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Rationing and vibration monitoring of knife refiners

S Vikharev, V Sivakov and A Sannikov

Faculty of technical mechanics and the equipment of pulp and paper manufactures,
Ural State Forest Engineering University, 36 Siberian tract, Ekaterinburg, 620100,
Russia

E-mail: cbp200558@mail.ru

Abstract. The subject of the research is rationing and monitoring of the vibration of knife refiners. GOST 26493-85, specifying the permissible values of the vibration amplitude of the mills, is outdated. This standard does not take into account new designs of knife refiners and the requirements of national and international standards. It is proposed to establish two criteria for assessing the vibration state of the refiners. The first criterion normalizes the amplitude of vibration in octave strips of frequencies, while the second criterion specifies the vibration trend on the general level. It is proposed to use the vibration velocity as the measured parameter. The necessity of separating the refiners into two groups was revealed: with a disc or cone diameter up to 1000 mm and with a diameter over 1000 mm. The boundaries of zones and vibration trends are determined: good; satisfactorily; need improvement and unacceptable. After that, a decision is made to limit the functioning of these machines (prevention and stop). The introduction of standards and vibration monitoring will accelerate the transition to repairs of machines on the technical condition. Methods of rationing and monitoring can be used in other industries, for example, in the mining and metallurgical industries.

1. Introduction

Knife refiners are the main technological equipment for grinding fibrous materials in the pulp and paper industry. These machines are highly dynamic and differ in the type of grinding material, design and drive power [1-5]. The dynamics of knife refiners was studied in [5-9].

There are hygienic and technical rationing kinds of vibration. The basis of hygienic rationing in accordance with GOST 12.1.012-2004 is made up by the criteria of human health when exposed to vibration, taking into account the intensity and severity of labour. Technical rationing in accordance with GOST 26493-85 establishes the permissible values of the amplitude of vibration for the equipment for pulp and paper production, including refiners. Vibration characteristics serve as criteria for the quality, reliability and safety of equipment. However, GOST 26493-85 is outdated, so it does not take into account new designs of knife refiners and the requirements of national and international standards. The rotor of the refiner, as a rule, has rigid supports in the vertical direction and flexible in the horizontal direction [10].

The purpose of the work is rationing and monitoring of the vibration of knife refiners.



2. Methods and materials

It is proposed to establish two criteria for assessing the vibration state of knife refiners. The first criterion normalizes the amplitude of vibration in the octave strips of frequency, while the second criterion normalizes the vibration trend according to the general level.

The first criterion is related to the determination of the boundaries of vibration parameters established from the condition of permissible dynamic loads on bearings and permissible vibration transmitted to the supports and the foundation. The maximum value of this parameter is compared with the boundaries of the zones, which are set on the basis of experimental data.

To assess the vibration of the mill and make decisions about the necessary actions in a particular situation, the following status zones are established. Zone A - as a rule, the vibration of new refiners put into operation falls into this zone. Zone B - machines the vibration of which falls into this zone are usually considered suitable for operation without a time limit. Zone C – refiners the vibration of which falls into this zone are usually considered unsuitable for long-term continuous operation. Such machines can operate for a limited period of time before the start of repair work. Zone D - vibration levels in a given zone can usually cause serious damage [11].

The vibration parameters of knife refiners have been measured at the pulp and paper and wood processing enterprises for a long time under controlled operation. The duration of controlled operation has been from one to two decades.

Allowable vibration parameters for determining the boundaries of zones are determined by the formula:

$$[X]_c = \bar{X} + k \cdot \sigma_X, \quad (1)$$

where $[X]_c$, \bar{X} - statistically permissible and arithmetic mean value of vibration amplitude for a specific zone; σ_X – standard deviation of the vibration amplitude for a specific zone; k - distribution quantile.

The quantile is taken from the Student's t-distribution, which takes into account the number of measurements and the confidence level, $k \approx 2$ [11].

$$\bar{X} = \sum_{i=1}^N \frac{X_i}{N}, \quad (2)$$

$$\sigma_X = \left[\sum_{i=1}^N (X_i - \bar{X})^2 / N \right]^{1/2}, \quad (3)$$

where X_i – vibration amplitude of the i -th refiner; N - number of similar refiners.

3. Results and discussion

When rationing the vibration of the knife refiners, it is advisable to use vibration velocity, since the vibration spectrum of these machines contains a large number of higher harmonic components. Vibration assessment using mean square values eliminates the need to determine the phase angle between the individual components. The amplitude of vibration of the refiners is normalized in the form of root-mean-square values of vibration velocity in octave strips of frequency. Portable instruments are used to measure the vibration, the metrological characteristics of which comply with the requirements of GOST ISO 2954. Vibration is measured in the nominal mode of the refiner in three mutually perpendicular directions: vertical, horizontal-transverse and horizontal-axial with respect to the axis of the machine shaft.

Changes in the unbalance of the rotor, bearing characteristics, misalignment of shafts and other defects with a sufficient degree of reliability can be detected with periodic monitoring using permanently installed or portable equipment. Automated systems can be used to track changes in the technical state of the refiners. Vibration measurements should be carried out at the same positions and orientation of

the sensors in the same mode of the refiner operation. Care must be taken to ensure that the resonance of system of pipes does not coincide with typical frequencies of excitement (usually it is the first and second harmonicas of frequency of rotation) as such resonance can cause the increased vibration level.

The vibration parameters of various refiner sizes at nominal operation for B/C zone borders are shown in table 1.

Table 1. Vibration parameters of refiners for B/C zone borders.

Diameter of the disk (cone) of the refiner, mm	The average square value of the vibration velocity, mm / s, in octave strips with extreme frequencies, Hz					
	2.8-5.6	5.6-11.2	11.2-22.5	22.5-45	45-90	90-180
300	-	1.0	1.5	1.5	1.4	-
500	-	1.0	1.6	1.7	1.5	-
630	-	1.1	1.6	1.6	1.6	-
800	-	1.1	1.8	1.7	1.6	-
1000	-	1.2	1.8	1.8	1.8	-
1250	-	1.4	2.4	2.5	1.8	-
1500	-	1.7	2.7	2.6	1.7	-
1650	-	1.8	2.8	2.8	1.8	-

A statistical analysis of the vibration parameters of refiners of various sizes using the Statistica 13 program was carried out. Analysis of the obtained results shows that the vibration parameters of refiners of various sizes do not obey the law of normal distribution, i.e., they are statistically heterogeneous. To ensure the homogeneity of he obtained results, the necessity of separating the refiners into two groups was revealed: with a disc or cone diameter up to 1000 mm inclusive and with a diameter over 1000 mm The A/B, B/C, C/D boundaries of the zones of the vibration parameters of the refiners are given in table 2.

Table 2. Vibration parameters of the refiners.

Diameter of the disk (cone) of the refiner, mm	Boundaries of the zones	The average square value of the vibration velocity, mm/s, in octave strips with extreme frequencies, Hz						Vibro velocity trend, (mm/s)/h
		2.8-5.6	5.6-11.2	11.2-22.5	22.5-45	45-90	90-180	
up to 1000 mm inclusive	A/B	-	0.5	0.8	0.8	0.8	-	-
	B/C	-	1.2	1.8	1.8	1.8	1.5	-
	C/D	-	1.6	2.6	2.6	2.6	-	2.0
over 1000 mm	A/B	-	0.8	1.4	1.4	0.8	-	-
	B/C	-	1.8	2.8	2.8	1.8	-	2.0
	C/D	-	2.7	4.0	4.0	4.0	-	3.0

If the peak values of vibration are measured, then a table similar to table 2 can be constructed. For this, the zone boundaries should be multiplied by a factor of $\sqrt{2}$. After that, the table can be used to estimate the vibration state from peak measurements, provided that one frequency component dominates in the vibration spectrum (usually it is the reverse frequency). When using a pliable foundation, the values of the vibration parameters should be multiplied by a factor of 1.56 [4].

The zone, which corresponds to the vibration state of a specific refiner, is determined by comparing the maximum measured amplitude and vibration trend values with the values of table 2. The qualitative assessment is carried out in the following four positions: good (zone A); satisfactory (zone B, acceptable); improvement needed (zone C, still valid); not allowed (zone D).

Exceeding the trend of vibration more than the permissible values in table 2 requires taking measures even in the case when the boundary of zone C according to the first criterion has not yet been reached. Such changes can be fast or gradually increasing in time and indicate damage to the machine in the initial stage or other problems. If significant changes in vibration are found, it is necessary to investigate the possible causes of such changes in order to prevent dangerous situations. If the changes in vibration exceed 25% of the value of the upper boundary of zone B, such changes should be considered as significant, especially when they are of extraordinary nature. In this case, it is necessary to conduct diagnostic studies to identify the causes of this change and determine what measures need to be taken.

For long-term operation of knife refiners restrictions on the functioning of two forms are established. Alert - to indicate that the amplitude or trend of vibration has reached a certain level when recovery actions may be required. In this form, the machine can be operated for a period of time while conducting research on the causes of changes in vibration and determine the complex of necessary measures. Stop - to determine the value of vibration, above which further operation of the refiner can lead to its damage. Upon reaching this level, one should take immediate measures to reduce vibration or stop the machine.

For different sizes of refiners, the "alert" level can vary significantly: increase or decrease. Usually this level is set relative to a certain base value (baseline) determined for a particular machine and a specific position and direction of measurements according to the operating experience of this machine.

It is recommended to set the "alert" level above the baseline to a value equal to 25% of the value of the upper limit of zone B. If the base value is low, the "alert" level may be below zone C. If the base value is not defined, for example, for new machines, the initial setting of the "alert" level should be carried out either on the basis of operating experience of similar refiners, or relative to the agreed acceptable value. After some time, according to the observations of the vibration of the machine, it is necessary to establish a constant baseline and adjust this level accordingly. It is recommended that the alert level does not exceed the upper limit of zone B by more than 1.25 times. A change in the base value (for example, due to a refiner overhaul) may require a corresponding change in the "alert" level.

The "stop" level is usually associated with the need to prevent refiner failures. It may depend on various design features of the machine, used to ensure that the machine can withstand the effects of increased dynamic forces. Thus, "stop" level, as a rule, will be the same for refiners of similar structures and will not be associated with the baseline. Due to the diversity of the refiners of various designs it is not possible to give a clear guide to the exact determination of the "stop" level. Usually, the "stop" level is set within C or D zones, but it is recommended that it does not exceed by more than 1.25 times the upper limit of C zone.

In addition to measuring vibration and assessing the condition of the machine, it is allowed to measure shaft vibration as per GOST ISO 7919-3-2002. However, there is no simple way to calculate the shaft vibration from the bearing housing vibration and vice versa. The difference between absolute and relative vibration characterizes the vibration of the bearing housing, but may not be numerically equal to it due to the neglect of phase relations [12]. Thus, if GOST ISO 7919-3-2002 is also used to assess the vibration state of the refiner, independent measurements should be made of the shaft vibration and the vibration of the housing or bearing support. If, as a result of applying the criteria of this standard, different estimates of the vibratory state of the refiner will be obtained, the final assessment should be the one that imposes large restrictions on the possibilities of operation.

4. Conclusion

The article attempts to standardize and monitor the vibration of knife refiners. It is proposed to establish two criteria for assessing the vibration state of the refiners. The first criterion normalizes the amplitude of vibration in the octave strip frequency, while the second criterion normalizes the vibration trend according to the general level. As the measured parameter, it is advisable to use the vibration velocity.

The necessity of separating the refiners into two groups was revealed: with a disc or cone diameter up to 1000 mm inclusive and with a diameter over 1000 mm.

The boundaries of the zones and the trend of the vibration of the refiners are determined. A qualitative assessment of the vibration intensity of the refiners is carried out in the following four positions: good; satisfactorily; need improvement and unacceptable. After that, a decision is made to limit the functioning of these machines (alert and stop).

The introduction of standards and vibration monitoring will accelerate the transition to repairs of machines on the technical condition. Methods of rationing and monitoring can be used in other industries, for example, in the mining and metallurgical industries.

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