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FAULT DIAGNOSTIC METHODS OF A CENTRIFUGAL PUMP

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Abstract: *For each rotating machine, the appropriate type of maintenance (corrective, preventive or predictive) must be chosen according to the criteria of safety, productivity, the cost of replacing the equipment and the frequency of breakdowns.*

In the context of condition monitoring, bearing wear is one of the main causes of failure in rotating machines which are monitored and diagnosed in real time to increase their life and guarantee their availability in the industry. Vibration analysis and oil analysis are popular techniques used for monitoring and detecting most bearing malfunctions.

The objective of this work is to study the tools for the diagnosis of faults simulated on the bearings, and the implementation of the diagnosis by the identification of the faults.

We have focused on two monitoring techniques to ensure the proper functioning of rotating machines, the first: overall level monitoring and frequency analysis of bearing defects, and the second, monitoring the wear index by the Ferro-graph method to diagnose and study failures.

Key words: *Rotating machines - diagnostics - faults - vibration analysis - oil analysis.*

1. INTRODUCTION

The maintenance function is a strategic component of the company, participating in all actions aimed at guaranteeing the quality of the manufactured product, and in the acquisition of new equipment [1].

Conditional preventive maintenance is an essential element in the industrial maintenance plan, which ensures the diagnosis and monitoring of rotating machinery, and the detection of potential failures in this machinery before and after its operation[2], with different techniques: infrared Thermography, acoustic emission, oil analysis, vibration analysis [3], [4], [5].

Oil analysis and vibration analysis are one of the most widely used techniques that detect increasingly precise defects.

Vibration analysis is the most complicated technique for what it requires expensive devices and the precision of the analysis, but on the other hand, it is the most effective and precise technique in terms of diagnosis and monitoring, because the analysis of the vibrations resulting from the rotation of the machines contains many coded messages which contain various defects, where vibration analysis ensures the detection of all possible defects and determine their type and degree of severity [6].

The detection of bearing faults, for example, is done by analyzing the vibrations recorded with accelerometers set up for diagnosis.

Lubrication ensures the protection of the internal parts of the machines and reduces the percentage of friction, and wear that occur between the mechanical parts. The oil analysis will make it possible to detect and monitor the following potential malfunctions:

- Pollution of the circuit (solid matter, water, etc.)
- Wear of components (pumps, motors, distributors, etc.)

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- Filtration efficiency (level of pollution, etc).
- Residual characteristics of the lubricant.

It is therefore very important to have a Ferro-graphic analysis technique, which allows to know the catastrophic failures of the equipment thanks to fast and precise prediction of the abnormal or critical wear of the machine [7], and saves time and money.

The objective of our work is to apply vibration analysis and oil analysis in the diagnosis of a pump bearing fault, located at the level of the atmospheric distillation unit (Skikda refinery), in order to optimize preventive maintenance, and to know the evolution of this defect.

2. WORK METHODOLOGY

The 10MP15A is a circulation pump located at the level of the atmospheric distillation unit (Skikda refinery), it sucks the flow of circulation to make a better separation of gasoline.

Fig.1. Photo of the installation of our machine.

We have several interventions were carried out on the pump because of its degradation, we notice that most of the interventions are at the level of the bearings of the pump (change of the bearings), as shown in the following table.

Table 1

History of interventions on the 10MP15A pump.

Date intervention	Designation of the intervention Causes – remedies
19/08/2021	- Disassembly of the pump for general overhaul v3 (change of bearings, GM)
28/01/2022	- Checking the pump when stopped: check for slat play (good) + check for GM (no leaks) - control of the pump running: no noise (condition good).
28/02/2022	- Refitting the oil seal ring
24/04/2022	-Disassembly of the pump and transfer to the workshop to change the bearings and the balancing of the rotor.

2.1. APPLICATION OF VIBRATION ANALYSIS ON THE 10MP15A PUMP

According to the ISO 10816-2 standard, our machine is ranked third. So the areas of operation of the motor pump are as follows:

- Good: less than 1.8 mm/s.
- Eligible: from 1.8 to 4.5 mm/s.
- S- Eligible: de 4.5 to 11.2 mm/s.
- Un-eligible: better than 11.2 mm/s.

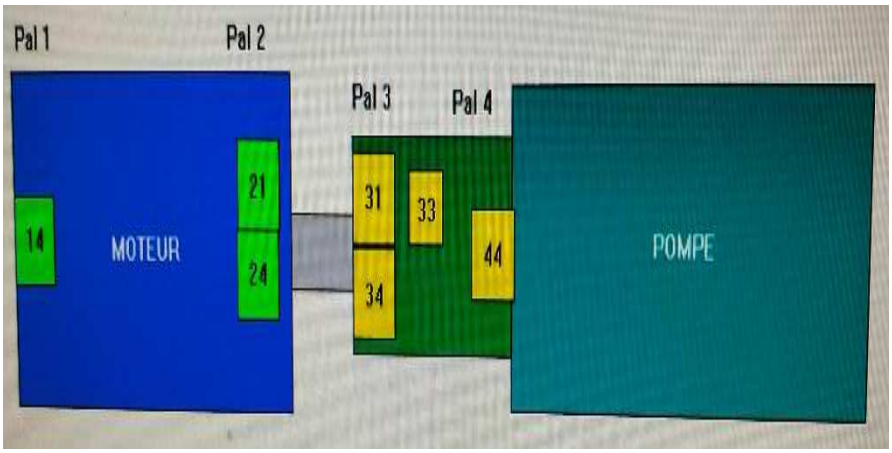

Fig.2. The measuring points.

Pal 3: rolling bearing (thrust bearing) coupling side (pump side).
Pal 4: rolling bearing (ball bearing) suction side of the pump

The measurement at the global level based on the value of the evaluated amplitude

According to the measurements carried out on the pump in the dates 29/01/2019, 25/02/2019, 16/04/2019, 02/05/2019, in the different points, we obtain the following table and trend curves.

Table 2

Résults obtained.

Date	Measured variable	Pal3 Ax	Pal 3 Rv	Pal 3 Ro	Pal 4 Ro
29/01/2019	Accélération (g)	1,4	1,5	1,3	1,2
	Speed (mm/s)	0,8	4,0	2,2	1
25/02/2019	Accélération (g)	2,3	2,9	3,3	2,9
	Speed (mm/s)	1,1	4,2	2,8	1,5
16/04/2019	Accélération (g)	7,3	8,8	8,0	6,7
	Speed (mm/s)	4,2	10	9,7	5,2
02/05/2019	Accélération (g)	0,8	0,4	0,5	0,4
	Speed (mm/s)	2,0	0,1	3	2,5

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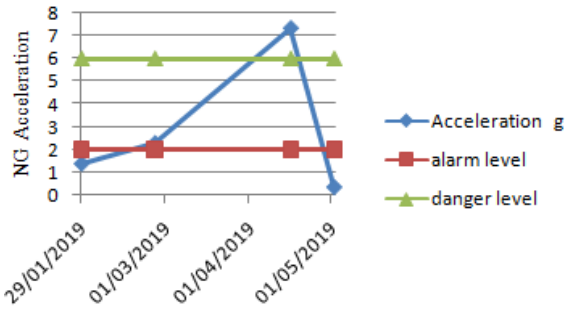

Fig.3. The trendline for the point 3Ax.(NG acc)

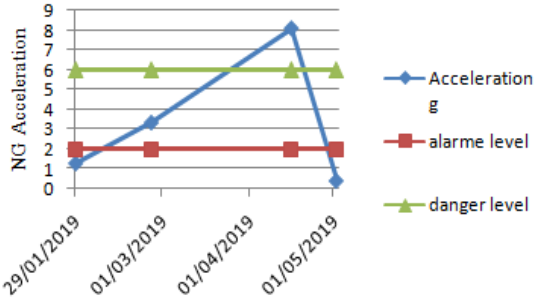

Fig.4. The trendline for the point 3Ro. (NG accélération)

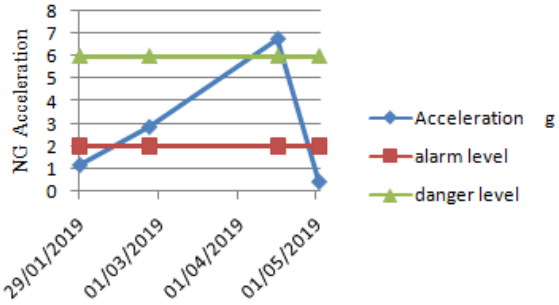

Fig.5. The trendline for the point 4Ro. (NG accélération).

- **INTERPRETATION OF RESULTS**

The overall level of acceleration of the bearings 3 and 4 exceed the danger threshold (6g), this proves that there is a rolling defect on the bearings.

Measurements of overall levels of 02/05/2019 at the pump bearings, hows that there is a decrease in vibration intensity below the acceleration and speed alarm threshold, after the operation to restore proper operation (changing the bearings and balancing the rotor) on the date of the 24/04/2019 according to the table of interventions.

The measurement at the global level is an approximate method of signal analysis, for this purpose, and to identify and locate the defect we pass to the spectral analysis.

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2.1.1. Spectral Analysis

In a spectrum all the components of the vibration signal are represented in the form of peaks which allows us to locate the anomaly.

The observation of the spectrum offers a possibility of analysis by the search for the

characteristic frequencies of the defects Bearings are among the most stressed components of machinery and are a frequent source of failure. The defects that can be encountered are the following: spalling, seizing, corrosion (which leads to spalling), etc. In most cases, the degradation results in a spalling of one of the races or of a rolling element of the bearing, producing a shock with each passage.

Defective bearings generate vibrations of frequencies equal to the rotational speeds of each part of the bearing. They correspond in particular to the rotation of the balls, rollers or cage and to the passage of the balls on the rings [8].

Knowledge of bearing kinematics is summarized by four frequencies, for the 10-MP15A pump, the bearing frequencies used are indicated in the following table:

Table 3

Characteristic rolling frequencies.

Reference of Rolling	**Fr of outer ring**	**Fr of inner ring**	**Fr of Cage**	**Fr of the Items**
3316D SKF	147,86 Hz	197,48 Hz	10,56 Hz	118,88 Hz

- **Generalized degradation of a bearing**

The evolution of bearing spalling leads to the appearance of many hard shocks which excite the resonance frequencies (high frequencies) of the bearing, the associated spectrum presents a dome increases with degradation.

The following spectrum represents a high frequency spectrum of the degradation point 3Ro:

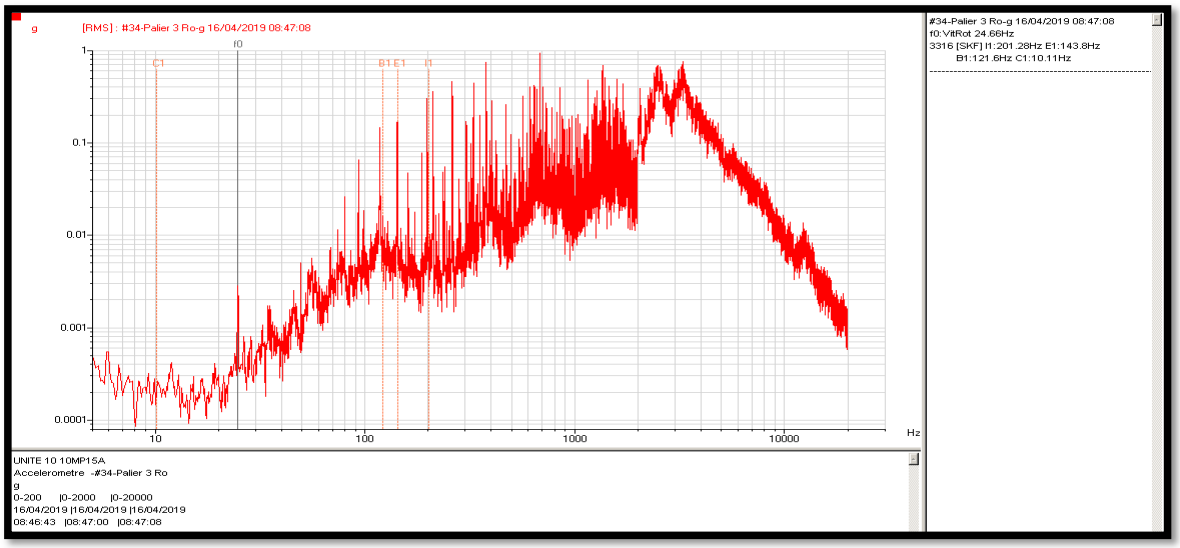

Fig.6. Spectrum of the point 3Ro.

We clearly see a dome in the high frequency region (1000-20000) Hz with significant acceleration amplitudes, which represents generalized bearing degradation.

- **Localized degradation**

The associated spectrum is a spectrum of lines at the frequency of the shock, the amplitude of the shock being low, a localized defect creates a periodic impact, the frequency of repetition of the impact depends on the location of the defect (inner ring, outer ring, balls, cage), the characteristic fault frequencies depend on the bearing geometry

The spectrum of the point 3Rv represent in the following figures:

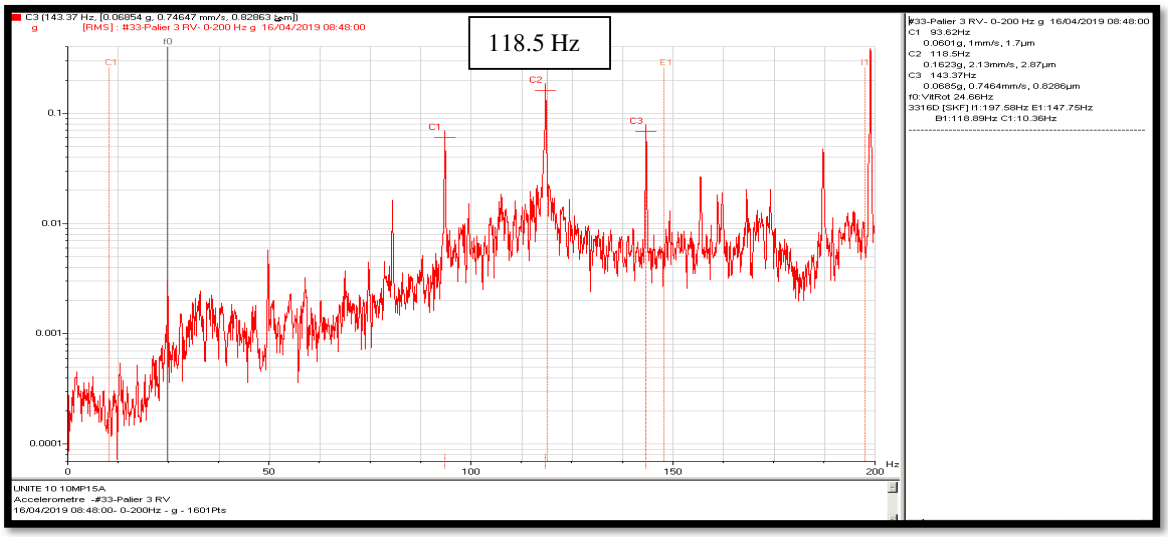

Fig.7. Spectrum of the point 3Rv (0 – 200) Hz.

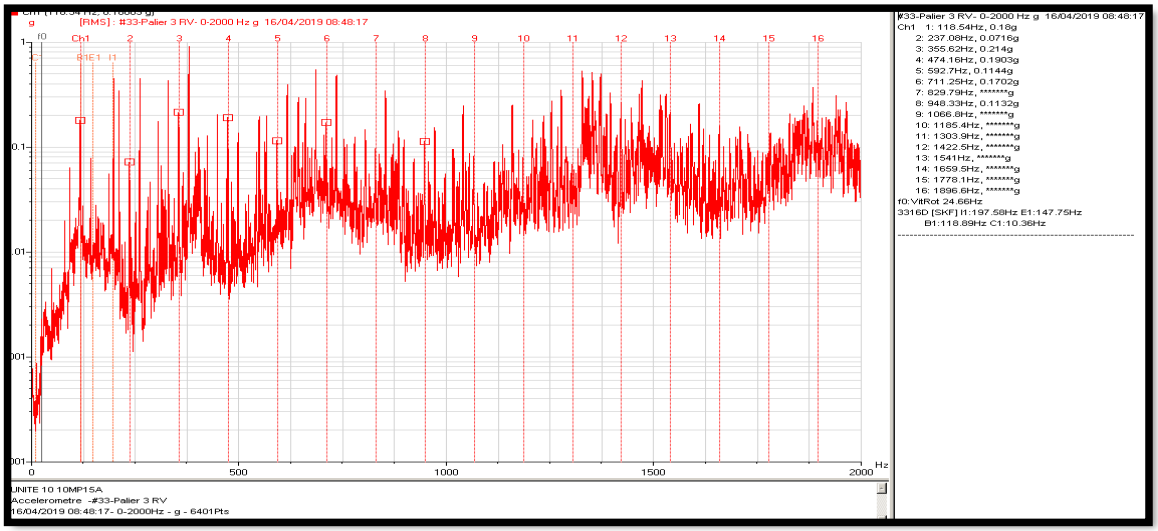

Fig.8. Spectrum of the point 3Rv (0 – 2000) Hz

From the spectra above, we see a peak at the frequency of 118.5 Hz with amplitude of (0.16 g, 2.13 mm/s) and two Sidebands of Fr which is that of the ball defect Fb (BSF), we also observe Lines at the fault frequency (1xFb, 2xFb, 3xFb, etc.) reflecting periodic shocks.

2.2. OIL ANALYSIS

The analysis of oils makes it possible to note the anomalies of operation of the machines, incriminate a organ of the installation and to inform on the state of the wear of the equipment, without dismantling the equipment to diagnose.

The purpose of our study is to monitor rotating machines by the method of oil analysis for the detection and identification of defects in the centrifugal pump, following analyzes by Ferrography, applied to the lubricant during their functioning.

2.2.1. Ferro graphy

Very advanced diagnostic procedure to detect large particles larger than 10 microns.

This test performed to determine the types and amounts of wear particles.

It provides additional information on the mechanism, location and extent of wear and any contaminants. Oil analysis therefore makes it possible to detect pollution (internal or external), wear (normal or abnormal) of the equipment and the ability of the lubricant to fulfill its function.

- **Direct Read Ferrograph DR-7**

Is a trending instrument, providing readings that measure the amount of metal particles, large (DL) and small (DS) in a known oil sample.
With: DL; Large particle.

DS; Small particle.

Fig.9. Ferro graph DR.7.

We took an oil sample from the 1OMP15A pump, and tested the sample at the lab level with DR-7. [7]

For a 1:1 dilution factor :

Table 4

Result for test N°01.

Test	Opaque	DL	DS
N°01	No	105,2	98, 3

In the 1:1 dilution mode, DL and DS values greater than 90, the test is invalid and should be repeated the test with the 10:1 dilution mode

The results obtained in the 10:1 dilution mode as follows:

Table 5

Result for test N°02.

Test	Opaque	DL	DS
N°02	No	634,7	527,6

In the 10:1 dilution mode, DL and DS values less than 900, the test is valid.

Table 6

Result for test N°03.

Test	Opaque	DL	DS
N°03	No	7640,4	6270,6

In the 100:1 dilution mode, the values of DL and DS lower than 9000, the test is valid.

Quantitative information obtained from Ferrography signals can be used as an indication for the change in the wear situation of an operating machine, the two readings of DL and DS correspond to the concentration of large and small particles in the sample.

The wear particle concentration (WPC) (equation1), the percentage of large particles (PLP) (equation 2), and the wear severity index (WSI) (equation 3) presented in the table (7), with:

$$WPC = \frac{DL+DS}{V} \quad (1)$$

v: sample volume in ml

$$PLP = \frac{L-S}{L+S} \quad 100 \quad (2)$$

$$ISU = n^2(L^2 - S^2) \quad (3)$$

n: the dilution factor

Table 7

The WPC, PLP and ISU values for the three tests

Test	Opaque	WPC	PLP	ISU
N°01	No	203,5	3,4	13.62^{x} 10^2
N°02	No	116,23	9.2	124.48 $^{x}10^2$
N°03	No	149,11	15.9	3533.6 $^{x}10^2$

We notice:

The wear severity index is a means of identifying the mode of abnormal wear

An increase in WPC and PLP indicates abnormal wear.

3. CONCLUSION

The technique of oil analysis and vibration analysis is one of the most effective and necessary techniques to monitor rotating machinery according to the plan of conditional preventive maintenance, thanks to the protection and monitoring that they guarantee to machinery rotating.

In our work, we focus on two monitoring techniques to ensure the proper functioning of rotating machinery.

The 10-MP15A pump motor undergoes several major interventions (change of bearings, GM change, general overhaul v3).
The overall levels of the pump bearings exceed the danger thresholds in this period. This is significant in the presence of an anomaly, according to the spectra carried out in this period, note that there is a bearing defect.

Following an oil analysis by the DR-7 direct reading Ferro-graphy we carried out an oil sample test from the 10-MP15A pump and we obtained a result of DL and DS but this test we do not cannot give an opinion on the condition of the oil because it is based on monitoring the evolution (trend) of DL and DS over time.

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METODE DE DIAGNOSTICARE A DEFECTELOR UNEI POMPE CENTRIFUGALE

Rezumat:

Pentru fiecare mașină rotativă trebuie ales tipul adecvat de întreținere (corectivă, preventivă sau predictivă) în funcție de criteriile de siguranță, productivitate, costul înlocuirii echipamentului și frecvența defecțiunilor.

În contextul monitorizării stării, uzura rulmenților este una dintre principalele cauze de defecțiune la mașinile rotative care sunt monitorizate și diagnosticate în timp real pentru a le crește durata de viață și a garanta disponibilitatea lor în industrie. Analiza vibrațiilor și analiza uleiului sunt tehnici populare utilizate pentru monitorizarea și detectarea majorității defecțiunilor lagărului.

Activitatea noastră se concentrează pe două tehnici de monitorizare pentru a asigura buna funcționare a mașinilor rotative, prima: monitorizarea nivelului general și analiza frecvenței defectelor lagărelor, iar a doua monitorizarea indicelui de uzură prin metoda ferrografică pentru diagnosticarea și investigarea defecțiunilor.

Cuvintecheie: Mașini rotative - diagnosticare - defecțiuni - analize vibrațiilor - analiza uleiului

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