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# Features of the rotor dynamics of knife refining machines

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**Abstract.** The paper researches the features of the rotor dynamics of knife refining machines. The rotor of these machines turns in the pulp. The total imbalance of the refiner rotor consists of mechanical, hydraulic and hydrodynamic components. The mechanical imbalance of the refiner rotor changes due to the plate wear. In the knife refining machines, it is advisable to use automatic balancing devices to compensate for the imbalance of the rotor during operation of the refiner without stopping it. The methodology for calculating the beats of the rotor plate has been developed and tested. The operational cross-knife gaps of the knife refining machines are comparable to the beats obtained. It is recommended to eliminate gaps in the design of the rotor assembly, i.e. use bearings with tensioner and use a stator to make refiner adjustment. The developed methodology for calculating beats can be used in other similar machines, for example, in centrifugal pumps.

## 1. Introduction

Knife refining machines are the main technological equipment for refining fibrous materials in the pulp and paper industry. Refiners are machines with increased dynamism. The main source of oscillations of knife refining machines is the imbalance of the rotor [1-3]. The rotor of these machines rotates in the pulp. The gap between the refining sets of the rotor and the stator constitutes fractions of a millimetre and depends on the type and concentration of the fibrous mass and the mode of the refiner operation [1,4]. For an effective refining process in knife refining machines, it is necessary to ensure the stability of the gap between the rotor and stator plate [5]. During refining, axial forces act on the rotor and stator, which consist of constant, periodic and random components [6].

## 2. Rotor imbalance

The total imbalance of the refiner rotor consists of mechanical, hydraulic and hydrodynamic components. Mechanical imbalance of the refiner rotor consists of static and momentary imbalances and depends on the quality of the balancing of the rotor and the plate. This rotor imbalance consists of three components [6]: structural, technological and operational. Structural imbalance occurs due to asymmetrical grooves, cuts on the rotor, heterogeneity of the material, beats of the trunnions, etc. Technological imbalance consists of the errors of manufacture and assembly of the rotor elements. An example of this imbalance can be the mass centre displacement of the rotor plate during its installation. Operational imbalance arises from the uneven wear of the plate and the temperature distortions of the rotor. The mechanical imbalance of the refiner rotor changes during the plate operation and can increase up to four times compared with this indicator at the beginning of its operation.

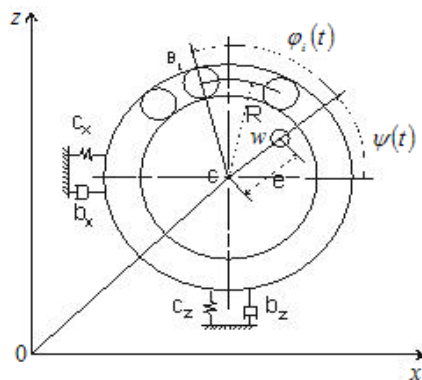


Hydrodynamic imbalance arises due to the uneven filling of the rotor interstitial channels with a fibrous suspension, which leads to a mismatch of the mass centre of this suspension with the axis of the rotor rotation [7]. Hydrodynamic and mechanical imbalances occur at the frequency of the rotor rotation.

Hydraulic imbalance occurs when the axes of the rotor rotation and the mass in the refining chamber are different due to their misalignment. The frequency of the mass rotation is less than the frequency of the rotor rotation [5], as confirmed by the researches [6]. The ratio of the lag of the mass rotation speed in the refining chamber to the rotor rotation frequency depends on the concentration and type of the material being refined and is in the range of 0.77–0.90. When refining the chips, a lot of steam is released [1,5]. The steam unevenly fills the inter-breed rotor channels, which leads to an increase in hydrodynamic imbalance. The coefficient taking into account the hydrodynamic imbalance of the rotor reaches maximum values when refining chips and equals to 1.4.

### 3. Rotor automatic balancing

Automatic balancing devices (ABD) of machines are known [8-10]. In the design of the refiner rotor, it is advisable to use the ABD, which allows compensating for the unbalance of the rotor without stopping it. The dynamic model of the passive ABD as applied to the refiner rotor is shown in figure 1, where  $W$  is the centre of the rotor mass, excluding the moving masses of the ABD, for example, balls. The centre of mass is located at  $e$  distance from the axis of rotation at  $C$  point.



**Figure 1.** Dynamic model of a refiner rotor with an automatic balancing device.

The mathematical model of the refiner rotor with a passive auto-balancing device was obtained on the basis of the Lagrange equations in [2]. With a flexible rotor refiner, i.e. working in the resonant mode, the balancing balls will move under the action of inertial forces to the “easy” place of the rotor, thereby compensating for the operational imbalance. However, the rotors of the knife refining machines are rigid, i.e. they work in pre-resonance mode [3]. To transfer the operation of the refiner rotor into a flexible mode, it is necessary to reduce the rigidity of the bearing supports to transfer the operation of the rotor into a resonant mode and to ensure the operation of the ABD. Knife refining machines with ABD are designed [11-13]. Automatic balancing of the refiner rotor should be done when changing the plate and increasing the imbalance of the rotor. This reduces the dynamic loads on the supporting elements of the rotor and supporting structures.

### 4. Stability of the inter-knife gap

The rotor unit of the refiner is a high-precision unit, which must ensure a stable position of the blade disc during refining. The stability of the rotor disk position depends on the accuracy of the bearings and parts of the rotor assembly, on the quality of installation, on the bearing adjustment (radial clearance size), related to the instability of the support temperature and changes in the clearance size.

It is necessary to distinguish the skew of the stator plate and the beating of the rotor plate. The stator skew occurs due to improper installation of the plate and (or) insufficient rigidity of the refiner design [6]. The method of vibration diagnostics of the stator skew was proposed in [14]. The rotor beatings are caused by the skewing of the blade on the refiner shaft, insufficient rotor design, gaps in the rotor

assembly design elements, including radial gaps in bearings and dynamic forces arising from the operation of the refiner.

The study of the dynamics of the refiner rotor was carried out in [2]. Based on these studies, a method has been developed for calculating the rotor beats for pendulum oscillations of trunnions in bearings. The technique is implemented using the Matlab software package. The research results are presented in the table 1.

**Table 1.** Investigation of the rotor beating of knife refining machines.

Refiner brand	Disc (cone) diameter, mm	Rotation frequency, rpm	Nominal gap, mm			Rotor beating, mm
			Front bearing	Rear bearing	Body-case (shaft disc)	
MD-31	1000	600	0.40-0.50	0.40-0.50	0.20-0.25	0.63-0.81
MD-14	630	1000	0.30-0.40	0.30-0.40	0.15-0.20	0.41-0.57
MD-2U5	800	750	0.35-0.45	0.35-0.45	0.20-0.25	0.52-0.68
MD-3SH7	1000	1500	0.50-0.65	0.50-0.65	-	0.52-0.70
MD-4SH7	1250	1500	0.50-0.65	0.50-0.65	-	0.66-0.88
MDS-24	800	750	0.40-0.50	0.40-0.50	0.20-0.25	0.51-0.69
MDS-33	1000	630	0.40-0.50	0.40-0.50	0.20-0.25	0.52-0.73
TF-52	1350	1500	0.50-0.65	0.50-0.65	(0.05-0.10)	0.51-0.89
TWIN- 60	1500	1500	0.50-0.65	0.50-0.65	-	0.40-0.72
TWIN - 66	1720	2300	0.50-0.65	0.50-0.65	-	0.54-0.73
MKL-04	(600)	490	0.20-0.30	0.20-0.30	0.15-0.20	0.22-0.38
MKN- 03	(500)	600	0.20-0.30	0.20-0.30	0.15-0.20	0.30-0.42
MKL-02	(400)	1470	0.20-0.30	0.20-0.30	0.15-0.20	0.28-0.35
RF-4	(800)	500	0.25-0.35	0.25-0.35	0.20-0.25	0.40-0.58

Studies have shown that the main components of the beats are gaps in the rotor design elements. Not taking into account the remaining components leads to an error not exceeding 30%. The calculated face beats of the refiner rotors are within 0.2 - 0.9 mm. Operational inter-knife clearances of knife refining machines are comparable to the results obtained. Consequently, the design of the rotor assembly itself implies the possibility of a metallic contact between the rotor and the stator during refining of the pulp. This leads to intensive wear of the knives of the plate and reduced technical resource plate. To ensure the stability of the inter-gap clearance and increase the reliability of the plate in knife refining machines, it is recommended to exclude gaps in the designs of rotor assemblies, i.e. use bearings with tensioner and make refiner adjustment by a stator.

## 5. Conclusion

The main source of oscillation of the knife refining machines is the imbalance of the rotor. The total imbalance of the refiner rotor consists of mechanical, hydraulic and hydrodynamic components. The mechanical imbalance of the refiner rotor changes during the operation of the plate and can increase up to four times compared with this indicator at the beginning of its operation.

In the designs of knife refining machines, it is advisable to use automatic balancing devices to compensate for the imbalance of the rotor during operation of the refiner without stopping it.

To ensure the stability of the inter-gap clearance and increase the reliability of the plate, it is recommended to eliminate gaps in the rotor assembly design, i.e. use bearings with tensioner and to make refiner adjustment by a stator. The developed calculation method can be used for other similar machines, for example centrifugal pumps.

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