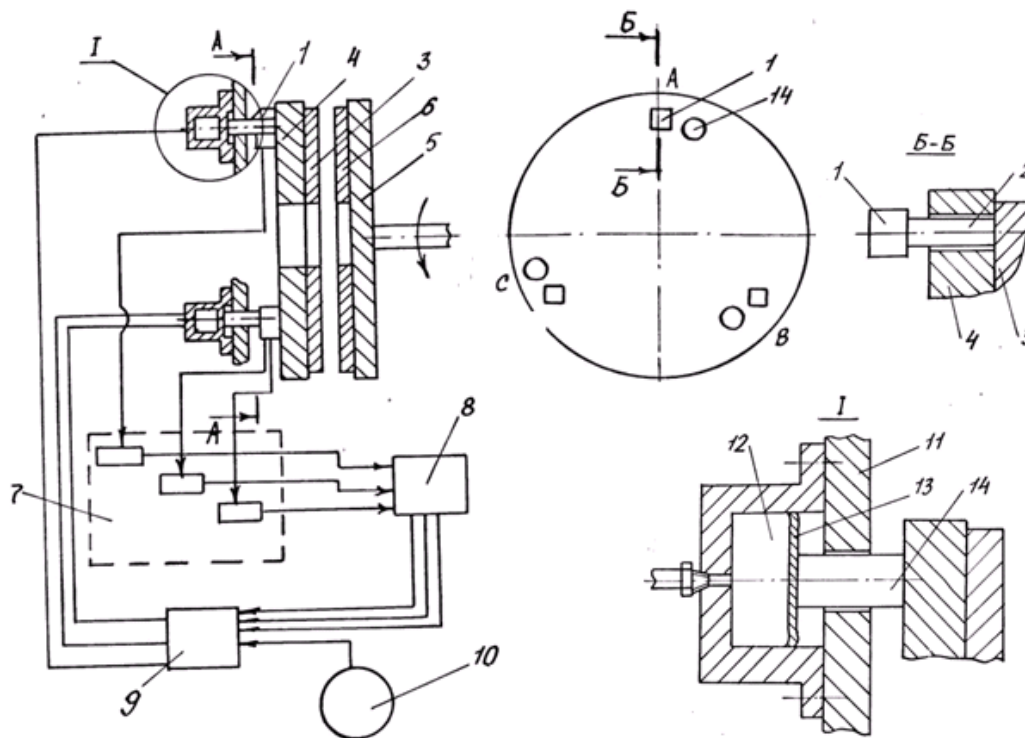


Figure 4. Device of rotor and stator garniture parallelism regulation: 1 - vibrator inventor; 2 - wave-guide; 3, 6 - garniture; 4 - stator; 5 - rotor; 7 - intensifier; 8 - comparator; 9 - control assembly; 10 - hydroelectric station; 11 - cover; 12 - chamber; 13 - relative frame wall; 14 - rod.

Control parallelism mode of rotor and stator is carried out as follows. Let us admit, there was sag of casing garniture in point A on 0.2 mm, the backlash between grinding elements of stator and rotor garniture has decreased in this point compared to other points B and C for 0.2 mm. Thus, the uniformity of vibration field of casing periphery has varied (see the table 1): in point A amplitude of vibration is 270 m/s^2 , in point B - 205 m/s^2 , in point C - 205 m/s^2 , in the field of minimum backlash the stator casing vibration amplitude has become higher than in points B,C. With parallelism of rotor and stator vibration field was even, point A - 380 m/s^2 , point B - 375 m/s^2 , point C - 380 m/s^2 .

The vibrator inventor (1) perceives vibration of different points of casing through wave-guides (2). Electrical signals from the vibrator inventor proportional to the vibration level enter the intensifier (7), then to the regulating block consisting of comparator (8), control assembly (9) and oil feeding systems (10). In the comparator (8) the amplitudes of signals, acting of the intensifier (7), are compared to each other. In our case the comparator will select the signal from the vibrator inventor, timbered in point A since the amplitude of this signal exceeds the amplitude of signals from points B, C and will give a control signal to the control assembly (9) which controls pressure of oil in the operating mechanism. Oil enters chambers (12) operating mechanism by means of the feeding system (10) through governor valves of the control assembly (9) and attacks the relative frame wall (13), rod (14) and stator (4), transposing them in this or that side. In our situation the governor valve of the channel A will work. So, pressure in chamber (12) of the final control devices (A) will vary in such a manner that rod (14) and the stator (4) will be established in such position at which the vibration amplitude in all points A, B, C will not be balanced that testifies to the parallelism of rotor and stator.

4. Conclusion

New methods and means of operational engineering of knife grinding machines are proposed. Advantages of the offered methods of diagnosis are shown. The positive approbation of the methods

under production conditions is led. The application of the developed methods and tools by the technical diagnostics services at the enterprises of the industry has increased the efficiency of the operational engineering of the grinding process of knife grinding machines. Methods and means of operational engineering are recommended to be used in the operation and design of knife grinding machines. The developed methods and tools can be used in other industries, for example, in the mining and metallurgical industries

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