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Predictive Maintenance by Vibratory Analysis: Real Case Application on Turbopumps

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Abstract: Equipment availability depends at the same time on these 3 fundamental parameters: Reliability or the number of failures; reparation celerity of failures. Maintenance and Rules defined for maintenance and repair: Maintenance logistics. It will be noticed that there are interactions between these various aspects. A maintenance policy cannot be defined without the characteristics of the system to maintain and the capacity of the logistical support. Responsibility frontier between the manufacturer and the user is versatile and variable in each case. Maintenance costs are often considerable and can be appreciably reduced by a predictive maintenance. The aim of this study, is to present on an industrial case, the advantages of the predictive maintenance carried out to a monitoring and a vibratory diagnosis on turbo-pumps. Various techniques of analysis are applied, the results show that predictive maintenance in this application allowed to reduce the costs of maintenance, the number of breakdown, the downtime and to increase the lifespan of the machines and their availability. Technical resources used as sensors, instrumentation, diagnosis data base constitution and the follow-up of the machines are presented.

Key words: Predictive maintenance, vibratory analysis, real case, technical resources, breakdown

INTRODUCTION

The optimization of maintenance by reliability and conditional maintenance constitutes two important levers, making possible reduction of maintenance costs while controlling the two essential stakes that are the safety and the availability of the industrial tool.

A real case study of turbo-pumps is herein exposed. This machinery is vital for a major petrochemical complex of Annaba city. Before these tests on turbo-pumps, we noted that the majority of the defects affecting these installations were identified afterwards repair operations.

We also noticed the maintenance team occurred without any preliminary idea of the nature and the origin of the failure, causing much time to locate the defect and of course limit the effectiveness of the intervention.

Predictive maintenance by vibratory analysis on-line is used as a tool to help with the decision of maintenance, determine and locate failures. The specifics of the analysis methodology adopted, outcomes and practical lessons learnt are discussed.

Pumps ensure diverse functions and are the essential auxiliaries of a great number of industrial or domestic facilities. They transform the mechanical power into hydraulic power.

The considered installation is a horizontal multicellular centrifugal pump driven by a steam turbine as shown in Fig. 1. It turns at a speed of 2965 RPM, providing a flow of 168 $m^3 h^{-1}$. It ensures the transport of demineralised water with a pressure of 105 Bars. Demineralised water is used in steam generation, essential for manufacturing units (Asmidal, 2002).

PARETO analysis: Failure Modes, Effects and Criticality Analysis (FMECA), a well established tool for both reliability and maintainability analysis, is employed. FMECA is a technique used to identify, prioritize and eliminate potential failures from the system. Using

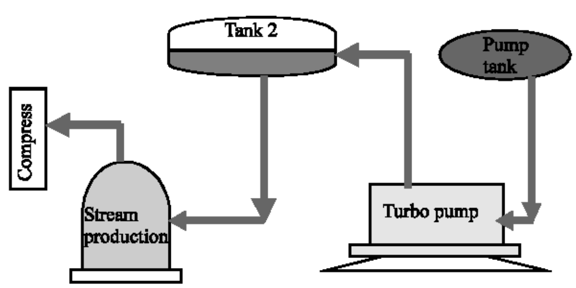

Fig. 1: Demineralised water

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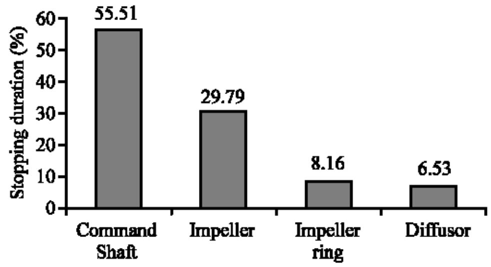

Fig. 2: Subsystems pareto analysis

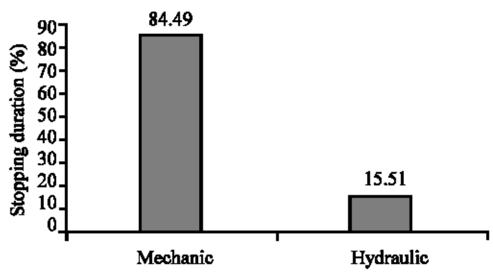

Fig. 3: Causes of failure pareto

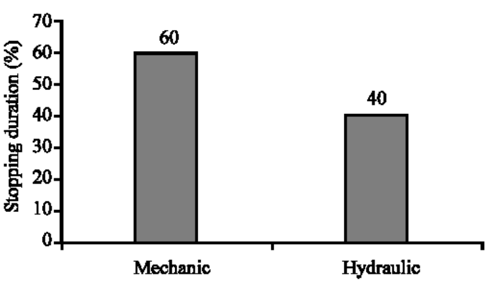

Fig. 4: Failure modes

statistical PARETO analysis, we determine periodicities of intervention on our system. As presented in Fig. 2-4 below, we can see that 55.51% of the stopping duration is due to shaft command caused mechanically in 84.49% of the time by a mechanical mode in 60% of failures analysed.

FAILURE MODES ANALYSIS

FMECA analysis shows that several modes of failures are considered critical (Boulenger and Pachaud, 1995):

- Low flow of the pump due to the variation of its speed. This mode is very frequent and influences directly the level of the accumulating balloon and its internal pressure.

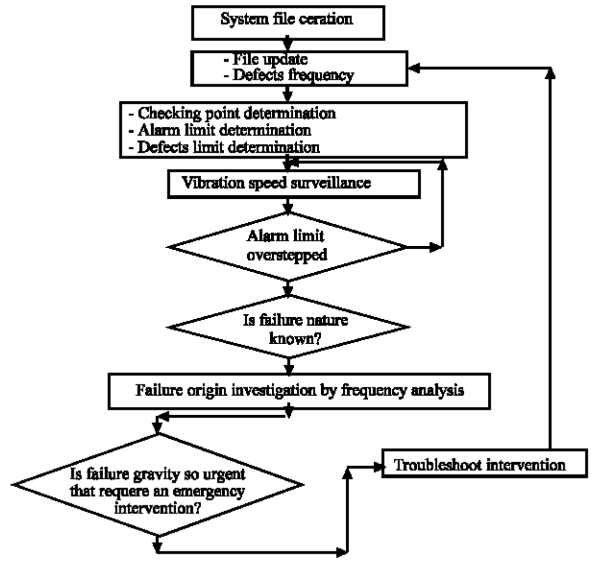

Fig. 5: Monitoring strategy

- The vibrations are due, either with the wear of the case ring, or because of a clearance between bearing and shaft; this causes a leakage of the pump on turbine side. This mode influences directly the pressure of the pump and the accumulating tank.
- The assembly of the wheels is also a critical problem detected by very high vibrations and an abnormal noise; it causes the emergency stopping of the pump and a revision of 16 h at least.
- Misalignment is one of the breakdowns most met, causing the stopping of the pump.

Monitoring program development: The technical starting of the monitoring programme by vibratory analysis requires a meticulous preparation, it comprises three distinct phases: Make up of the system (turbo pump) file, monitoring parameter setting, defects various signatures definition (Boulenger and Pachaud, 1998). The monitoring strategy is presented in the Fig. 5.

CHECK POINTS DETERMINATION

Check points localisations depend on the number of bearing on the shaft. In this case, there is four positions, 2 on the turbine and 2 on the pump (Fig. 6). The vibration amplitude is monitored on 3 directions, vertical, horizontal and axial (Fig.7).

Alarm and alert limit determination: Considering the diversity of the machines, it is impossible to have a universal and absolute values of criticality levels. There are guides that propose values of vibration levels to

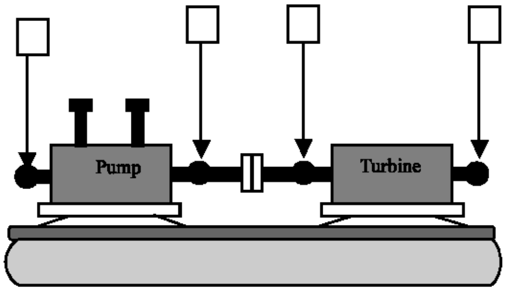

Fig. 6: Check points localisation

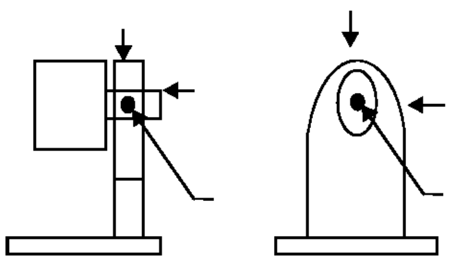

Fig. 7: Vertical, horizontal and axial check points position

establish the criticality of the machines and help to establish the levels of alarm and alert.

The international standard ISO 2372 and NF E90-300 (Monchy, 2000) gives the vibratory criteria which are based on that fact: Similar machines of the same size must have the same vibratory energy, thus the same level of effective speed Vf (between 10 and 1000Hz).

The studied turbo-pump with 773kW of power is categorized in the G group. On Table 1, we choose an alarm limit of 11.2 mm s^{-1} and an alert limit of 7.1 mm s^{-1}, thus considering the oldness of the machine.

Vibration speed amplitude surveillance: Figure 8 represents the evolution of the real speed (Veff) indicator measured on the bearing 1.2.3 and 4 of the turbo-pump according to three directions (Horizontal, vertical and axial) for a 7 months period.

Sharp increase in vertical real speed according to radial direction reaches 13.6 mm s^{-1}.

Checking shows it was about a wear on the bearing number 03 which caused in its turn an excessive vibration on the bearing number 02. These vibrations affected the bearing number 04.

A monitoring based on such criteria will detect in an undifferentiated way the unbalance, misalignment and certain electric defects at an advanced stage.

Monitoring by frequency analysis: The amplitude evolution of vibration speed is often insufficient to identify the nature, the origin and to control the evolution of a failure. One can get a first assumption about the nature of the defects using vibration amplitude evolution. Frequency analysis is an other criteria more accurate to confirm or infirm an assumption.

Table 1: Severity table vs. speed and power

Security vibratory criterions			Veff	
ISO 2372 NF E90-300			En mm s^{-1}	En dB
			45	153
Stop	Stop	Stop	28	149
			18	145
		In just	11.2	141
	In just	Tolerable	7.1	137
In just	Tolerable	Range	4.5	133
Tolerable	Range	Acceptable	2.8	129
Range	Acceptable		1.8	125
Acceptable		Good	1.12	121
	Good	Function	0.71	117
Good	Function	Range	0.45	119
Function	Range		0.28	109
Range			0.16	105
K group	M group	G group		
< 15KW	15 to 75KW	> 75KW		

Table 2: Failure natures according to vibration amplitude and frequency

	Vibration		
Failure nature	Frequency Hz	Amplitude mm s^{-1}	Direction
Oil vortex	21 - 24	4.48	Radial
Rotor/bearing friction	25	4.48	Radial
Unbalance defect	50	8.96	Radial
Settlement defect	50/100/150/200	8.96	Radial
Misalignement defect	100	6.72	Radial and axial
Critical speed	21.66	11.2	Radial

Table 2 shows failure natures according to vibration amplitude and frequency based on the standard ISO 2372/VD1 2056 (Georjan and Deborde, 1994).

Graphics below the frequency analysis of our turbo-pump during 7 months.

On Fig. 9, the horizontal spectrum shows an inadmissible value of 9.8 mm s^{-1} at 50 Hz. Using Table 2, we can see it is an unbalance defect. It illustrates too the need for taking measurements according to 2 radial directions only one measurement carried out in vertical radial direction (7.5 mm s^{-1}) would not have allowed the identification of the defect.

According to Fig. 10, we notice the appearance of an unbalance revealed 50Hz frequency which reaches 10.5 mm s^{-1}, judged inadmissible ; we can also see the appearance of an angular misalignment revealed by the increase in the amplitude at 100Hz which reaches the value 5.8 mm s^{-1}, considered to be inadmissible.

On Fig. 11, we observe at 50Hz the amplitude reaches the 11.2 mm s^{-1}, which means defect of unbalance on the rotor of the pump; we can also see the appearance of a misalignment on the level of the coupling, this defect of a nature 02 reached the value 7.2 mm s^{-1} at 100Hz.

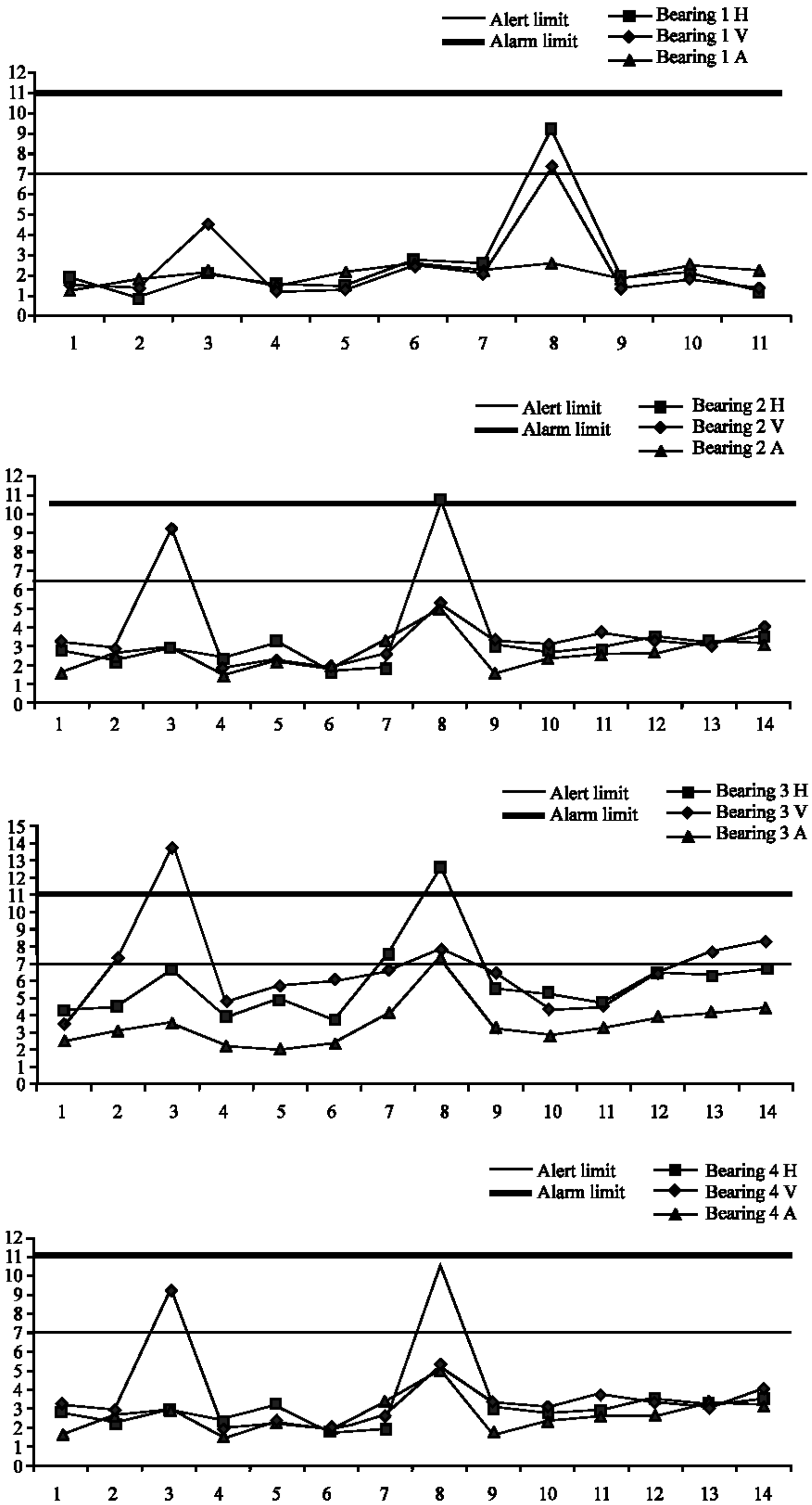

Fig. 8: Amplitude Veff curve tendency of bearing 1, 2, 3 and 4 in mm s^{-1} time range: 15 days

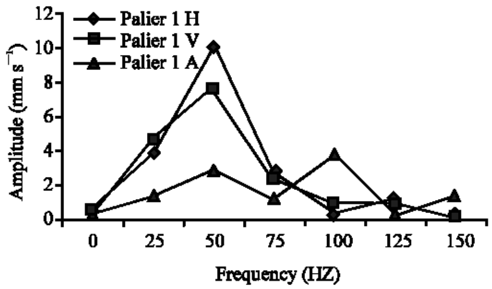

Fig. 9: Frequency spectrum- bearing 01

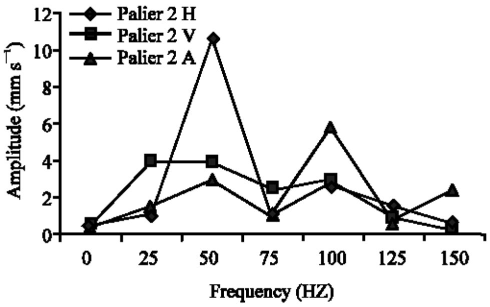

Fig. 10: Frequency spectrum-bearing

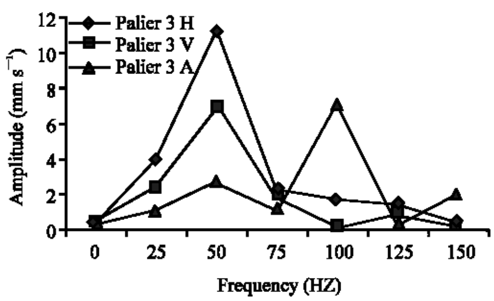

Fig. 11: Frequency spectrum-bearing 03

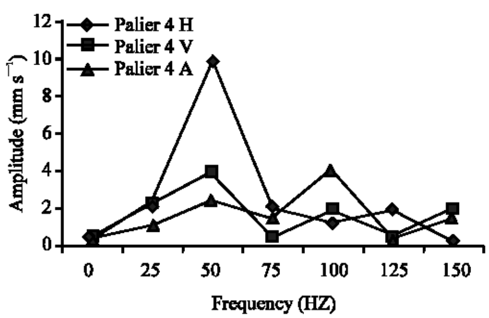

Fig. 12: Frequency spectrum- bearing 04

This figure shows the appearance of an unbalance on the rotor of the pump 50Hz which reaches the value 10 mm s^{-1} a sufficiently high value to highlight the defect.

The monitoring by frequency analysis is the most elaborate mode and most reliable that can be currently implemented to ensure the monitoring of a turbo-machinery. This mode of monitoring has two great advantages which should enable it to be an essential standard of monitoring:

- It allows detection at a stage of the near total of the defects suitable to affect the vibratory behaviour of a shaft and bearings.
- It provides sufficiently precise information to make it possible to identify, locate a defect or to define easily the complementary measures to its identification.

CONCLUSION

This research illustrates the importance of monitoring based on vibratory analysis. This technique allows predictive diagnostic of almost failures on turbo machinery (unbalance, misalignment Y), then a reduction of breakdowns and maintenance coast.

In this real case, vibratory and frequency analysis permitted an inestimable gain of time to get a good diagnostic and to prepare accurate reparation before a breakdown interrupting normal work of the process.

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