Mechanical Science Reports

Analysis of shaft alignment on vibration and motor power consumption in cooling water pumps

Dimas Yudha Satria Utama[a], Moh. Arif Batutah[b], Suhariyanto[c],
[ab] Department of Mechanical Engineering, Muhammadiyah University of Surabaya,
[c] Department of Mechanical Engineering, Sepuluh Nopember Institute of Technology
Surabaya, Indonesia

Email: dimas.tugas1@gmail.com, arifbatatutah@ft.um-surabaya.ac.id, suhariyanto@its.ac.id

Abstract

Motors and pumps are the crucial components for various industrial production processes such as manufacturing, oil and gas, and chemical processing. However, one common issue affecting their reliability and efficiency is shaft misalignment. Research indicates that 30–40% of major financial losses in industrial operations are caused by misalignment, while 42–50% of motor failures are due to bearing damage. It is caused by poor alignment, insufficient lubrication, or improper installation. This study focuses on evaluating the effect of shaft alignment on vibration levels and motor power consumption in a cooling water pump at the Koto Panjang Hydroelectric Power Plant. A quantitative experimental approach was applied to measure and compare equipment performance before and after alignment. Results show that alignment reduces the highest axial vibration velocity by 8.35 mm/s and vertical vibration by 1 mm/s. Furthermore, motor power consumption decreases by 8.35%, as demonstrated by a reduction in average motor current from 76.8 A to 71.2 A. The vibration pattern confirms the angular misalignment as the dominant factor contributing to instability. These findings show the importance of routine shaft alignment, not only for minimizing vibration and extending equipment lifespan but also for enhancing energy efficiency and reducing operational costs.

Keywords: alignment, cooling water pump, misalignment, vibration

1. Introduction

Modern industry heavily depends on motors and pumps as vital components in various production processes for fluid transfer, especially in the manufacturing, oil and gas, and chemical processing sectors [1], [2]. The role of advanced diagnostic tools in maintaining the reliability of induction motors is crucial. The use of the discrete wavelet transform (DWT) is to identify motor misalignment in induction motors, a common failure source often linked to poor installation. A misaligned shaft exhibited higher vibration amplitudes and faster running speeds with harmonic patterns. Vibration analysis is a reliable method for diagnosing mechanical issues and preventing further failures in rotating equipment. Therefore, shaft alignment monitoring directly improves pump performance and operational safety [3], [4]. Motors and pumps play an important role in transmitting energy and transferring fluids; thus, the performance of fluid processes greatly determines the productivity and overall system reliability [4], [5].

Maintaining proper shaft alignment is a challenge in marine propulsion systems, particularly under the influence of ship hull deformation (SHD) caused by operational factors like waves, load, and speed. The conventional monitoring methods using eddy current displacement sensors fail to account for SHD effects [6]. However, shaft misalignment in motors and pumps often becomes a primary cause of reduced energy efficiency, leading to premature wear and potential operational failures, which negatively impact maintenance costs and production continuity [7], [8]. Excessive vibration issues in the Primary Air Fan (PAF) at the Central Java 2 Adipala coal-fired power plant are one of the misalignment problems caused by frequent equipment trips. Therefore, vibration monitoring and control strategies directly reduce downtime and improve reliability in industrial energy systems [9]. Moreover, misalignment directly impacts efficiency, not just in industrial machinery but also in renewable energy systems, reinforcing the universal importance of alignment monitoring and correction [10].

Shaft misalignment is a common defect in rotating machinery besides imbalance, and it can also cause significant financial losses for industrial facilities [11], [12]. As faced by industrial areas, excessive vibration caused by misalignment or bearing issues leads to critical failures, downtime, and high maintenance costs. These issues arise as the conditions and works of each machine vary. Therefore, they face a burdensome load in their work and experience performance degradation [13], [14]. The shaft misalignment is a critical failure mode, commonly studied alongside other severe faults in pumps and induction motors. It implies that misalignment can occur at varying severities and operating conditions, making it a versatile and recurring problem in real-world machinery [15]. The impact of misalignment can result in efficiency reductions between 30 and 40% due to machine downtime, component replacement, inventory management, and energy lost [16]. Therefore, it clearly shows that misalignment reduces energy efficiency, forcing the motor to consume significantly more power. It reinforces the causal relationship that the greater the misalignment, the higher the energy loss, and it indicates that different misalignment levels directly affect efficiency, and the study experimentally quantified that correlation [17], [18]. Additionally, this fault increases the risk of bearing failure, which accounts for nearly half of motor failures, caused by manufacturing defects, inadequate lubrication, and improper installation processes [19], [20]. Moreover, it also results in efficiency loss in the short term and vibration-induced electrical and mechanical degradation, including short circuits and wear in stator windings [21], [22]. One contributing factor to misalignment is the "soft foot" condition on machine mounts, where unequal contact between the machine foot and foundation leads to uneven load support [23].

Misalignment also affects the vibration stability of the system, especially at half switching speed, where stability decreases as the misalignment angle increases [24]. This adds complexity to the system dynamics, potentially causing chaotic operational behaviour as structural stiffness rises. The negative impacts of misalignment on rotating machines include significant energy loss, as well as reduced operational efficiency and availability of industrial equipment [18], [25]. Therefore, early detection of shaft misalignment is crucial to maintain machine performance and to prevent further damage. The shaft alignment process is a critical step that must be carried out to ensure the motor shaft position aligns with the pump shaft, both angularly and parallelly, to minimize operational issues and financial losses [26], [16], [27]. This is especially important for machines running continuously, such as cooling water pumps (Raw Water) in power generation industries, which are prone to misalignment over time.

Research on shaft misalignment represents a prevalent and critical fault in pump systems, often resulting in elevated vibration levels, excessive energy consumption, and accelerated mechanical degradation. Such conditions compromise operational efficiency and reliability in the conditions of increased maintenance costs and the risk of unplanned downtime. Accordingly, this study aims to explore the relationship between shaft alignment, vibration, and motor power consumption on pumps, to formulate effective solutions to mitigate these adverse effects and enhance system performance.

2. Methods

The research was conducted at PT Nusantara Power Unit Pembangkit Pekanbaru, specifically at the Koto Panjang Hydroelectric Power Plant service unit, located on Bangkinang – Jalan Payakumbuh, Merangin Village, Kuok District, Kampar Regency, Riau Province. The experimental object of this research was a cooling water pump driven by an IEC 60034 motor with a rated power of 45 kW. The primary instruments used in this study included an SKF Shaft Laser Alignment Tool TKSA 51 for alignment measurement, a vibration meter for monitoring dynamic responses, and an electrical measuring device for recording current and voltage to estimate motor power consumption.

This research was designed to evaluate the performance of the pump and motor under two operating conditions. They are pre-alignment, the initial condition with misalignment, while post-alignment is the condition after shaft alignment correction.

1. Measurement points were located at four positions: motor non-drive end (NDE), motor drive end (DE), pump NDE, and pump DE.
2. Vibration was recorded in three axes (horizontal, vertical, and axial) at each point.
3. Power consumption was measured under constant load conditions to ensure comparability between the two states.

Motor power consumption was determined by measuring line current and voltage using a clamp ammeter, with data recorded under identical load conditions for both alignment states. The shat alignment process was then conducted following the correction and horizontal shifting of the motor base. After alignment, vibration, and power consumption measurements were repeated at the same locations and directions.

The collected data were analysed by comparing vibration amplitudes and motor current before and after alignment. Changes in vibration severity were interpreted with reference to ISO 10816 vibration standards, while reductions in power consumption were expressed as a percentage of energy savings. This procedure enabled a systematic evaluation of the relationship between shaft alignment, vibration behaviour, and energy efficiency in centrifugal pump operation.

3. Results and Discussion

At the initial stage, measurements or data acquisition of shaft alignment were conducted using the SKF Laser Alignment Tools TKSA 51. Before performing the shaft alignment work, a soft foot inspection was first carried out, as shown in Figure 1.

Figure 1. Soft foot inspection results

The results of the soft foot inspection are shown in the figure above, with measurement values around the motor foot points recorded as 0.03 mm, 0.00 mm, 0.02 mm, and 0.04 mm. These values indicate gaps or imbalances at each motor foot, illustrating the amount of correction needed to level the machine. The ideal soft foot value is as close to zero as possible, and the industry standard typically used for raw water pumps is less than 0.05 mm. Although such small soft foot conditions may not cause immediate damage, they can adversely affect the long-term health of the machine, as indicated in Table 1.

Tabel 1. Shaft misalignment measurement results

Parameter	Vertical	Horizontal
Offset (mm)	-0,03	0,14
Angle (mm/100 mm)	-1,05	0,40

Referring to the tolerance limits set by the SKF laser alignment tool according to motor speed categories (rpm), for motors with rpm between 1000 and 2000, the upper limit for offset is 0.1 mm, and for angular error, 0.08 mm per 100 mm, as shown in Table 2.

Table 2. Shaft alignment tolerance

	Tolerance	
Speed (rpm)	Offset (mm)	Angular Error (mm/100 mm)
0-1000	0,13	0,10
1000-2000	0,10	0,08
2000-3000	0,07	0,07
3000-4000	0,04	0,06
4000-5000	0,03	0,05
5000-6000	0,03	0,04

Based on the alignment measurement results, the vertical offset position, with a result of 0.03 mm, is still within tolerance limits, indicating that the vertical position of the motor shaft is satisfactory. This means that the vertical shaft position of the motor is relatively aligned with the pump shaft. Next, the horizontal offset position shows a result of 0.14 mm, which exceeds the tolerance limit, indicating a horizontal displacement that can cause vibration and excessive load on the shaft. The vertical angle is quite large and out of tolerance, indicating that the motor shaft is tilted vertically, which can cause excessive vibration, stress on the bearings and couplings, wear, and reduced machine efficiency. Furthermore, the angular error in the horizontal position yields a result of 0.40 mm/100 mm, similar to the angular error in the vertical position. The horizontal position also exceeds tolerance, indicating a horizontal tilt angle that requires correction to achieve perfect shaft alignment. The measured results are usually reported in Hz and mm/s, taken from three directional axes: vertical, horizontal, and axial on the bearings alternately at the NDE (Non-Drive End) and DE (Drive End) of both the motor and the Raw Water pump, as shown in Table 3.

Table 3. Pre-alignment vibration values

Location	Vibration Values			
	Motor		Pump	
	NDE	DE	NDE	DE
Horizontal (mm/s)	7.66	8.2	3.36	6.54
Vertical (mm/s)	4.78	3.69	6	7.89
Axial (mm/s)	6.11	11.15	6.29	3.86

Based on the vibration measurement results of the Raw Water 3.1 motor at the Horizontal location, the vibration values are quite high with NDE at 7.66 mm/s and DE at 8.2 mm/s, both marked in red, indicating critical vibration levels that require immediate attention. At the Vertical location, NDE shows a value of 4.78 mm/s (red), while DE is lower at 3.69 mm/s (orange), indicating variation in vibration levels that still need to be monitored.

Data vibration measurements on the pump at the Horizontal location show vibration values of 3.36 mm/s (orange) at NDE and 6.54 mm/s (red) at DE, indicating that the DE side of the pump experiences quite high vibration and requires attention. At the Vertical location, NDE reaches 6 mm/s (red) and DE 7.89 mm/s (red), both showing high vibration levels that could potentially interfere with pump performance. At the Axial location, NDE is 6.29 mm/s (red) and DE is 3.86 mm/s (orange), indicating significant vibration, especially on the NDE side, as illustrated in Figure 2.

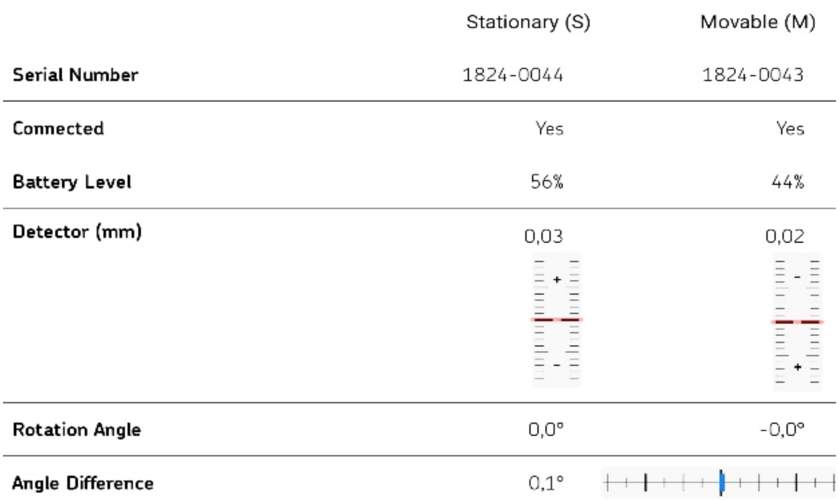

Figure 2. Adjustment of the Height and Alignment of Both Sensors

After the installation of the stationary sensor and the movable sensor, and the adjustment of the height and angle between the two sensors has been carried out, the sensor setup procedure is complete, and the alignment data collection work is ready to be performed. At the initial measurement stage, data will be taken at three positions. It is at 0°, 90°, and 180°.

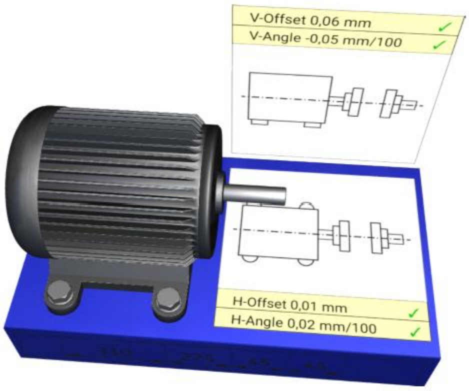

Figure 3. Measurement results after repairs

The shaft alignment measurement was conducted to ensure the conformity of the position and angle between the motor and the components installed in the assembly, as illustrated in Figure 3. The main parameters measured include vertical offset (V-Offset), horizontal offset (H-Offset), as well as vertical angular deviation (V-Angle) and horizontal angular deviation (H-Angle). The measurement results after the alignment correction are shown in Table 4.

Table 4. Parameter values before and after alignment

Parameter	After correction
Offset Vertical (mm)	0,06
Offset Horizontal (mm)	0,01
Angle Vertical (mm/100 mm)	-0,05
Angle Horizontal (mm/100 mm)	0,02

After the alignment process was carried out on the shaft of the raw water pump and vibration measurements were conducted, the data obtained are presented in Table 5 as follows.

Table 5. Vibration values after alignment

Location	Vibration Values			
	Motor		Pump	
	NDE	DE	NDE	DE
HORIZONTAL (mm/s)	2,96	2,08	2,68	4,36
VERTIKAL (mm/s)	3,78	0,92	2,94	4,4
AXIAL (mm/s)	1,87	2,8	2,44	2,16

The vibration value on the motor in the horizontal direction at the NDE side is 2.96 mm/s, which falls into the moderate category (yellow), while at the DE side it is 2.08 mm/s, which is still in the safe category (green). This indicates that the horizontal vibration of the motor is relatively controlled. Next, in the vertical direction, the vibration value at the NDE side is 3.78 mm/s, categorized as moderate, while at the DE side, it is only 0.92 mm/s, classified as safe. In the axial direction, the axial vibration values on both sides of the motor (NDE 1.87 mm/s and DE 2.80 mm/s) are within safe limits. For the pump, in the horizontal direction, the vibration at the NDE side of 2.68 mm/s is categorized as safe, while at the DE side, it is 4.36 mm/s, falling into the moderate category. In the vertical direction, the vibration value at the NDE side is 2.94 mm/s, which is safe, but at the DE side, it is 4.40 mm/s, categorized as moderate. Axial vibrations at the NDE and DE sides of the pump are 2.44 mm/s and 2.16 mm/s, respectively, both categorized as safe, indicating stable conditions in the axial direction.

The results of motor voltage and current measurements using transducers installed on the MCC (Motor Control Centre) panel are shown in Table 6 below.

Table 6. Current measurement before and after alignment

Condition	Current Motor (A)			Average current
	R	S	T	
Before alignment	76	77	77	76,8
After alignment	71,8	71,3	70,7	71,2

Calculation of Electrical Power Consumption with Voltage (V): 383.7 Volts and Power Factor (cos φ): 0.86, as shown in Table 7.

Table 7. Motor Power Calculation Results

Condition	Motor power (kW)
Before alignment	44,3
After alignment	40,6

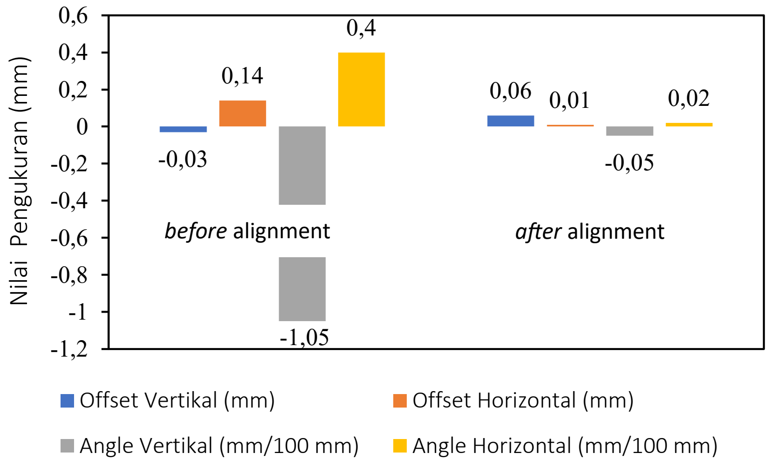

Figure 4. Histogram before and after shaft alignment

The graph above explains the condition of misalignment and the condition after corrective shaft alignment was performed. The measurement values before correction showed considerable variation, especially in the angular error parameters (vertical and horizontal angles) with values of -1.05 mm/100 mm and 0.4 mm/100 mm, respectively, compared to the tolerance value of 0.08 mm/100 mm. After correction, the vertical angle changed by 1 mm to -0.05 mm/100 mm. The horizontal angle decreased by 0.38 mm from 0.4 mm/100 mm to 0.02 mm/100 mm. The relatively flat orange line close to the zero axis in the graph indicates that the correction successfully stabilized the position and angle of the shaft effectively.

Vibration analysis functions as a diagnostic tool capable of detecting many problems, including imbalance, misalignment, bearing failure, and gear damage inside the gearbox. In Figure 5 below, the vibration velocity before and after repair is depicted.

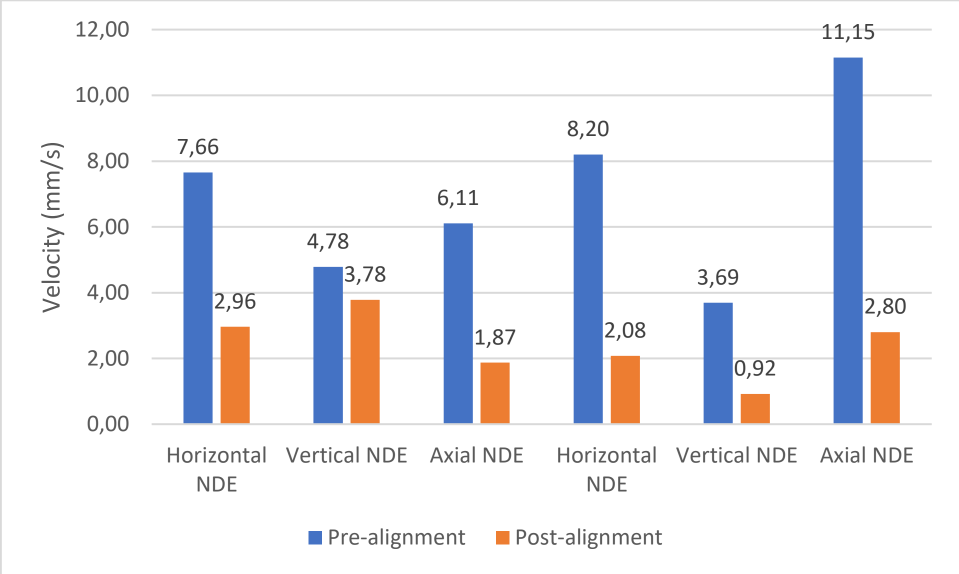

Figure 5. Vibration value graph before and after alignment

The vibration value at the axial DE point before repair was 11.15 mm/s. After the repair was conducted, the vibration value decreased to 2.8 mm/s. On the horizontal DE side, the vibration decreased from 8.20 mm/s before repair to 2.08 mm/s after repair.

A study in "Vibration Analysis & Condition Monitoring for Rotating Machines" emphasizes that measuring and controlling vibration is crucial for predictive maintenance [21]. The reduction in vibration values is an indicator of the effectiveness of the alignment in reducing imbalance and excessive friction that trigger vibrations, as shown in Table 8.

Table 8. Decrease in vibration velocity

Measurement Point	***Before* Alignment (mm/s)**	***After* Alignment (mm/s)**	**Impairment value (mm/s)**
Horizontal NDE Motor	7,66	2,96	4,70
Vertical NDE Motor	4,78	3,78	1,00
Axial NDE Motor	6,11	1,87	4,24
Horizontal DE Motor	8,2	2,08	6,12
Vertical DE Motor	3,69	0,92	2,77
Axial DE Motor	11,15	2,8	8,35

Based on the vibration velocity measurement data in Tables 3 and 5 and the graph in Figure 5, all measurement points show a decrease in vibration velocity. The largest decrease in vibration velocity occurred at the Motor Axial DE point with a reduction of 8.35 mm/s, while the smallest decrease was at the Motor Vertical NDE point with a reduction of 1 mm/s after repair.

Vibration Pattern Identification

The spectrum data on the induction motor vibration at the horizontal DE side, vertical DE, and axial DE sides show the vibration pattern caused by misalignment. In Figure 6, the highest signal is located at a frequency of 24.42 Hz. The dominant peak at 1x RPM is very clear, indicating a strong dynamic force in the horizontal direction. A peak at 2x RPM is also visible, indicating angular/parallel misalignment. The amplitude of the peak at 1x RPM is very high, followed by the peak at 2x RPM in the axial direction at both bearings. Figure 8 shows a strong axial force, which is usually associated with angular misalignment, causing thrust force in the axial direction.

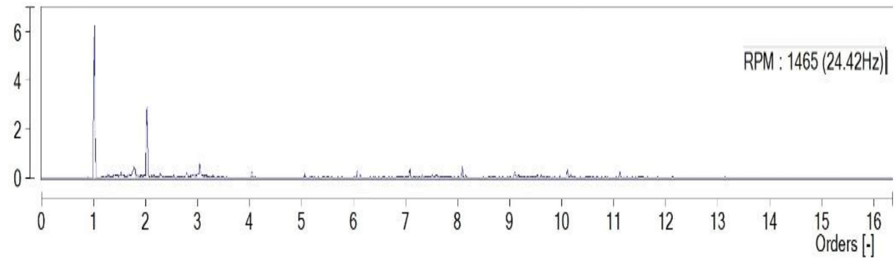

Figure 6. Horizontal DE Motor Vibration Spectrum

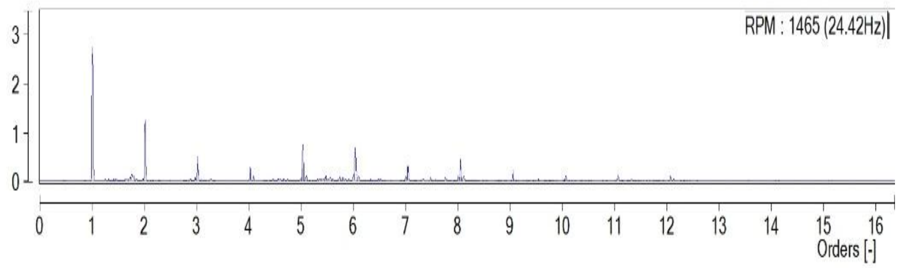

Figure 7. Vertical DE Motor Vibration Spectrum

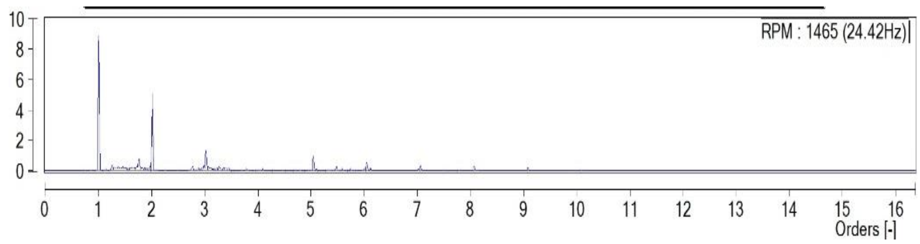

Figure 8. Axial DE Motor Vibration Spectrum

Figures 6 to 8 present the vibration spectrum of the motor drive end (DE) in the horizontal, vertical, and axial directions at 1465 RPM (24.42 Hz). The spectra clearly reveal dominant peaks at the fundamental running frequency and its harmonics. These patterns are characteristic indicators of shaft misalignment, particularly angular misalignment, which typically generates significant vibration components in both axial and radial directions.

In the horizontal spectrum, in Figure 6, strong amplitudes at the 1× and 2× running frequencies reflect coupling forces induced by misalignment. The vertical spectrum, in Figure 7, shows similar harmonic components but with lower amplitude compared to the horizontal direction, suggesting uneven load distribution across the motor bearings. The

axial spectrum, in Figure 8, exhibits the highest amplitudes. It reaches nearly 10 mm/s, which is a distinct signature of angular misalignment. High axial vibration is widely recognized in the literature as a primary symptom of shafts not being collinear.
The reduction in power consumption, as calculated in Table 7, decreased from 44.3 kW to 40.6 kW after alignment using Equation (1), resulting in a value of 8.35% as follows:

$$\frac{44{,}3-40{,}6}{44{,}3} x\ 100\ \% = 8{,}35\% \qquad (1)$$

This indicates power savings, which aligns with the reduction in vibration values seen in the vibration graph previously analysed in Figure 6. After the alignment process on the motor and pump shafts, all measurement points showed a decrease in vibration velocity. The largest decrease in vibration velocity was at the Motor Axial DE point with 8.35 mm/s, and the smallest decrease was at the Motor Vertical NDE point with 1 mm/s after repair. This reduction indicates that alignment successfully reduced shaft misalignment, which is the main source of excessive vibration. Vibration spectrum analysis usually indicates the presence of angular misalignment, which causes excessive dynamic loads, friction, and mechanical losses. After alignment, load distribution becomes more balanced, friction and dynamic forces decrease, resulting in lower motor current demand and more efficient power consumption. This is consistent with the study "Experimental investigation on shaft motor coupling misalignment impact on energy consumption," which explains that misalignment in machine shafts can cause an increase in energy consumption of about 15% [18]. The level of escalation depends on the severity of the misalignment. Empirical studies show that machines exhibiting shaft misalignment require increased motor energy for rotation, leading to energy waste and higher operational costs. By implementing corrective alignment measures, power consumption can be significantly reduced, potentially by 15% or more, while also enhancing machine longevity and optimizing operational efficiency.

4. Conclusion

The observation results obtained the following conclusions: After the alignment process on the motor and pump shafts, all measurement points showed a decrease in vibration velocity. The largest decrease in vibration velocity was at the Motor Axial DE point with 8.35 mm/s, and the smallest decrease was at the Motor Vertical NDE point with 1 mm/s after repair. This reduction indicates that alignment successfully reduced shaft misalignment, which is the main source of excessive vibration. Motor power consumption decreased by approximately 8.35%, reflected by the average motor current decreasing from 76.8 A to 71.2 A. This shows that alignment not only improves mechanical performance but also operational energy efficiency. The vibration pattern caused by misalignment, based on the spectrum data analysis, indicates a high 1X peak in the axial direction, and smaller 2X and 3X peaks, which are harmonics arising from angular misalignment.

References

[1] M. A. Batutah and H. Huda, "Analysis of Pump Installation Design for Clean Water in Pt Pamapersada Nusantara , Indo District - Bontang, East Kalimantan in Barak 15 Junior Staff Camp 2000," *J. Chemurg. 6*, vol. 6, no. 200, pp. 86–96, 2022, doi: https://dx.doi.org/10.30872/cmg.v6i2.9395.

[2] I. Mendoza and G. Zurita, "Shaft Alignment Measurement System Developed for Industrial Applications," *Investig. Desarro.*, vol. 18, no. 1, pp. 91–102, 2018, doi: https://dx.doi.org/10/23881/idupbo.018.1-7i.

[3] P.P.S Saputra, "Pendeteksian Misalignment Menggunakan Multi Level Transformasi Wavelet Haar dan Coiflet pada Motor Induksi," *J. JEETech*, vol. 1, no. 1, pp. 1–6, May 2020, doi: https://doi.org/10.48056/jeetech.v1i1.1.

[4] F. Rachmanu, "PEMANTAUAN KONDISI POMPA SENTRIFUGAL P-12A MENGGUNAKAN ANALISIS VIBRASI STUDI KASUS DI PT. X," *Ramatekno*, vol. 2, no. 1, pp. 14–19, 2022, doi: https://doi.org/10.61713/jrt.v2i1.34.

[5] Z. Anthony and E. Erhaneli, "Kinerja Motor Induksi 1-Fasa Disain 4 Kumparan Dengan Kapasitansi Kapasitor Jalan Terkendali," *Elkha*, vol. 12, no. 1, 2020, doi: https://doi.org/10.26418/elkha.v12i1.37857.

[6] S. Arhun, A. Hnatov, V. Mygal, and N. Kunicina, "Elevating electric motor performance through rigorous vibration control and standardization," *Adv. Mech. Eng.*, vol. 16, no. 6, pp. 1–9, 2024, doi: https://doi.org/10.1177/16878132241262677.

[7] D. L. Branković, Z. N. Milovanović, and V. Z. J. Milovanović, "The Importance of Technical Diagnostics for Ensuring the Reliability of Industrial Systems BT - Reliability and Maintainability Assessment of Industrial Systems: Assessment of Advanced Engineering Problems," M. Ram and H. Pham, Eds., Cham: Springer International Publishing, 2022, pp. 143–187. doi: https://doi.org/10.1007/978-3-030-93623-5_8.

[8] J.-W. Cheng, W.-J. Bu, L. Shi, and J.-Q. Fu, "A real-time shaft alignment monitoring method adapting to ship hull deformation for marine propulsion system," *Mech. Syst. Signal Process.*, vol. 197, p. 110366, 2023, doi: https://doi.org/10.1016/j.ymssp.2023.110366.

[9] I. Darmawan, K. Kholistianingsih, A. Purwanto, P. Yulianto, and S. Pramono, "Pengurangan Gangguan Akibat Kegagalan Pengukuran Vibrasi pada Primary Air Fan (PAF) di PLTU Jateng 2 Adipala Operation and Maintenance Services Unit," *J-Proteksion J. Kaji. Ilm. dan Teknol. Tek. Mesin*, vol. 7, pp. 35–46, Feb. 2023, doi: https://doi.org/10.32528/jp.v7i2.8306.

[10] L. Evans, I. Ashton, and B. G. Sellar, "Impact on Energy Yield of Varying Turbine Designs under Conditions of Misalignment to the Current Flow," *Energies*, vol. 16, no. 9, pp. 1–17, 2023, doi: https://doi.org/10.3390/en16093923.

[11] L. K.K., L. D.L., and K. D.F., "Experimental Investigation of the Effect of Coupling Misalignment of a Centrifugal Pump Unit on Its Vibration and Noise Characteristics," in *2022 International Conference on Dynamics and Vibroacoustics of Machines (DVM)*, IEEE, Sep. 2022, pp. 1–10. doi: 10.1109/DVM55487.2022.9930934.

[12] P. Kumar and H. Hirani, "Misalignment effect on gearbox failure: An experimental study," *Measurement*, vol. 169, p. 108492, 2021, doi: https://doi.org/10.1016/j.measurement.2020.108492.

[13] S. Lee, T. Kim, and T. Kim, "Multi-domain vibration dataset with various bearing types under compound machine fault scenarios," *Data Br.*, vol. 57, p. 110940, 2024, doi: https://doi.org/10.1016/j.dib.2024.110940.

[14] S. Chen, Z. Liu, X. He, D. Zou, and D. Zhou, "Multi-mode fault diagnosis datasets of gearbox under variable working conditions," *Data Br.*, vol. 54, p. 110453, 2024, doi: https://doi.org/10.1016/j.dib.2024.110453.

[15] S. Bruinsma, R. D. Geertsma, R. Loendersloot, and T. Tinga, "Motor current and

vibration monitoring dataset for various faults in an E-motor-driven centrifugal pump," *Data Br.*, vol. 52, p. 109987, 2024, doi: https://doi.org/10.1016/j.dib.2023.109987.

[16] G. Nan, S. Yang, and D. Yu, "Misalignment and Rub-Impact Coupling Dynamics of Power Turbine Rotor with Offset Disk," 2024. doi: https://doi.org/10.3390/app14031298.

[17] A. A. S. R. de Sousa and M. R. Machado, "Experimental vibration dataset collected of a beam reinforced with masses under different health conditions," *Data Br.*, vol. 52, p. 110043, 2024, doi: https://doi.org/10.1016/j.dib.2024.110043.

[18] M. F. Yahya, R. M. Dan, and N. A. Aqila, "Experimental investigation on shaft motor coupling misalignment impact on energy consumption," 2024, p. 060011. doi: https://doi.org/10.1063/5.0228180.

[19] T. Mashiyane, D. Desai, and L. Tartibu, "Numerical simulation of the effect of angular misalignment on the dynamic behaviour of bearing," *MATEC Web Conf.*, vol. 370, p. 09003, 2022, doi: https://doi.org/10.1051/matecconf/202237009003.

[20] A. Triyanto, O. Supriadi, and R. Maulana, "Analisis Parallel Misalignment Pada Motor Tiga Fasa Menggunakan Digital Diagnostics System," *Epic J. Electr. Power Instrum. Control*, vol. 7, no. 1, pp. 21–31, 2024, doi: https://doi.org/10.32493/epic.v7i1.38741.

[21] M. Vishwakarma, R. Purohit, V. Harshlata, and P. Rajput, "Vibration Analysis & Condition Monitoring for Rotating Machines: A Review," *Mater. Today Proc.*, vol. 4, no. 2, pp. 2659–2664, 2017, doi: https://doi.org/10.1016/j.matpr.2017.02.140.

[22] Ö. Yılmaz, M. Aksoy, and Z. Kesilmiş, "Misalignment fault detection by wavelet analysis of vibration signals," *Int. Adv. Res. Eng. J.*, vol. 3, no. 3, pp. 156–163, 2019, doi: https://doi.org/10.35860/iarej.451528.

[23] I. G. Widodo, A. Khoryanton, and A. Pramono, "Analysis of vibration due to misalignment in the clutch cluster installation of centrifugal pump," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1108, no. 1, p. 012037, 2021, doi: https://doi.org/10.1088/1757-899x/1108/1/012037.

[24] J. Zhang, Y. Deng, G. Gao, and H. Zhu, "Design and Simulation of an Automatic Alignment System for Ship Multi-Support Shafting," *J. Mar. Sci. Eng.*, vol. 13, no. 1, 2025, doi: https://doi.org/10.3390/jmse13010087.

[25] R. Nawir, Y. Dwianda, A. Febrianton, and P. Irwan, "The Effect of Misalignment to Vibration, Electric Current and Shaft Rotation Speed on Gear Transmission," *J. Ocean. Mech. Aerosp. - Sci. Eng.*, vol. 66, no. 1, pp. 14–19, 2022, doi: http://dx.doi.org/10.36842/jomase.v66i1.278.

[26] R. R. Tashbulatov, N. A. Atroscshenko, and N. A. Lisovskiy, "Application of combined vane pumps-electric motors with rim transmission of the torque to the impeller," *Neft. khozyaystvo - Oil Ind.*, vol. 2021, no. 04, pp. 124–127, 2021, doi: https://doi.org/10.21595/lger.2021.22288.

[27] L. M. Hassan and J. K. Ali, "Diagnosing the Effect of Misalignment on a Rotating System using Simulation and Experimental Study," *Al-Kitab J. Pure Sci.*, vol. 6, no. 2 SE-Articles, pp. 46–64, Jan. 2023, doi: https://doi.org/10.32441/kjps.06.02.p5.