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Vibration analysis for failure detection in clean water distribution pumps: A case study in an oil and gas training center

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Abstract

The clean water distribution pump plays a crucial role in delivering clean water to consumers. Over time, increased noise levels indicate potential damage to pump components, which, if left unaddressed, can lead to severe failures and costly repairs. One of the analyzes of pump damage is vibration analysis. With vibration analysis, damage to the pump in the form of misalignment, mechanical looseness, bent shaft, bearing damage, worn gears, cavitation can be identified. The purpose of this research is to determine the characteristics of vibrations that occur in the pump, so that we can detect damage and failures that occurs and suggest maintenance action. Vibration analysis is carried out using a vibration analyzer to determine the vibration spectrum that occurs in the axial, radial and tangential directions, then analyzing the type of damage and appropriate maintenance to be carried out. The results showed that this pump indicated: extreme motor free end bearing looseness with a severity score of 99/100, serious motor free end bearing wear with a severity score of 72/100, serious motor drive end bearing looseness with a severity score of 53/100, and moderate motor drive end bearing wear with a severity score of 37/100. and based on the ISO 10816-3 standard, it is recommended that the motor free end bearing be replaced because vibration will cause damage and for the drive end bearing motor it is only recommended to operate for a short time.

Keywords:
Structural failure, drive shaft, finite element method, stress intensity factor, fracture toughness

1. Introduction

Predictive maintenance involves estimating machine damage through the analysis of equipment operating conditions, typically using direct observation or advanced monitoring tools. This method enables the timely determination of necessary maintenance actions. Early detection of equipment damage is crucial, as it helps prevent more severe issues from developing [1].

The clean water distribution pump at an oil and gas training center is essential for supplying clean water to consumers. If the pump becomes damaged, it will disrupt water distribution, negatively impacting both consumers and the company. As the pump operates, increased noise levels may indicate underlying issues, such as damaged components or structural problems. Even minor damage can lead to more significant complications, and repairs resulting from major failures can be time-consuming and costly.

Machine damage, specifically to the pump, can be predicted through an analysis of its operating conditions, with vibration analysis being a key method. By examining vibrations, potential issues such as imbalance, misalignment, mechanical looseness, bent shafts, bearing damage, gear wear, cavitation, and resonance in rotating equipment can be identified. This proactive approach enables appropriate maintenance to be conducted before the damage escalates.

Vibration analysis to predict damage that occurs in rotating equipment is often carried out [2], [3], [4], [5], [6], [7], [8], [9], [10], [11] as well as vibration analysis for specific research or vibration research on certain components, such as variable effects of misalignment [12] and vibration in motor bearings [13]. Vibration analysis is carried out using various techniques such as MEMs accelerometer [14], spectral analysis [15]. However, previous research does not match the industrial case. because it takes a lot of effort to analyze and to determine the problems that occur.

Research utilizing a vibration analyzer has been conducted to detect damage in single-stage centrifugal fire pumps [16]. The results demonstrate effectiveness and efficiency in analyzing and identifying pump damage. Consequently, this study employed a vibration analyzer to predict damage in clean water distribution pumps.

The primary objective of this research is to determine the vibration characteristics obtained during conditional vibration monitoring, enabling the identification of potential problems.

2. Research methodology

2.1 System design of clean water distribution pump

This research measures vibrations from clean water distribution pumps using a vibration analyzer equipped with transducers attached to specified locations. The vibration analyzer processes the resulting vibration spectrum, and the data is subsequently downloaded to a computer via USB cable, as illustrated in Fig. 1. Measurements were taken five times at each measurement point, and the analysis was conducted to draw conclusions. This process was repeated for each measurement period to ensure robust final conclusions. The object of the research is the oil and gas training center's pump, with specifications as in Table 1.

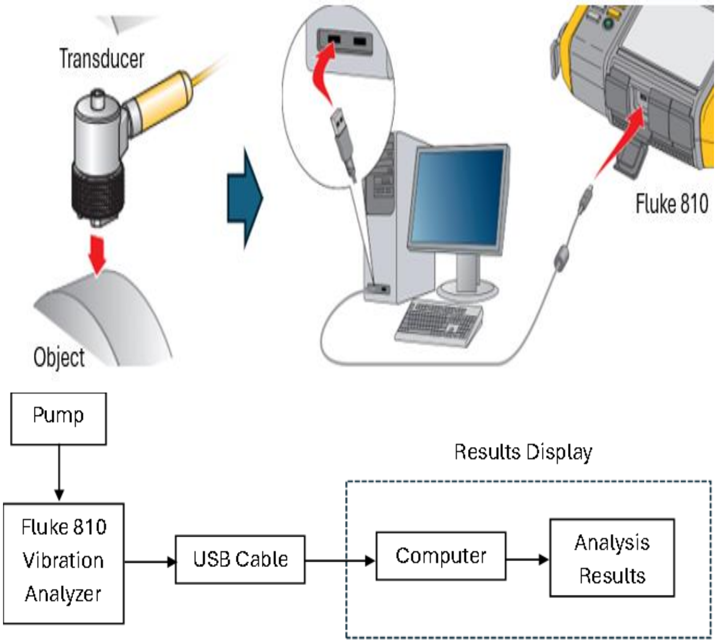


Fig. 1. System design block diagram

Table 1. Machine (Object) specification

Pump type	Motor type	Motor speed	Power	Motor mounted	Trans-mission	Pump drive
Multistage centrifugal pump	VFD	1450 (rpm)	110 (kW)	Horizon-tal	Coupling	Electric motor-non-variable speed

2.2 Vibration measurement scheme

Vibration analysis was conducted using the Fluke-810 Vibration Tester at four locations: the motor-free end (location 1), motor drive end (location 2), pump drive end (location 3), and pump-free end (location 4). The analysis focused on the axial, tangential, and radial axes, as illustrated in Fig. 2.

The measurement process began by entering machine data into the Vibration Analyzer and attaching the transducer to the designated measurement points. The Vibration Tester then processed the resulting vibration spectrum and displayed the analysis in both textual and graphical formats. This information facilitates the assessment necessary for determining appropriate maintenance measures. Monitoring is carried out periodically in August, October, and December.

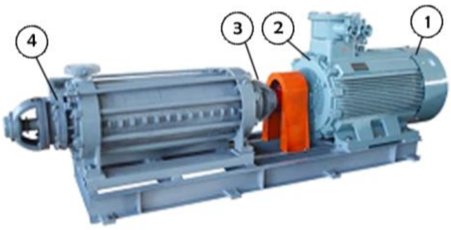


Fig. 2. Vibration Measurement Scheme

The standard used in this research refers to the ISO 10816-3 Standard – ISO Guidelines for Machine Vibration Severity. ISO 10816-3 Vibration Standard is based on the type of machine, type of driving force, and equipment foundation, which are grouped into four groups. Group 1, Machines big with power 300 kW engine up to 50 MW and with Rigid and flexible foundations. Group 2, Machines currently with Power 15 kW engine up to 300 kW and with rigid foundation or flexible.

Group 3, Radial, axial, mixed flow pumps with power < 15 kW, with an external driver. Standard ISO 10816-3 also shows fault severity on four parameters (New machine condition/Slight, unlimited long-term operation allowable/Moderate, short-term operation allowable/Serious, and vibration causes damage/Extreme), as shown in Fig. 3 [2].

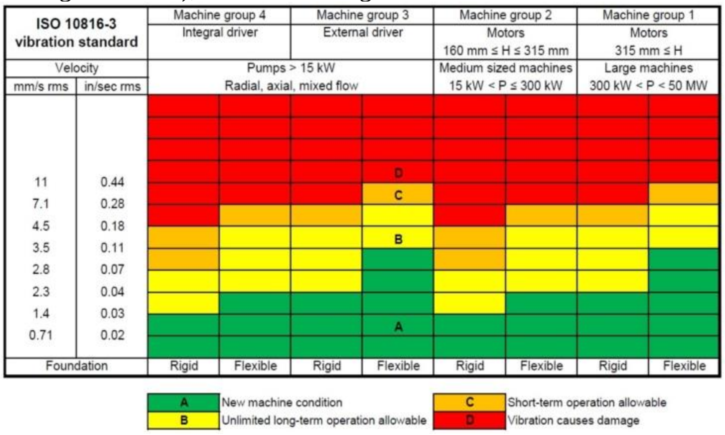


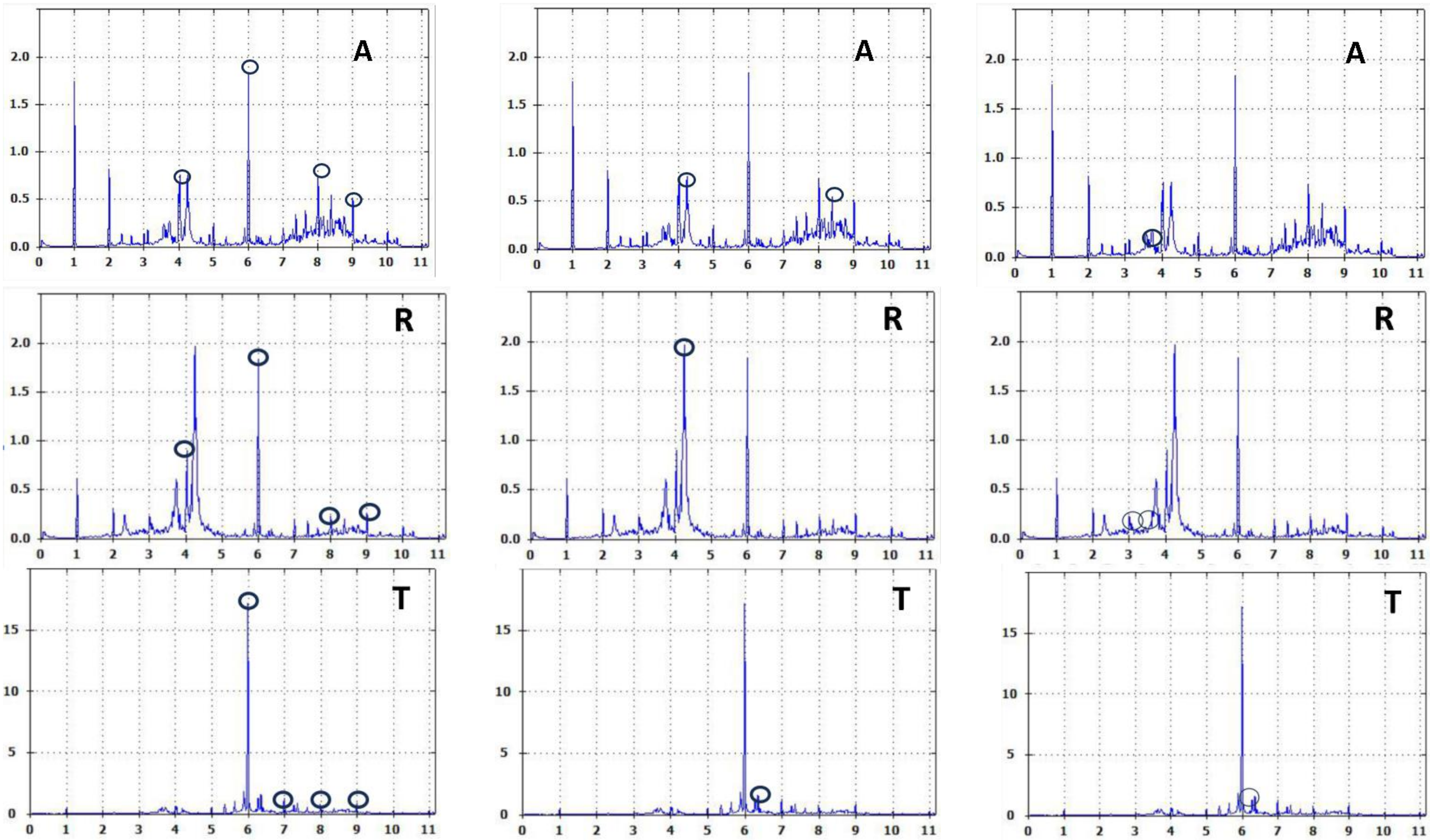
Fig. 3. ISO 10816-3 Standard

3. Results and discussion.

To determine the type of damage to the clean water distribution pump, measurements are conducted over three distinct periods. During each period, multiple samples are collected to facilitate accurate conclusions.

3.1 Monitoring in August

Based on multiple sample measurements conducted in August, it can be concluded that the clean water distribution pump is damaged (Fig. 4).



Fault description	Fault severity	Severity Score	Severity Scale
Motor Free End Bearing Looseness	Extreme	84/100	

Fault description	Fault severity	Severity Score	Severity Scale
Motor Free End Bearing Wear	Moderate	44/100	

Fault description	Fault severity	Severity Score	Severity Scale
Motor Drive End Bearing Wear	Slight	4/100	

(a) Motor free end bearing looseness spectrum (b) Spectrum of Motor Free End Bearing Wear (c) Spectrum of Motor Drive End Bearing Wear

Fig. 4. Vibration monitoring and analysis in August

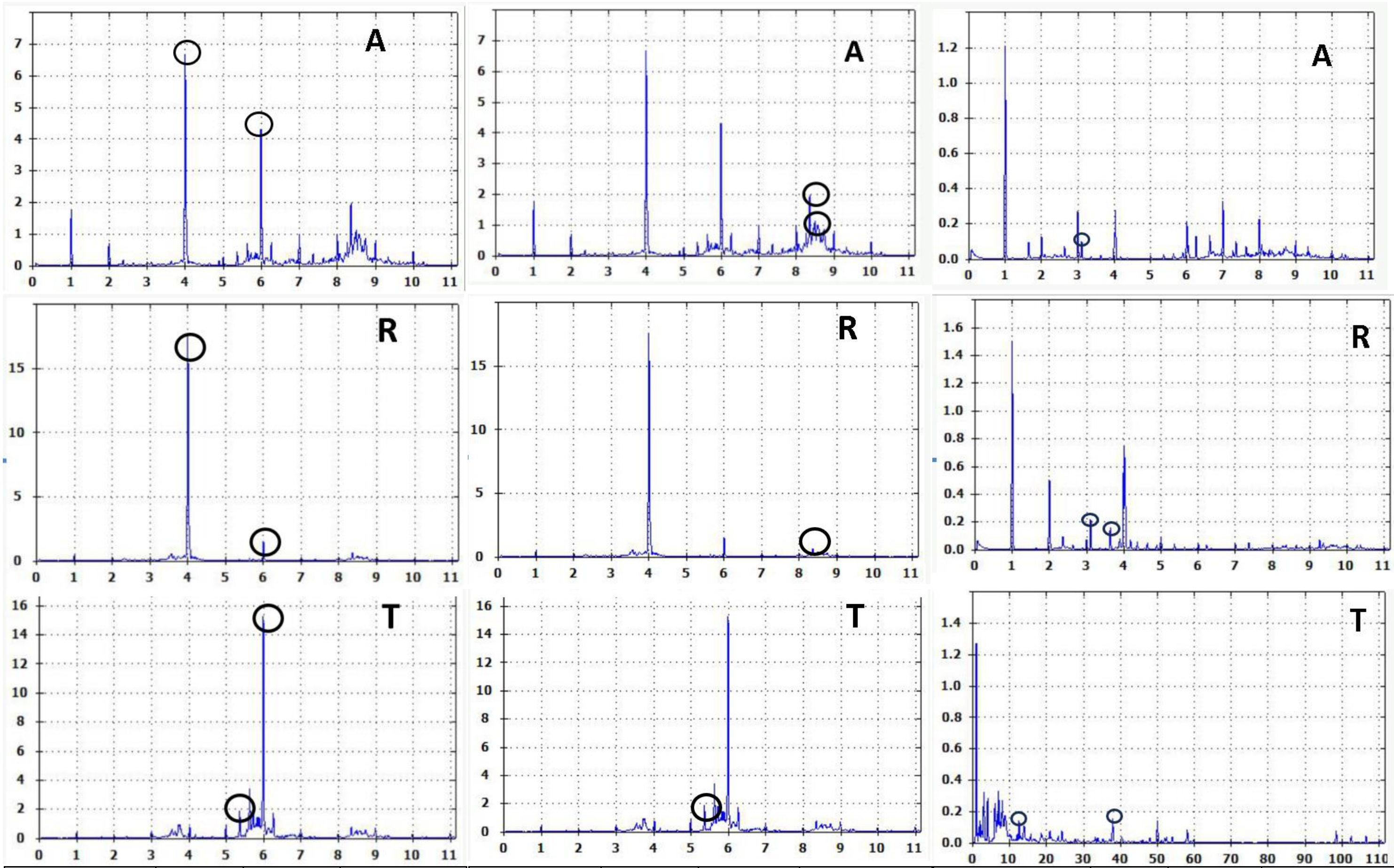
Specifically, at Location 1, the vibration spectrum in the axial, radial, and tangential directions indicates severe bearing looseness. This is illustrated in Fig. 4(a), where the X-axis represents amplitude (order) and the Y-axis represents frequency (mm/sec). The severity score for this condition is 84 out of 100.

At Location 1, Moderate bearing wear also occurred as shown in Fig. 4(b) (The X axis shows Amplitude (order) and Y axis shows Frequency (mm/sec)), with a severity score of 44/100. At location 2, Slight Bearing wear is indicated as shown in Fig. 4(c) The X axis shows Amplitude (order) and the Y axis shows Frequency (mm/sec)), with a severity score of 4/100.

The conclusions drawn from the vibration monitoring conducted in August indicate that the pump distribution exhibited Extreme Motor Free End Bearing Looseness, with a severity score of 84/100. Additionally, Moderate Motor Free End Bearing Wear was observed, with a severity score of 44/100, and Slight Motor Drive End Bearing Wear, with a severity score of 4/100 (Fig. 4).

3.2 Monitoring in October

Based on multiple sample measurements conducted in October, it can be concluded that the clean water distribution pump is likely damaged. Notably, at location 1, the vibration spectrum in the axial, radial, and tangential directions indicates significant bearing looseness, as illustrated in Fig. 5(a) (where the X-axis represents Amplitude (order) and the Y-axis represents Frequency (mm/sec)). This condition has been assessed with a severity score of 93/100.



Fault description	Fault severity	Severity Score	Severity Scale
Motor Free End Bearing Looseness	Extreme	93/100	

Fault description	Fault severity	Severity Score	Severity Scale
Motor Free End Bearing Wear	Serious	52/100	

Fault description	Fault severity	Severity Score	Severity Scale
Motor Drive End Bearing Wear	Slight	22/100	

(a)Spectrum of Motor Free End Bearing Looseness (b) Motor Free End Bearing Wear Spectrum (c) Spectrum of Motor Drive End Bearing Wear

Fig. 5. Vibration monitoring and analysis in October

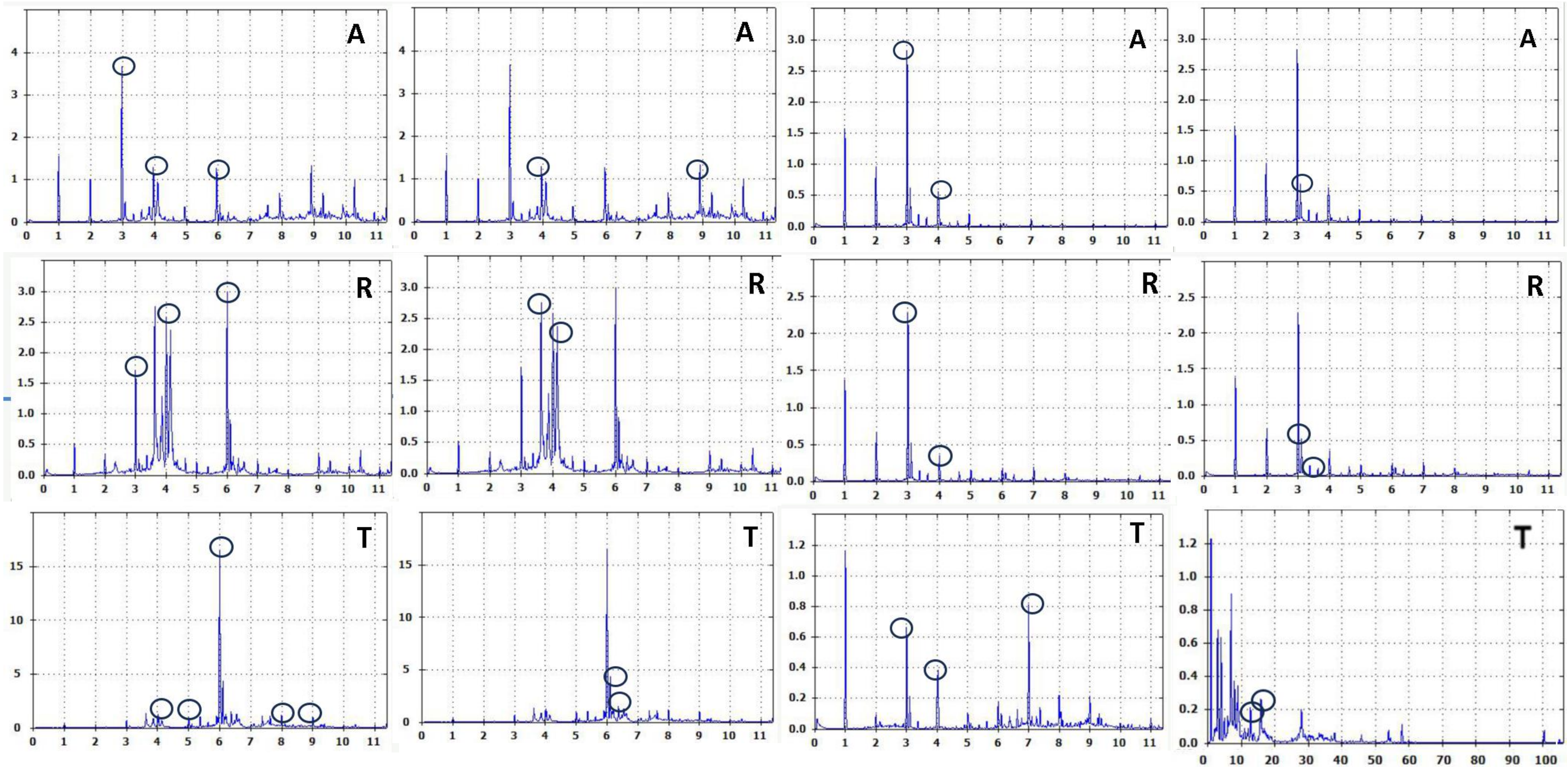
At Location 1, Serious bearing wear also occurred as shown in Fig. 5 (b) (The X-axis shows Amplitude (order) and the Y-axis shows Frequency (mm/sec)), with a severity score of 52/100. At location 2, Slight Bearing wear is indicated as shown in Fig. 5(c) (The X-axis shows Amplitude (order) and the Y-axis shows Frequency (mm/sec)), with a severity score of 22/1008.

The conclusions from vibration monitoring in October were that the pump distribution indicated Extreme Motor Free End Bearing Looseness, with a severity score of 93 100, serious motor free end bearing wear, with a severity score of 52 100, and Slight Motor Drive End Bearing Wear, with a severity score of 22 100 (Fig. 5).

3.3 Monitoring in December

Based on multiple sample measurements conducted in December, it can be concluded that the clean water distribution pump is likely damaged (Fig. 6).

At location 1, the vibration spectrum, analyzed in axial, radial, and tangential directions, reveals significant bearing looseness, as illustrated in Fig. 6(a). It. shows the X-axis represents Amplitude (in orders) and the Y-axis represents Frequency (in mm/sec). The severity score for this condition is 93 out of 100.



Fault description	Fault severity	Severity Score	Severity Scale
Motor Free End Bearing Looseness	Extreme	99/100	

Fault description	Fault severity	Severity Score	Severity Scale
Motor Free End Bearing Wear	Serious	72/100	

Fault description	Fault severity	Severity Score	Severity Scale
Motor Drive End Bearing Looseness	Serious	53/100	

Fault description	Fault severity	Severity Score	Severity Scale
Motor Drive End Bearing Wear	Moderat	37/100	

(a) Motor Free End Bearing Looseness Spectrum (b) Spectrum of Motor Free End Bearing Wear (c) Spectrum of Motor Drive End Bearing Looseness (d) Spectrum of Motor Drive End Bearing Wear

Fig. 6. Vibration monitong and analysis in December

At Location 1, serious bearing wear also occurred as shown in Fig. 6(b) (the X axis shows Amplitude (order) and Y axis shows Frequency (mm/sec)), with a severity score of 72/100. At location 2, serious bearing looseness is indicated as shown in Fig. 6(c) (the X axis shows amplitude (order) and the Y axis shows frequency (mm/sec)), with a severity score of 53/100. At location 2, Moderate Bearing wear is also indicated as shown in Fig. 6(d) (the X axis shows Amplitude (order) and Y axis shows Frequency (mm/sec)), with a severity score of 37/100.

The conclusions drawn from the vibration monitoring conducted in December indicate several critical issues with the pump distribution. Specifically, there was extreme motor free end bearing looseness, which received a severity score of 99/100. Additionally, serious wear was observed in the motor free end bearing, with a severity score of 72/100, and moderate wear in the motor drive end bearing, which garnered a severity score of 37/100. Furthermore, serious looseness was detected in the motor drive end bearing, assigned a severity score of 53/100. (Fig. 6)

3.4 Recapitulation of Monitoring Results

Summary of monitoring carried out from month October until December 2023. The results obtained are as in Table 2. while the level of damage is shown in Fig. 7. The level of damage is getting bigger. This is indicated by a graph of damage that is climbing upwards

Table 2. Recapitulation of Monitoring Results

Diagnose	Severity Score (/100)		
	Aug.	Oct.	Dec.
Motor Free End Bearing Looseness	84	93	99
Motor Free End Bearing Wear	44	52	72
Motor Drive End Bearing Wear	4	22	37
Motor Drive End Bearing Looseness			53

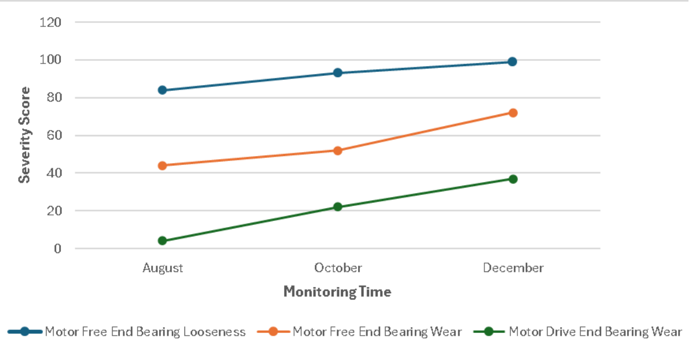


Fig. 7. Fault Rate

4. Conclusions.

Based on the research results, it can be concluded that the clean water distribution pumps used in oil and gas training exhibit several critical issues. Specifically, there is extreme looseness in the motor free end bearing, which has a severity score of 99/100. Additionally, there is serious wear in the motor free end bearing with a severity score of 72/100, serious looseness in the motor drive end bearing with a severity score of 53/100, and moderate wear in the motor drive end bearing with a severity score of 37/100. According to the ISO 10816-3 standard, it is recommended that the motor free end bearing be replaced due to the potential for vibration to cause further damage. For the motor drive end bearing, it is advised to operate the equipment only for a limited duration.

References.

[1] G. Senapaty and U. Sathish Rao, "Vibration based condition monitoring of rotating machinery," *MATEC Web Conf.*, vol. 144, p. 01021, 2018, doi: 10.1051/matecconf/201814401021.

[2] A. Arifin, "Vibration Analysis of Unbalance on Axial Fan Engine 5.5 KW," *Int. J. Adv. Eng. Res. Sci.*, vol. 5, no. 9, pp. 273–280, 2018, doi: 10.22161/ijaers.5.9.31.

[3] K. N. EDE, E. A. OGBONNAYA, M. T. LILLY, S. O. T. OGAJI, and S. D. PROBERT, "Vibration Monitoring of Rotating Systems," *Engineering*, vol. 02, no. 01, pp. 46–54, 2010, doi: 10.4236/eng.2010.21006.

[4] N. Tenali, D. P. R. Babu, and K. C. K. Kumar, "Vibrational Analysis in Condition Monitoring and faults Diagnosis of Rotating Shaft - Over View," *Int. J. Adv. Eng. Res. Sci.*, vol. 4, no. 1, pp. 216–220, 2017, doi: 10.22161/ijaers.4.1.35.

[5] N. Carnegie *et al.*, "Analisa Level Getaran Cooling Water Pump 1," pp. 25–32.

[6] J. Noe and R. McKeirnan Jr., "Gas Turbine Generator Set," vol. 960, no. 4, pp. 3–4, 1996.

[7] D. Romahadi, H. Xiong, and H. Pranoto, "Intelligent system for gearbox fault detection & diagnosis based on vibration analysis using Bayesian Networks," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 694, p. 12001, 2019, doi: 10.1088/1757-899X/694/1/012001.

[8] Y. Yasir, A. Alimin, and S. Ramasih, "IDENTIFICATION OF INDUCED DRAFT FAN (IDF) DAMAGE IN BOILER WASTE GAS SYSTEM," *VANOS J. Mech. Eng. Educ.*, vol. 4, 2019, doi: 10.30870/vanos.v4i1.6111.

[9] M. H. Mohd Ghazali and W. Rahiman, "Vibration Analysis for Machine Monitoring and Diagnosis: A Systematic Review," *Shock Vib.*, vol. 2021, 2021, doi: 10.1155/2021/9469318.

[10] K. Kamaras, A. Garantziotis, and I. Dimitrakopoulos, "Vibration Analysis of Rolling Element Bearings (Air Conditioning Motor Case Study)," no. 1986, 2017, [Online]. Available: https://fnt.com.cy/images/Rolling Element Bearings Vibration Analysis.pdf.

[11] D. Galar, A. Parida, A. Gustafson, and L. Berges, "Use of Vibration Monitoring and Analysis as KPIs in Paper Industry," *Comadem2011*, no. May, pp. 135–147, 2011, [Online]. Available: https://www.researchgate.net/publication/260341611_Use_of_Vibration_Monitoring_and_Analysis_as_KPIs_in_Paper_Industry.

[12] A. Akbar, D. W. Karmiadji, P. Studi, M. Teknik, and U. Pancasila, "Analisis Getaran Pengaruh Variabel Misalignment," *Teknobiz J. Ilm. Progr. Stud. Magister Tek. Mesin*, vol. 11, no. 3, pp. 141–150, 2021, [Online]. Available: http://journal.univpancasila.ac.id/index.php/teknobiz/article/view/2901.

[13] I. M. Mara, A. D. Catur, and A. A. Zulkarnaen, "Analisa Vibrasi untuk Mengindikasikan Kerusakan Bantalan Motor Induksi Seri 6857AA5 pada Pompa 62PU003 di PT Amman Mineral Nusa Tenggara," *Din. Tek. Mesin*, pp. 1–8, 2018.

[14] S. B. Chaudhury, M. Sengupta, and K. Mukherjee, "Vibration Monitoring of Rotating Machines Using MEMS Accelerometer," *Int. J. Sci. Eng. Res. ISSN (Online*, vol. 2, no. 9, pp. 2347–3878, 2014.

[15] M. J. E. Salami, A. Gani, and T. Pervez, "Machine condition monitoring and fault diagnosis using spectral analysis techniques," *First Int. Conf. Mechatronics*, pp. 690–700, 2001.

[16] H. Novianto and Sujono, "Vibration Analysis of Fire Pump of PEM Akamigas Cepu: A Case Study," *J. Renew. Energy Mech.*, vol. 6, no. 02, pp. 54–62, 2023, doi: 10.25299/rem.2023.vol6.no02.11972.