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Vibration Analysis for Condition Monitoring in the Oil Industry: A Case Study

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Abstract

Condition monitoring in the oil industry, especially in harsh environments, often requires robust and reliable techniques. Predictive maintenance (PdM) involves monitoring machine performance by tracking changes in key indicators such as temperature, noise intensity, and vibration levels using specialized equipment. Since the change in some of the indicators is a reflection of the condition shall be deemed aware of the vibration is one of the indicators upon which to build predictive maintenance. Pumps are essential assets in most industrial applications. Historically, maintenance strategies have evolved from reactive (breakdown) maintenance to preventive and, more recently, proactive maintenance, and proactive maintenance. In order to prevent damage and maintain pumps, it is necessary to adopt an suitable system to detect failures before occur. This research demonstrates, through case studies from the Mellitah Complex in Libya, that vibration analysis successfully identified specific faults-including bearing defects, rotor unbalance, and soft foot-enabling timely correct maintenance and preventing costly downtime. This research

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validated the application of vibration-based condition monitoring for critical rotating equipment at the Mellitah Gas Complex.
Keyword: Condition monitoring, Vibration technique, Oil and gas industry, Harsh environment.

تحليل الاهتزازات لمراقبة حالة المعدات في الصناعات النفطية: (دراسة حالة)

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الملخص

غالبًا ما تتطلب مراقبة حالة مغذات الصناعات النفطية وخاصةً في البيئات القاسية، تقنياتٍ قوية وموثوقة. تتضمن الصيانة التنبؤية ومراقبة أداء الآلات من خلال تتبع التغيرات في المؤشرات الرئيسية، مثل درجة الحرارة، وشدة الضوضاء، ومستويات الاهتزاز، باستخدام معدات متخصصة. ونظرًا لأن التغير في بعض المؤشرات يعكس حالة الحقول، فإن الوعي بالاهتزاز يُعد أحد المؤشرات التي تُبنى عليها الصيانة التنبؤية. المضخات هي اداء أساسية في معظم التطبيقات الصناعية. تاريخيًا، تطورت استراتيجيات الصيانة من الصيانة التفاعلية (الأعطال) إلى الصيانة الوقائية، ومؤخرًا، الصيانة الاستباقية، الصيانة الوقائية والصيانة الاستباقية من أجل منع الضرر وصيانة المضخات، من الضروري اعتماد نظام مثالي للكشف عن الأعطال قبل حدوثها. في هذا البحث من خلال دراسة الحالة من مجمع مليتة في ليبيا تبين أن تحليل الاهتزاز حدد بنجاح أعطالًا محددة، بما في ذلك عيوب التحميل وعدم توازن الدوار، مما يتيح الصيانة المعالجة في الوقت المناسب ومنع التوقف المٌكلف. تتضمن هذه الطريقة مراقبة اهتزازات المضخات وقدرتها على

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اكتشاف الأعطال قبل حدوثها. مجهزة بالأجهزة والمعدات اللازمة لتكون قادرة على العمل بشكل فعال. كعينات، تم اختيار مجموعة من المضخات ونافخات الهواء لإجراء الاختبارات عليها بهذه الطريقة لمراقبة طبيعة الاهتزاز.
الكلمات الرئيسية: مراقبة الحالة، تقنية الاهتزاز، الصناعات النفطية، البيئة القاسية.

1. Introduction

Maintenance is the routine and required process for keeping a particular machine or asset in its normal operating condition, so that it can deliver its expected performance or service without causing any loss of time, accidental damage or breakdown. companies in all areas of industry, maintenance strategies play a vital-role - looking after assets and keeping track of equipment in order to secure productivity. Without an effective maintenance strategy, a company will lose significant amounts of money due to lost production capacity, the cost of keeping spare parts, quality deficiencies and damages for absent or late deliveries [1].

1.1 Maintenance management of Oil & Gas Industry

A harsh environment in the oil and gas context is characterized by extreme conditions such as high temperature, pressure, and chemically active substances that accelerate equipment degradation. Depending on the nature of application sometimes multi extharshreme conditions coexist and make the situations more challenging. For nuclear applications, high-temperature exists with the high radiation condition [2]. And for oil and gas applications high temperature conditions exist with the chemically active environment [3].

Some industries have recently started to apply a new maintenance approach called ‘condition-based maintenance’ (CBM). The idea of this approach is based on the acquisition, processing and analysis of machine parameters. These parameters, include vibration, acoustics, and speed, provide valuable information about the machine’s condition which can be used to assess the condition of the machine and help for planning the scheduling of maintenance work. Oil and gas applications include high-temperature and chemically active environment conditions. Due to the harsh environment and the importance of the pumps, they are the most suitable candidates for

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condition monitoring. Multiple sensors are used to monitor various parameters like temperature, vibration and pressure. With this strategy, preventive maintenance (PM) is carried out based on knowledge of the condition of a machine or process instead of a predetermined plan or schedule. Ideally, this maintenance is able to exploit the maximum running time of a machine or process and yet keep the maintenance cost to a minimum. The key to condition based maintenance is knowledge of the condition of the machine, this can be obtained by employing various monitoring techniques that constitute the so-called condition monitoring.

1.2 Vibration Method Review

Researches on feature extraction methods from vibration signals used for rotating machines condition monitoring were reviewed in [4]. A condition monitoring strategy for pumps in the Oil and Gas Industry was proposed in [5], this strategy based on the standard pressure monitoring data gathered from pumps. An extreme environment [6,7], and a hostile environment. Working environment with extreme conditions like pressure, temperature, and humidity was described in [8, 9]. The review of the literature indicates this environment definition is dominated by high-temperature conditions [10, 11]. There are other parameters, which contribute to the definition of a harsh environment like high radiations [12,13,14,15], low temperature, high humidity, intense vibrations and high pressure [9]. In addition to the condition which is significant corrosion-related degradation due to a chemically active environment such as high salinity [6].

In typical plant, available systems are capable of routine monitoring, trending, and mechanical condition evaluation of all mechanical equipment. This type of program can be used to schedule maintenance (SM) on all rotating as pumps and reciprocating and most continuous process mechanical equipment. The direct correlation between the mechanical condition and recorded vibration data of each machine in the plant can be provided by monitoring the vibration from plant machinery. Using vibration monitoring techniques, the mechanical condition degradation of within plant machinery can be detected. Used properly, vibration

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analysis can identify the failure mode of plant machinery before serious damage occurs [16].

2. Rotating Machines monitoring

Rotating machines are commonly used in the majority of industrial processing facilities, including oil and gas facilities. Condition monitoring of these systems, particularly vibration monitoring, helps prevent losses caused by unbalanced forces, misalignment, and improper lubrication of ball bearings, metal fatigue and cracks occurring in welded or constructed parts, and/or locking of the ball bearings due to excessive heating [17]. Ebersbach and Peng [18] explore the use of expert systems with vibration analysis to help prevent these losses; while Saxena and Saad [19] have developed an artificial neural network classifier for rotating machines condition monitoring.
Every industrial process that underpins our modern civilization requires the transfer of liquids from one pressure level to another and from one place to another. Pumps are, therefore, an essential part of all industrial processes and as such, an integral part of all modern economic and social developments [20]. Due to their simplicity and ability to generate relatively high-pressure ratio in a short axial distance, Centrifugal pumps compared to axial compressors are commonly used This applies to a large number of applications and services including electric power plants, water supply plants oil refineries, chemical plants, food processing and hydraulic power services [21, 22].
Pumps are classified into two primary categories: displacement and kinetic (dynamic) energy. For particular services, these two groups are further split into smaller groups [23]. By adding energy to the liquid, both kinds of pumps can move it through a pipeline and raise the pressure. A centrifugal pump one of the kinetic energy pumps is composed of two main parts: motor and pump. motor faults, they may occur in the stator, rotor shaft. In case of pump faults, originate in the impeller, casing, seal, shaft or bearing. All faults relating to the pump components are considered as mechanical faults. Mechanical faults may cause physical damage to pump components. Adapting a system for monitoring can significantly improve the financial output of a plant. Generally, there are two ways of monitoring a centrifugal pump: (1) performance monitoring and (2)

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condition monitoring [24, 25]. Depending on the parameters that may be used for the pump monitoring, these two methods can be further classified. Concerning condition and performance monitoring, it should be understood that it is not a question of choosing one or the other. Often, both methods can be found in the same plant and are very complementary.

3. Research objective

One important method for securing productivity and lowering production costs is to have an affective maintenance strategy.

- The basic goal of this investigation is analyzing the vibration condition of pumps, blowers and fans which used for transportation of a Gas industry (Mellitah Complex - Libya).
- This work outlines the procedure for early detection the rolling bearings failure using vibrating signature.

4. Predictive maintenance program

Condition monitoring is one type of condition-based maintenance; based on collecting, processing and analyzing data from the monitored machine in order to determine the actual operating condition of a system or component at any instant. A data-informed decision on whether to repair or replace a component is then made. This approach is feasible due to the significant developments achieved in data acquisition, sensors, signal processing techniques.
A vibration predictive maintenance program consists of three logical steps: Detection, Analysis and Correction. The first step of the program, detection, simply involves measuring vibration data at certain locations on each machine included in the program on orderly scheduled basis. Normally, machines are checked on a monthly basis. However, more critical machines may be checked more frequently or, continually with permanently installed on-line vibration monitoring systems.
To take a measurement of a machine's vibration level, a simple hand-held vibration meter can be used. The instrument includes a transducer that is held or attached to the bearing cap of the machine. The transducer converts the machine vibration into an equivalent electrical signal that read on the meter as a vibration level. Ordinary vibration reading data taken with this instruments can be logged on a data sheet. This sheet includes a drawing of the machine to help the vibration technician identify measurement locations and

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positions. The form also includes provisions for recording the data in both tabular form as well as graphic trends to provide a clear history of the machine's condition.
Once the collected data has been downloaded to PC, reports can be generated to reveal those machines that have experienced a significant increase in vibration, indicating problems. The generated report identifies the specific machines, measurement points, vibration levels, alarm levels and percentage change from the last reading for those machines with developing problems.

Once machinery problems have been detected, the next step is to identify the specific problem for scheduled correction. The aim of vibration analysis is to identify particular issues with machinery by revealing their unique vibration characteristics. Finally, once problems have been detected and identified, required corrections can be scheduled for a convenient time.

4.1 Vibration Measurement procedure

As illustrated in Fig (1), Vibration measurements should be taken at the inboard and outboard bearings of a pump and motor in axial, horizontal, and vertical directions [26]. In case a more intensive analysis is required, measurements also should be taken at multiple points on the pump base as shown in Fig (2). Electronic probes or sensors can be affixed at these specific locations to transmit electronic signals to a vibration analyzer. Measurements should be taken at operating speed for constant-speed motors and at varying speeds for pumps operating on variable speed drives [27].

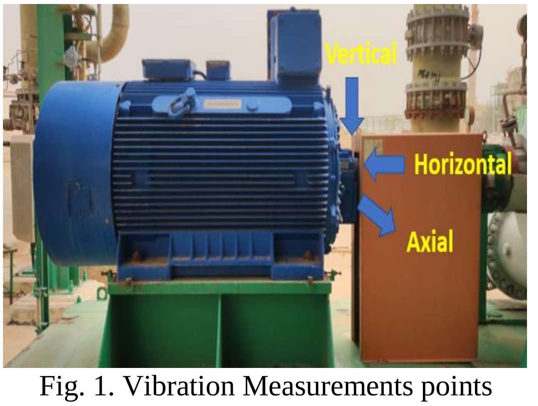

Fig. 1. Vibration Measurements points

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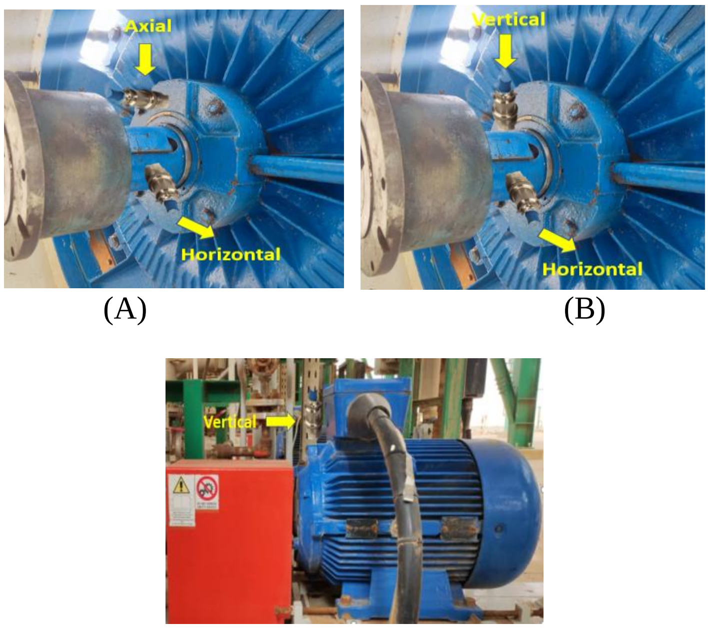

(A) (B)

(C)

Fig. 2. A. axial and Vertical Measurements. B. Horizontal and Vertical. C. Vertical on a Motor's inboard bearing

Causes of vibrations include imbalance, a soft foot, and a bent shaft. Mechanical looseness, misalignment, and resonance can generate vibrations at frequencies multiples of rpm. Case study 2 will later demonstrate a classic case of imbalance Failing bearings typically produce non-integer multiples of pump speed. Hydraulic oscillations show frequencies that are a product of the number of impeller vanes multiplied by rpm [4].

4.1.1 Case studies

The following cases study provides an example of how comparative analysis was successfully used in Mellitah Gas complex. Baseline testing for machines involves establishing initial performance measurements which can be used as reference point when a machine is installed. Measurements include flow rate, pressure, power consumption, and vibration levels. The Purpose of baseline data helps detect deviations from normal operation. These values represent the starting point for future comparisons Enabling predictive maintenance by tracking performance trends.

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5. Case studies description:

5.1. Project overview

In this work, the Mellitah (Mellitah Complex, Libya) oil & Gas station is used as an example of practical application. The Gas Complex located in western Libya is a collaborative effort between the National Oil Corporation (NOC) of Libya and a leading IOC (Independent Oil Company). The complex is located in west Libya and comprises an onshore gas facility, offshore structures, a gas compressor station, and pipelines that transport crude oil and gas. Similarly to other state-of-the-art oil and gas complexes around the world, the Gas Complex makes use of condition monitoring in order to ascertain that it is running at optimized performance.

5.2. Condition Monitoring Systems

The Gas Complex has successfully integrated condition monitoring systems to guarantee the safety and effectiveness of its operations. The integrated systems are capable of identifying faults and predict equipment malfunctions in advance, preventing any potential failures. In employing condition monitoring, the complex has made use of both its in-house staff as well as external companies, with the international contractor being known to supply the complex with predictive and preventive execution, for example. Condition monitoring systems that are used in the oil and gas industry and within the complex in this regard include vibration analysis, thermal imaging, and oil analysis.

5.3. Equipment used

The standard version of Movipack includes two laser-sighting contactless sensors that allow, without any additional accessories, to complement data collections with temperature (Pyrometry) and rotation speed (Tachometry) measurements. Since they usually require handling external accessories, these supplementary measurements are frequently overlooked despite their ability to enhance understanding of the machines. As shown in Fig 3.

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Fig. 3. Movipack Ex

Experimental work:

In this work, data collected during scheduled predictive maintenance (CBM) as following:

1- Feeding Pump Discharging the Condensate (Water vapor liquid) from Tank to Boiler.

2- Feeding Pump discharging sea water (Sea Water Intake Pump from the sea up to the distillation units which is the main pump feeding all the plant with cooling water and boiler feed water (BFW) to all boilers.

3- Combustion Air Blower Feeding the Thermal Reactor with oxygen required to achieve the perfect ratio between which is controlled by air quantity given to the Reactor.

4- Combustion Air Fan feeding the thermal Incinerator with oxygen required to burn all the toxic sulfur compounds for environmental protection.

5- Feeding Pump Discharging Sea water (Sea Water Intake Pump) from the Sea up to the Distillation units which is the

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main Pump Feeding all the Plant with Cooling Water and Boiler feed water (BFW) to all Boilers.

6- Feeding Pump discharging sea water (Sea Water Intake Pump) from the sea up to the distillation units which is the main pump feeding all the plant with cooling water and boiler feed water (BFW) to all boilers.

Case Study 1:

In **Mellitah Gas complex** studying a pump discharging the condensate (Water Vapor Liquid) from tank to boiler. During periodic detection by prediction method, vibration level was abnormal.

On 07- 01- 2023, for schedule checking in monitoring, (mentioned above) data vibration signals of bearings were Measured, the data has been collected for analyzing; results were abnormal (High frequency vibration detected on the pump DE bearing). Trends and spectra in table 1 below show the value of vibration on different points of the Motor and pump as following:

TABLE 1. Value of vibration on different points of the Motor and Pump

Driven DEH	Ovrl:Vib.veloci ISO	6.65 mm\s
	Ovrl:Acc.20kHz@750-	4.41 g
	Bearing defect	6.97 DEF
DRIVEN NDE H	Ovrl:Acc.20kHz@750-	3.57 mm\s
	Bearing defect	6.21 DEF

Where: ISO is international organization for standardization, (Ovrl:Vib.veloci) is overall of vibration velicity, (Acc.20kHz@750-) is acceleration at 20 kHz (750Hz-20kHz) range, (DEH) is Driven End Horizontal and (NDE H) is Non driven end Horizontal.

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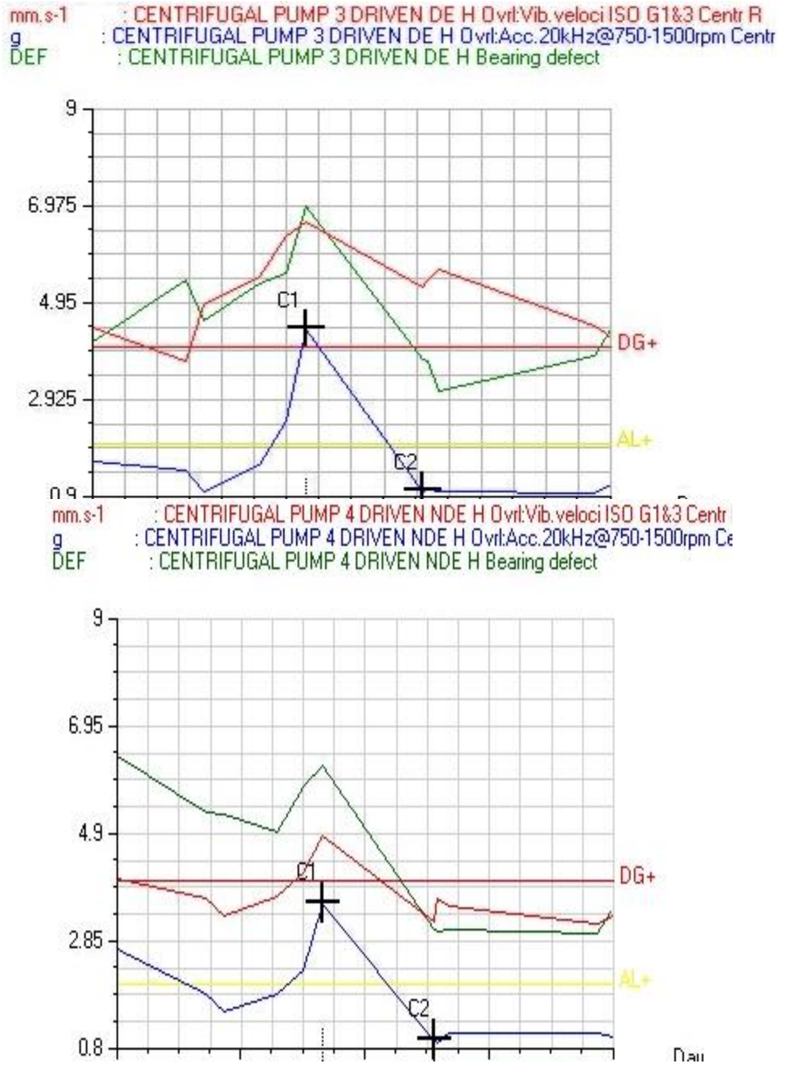

Fig. 4. Vibration values (Velocity, Acceleration and Bearing defect) the Pump DE&NDE

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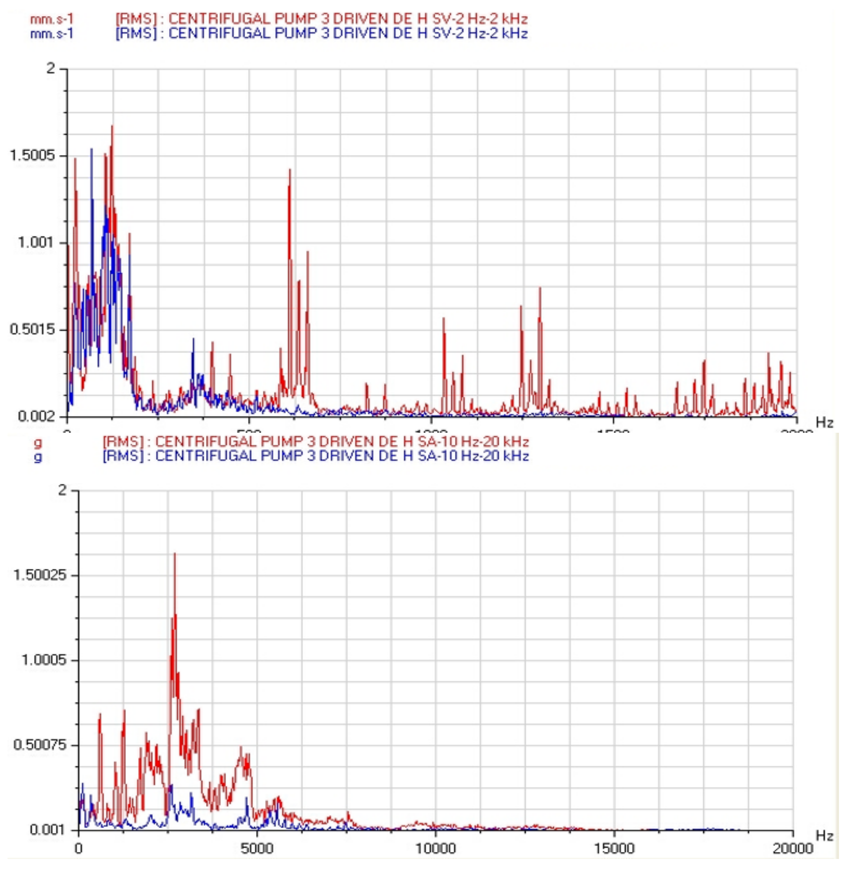

Fig. 5. Vibration amplitude, on the Pump drive end, frequency 0 to 2000Hz& 20000Hz.

Red line shows the values before changing the bearings and Blue one shows the values after changing the bearings.

The high-frequency acceleration and elevated 'Bearing defect' metric (6.97 DEF) are characteristic of failing rolling element bearings, often showing increased energy in specific frequency bands related to the bearing's fundamental train frequency (FTF) or ball pass frequency.

As illustrated in Fig (4, 5), Data of bearing showing that the main causes of vibration are defects in bearing. Reference to table 1, vibration level **before** Maintenance which depended for problem diagnosis. According to vibration diagnosis, it is obvious that the pump bearings are damaged. Decision taken that bearing of pump should be replaced.

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Maintenance Results:

In Next day (09-01-2023), defected bearing were replaced and then pump has operated. After the bearings were replaced. Vibration values decreased significantly; there could have been serious losses if the damage was not detected as shown in Table 2 below:

TABLE 2. Value of vibration on different points of the Motor and Pump after maintenance

Driven DEH	Ovrl:Vib.veloci ISO	5.3 mm\s
	Ovrl:Acc.20kHz@750-	1.03 g
	Bearing defect	3.7 DEF
DRIVEN NDE H	Ovrl:Acc.20kHz@750-	3.57 mm\s
	Bearing defect	6.21 DEF

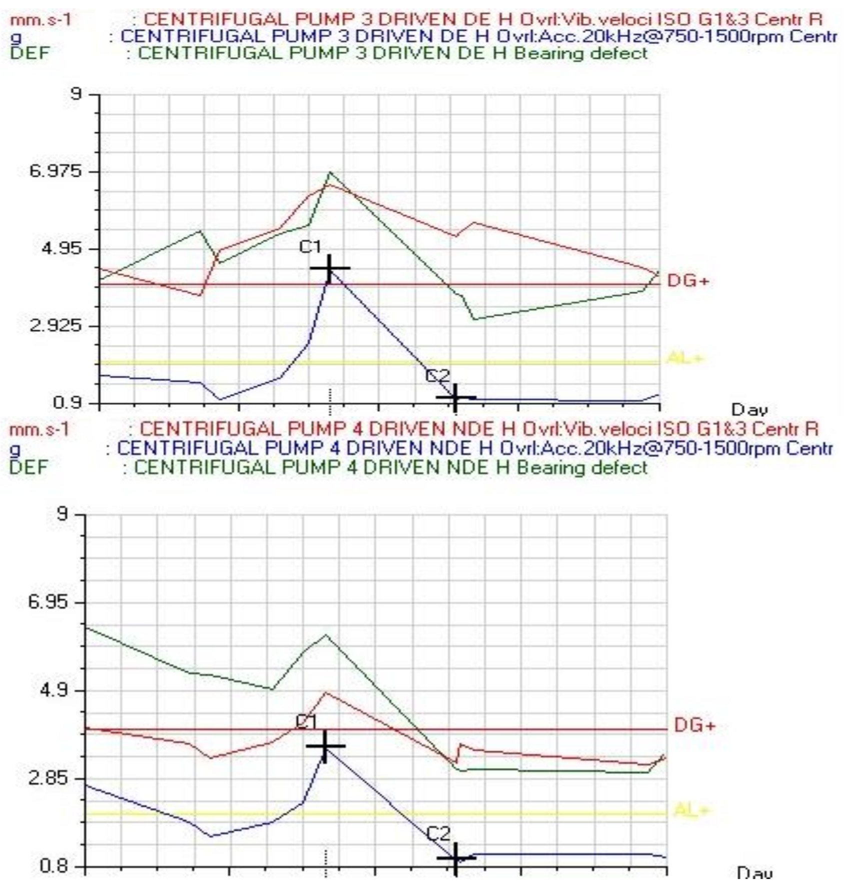

Fig. 6. Vibration values (velocity, acceleration and bearing defect) taken on the pump DE& NDE

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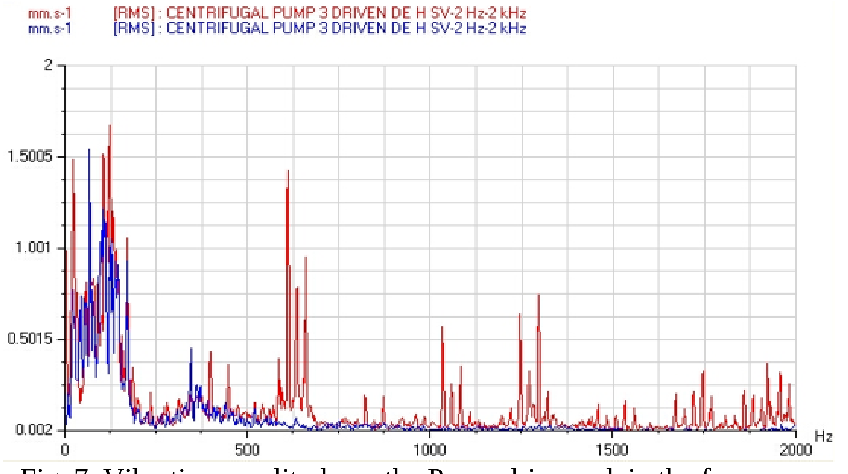

Fig. 7. Vibration amplitude on the Pump drive end, in the frequency range from 0 to 2000 and from 0 to 20000Hz.

The red line shows the values before changing the bearings and the blue one shows the values after changing the bearings

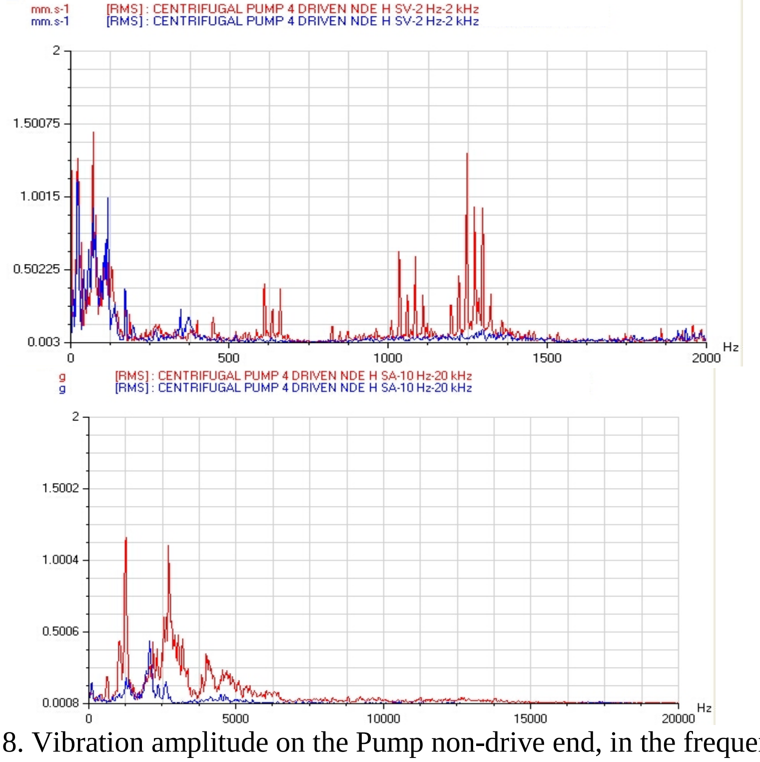

Fig. 8. Vibration amplitude on the Pump non-drive end, in the frequency range from 0 to 20000 and from 0 to 20000Hz.

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The red line shows the values before changing the bearings and the blue one shows the values after changing the bearings

Noticeably That, vibration data are Normal as showing in table 2, with comparison vibration curve before and after maintenance, the deference was clear.

Case Study 2:

This case in **Mellitah Complex** studying feeding pump discharging sea water (Sea Water Intake Pump from the sea up to the distillation units which is the main pump feeding all the plant with cooling water and boiler feed water (BFW) to all boilers, during periodic detection by prediction method, vibration level was abnormal (High frequency vibration detected on the pump DE bearing). Trends below show the value of vibration on different points of the Motor and pump.

Fig. 9. Sea Water Intake Pump

TABLE 3. Value of vibration on different points of the Motor and Pump

Driven DEH	Ovrl:Acc.20kHz@750-	4.77 g
	Bearing defect	7.27 DEF

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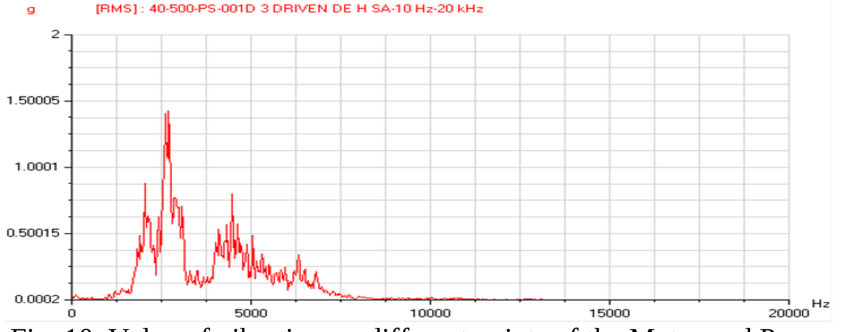

Fig. 10. Value of vibration on different points of the Motor and Pump

Data of bearing showing that the main causes of vibration are defects in bearing. Reference to Table 3 shows the vibration level before maintenance, which depended for problem diagnosis. decided that bearing of pump should be replaced.

Maintenance Results:

Next day defected bearing was replaced, then pump has operated. Vibration check after bearing replacement. Vibration levels and spectrum were recorded at three position on the Motor and pump horizontal, vertical and axial direction. all Good as shown below:

TABLE 4. Value of vibration on different points of the Motor and Pump after maintenance

Driven DEH	Ovrl:Acc.20kHz@750-	1.29 g
	Bearing defect	4.48 DEF

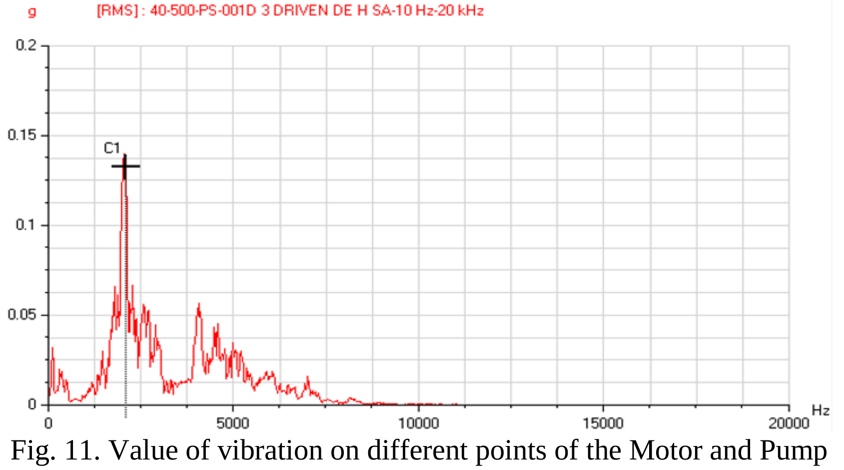

Fig. 11. Value of vibration on different points of the Motor and Pump after maintenance

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Noticeably that, vibration data are normal as showing in Table 4, with comparison vibration curve before and after maintenance, the deference was clear.

Case Study 3:
This case in **Mellitah Gas Complex** studying combustion Air Blower feeding the thermal reactor with Oxygen required to achieve the perfect ratio between (**H_2S & SO_2**) which is controlled by air quantity given to the Reactor, during periodic detection by Prediction method, vibration level was abnormal (High Acceleration value on the blower from airflow). The value is randomly and variable even on close points of measurement. Is large also in axial direction on the blower High amplitude sidebands around GMF often suggest.


Fig. 12. Air Blower

On 14- 02- 2023, for schedule checking in monitoring, during detecting machine. After measuring data vibration signals of bearings, results were abnormal vibration level. Table 5, trends

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below show the value of vibration .data collected were put to PC for analyzing and results were abnormal as following:

TABLE 5. Value of vibration

Driven NDEH	Ovrl:Accel.20kHz@3000	11.1 g
	Bearing defect	7.97 DEF
	Temperature	77.2 C^0

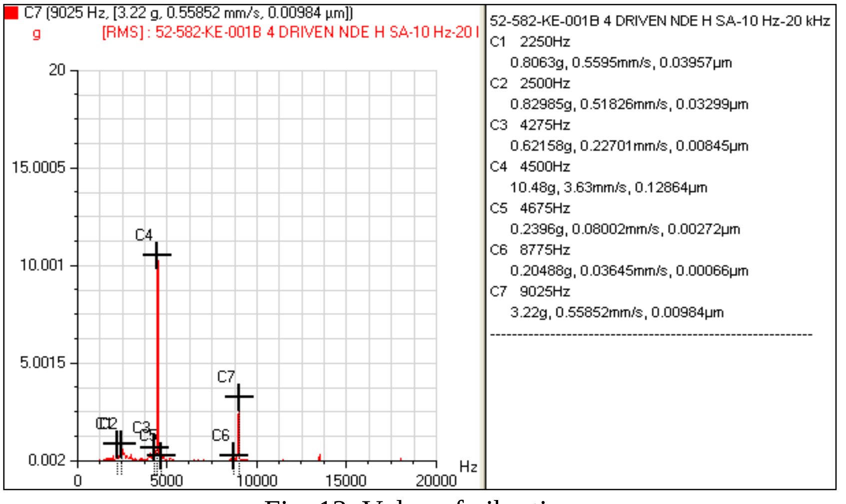

Fig. 13. Value of vibration

Data of bearing showing that the main causes of vibration are high vibration detected on the gearbox NDE, and reference to table 5 shows the vibration level before maintenance, which depended for problem diagnosis. Recommended to check bearing clearance gear eccentricity, and back –lash so that decided that bearing of pump should be replaced.

Maintenance Results:

In next day defected bearing were replaced and it has operated, vibration data have taken. The overall vibration levels are good. As shown below:

TABLE 6. Value of vibration after maintenance

Driven NDEH	Ovrl:Accel.20kHz@3000	1.44 g
	Bearing defect	4.39 DEF
	Temperature	52C^0

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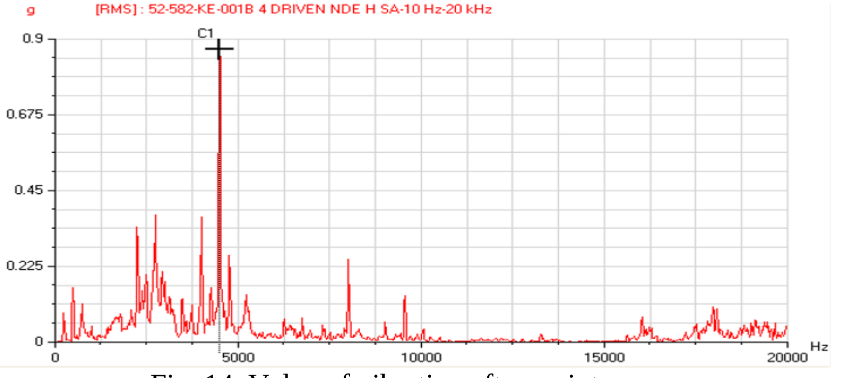

Fig. 14. Value of vibration after maintenance

Noticeably That, Vibration data are normal as showing in table 6, with comparison vibration curve before and after maintenance, the deference was clear.

Case Study 4:
This Case in **Mellitah Gas Complex** studying combustion Air Fan feeding the thermal incinerator with Oxygen required to burn all the Toxic Sulfur compounds for environmental protection. During periodic detection by prediction method, vibration level was abnormal (Soft Foot on the EM, Fan NDE bearing over loaded).

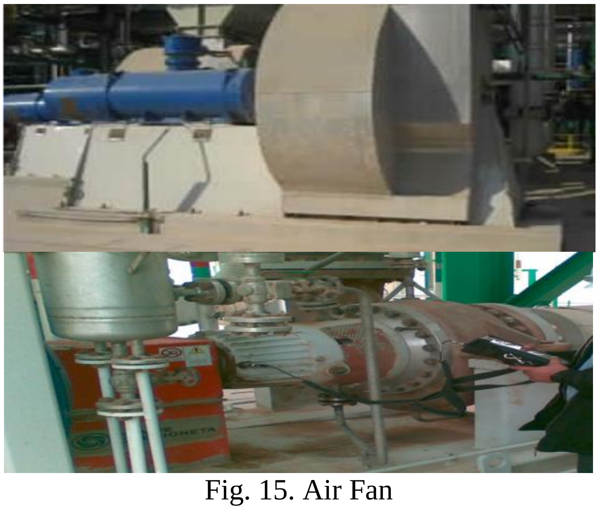
Fig. 15. Air Fan

On 16- 02- 2023, for schedule checking in monitoring, after measuring data vibration signals of bearings, results were abnormal

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vibration level. Table, trends below show the value of vibration on different points. Data collected were put to PC for analyzing; Results were abnormal.

TABLE 7. Value of vibration on different points

Motor NDEH	Ovrl:Vib.veloci ISO	7.77 mm\s
	F0 - Rotation speed	7.61 mm\s
Motor DEH	Ovrl:Vib.veloci ISO	7.91 mm\s
	F0 - Rotation speed	7.69 mm\s
Driven NDEH	Bearing defect	8.6 DEF

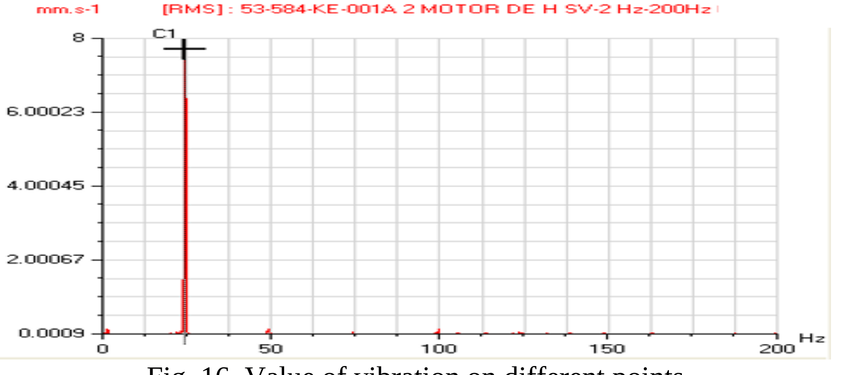

Fig. 16. Value of vibration on different points

Data of bearing showing that the main causes of vibration are defects in bearing. Reference to table 7 shows the vibration level before maintenance, which depended for problem diagnosis. Decided that bearing should be replaced due to soft foot. So, check the Fan clearance was recommended.

Maintenance Results:
In next day defected bearing were replaced and has operated vibration data have taken. Overall vibration levels are good as following below:

TABLE 8. Value of vibration on different points after maintenance

Motor NDEH	Ovrl:Vib.veloci ISO	2.5 mm\s
	F0 - Rotation speed	2.07 mm\s
Motor DEH	Ovrl:Vib.veloci ISO	2.9 mm\s
	F0 - Rotation speed	2.03 mm\s
Driven NDEH	Bearing defect	3.44 DEF

http://www.doi.org/10.62341/eiht6745

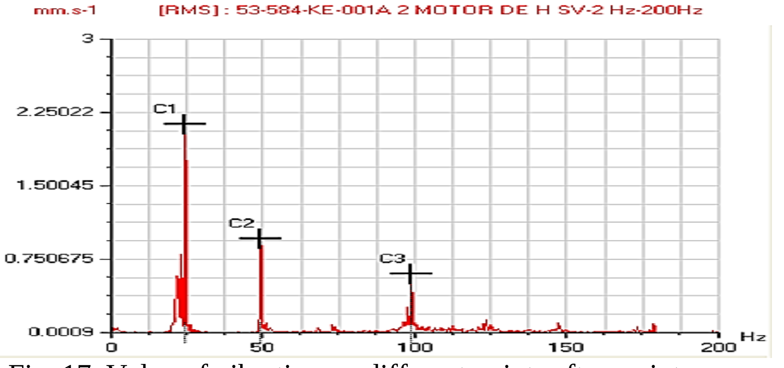

Fig. 17. Value of vibration on different points after maintenance

Noticeably that vibration data are normal as showing in table 8. With comparison vibration curve before and after maintenance, the deference was clear.

Case Study 5:
This case in **Mellitah Gas Complex** studying feeding pump discharging sea water (Sea Water Intake Pump)(see figure 18) from the sea up to the distillation units which is the main pump feeding all the plant with cooling water and boiler feed water (BFW) to all boilers, during periodic detection by prediction method, vibration level was abnormal (Rotor unbalance causes high vibration at 1x rpm).


Fig. 18. Sea Water Intake Pump

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On 01- 04- 2023, for schedule checking in monitoring. After measuring data vibration signals of bearings, results were abnormal vibration level. Table, trends below show the value of vibration on different points of the Motor and pump as following below:

TABLE 9. Value of vibration on different points of the Motor and Pump

MOTOR NDE H	Ovrl:Vib.veloci ISO	10.1 mm\s
	F0 - Rotation speed ISO	8.67 mm\s

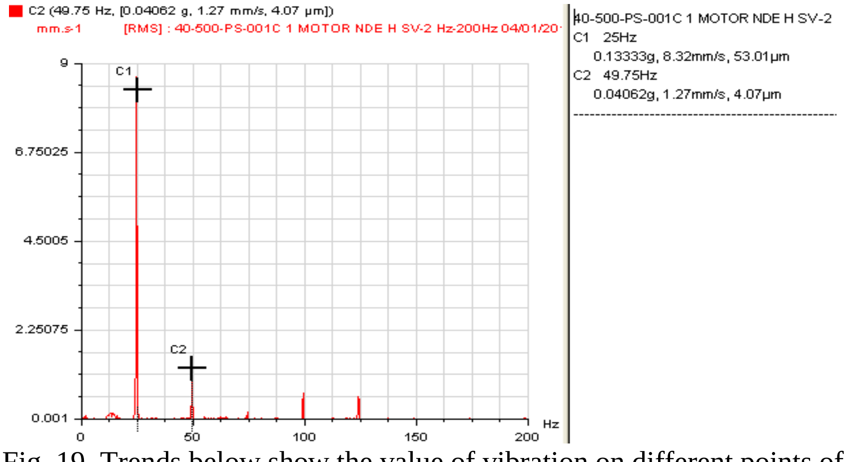

Fig. 19. Trends below show the value of vibration on different points of the Motor and Pump

Maintenance Results:
Based on data above, Rotor balancing is required**.** 0n (05-04-2023) pump has operated, Vibration check after balancing. Vibration levels and spectrum were recorded at three position on the Motor and pump horizontal, vertical and axial direction all are good as show below in Table 10:

TABLE 10. Value of vibration on different points

Driven NDE H	Ovrl:Acc.20kHz@750	1.61 mm\s
	F0 - Rotation speed ISO	0.82 mm\s

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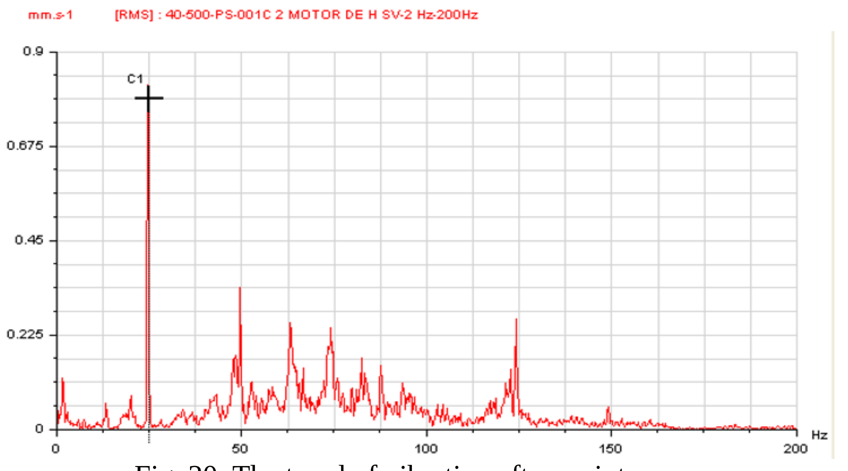

Fig. 20. The trend of vibration after maintenance

Noticeably that, vibration data are normal as showing in Table 10. With comparison vibration curve before and after maintenance, the deference was clear.

Case Study 6:
This case in **Mellitah Gas Complex** studying combustion Air Blower feeding the thermal reactor with Oxygen required to achieve the perfect ratio between (**H_2S & SO_2**) which is controlled by air quantity given to the reactor. During periodic detection by prediction method (daily checking).

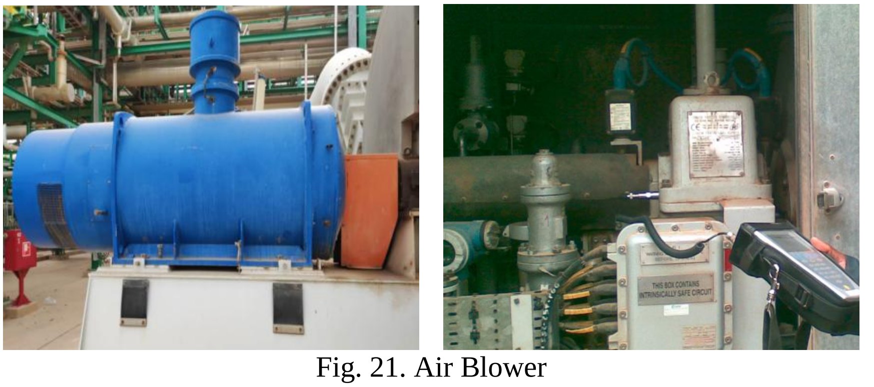
Fig. 21. Air Blower

On 05- 04- 2023, for schedule checking in monitoring. After measuring data vibration signals of bearings, results were normal vibration level.

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Trends below show the value of vibration. Data collected were put to PC for analyzing. Results were normal.

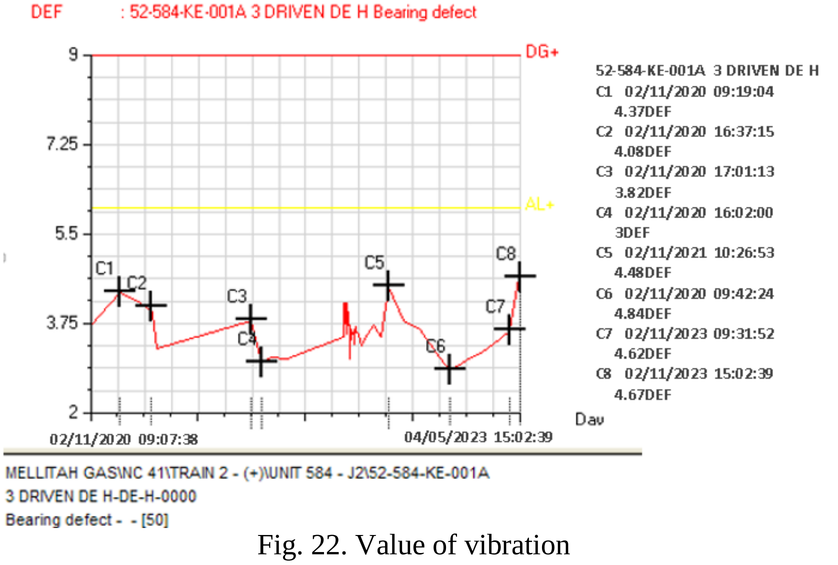

Fig. 22. Value of vibration

6. Result discussion

Baseline measurements were taken (see figure 23), the current and historical data are collected under similar operational conditions. Baseline testing for pumps involves establishing a reference point measurement. Maintaining accurate baseline data ensures effective pump management and early detection of issues. Here's what it entails:

Vibration analysis provides a critical warning window, detecting faults from early stages to severe degradation. The lead time before failure varies significantly, depending on the specific fault type, machine design, and operating conditions. It can range from weeks for gradual issues like imbalance to just days or hours for rapidly developing problems such as severe bearing defects. Vibration analysis provides early fault detection, enabling planned repairs instead of catastrophic failures. This prevents extensive production losses, avoids secondary equipment damage, and eliminates emergency intervention premiums. The economic impact is dramatically lower total downtime costs, transforming expensive, reactive shutdowns into controlled, efficient maintenance events,

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securing continuous operations and major financial savings for the facility.

Baseline Data			Before maintenance			After maintenance		
Case 1: Feeding Pump (**51-582 BA 001 A**)								
Driven DEH	Ovrl:Vib.veloci ISO	5.1 mm\s	Driven DEH	Ovrl:Vib.veloci ISO	6.65 mm\s	Driven DEH	Ovrl:Vib.veloci ISO	5.3 mm\s
	Ovrl:Acc.20kHz@750-	1.2 g		Ovrl:Acc.20kHz@750-	4.41 g		Ovrl:Acc.20kHz@750-	1.03 g
	Bearing defect	6.97 DEF		Bearing defect	6.97 DEF		Bearing defect	3.7 DEF
DRIVEN NDE H	Ovrl:Acc.20kHz@750-	3.2 mm\s	DRIVEN NDE H	Ovrl:Acc.20kHz@750-	3.57 mm\s	DRIVEN NDE H	Ovrl:Acc.20kHz@750-	3.57 mm\s
	Bearing defect	6.21 DEF		Bearing defect	6.21 DEF		Bearing defect	6.21 DEF
Case 2: Feeding Pump (**40-500-PS-001D**)								
Driven DEH	Ovrl:Acc.20kHz@750-	1.11 g	Driven DEH	Ovrl:Acc.20kHz@750-	4.77 g	Driven DEH	Ovrl:Acc.20kHz@750-	1.29 g
	Bearing defect	3.8 DEF		Bearing defect	7.27 DEF		Bearing defect	4.48 DEF
Case 3: Combustion Air Blower (**52-582 KE 001A**)								
Driven NDEH	Ovrl:Accel.20kHz@3000	1.5g	Driven NDEH	Ovrl:Accel.20kHz@3000	11.1 g	Driven NDEH	Ovrl:Accel.20kHz@3000	1.44 g
	Bearing defect	3.8 DEF		Bearing defect	7.97 DEF		Bearing defect	4.39 DEF
	Temperature	50C⁰		Temperature	77.2 C⁰		Temperature	52C⁰
Case 4: Combustion Air Fan (**52-584 KE 001A**)								
Motor NDEH	Ovrl:Vib.veloci ISO	2.2 mm\s	Motor NDEH	Ovrl:Vib.veloci ISO	7.77 mm\s	Motor NDEH	Ovrl:Vib.veloci ISO	2.5 mm\s
	F0 - Rotation speed	2.1 mm\s		F0 - Rotation speed	7.61 mm\s		F0 - Rotation speed	2.07 mm\s
Motor DEH	Ovrl:Vib.veloci ISO	2.6 mm\s	Motor DEH	Ovrl:Vib.veloci ISO	7.91 mm\s	Motor DEH	Ovrl:Vib.veloci ISO	2.9 mm\s
	F0 - Rotation speed	2.1 mm\s		F0 - Rotation speed	7.69 mm\s		F0 - Rotation speed	2.03 mm\s
Driven NDEH	Bearing defect	3.6 DEF	Driven NDEH	Bearing defect	8.6 DEF	Driven NDEH	Bearing defect	3.44 DEF
Case 5: Feeding Pump (**40-500-PS-001C**)								
MOTOR NDE H	Ovrl:Vib.veloci ISO	1.5 mm\s	MOTOR NDE H	Ovrl:Vib.veloci ISO	10.1 mm\s	Driven NDE H	Ovrl:Acc.20kHz@750	1.61 mm\s
	F0 - Rotation speed ISO	0.7mm\s		F0 - Rotation speed ISO	8.67 mm\s		F0 - Rotation speed ISO	0.82 mm\s

Figure .23. Baseline Data

7. Conclusion

This research validated the application of vibration-based condition monitoring for critical rotating equipment at the Mellitah Gas Complex, Libya. The analysis of six distinct cases revealed that the primary failure mechanisms were bearing degradation (Cases 1, 2, 3, 4) and rotor unbalance (Case 5). The technique provided a critical lead time of several days to weeks, allowing for scheduled interventions. For instance, in Case 1, replacing the bearing based on vibration trends prevented a catastrophic failure in a condensate feed pump, which would have halted boiler operations. The study conclusively demonstrates that for this specific complex, a monthly vibration monitoring schedule is sufficient for detecting these common faults, but more critical units like the Sea Water Intake Pumps may benefit from a higher frequency of inspection due to their operational criticality.

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Thus far, unbalance and misalignment are the developing faults that can be detected. However, there are many more defects that can occur due to the excessive vibration. Hence, regular maintenance is recommended for the pumps as the vibration defects are amplifying over time. The results, comments, and conclusions contained in this work can only apply to the Tested pumps. Whilst some of the obtained results agreed with those obtained in previous research, others do not. The reason for this is most probably the difference in the tested pump specifications. Therefore, to generalize any result for all centrifugal pumps, the same work should be repeated using a wide variety of centrifugal pumps.

Recommendations

Based on the findings from the Mellitah Complex, the following specific recommendations are made:

1. **Focus on Bearing Health**: Given that 4 out of 6 faults were bearing related, the maintenance program should prioritize high-frequency vibration measurements (acceleration enveloping) on all pump and blower bearings, with established alarm levels specific to each machine type.
2. **Baseline and Trend Specific Parameters**: For pumps like the Sea Water Intake units, baseline vibration velocities should be established post-installation. Trends should specifically monitor 1x RPM amplitude to catch unbalance early, as seen in Case 5.

3. **Procedure for Soft Foot**: The occurrence of 'soft foot' in Case 4 suggests that alignment procedures should include a mandatory soft foot check before final alignment is performed.

4. **Economic Justification**: The cost of the vibration analysis equipment and man-hours was significantly lower than the potential production loss from a single pump failure, justifying the expansion of this program to other similar assets within the complex."

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