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Investigation of Pump and Motor Healthiness Based on Vibration Analysis at UTHM Biodiesel Plant

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Abstract

Vibration is an unavoidable phenomenon in the operation of pump and motor. Vibration can occur due to imbalance, misalignment, wear, and looseness. The machine collapse may result in costly downtime. However, predicting and monitoring machine health and condition remains a challenge. Hence, an efficient diagnosis system is needed to predict the condition and consistent lead time of the machine. This study is to measure the vibration of several centrifugal pumps and motor available at UTHM Biodiesel Plant and monitor the centrifugal pump and motor health based on the vibration data. The centrifugal pumps are divided into 2 parts which are pump and motor where both consists inboard and outboard point. The measurement was conducted at three points which are horizontal, vertical, and axial. The recorded data was then analyzed and evaluated referring to ISO 10816-3. The results demonstrated that by carefully controlling the process parameters, it is possible to measure and analyze the vibration and monitor the pump and motor health based on the vibration data. It was essential to know the maximum frequency to avoid damage to the pump and motor. The findings of this study contribute to the industry which can help identify faults or detect warning signs of potential failures and give maintenance staff time to schedule required repairs and acquire needed parts.

1. Introduction

Rotating machinery is widely used in industry and is a critical machinery. The protection, consistency and effectiveness of rotating machinery are key apprehension in industries. Condition monitoring of a machines helps to retain the effectiveness and performance of a machine to its optimal level. The condition monitoring of a rotating machine is efficient, but often it is difficult and labor-intensive task for maintenance crew to troubleshoot the machine. To detect an abnormal condition, vibration information is widely used, since vibration signals contain the dynamic characteristics of the machine condition and therefore early detection of incipient failure can be easily detected [1].

Numerous vibration analysis methods have been used to diagnose the rotating machines' faults. It is necessary for the overall health of a machine. Because of tiny, insignificant flaws, machines will vibrate occasionally even under ideal operating conditions. Every machine has a vibration level that can be considered typical. But occasionally, the machine's vibration level goes up or gets too high. The sources of vibration in centrifugal

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pumps can be categorized into three types which are mechanical causes, hydraulic causes, and peripheral causes [2]. Some mechanical trouble is usually the reason. The reasons behind the excessive vibration include unbalance, misalignment, worn gears or bearings, looseness, and others. Once a failure has been detected, the maintenance engineer is to identify the symptoms, analyze the symptomatic information, interpret the various error messages and indications, and come up with the right diagnosis of the situation in terms of which components may have caused the fault and the reasons for the failure of the components [3].

1.1 Objective

This study aims to measure the vibration of several pumps and motors at UTHM Biodiesel Plant. The primary objectives include the measurement of vibrations in these essential components. Additionally, the research seeks to perform the monitoring and prediction of the pump and motor health based on the vibration data. Through this comprehensive approach, the study aims to enhance the understanding and proactive management of the machinery, ensuring optimal performance and longevity in the UTHM Biodiesel Plant.

1.2 Problem Statement

Rotating machinery is a critical machinery in plant operation. Failure may occur and lots of possible failures when dealing with rotating equipment. Hence, it is crucial to detect early for every failure that may happen. Vibration analysis is one of the powerful techniques to determine the failure. Correction may be performed before failure happens to increase plant reliability. This study is conducted to proof and predict few pumps condition that are mostly used in UTHM Biodiesel Plant.

1.3 Scope

This study focuses on specific scopes, primarily centered around the assessment of horizontal pumps, including the Cooling Tower Pump (CTP), P202, and P219, within the designated context. Vibration data is systematically collected at the bearings of both the pump and motor, covering both inboard and outboard positions. For each bearing point, comprehensive data is gathered at horizontal, vertical, and axial positions, providing a thorough understanding of the vibration dynamics. The data collection process utilizes a vibration analyzer, a tool employed to gather precise and detailed vibration data. The evaluation of this data is conducted in accordance with the ISO 10816-3 standard, ensuring a standardized and reliable assessment of the pump and motor conditions in alignment with established industry benchmarks.

1.4 Significance of Study

This research will provide efficient approach in predicting machine health and safety. Through this research, the industry will further realize conducting vibration analysis as a preventive measure against machine failure. In particular, the industry will gain more from this research. One of the most significant and useful techniques for determining the condition of machinery is analysis. Vibration data can be used to find errors or early warning indicators of impending malfunctions. Additionally, it can help find assets that are out of balance or misaligned, including rotating machinery and bearings. Vibration data can also be used to identify high and harmful vibration levels. Teams can identify equipment imbalance, looseness, misalignment, or bearing wear before it fails by analyzing vibration measurement data. In addition, the results shown by this study will provide important information about vibration analysis to the future researcher.

2. Material and Method

2.1 Model of Centrifugal Pump

For this investigation, three mostly operated centrifugal pumps have been selected which are Cooling Tower Pump (CTP), P219 and P202.

2.1.1 Cooling Tower Pump (CTP)

The main function of Cooling Tower Pump is to transfer water from water storage tank to the cooling tower. Figure 1 below shows the side view of Cooling Tower Pump (CTP).

Fig. 1 *Side view of Cooling Tower Pump (CTP)*

2.1.2 P219

The main function of P219 is to transfer liquid from T209 to VE201 or VE203. Figure 2 below shows the side view of P219.

Fig. 2 *Side view of P219*

2.1.3 P202

The main function of P202 is to transfer liquid from VE202 to VE203. Figure 3 below shows the side view of P202.

Fig. 3 *Side view of P202*

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2.2 Method

Prior to carrying out the work, a flowchart should be produced as a guide or work step to do during this experiment. The flowchart is shown in Figure 4. The flowchart is to make sure the experiment can be done as planned.

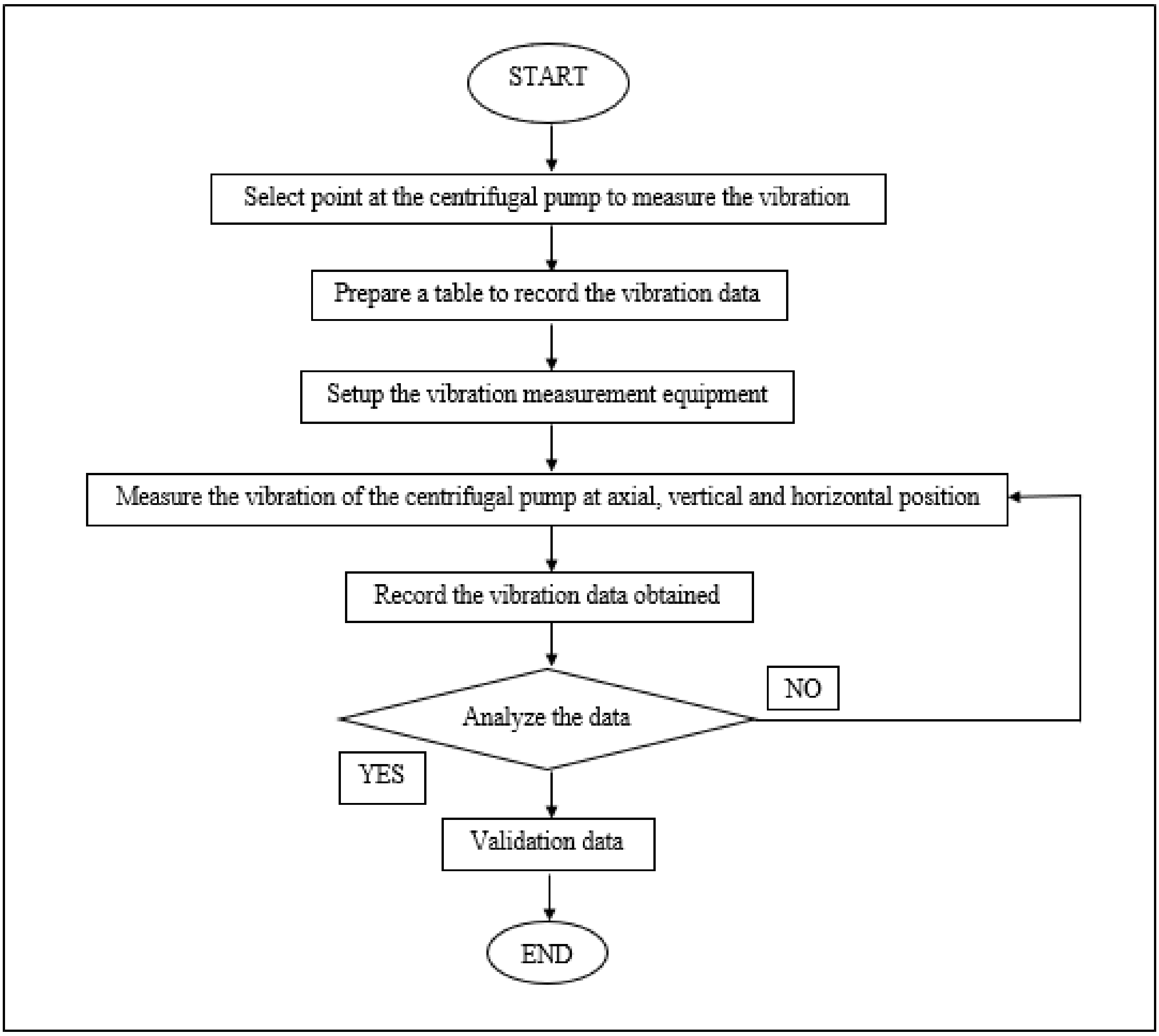
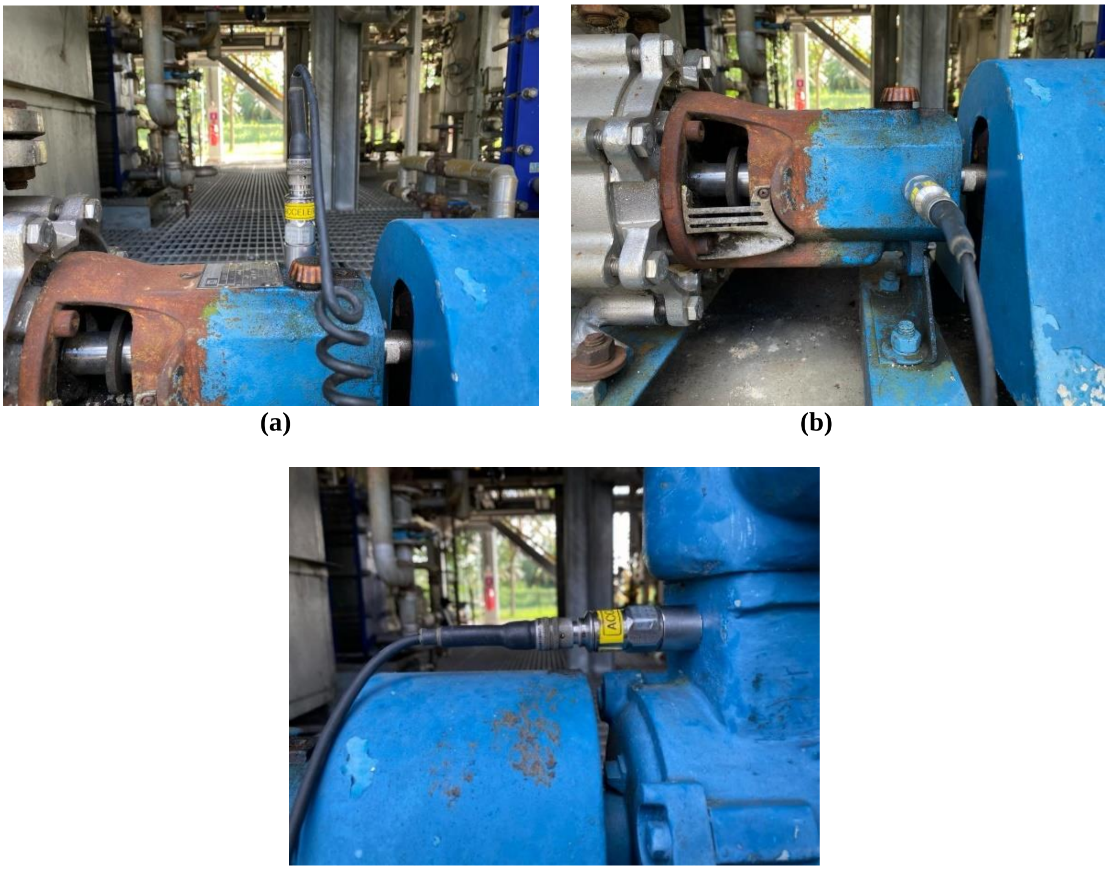


Fig. 4 *Experiment Flowchart*

2.3 Measurement of Vibration

The twelve points are chosen for vibration measurement at the centrifugal pump. The reading was measured in the vertical, horizontal, and axial position as shown in Figure 5 for both pump and motor. The equipment used for measuring the vibration on the centrifugal pump is the vibration analyzer as shown in Figure 6 below. The collected data is then analyzed referred to ISO 10816-3.



(a) (b)

(c)

Fig. 5 *Measurement position (a) Vertical position (b) Horizontal position (c) Axial position*

Fig. 6 *Vibration Analyzer*

2.4 Data Analysis

Table 1 below is the standard aims to classify the machine state in four different classes by means of vibration data for acceptance measurements and operational monitoring.

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Table 1 *Vibration Severity Chart ISO 10816 – 3*

ISO 10816 – 3		Machinery Groups 2 and 4		Machinery Groups 1 and 3	
Velocity		Rated Power			
CMVP 40 in/sec eq. Peak	CMVP 50 mm/sec RMS	15 kW – 300 kW		Group 1: 300 kW – 50MW Group 3: Above 15 kW	
0.61	11.0		DAMAGE OCCURS		
0.39	7.1				
0.25	4.5		RESTRICTED OPERATION		
0.19	3.5		UNRESTRICTED OPERATION		
0.16	2.8				
0.13	2.3				
0.08	1.4				
0.04	0.7	NEWLY COMMISSIONED MACHINERY			
0.00	0.0				
Foundation		Rigid	Flexible	Rigid	Flexible

Table 1 above shows the vibration severity chart ISO 10816 -3. The acceptable vibration levels for pumps and motors are set at below 0.16 in/sec (pk) or 2.8 mm/sec (rms). Under specific scenarios, different vibration expectations are outlined. In the case of newly commissioned machinery, which is assumed to be a brand-new, wear-free pump and motor operating under optimal conditions, an overall vibration level of 1.4 mm/sec (rms) or less, equivalent to 0.08 in/sec (pk), is deemed reasonable. For machinery in unrestricted operation, implying usage after initial installation, vibrations below 0.16 in/sec (pk) or 2.8 mm/sec (rms) are considered acceptable. In instances of restricted operation, where the motor or pump experiences vibrations ranging from 0.16 to 0.25 in/sec (pk) or 2.8 to 4.5 mm/sec (rms), potential imbalance or misalignment issues may be present, indicating the need for planned maintenance to mitigate vibration. When damage occurs and vibration levels surpass 0.25 in/sec (pk) or 4.5 mm/sec (rms), there is an elevated risk of harm to machine parts, including bearings. In such cases, immediate removal from service is recommended, accompanied by prompt corrective measures to reduce vibration, and prevent further damage.

3. Result & Discussion

3.1 Cooling Tower Pump (CTP)

As seen in Table 2, the velocity of vibration for horizontal, vertical, and axial points has different values for each measurement point. From the results obtained, the data collected from the vibration analyzer shows that the vibration for Cooling Tower Pump (CTP) for both pump and motor are higher at the horizontal and vertical part which exceed 2.8 mm/sec (rms) as shown in Figure 7 and Figure 8 below. During the experiment, this pump produced greater noise and vibration compared to P219 and P202. The pump may have a center-hung or an overhung impeller. If the impeller is center-hung, force unbalance often predominates over couple unbalance. In this case, highest vibration will typically be in the radial (horizontal and vertical) direction. Excessive vibration on the horizontal side of a centrifugal pump can be indicative of several potential issues, and it's essential to diagnose and address them promptly to prevent damage and ensure the pump's reliability. A larger pump with a higher motor power does not necessarily result in higher vibration levels by itself. Vibration levels in a centrifugal pump are influenced by various factors, and while the pump's size and motor power can play a role, they are not the sole determinants of vibration.

Table 2 *Average Vibration at Cooling Tower Pump (CTP)*

Point	Parameter Name	Variable Value	Unit or Dimension
1	Horizontal	7.46	mm/s
2	Vertical	3.18	mm/s
3	Axial	2.35	mm/s
4	Horizontal	4.97	mm/s
5	Vertical	2.06	mm/s
6	Axial	2.22	mm/s
7	Horizontal	11.92	mm/s
8	Vertical	5.64	mm/s
9	Axial	2.60	mm/s
10	Horizontal	12.23	mm/s
11	Vertical	3.30	mm/s
12	Axial	2.51	mm/s

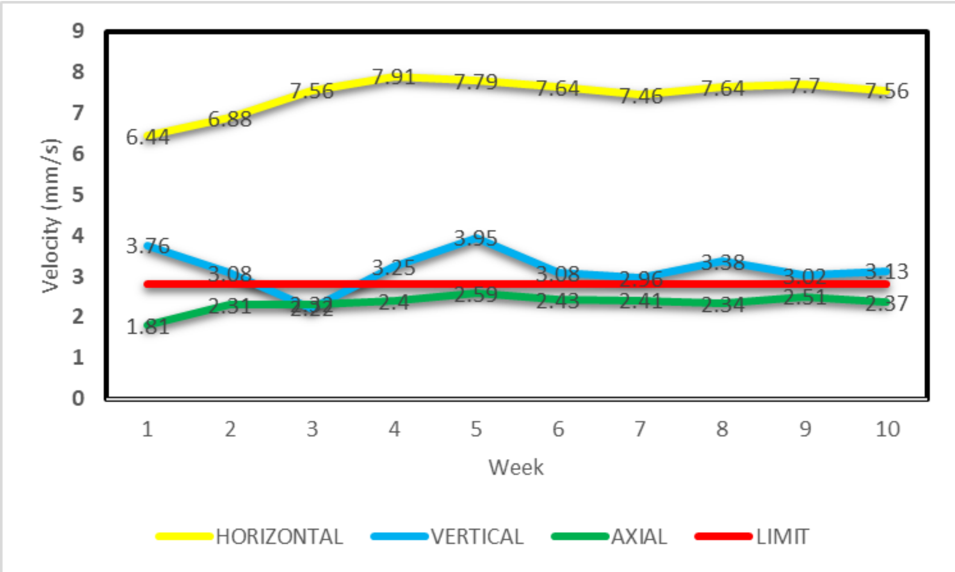

Fig. 7 *Pump (inboard) line graph*

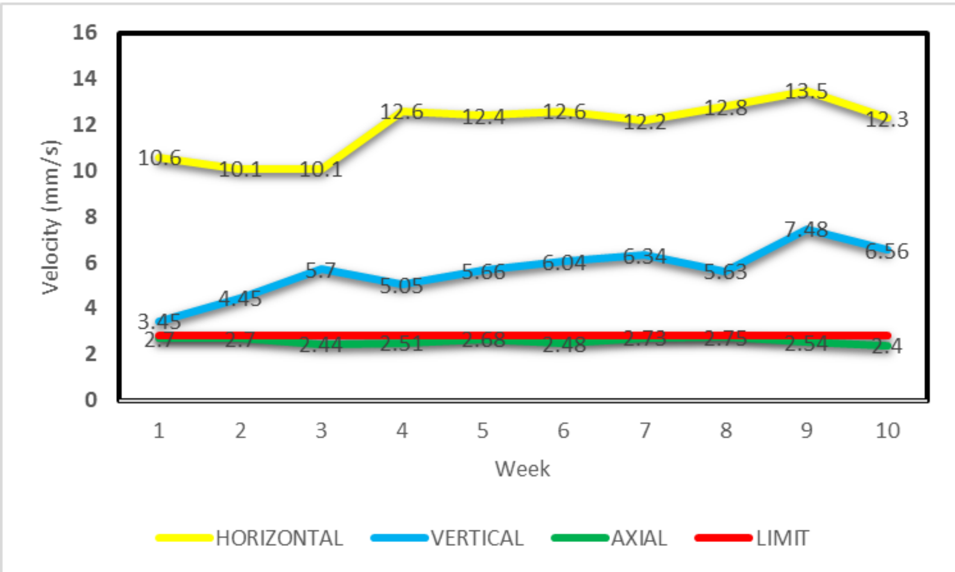

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Fig. 8 *Motor (inboard) line graph*

3.2 P219

For centrifugal pump P219, this pump shows lower vibration at motor side which below 2.8 mm/sec (rms) meanwhile at the pump side shows that the vibration exceeds 2.8 mm/sec (rms) at some week. During the experiment, this centrifugal pump produces greater noise compared to centrifugal pump P202. From Figure 9 and Figure 10 below, it shows that the vibration is inconsistent. If equipment is not precisely aligned and calibrated, internal fluids can cause specific types of vibrations. Such vibrations may be inconsistent and typically occur at an irregular frequency relative to rotor speed. Inconsistent vibration levels in a centrifugal pump from week to week can be attributed to various factors and conditions that change over time. The pump may be subjected to varying operating conditions such as changes in flow rate, pressure, and temperature. Different operating conditions can lead to changes in vibration levels. For example, increased flow rates can lead to higher vibrations due to increased hydraulic forces. The load on the pump may vary from week to week. Factors like changes in demand for the fluid being pumped or variations in the process being served can affect the pump's load and subsequently its vibration levels. The pump and its supporting structure may have specific resonant frequencies. If the operating conditions, such as speed or flow rate, coincide with these resonant frequencies, vibration levels can increase. This resonance effect may not occur consistently week after week. Environmental conditions, such as temperature and humidity, can affect the pump's behavior and vibration. For example, temperature changes can cause thermal expansion or contraction of components, which may influence vibration levels. Even though the average vibration as shown in Table 3 below is mostly under restricted operation, the pump still needs to be scheduled for maintenance since some reading at certain week above the acceptance limit.

Table 3 *Average Vibration at P219*

Point	Parameter Name	Variable Value	Unit or Dimension
1	Horizontal	2.60	mm/s
2	Vertical	2.91	mm/s
3	Axial	1.03	mm/s
4	Horizontal	2.59	mm/s
5	Vertical	2.19	mm/s
6	Axial	1.10	mm/s
7	Horizontal	1.99	mm/s
8	Vertical	1.83	mm/s
9	Axial	1.75	mm/s
10	Horizontal	1.51	mm/s
11	Vertical	0.985	mm/s
12	Axial	1.89	mm/s

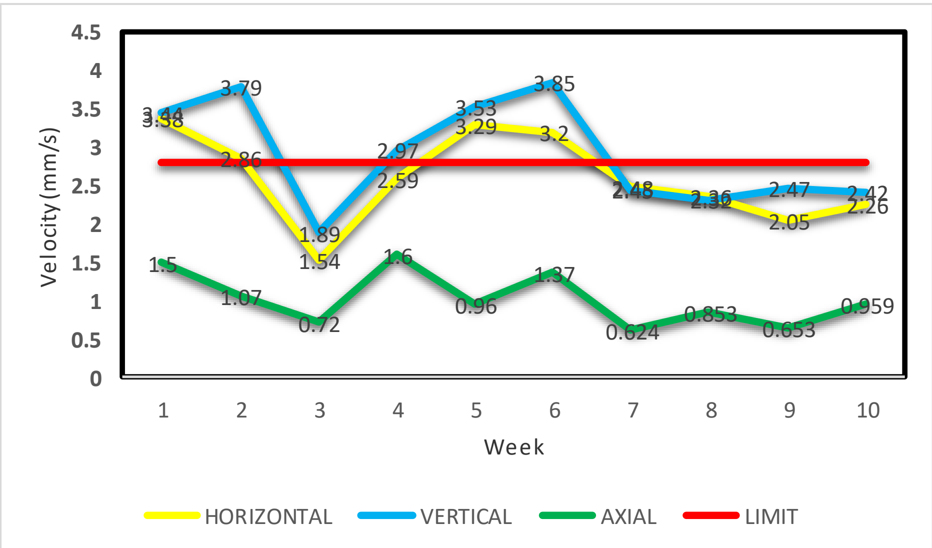

Fig. 9 *Pump (inboard) line graph*

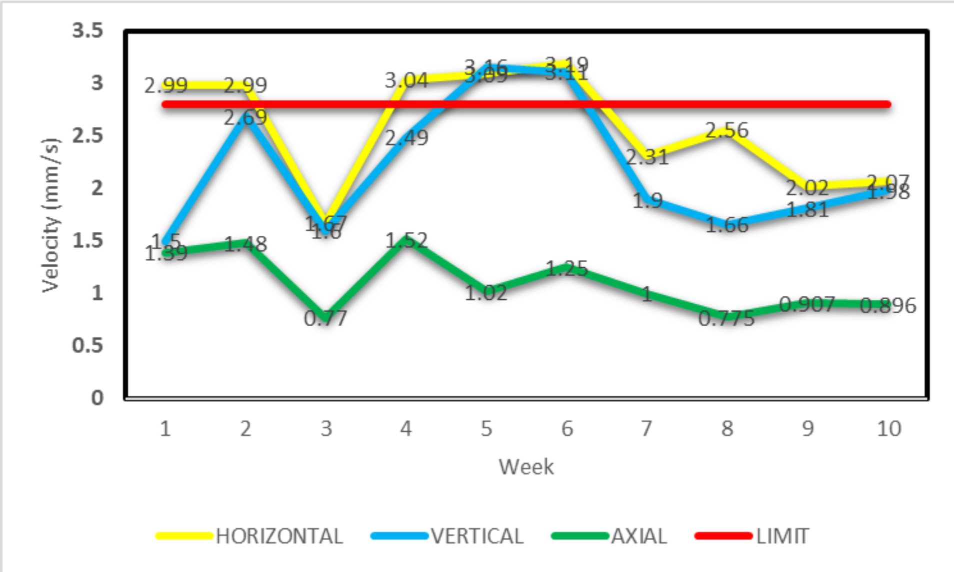

Fig. 10 *Pump (outboard) line graph*

3.3 P202

For P202, from Table 4 below, the average vibration show that the vibration is below the restricted operation which is 2.8 mm/sec (rms). During the operation, this pump produces less noise and almost zero vibration which indicates that the pump is in good condition. The pump operates smoothly without excessive vibrations, noise, or cavitation. The pump delivers a consistent and stable flow rate and pressure to meet the system requirements. From Figure 11 and Figure 12 below, the vibration measured at pump (inboard) and motor (inboard) are all below the restricted operation.

Table 4 *Average Vibration at P202*

Point	Parameter Name	Variable Value	Unit or Dimension
1	Horizontal	1.11	mm/s
2	Vertical	1.47	mm/s
3	Axial	0.637	mm/s
4	Horizontal	1.03	mm/s
5	Vertical	1.16	mm/s
6	Axial	0.85	mm/s
7	Horizontal	1.62	mm/s
8	Vertical	0.314	mm/s
9	Axial	1.49	mm/s
10	Horizontal	1.48	mm/s
11	Vertical	0.429	mm/s
12	Axial	1.52	mm/s

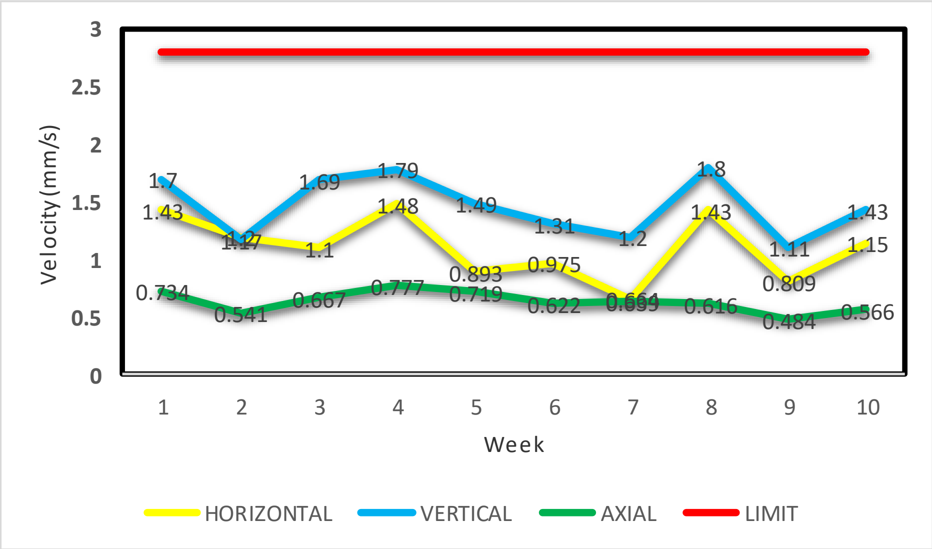

Fig. 11 *Pump (inboard) line graph*

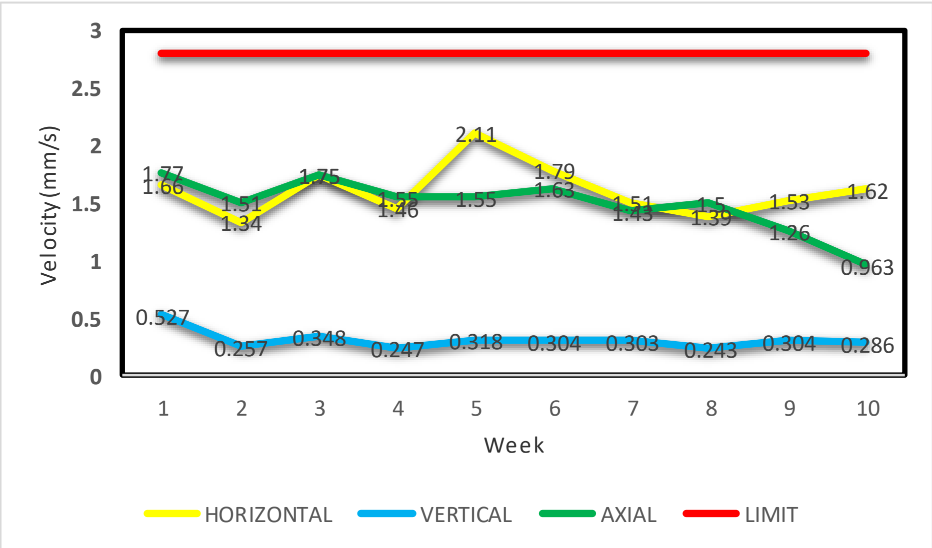

Fig. 12 *Motor (inboard) line graph*

4. Conclusion

From the vibration data obtained, the condition for both pump and motor were identified. Centrifugal pump P202 shows that both pump and motor operate in good condition where all the vibration level collected shows it below the restricted operation (2.8 mm/s). Meanwhile for centrifugal pump P219, the overall average shows that both pump and motor are in good condition but however, the centrifugal pump should be scheduled for maintenance since some reading recorded at certain week are above the restricted operation for example the vibration at horizontal position for the pump (inboard) for week 5 and 6 which both recorded 3.29 mm/s and 3.20 mm/s respectively. For the centrifugal pump at cooling tower, all the average vibration for each point indicated that the pump should be taken out of service as soon as possible, and corrective actions taken to reduce the vibration.

From the experiment conducted, the measuring data was recorded for horizontal, vertical, and axial direction. The horizontal and vertical direction measurement shows a higher vibration compared to the axial direction. In short, the objectives of these studies have been achieved since all the data were collected successfully and thus determined the condition for the centrifugal pump.

As for recommendation, the next researcher can utilize trend analysis tools to track vibration levels over time. Sudden increases in vibration may indicate a problem, while gradual changes may suggest wear or deterioration. Other than that, the next researcher must have experienced personnel or vibration analysts to interpret the data. Interpretation requires expertise to distinguish between normal variations and potential issues accurately. Eventually, the next researcher can conduct a calculation if possible and compare with the vibration data obtained to guarantee the accuracy of the outcome.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** Rafie Bahrin, Norrizal Mustaffa***; data collection****:* Rafie Bahrin***; analysis and interpretation of results:*** Norrizal Mustaffa***; draft manuscript preparation:*** Norrizal Mustaffa*. All authors reviewed the results and approved the final version of the manuscript.*

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