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Dynamic balancing of the mineral wool drum saw by correcting the knives masses

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Abstract. The article focuses on the process of balancing mineral wool drum saw. The saw had had tendency to lose balance in short period of time. Balancing parameters was analysed in terms of velocity and acceleration parameters. The route of correcting mass was designed by using knives with different weights. It's necessary to realise balancing by addition and subtraction the knives with incorrect masses. Most of balancing processes over the world are based on constant mass with additions or substations of masses, but it hadn't possibility to realise it in that case. The aim of this article is to present an alternative method of balancing atypical rotor, which has a tendency to frequently and spontaneously change the weight distribution. The presented balancing method is also interesting, because it can be an inspiration for the correction of some rotor solutions that are not adapted to balancing, but still need this procedure.

1 Introduction

Unbalance is the most common factor causing an increase of the vibration parameters in rotor machines. In industry 35% of all problems with rotating machines is related with unbalance [1, 8, 15]. One of the often-overlooked design features of rotating machines is the ability to apply balance correcting masses not only at the initial stage but also with periodic mass distribution corrections. Correcting masses distribution is necessary to limit the effects of the centrifugal forces of the rotors. High vibration amplitudes can lead a negative effect on bearing life by increasing dynamic loads and increasing cycle asymmetry, consequently leading to degradation of the operational top layer [9, 11, 12, 13, 14].

The balancing process is carried out by adding or subtracting masses on the rotor in theoretical terms by using the damping and stiffness inertia matrices. In practical case; vibration measurement devices with a built-in phase angle measurement module enable to choose reference point on the rotating shaft. In many devices, the manufacturer did not provide special holes for correcting masses, e.g. with screws, therefore it is necessary to correct the masses of the elements attached to the disc [1, 5, 6, 7, 8, 13, 16].

The aim of the publication is to introduce the recipient to the possibility of correcting the balance of the drum saw by changing the knives with appropriately corrected masses. The

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article is intended for scientists involved in the maintenance and construction of rotating machines.

2 Materials and methods

In the presented case study, the longitudinal saw in the mineral wool production line had been balancing three times. The saw was equipped in 40 knives. The mass one knife was about 400g with 50g tolerance. Fig. 1 shows the arrangement of bearing nodes in the presented longitudinal saw. The saw motor power is 7.5 kW. The rotations are regulated by an inverter. Measurements were made at the rotational speed of 1425 rpm, which is the nominal engine speed.

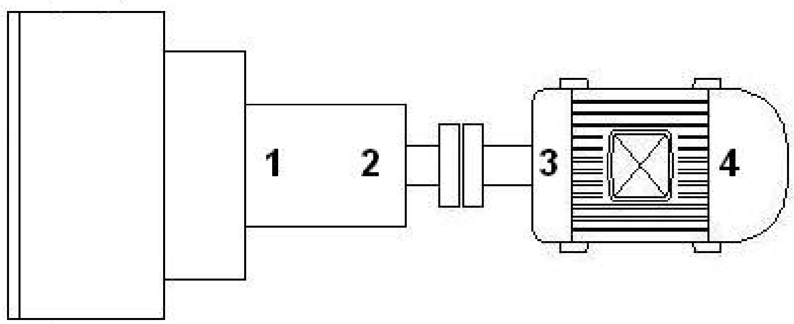

Fig. 1. Arrangement of bearing nodes in the longitudinal saw.

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The measurements were performed using the DIAMOND 401 AX device, equipped with Wilcoxon 780B acceleration sensors.

The main parameters that were used to determine the dynamic state of the machine were RMS and Peak (P-K) vibration velocity in the frequency range 2Hz - 1kHz, which is suggested in ISO 10816-3: 2009 / AMD 1: 2017 [2] and ISO 20816- 1: 2016 [3], as well as AVG and Peak (P-K) of the vibration acceleration envelope in the frequency range 500 Hz - 10 kHz, which was suggested in [10, 11, 13]. The frequency of vibration measurements was selected in accordance with the recommendations of the above-mentioned norms. FFT spectra of velocity and vibration acceleration were analysed. The described results were presented in the form of RMS vibration velocity in terms of the assessment of the saw balance state, while the Peak of the vibration acceleration envelope was a function informing about the possible deterioration of the bearing condition and, consequently, limiting the rationality of the balancing process.

Bearing nodes no. 1-4 have been assigned to the appropriate classes in accordance with the recommendations of the withdrawn standard ISO 10816-3: 2009 / AMD 1: 2017 [2]. Nodes no. 1, 2, 3 as rigid nodes were assigned to class II (acceptable class B – vRMS < 2,8 mm/s), while node no. 4, due to its susceptibility to vibrations, was assigned to class III (acceptable class B – vRMS < 4,5 mm/s).

To define the balancing criteria, the ISO 21940-11: 2016 [3] standard was used. The balancing accuracy class for centrifuges was G 6,3. The residual mass in the G 6,3 class was calculated using the formulas (1), (2) also taken from the above-mentioned standards.

$$e_{per} = \frac{G \cdot 10^3}{\omega} \quad (1)$$

$$U_{dop} = \frac{m \cdot e_{per}}{r} \quad (2)$$

The permissible residual unbalance was 16,9 g.

A series of measurements at each balancing showed that the highest RMS values of the vibration velocity before balancing were observed on bearing node No. 2, and the obtained measurements were proportional to the values obtained on the other bearing nodes, therefore it was assumed that only the above-mentioned measurements in relation to successive balancing cycles.

The introduction of correcting masses during balancing took place by removing the appropriate part of the mass from the used knives mounted on the drum and analysing the changes in the RMS coefficient value of the vibration velocity and the phase angle in which the highest centrifugal forces occur. The Diamond 401AX device showed, in relation to the measured vibration value in the phase angle - the same angle in which the corrective mass should be applied. The balancing process was carried out three times, each time with an interval of one month.

3 Results and discussion

The arrangement of mineral wool cutting knives is corrected by disassembling them, cutting them properly or replacing them with a knife of similarly smaller or larger mass, depending on the phase angle indicated by the device and the expected mass. Fig. 2, 3 and 4 present a balanced drum saw with attached knives that also function as corrective masses.

Fig. 2. View of the mating surface of the drum saw with mounted knives.

Fig. 3. View of the mating surface of the drum saw with mounted knives.

Fig. 4. View of drum knives.

The balancing procedure was preceded by a run-down chart to determine the critical speeds and, consequently, to exclude the influence of resonance on the values of the measured vibration parameters. The run-down chart showed the critical speeds of 730rpm, 990rpm and 1150rpm, at higher speeds there was a noticeable decrease in the average value of the vibration velocity. Fig. 5. present the chart of velocity to frequency ratio. Therefore, the influence of resonance on the formation of high vibrations of the saw was excluded, which made it possible to carry out the balancing.

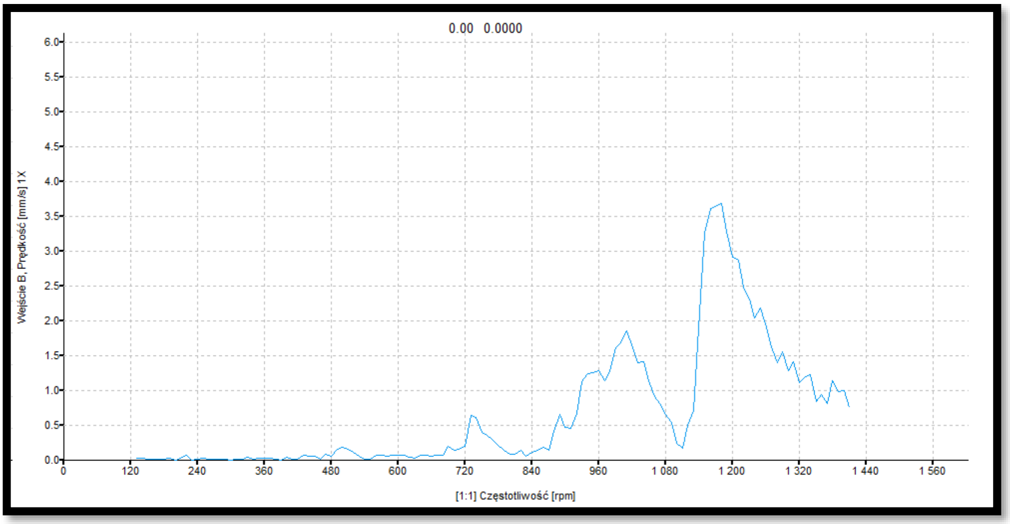

Fig. 5. Velocity chart relative to frequencies.

Table 1 presents the values of the RMS parameter of the vibration velocity in the radial vertical direction in the bearing node No. 2 before and after the balancing procedure. Fig. 6 presents a graph comparing the RMS vibration velocity values before and after the balancing procedure, with simultaneous comparison with the normative values. As can be seen in the graphs below - the obtained statistical value of the vibration velocity meets the normative conditions adopted for a given bearing node previously qualified as critical. Table 2 presents the steps of correcting arrangement of masses in correlation to centrifugal forces.

Table 1. The statistical values vRMS and residual masses before and after balancing in the cycles of measurements.

	v_{RMS} (mm/s)		Residual mass (g)	
Month	Before balancing	After balancing	Before balancing	After balancing
1	10,8	0,56	72,27	2,58
2	29,55	1,04	123,79	3,35
3	12,88	0,19	100,44	1,48

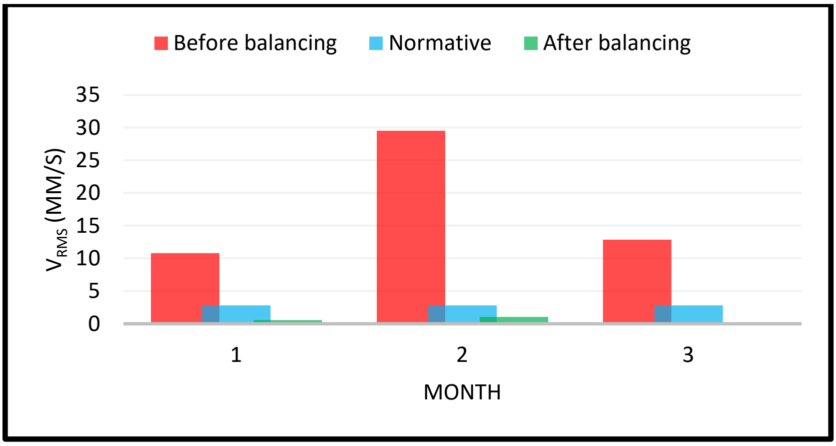

Fig. 6. Compare the normative values of RMS velocity with measured in measurements no. 1-3 before and after balancing.

Table 2. The statistical values vRMS and residual masses before and after balancing in the cycles of measurements.

Measurement Vertical direction	Surface 1			
	Correction mass		Amplitude	
	Value [g]	Degree [deg]	Value [g]	Degree [deg]
Initialize measurement	-	-	29,61	198,45
Measurement with test mass P1	5,00	0	30,54	199,90
Verification measurement M0	123,79	140	20,41	202,16
Verification measurement M1	85,30	143	9,98	224,62
Verification measurement M2	41,70	166	2,33	183,15
Verification measurement M3	9,76	124	1,43	192,92
Verification measurement M4	5,98	134	0,80	197,12
Residual mass	3,35	138		

4 Conclusion

Balancing is usually performed by screwing in screws or welding sheets, as well as by using dedicated methods. In the case of the described drum saw, there was no need for balancing, and it was necessary to use an unconventional method of correcting the mass distribution by using a mass heterogeneous knives cutting mineral wool. Despite the fact that mineral wool is not a hard and difficult-to-machine material, the saw was considered relatively often (once a month), and the dynamic condition of the bearings was also checked, which was good each time.

The saw motor is flange-mounted, which motivated the classification of node No. 4 to class III as a flexible node. The method of supporting the saw only in bearing nodes no. 1 and 2 may lead to a gyroscopic effect when the saw comes into contact with the material being cut, however, diagnostic tests could only be carried out with an unloaded system, which made it impossible to exclude this phenomenon.

During the balancing process, each time it was possible to obtain the appropriate residual mass much lower than the required one, the same applies to the RMS vibration velocity, which reached the values initially assumed in all bearing nodes. The balance correction by changing the mass distribution of the elements on the drum, although it is a non-standard solution, due to different models of component construction, may also be applied to other industrial devices in the future, already at the design stage.

References

1. A. Ibraheem, N. Ghazaly G. Abd el-Jaber *Review of Rotor Balancing Techniques*. Am. J. Ind. Eng., **6(1)**, 19 (2019)
2. ISO 10816-3:2009/AMD 1:2017 *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ — Amendment 1.*
3. ISO 20816-1:2016 *Mechanical vibration - measurement and evaluation of machine vibration: Part 1: General guidelines.*
4. ISO 21940-11:2016 *Mechanical vibration — Rotor balancing — Part 11: Procedures and tolerances for rotors with rigid behaviour.*
5. J. Kejian, Z. Changsheng, C. Liangliang, C. *Unbalance Compensation by Recursive Seeking Unbalance Mass Position in Active Magnetic Bearing-Rotor System. IEEE Transactions on Industrial Electronics* **62(9)**, 5655 (2015)
6. I. Kovtun, J. Boiko, S. Petrashchuk, T. Kalaczynski, *Theory and practice of vibration analysis in electronic packages*. 17th International Conference Diagnostics of Machines and Vehicles, 25-26 Sep 2018, Bydgoszcz, Poland (2018)
7. Z. Kulesza, *Dynamic behavior of cracked rotor subjected to multisine excitation.* J. So. Vib. **333(5)**, 1369 (2014)
8. T. Majewski, D. Szwedowicz, M. Melo, *Self-balancing system of the disk on an elastic shaft*. J. So. Vib. **359**, 2 (2015)
9. J. Musial, M. Szczutkowski, R. Polasik, T. Kalaczynski, *The Influence of Hardness of Cooperating Elements on Performance Parameters of Rolling Kinematic Pairs*. 58th International Conference of Machine Design Departments (ICMD), 6-8 Sep 2017, Prague, Czech Republic (2017)
10. M. Pineda-Sanchez, J. Perez-Cruz, J. Roger-Folch, M. Riera-Guasp, A. Sapena-Bano, R. Puche-Panadero, *Diagnosis of induction motor faults using a DSP and advanced demodulation techniques*. Proceedings of the 9th IEEE International Symposium on Diagnostics for Electric Machines, Power Electronics and Drives (SDEMPED '13), 69 (2013)
11. A. Sheraz, K. Jong-Myon, *Automated Bearing Fault Diagnosis Using 2D Analysis of Vibration Acceleration Signals under Variable Speed Conditions*. Intelligent Fault Diagnosis Based on Vibration Signal Analysis, 1070 (2016)
12. M. Szyca, *Aspects of transformation of exploitation top layer of rolling bearing race-way – rewiev*. Dev. Mech. Eng. 17(9), 103 (2021)
13. M. Szyca, J. Musiał, *Analysis of the BMA K2400 vertical centrifuge turbine in terms of balancing and vibration diagnostics*. Herald of Khmelnitsky National University **297(3)**, 3, 71 (2021)
14. T. Tomaszewski, P. Strzelecki, M. Wachowski, M. Stopel, *Fatigue life prediction for acid-resistant steel plate under operating loads*. Bulletin of the Polish Academy of Sciences-Technical Sciences **68(4)**, 913 (2020)

15. G. Yamamoto, C. da Costa, J. da Silva Sousa, *A smart experimental setup for vibration measurement and imbalance fault detection in rotating machinery*. C. St. Mech. Sys. Sig. Proc. **4**, 8 (2016)
16. J. Zachwieja, T. Jarzyna, *Dynamic Balancing of a Horizontal Rotor with a Cracked Shaft.* 10th International Conference on Applied Mechanics, 23 November 2018, Bydgoszcz, Poland (2019)