International Journal of Engineering Research
Volume No.4, Issue No.8, pp : 450-455
ISSN:2319-6890)(online),2347-5013(print)
01 August 2015

Preventive maintenance by vibratory analysis: case study

Amal Boukili, Mohammed El Hammoumi
Laboratoire Techniques Industrielles, Faculty of Science and Technology, Road Imouzzer B.P. 2202 Fez, Morocco, University of Sidi Mohamed Ben Abdellah.
Amal-boukili@usmba.ac.ma, M_elhammoumi@yahoo.fr

Abstract:The majority of the industrial machine components have to satisfy to the requirements of the high quality and incessantly increasing; so the machines maintaining in good state during the production has became a fundamental point for a product or a company success. Through the measure of the predictive maintenance, it is possible to satisfy these complex requirements with success and to reduce the costs of maintenance. However, an optimization of the maintenance is realized by a continued monitoring of degradation, by way of a control system on line "On Line", which can respond to industrial imperatives and which provides to define just the necessary at the level of interventions, "The machine can't be serviced except if only its state requires."For an effective maintenance, it takes precise and reliable measures. Nevertheless, the experience has shown that the vibratory measure is the most reliable parameter that gives the precociously and with a best ways the deterioration state of a turnable machine. It provides to identify the efforts as soon as they appear, before of an irreversible damage, it also provides, after analysis, to deduce the origin and to estimate the breakdown risks.In this context, a study had done inside a workshop of a phosphoric office, which adopt a continued surveillance (On-Line), in the hope of doing an optimal process of a conditional maintenance which can be developed in time toward an idealized by a vibratory indicator accomplishing satisfactory results.

Keywords: Conditional maintenance; Predictive maintenance; A vibratory analysis; Spectral analysis; Vibration of rotors.

I. Introduction

Among the major concerns of the industrial responsible, the low production yield due to stoppages and breakdowns unplanned and spontaneous of the machines.

Recent studies on the effectiveness of maintenance management have shown that more than a third of maintenance costs from unnecessary poorly performed operations. A bad maintenance policy has disastrous consequences on the quality of production, namely:

- The reparative maintenance: which consists of repairing the defective equipments. Evidently, this causes costs to repair itself, but it also has costs associated with delays due to the production stoppage. This can have a grave consequences especially if the plant uses a linear assembly line or the equipments depend on each other to produce.
- The corrective maintenance: Is when a machine starts to show symptoms of a defect, as for example an abnormal quantity of rejection, so it is important to tempt to correct the problem before a breakdown occurs.
- The preventive maintenance: this is to prevent breakage preventively with specific inspections. This provides to prevent production stoppages.
- The predictive maintenance: it provides to analyze the equipments and to determine that after a certain number of hours, some pieces will be replaced, and a preventive maintenance should be performed. In this manner, most of breakages are avoided since it never exceeds the expected useful life of pieces.

So to avoid breakages which would risk to slow down and even to stop production, the maintenance program should head for predictive maintenance, which contains many techniques, and given that the mechanical systems and machines constitute the majority of industrial equipment, the vibration control generally constitutes the key element of predictive maintenance programs.

The operation of Machines generates efforts, which often present the cause of the subsequent failures. To establish a diagnosis, we should rely on the fact that a machine emits outward many signals which are symptomatic of its operation, among these signals we find the vibrations that are directly dependent by forces that generated by the different internal elements in movement, and which have a great advantages due to the wealth of information that carry and their direct relationship with movements of the machine; these vibrations occupy a privileged place among the parameters to be considered for effective monitoring of the proper functioning of industrial machines.

The made measurements on machines in operation are easy to implement and the technique allows early detection of most faults encountered on production machines. Many anomalies such as the imbalance of shaft lines, games, bearing wear ... and even the electrical faults can be detected early enough to plan an intervention before failure.

The vibration analysis finds its use not only in the diagnosis of machine status for purposes of a predictive maintenance, but also in the framework of a recipe of a new equipment or be subject to a revision, as this technique allows the detection of abnormalities or assembly defect for the new equipment and for a coming equipment to do the purpose of a reconditioning, it provides to verify if this operation has well corrected the identified vibration anomalies which caused the decision making to stop. [i][ii]

II. General Information on the Vibration

1. *Definition of a vibration*

According to the standard AFNOR NF E 90-001: The vibration is a variation in relation with the time of a characteristic magnitude of movement or position of a mechanical system when the magnitude is alternately greater or smaller than a certain average or reference value. [ii]

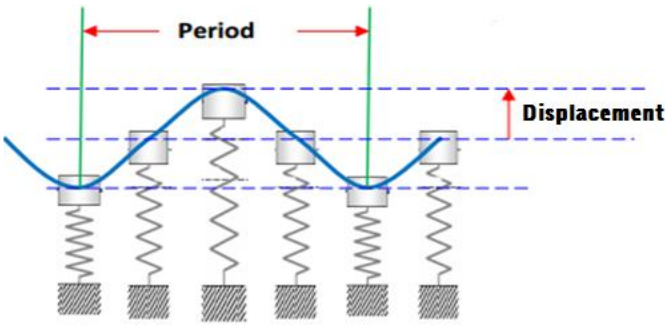

Figure1. Movement of a mass suspended to a spring

The vibration of a machine subjected to a periodic force can be described in terms of displacement, velocity or acceleration (figure 2).The velocity of the vibratory movement corresponds to the variation of its displacement per unit time. Acceleration represents a variation of the velocity per unit time.

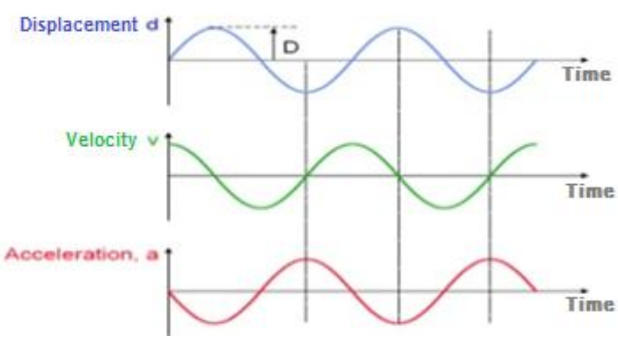

Figure2. Representation of the movement of a simple system

The vibration phenomena are periodic or aperiodic phenomena more or less complex, which directly depend on generated forces by different internal elements moving:

- Impulse Forces (shock);
- Transitional Forces (load variation);
- Periodic Forces (unbalanced);
- Random Forces (friction)

A vibration is characterized mainly by its frequency, its amplitude and its nature.

2. *Nature of vibration*

Any rotating machine in operation generates vibrations that can be classified as follows [iii] [iv]:

- The periodic vibrations of simple sinusoidal type (figure 3.a) or complex sinusoidal type (figure 3.b) representative of the normal or abnormal functioning of a certain number of mechanical organs (rotation of shaft lines, meshing...) or of a certain number anomalies (imbalance, misalignment, deformations, instability fluid bearings, bearings rings spill ...).

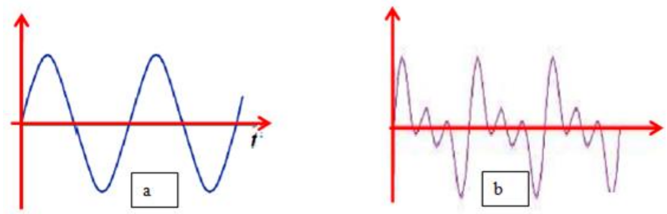

Figure3. The periodic vibration sinusoidal type

- The periodic vibrations of impulse type: (Figure 4) are so named by reference to the forces that generate these vibrations and their brutal character, brief and periodic. These shocks can be produced by natural events (automatic presses, hammer mills, reciprocating compressors, ...) or abnormal events such as scaling of bearings or defect on gears, excessive play, ...

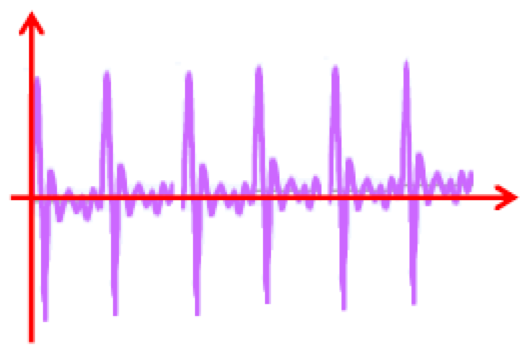

Figure4. The periodic vibrations impulse type

- The random vibration of impulse type: (Figure 5) can, for example, be generated by a lack of lubrication on a rolling, the cavitations of a pump, …

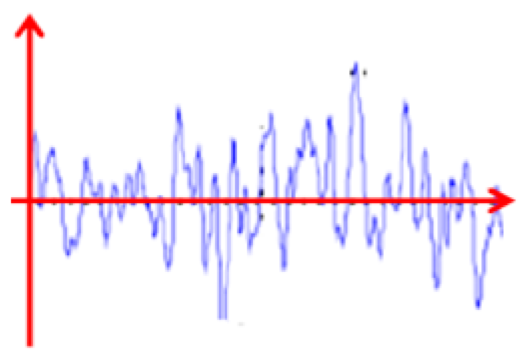

Figure5. The random vibration impulse type

III. Choice of Physical Quantities to be Measured

International Journal of Engineering Research
Volume No.4, Issue No.8, pp : 450-455

ISSN:2319-6890)(online),2347-5013(print)
01 August 2015

To monitor a machine, one has to choose the physical quantity to measure. This quantity is called setting or surveillance indicator.

1. Domain of surveillance

- Since the displacement is inversely proportional to the square of the frequency, the measure in displacement mode will effectively mitigate all average components and high frequency and amplify the low frequency components, its use is restricted to very low frequencies: F ≤ 100 Hz
- The velocity is inversely proportional to the frequency: The higher the frequency increases, the higher the velocity decreases: Its use is restricted to low frequencies: F ≤ 1000 Hz.
- The acceleration, representative of the dynamic forces, does not depend on the frequency: It is the privileged parameter in vibration analysis on a wide frequency domain: 0 ≤_F ≤ 20000 Hz [ii] (Figure 6)

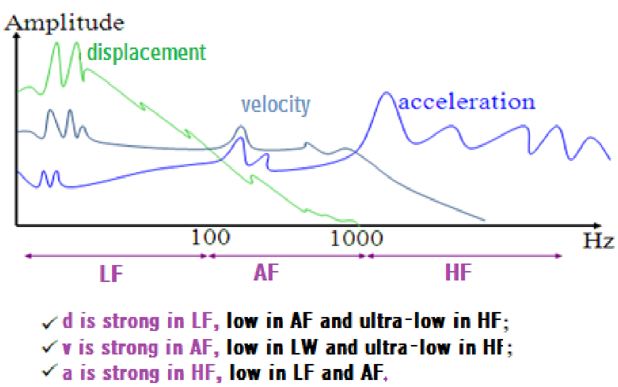

Figure6. Choice of physical quantities to be measured depending on the nature of defects sought

To find a defect, we measure the vibration amplitude in mode of displacement, velocity or acceleration, according to the frequency of the induced dominant vibratory component by low, average or high frequency.
These three modes are a good indicator of the origin of the phenomenon that allows to guide research, but do not establish a precise diagnosis.

IV. Vibratory indicators

1. Definition

A surveillance indicator is a vibration grandeur derived from three basic kinematics quantities characterizing a vibratory movement (acceleration, velocity, displacement), which is sensitive to the appearance or progression of a defect or a combination of defects. For a correct monitoring, the indicator must have two essential qualities: simplicity of the measure and the significance of their contents.
The description of the vibratory behavior of a machine, monitoring of its development, the formulation of a diagnosis need to appeal to numerous indicators and criteria. There are four types [v] : Scalar indicators, spectral indicators, vector indicators and time indicators.
According of their parameters, these indicators can be grouped into two main categories: the scalar energy indicators that quantify the vibratory energy not directly related to the dynamic forces which induce, and typological or behavioral indicators that quantify essentially the vibrational manifestations of each force and the machine whose default is the site taking into account the specificities dynamic of each machine, its vibratory transfer that is also specific for interacting with the process. [vi]

2. The scalar indicators

A scalar indicator associated with a raw signal or has been the object of prior treatment (filtering, demodulation), a characteristic quantity of its amplitude (effective value, peak amplitude, modulation rate...), and its amplitude distribution (crest factor, kurtosis) and its spectral composition (amplitude of a spectral component, effective value of a family of components, harmonic distortion...).
Their widespread use is easily explained by their ease of use: they reduce themselves to a number, easily lend themselves to automation management (archiving, evolution curves, and comparison with thresholds) [v] [vi].

3. The spectral indicators

A spectral indicator associated with a signal is a spectral representation of the latter (spectrum, zoom, cepstrum, spectrum modulation function, transfer function ...).
These indicators present a greater interest to be sensitive as well to developments in the form of a signal well as to those of its energy, and therefore they are insensitive to masking effects, provided that the resolutions of the chosen analysis for elaborate are in line with the repetition frequencies of the sought phenomena. Thus, they offer extremely the interesting prospects in the context of machine monitoring. Moreover, they constitute a considerable step forward in matching between indicator and default and the ease of their graphical comparison with a reference state greatly favors the interpretation of their evolution. [vi]

4. The vector indicators

A vector indicator associated with signals from several vibration sensors in a presentation space of the vibratory movement. These indicators are unfamiliar, orbit in the best known. But the use of partial or overall distorted, still anecdotal, This notion is also often approached indirectly when some specialists use the phase differences between points, and measurement directions to try to represent a given frequency the movement in the space of a line of trees or its bearing [vi].

5. The time indicators

A time indicator associates to a signal is a particular form of its temporal presentation obtained after filtering or demodulation. They have the advantage to be directly accessible to human interpretation. They allow obtaining difficult accessible information in the spectral domain such as the number of

ISSN:2319-6890)(online),2347-5013(print)
01 August 2015

shucked teeth, the duration of a periodic impulse phenomenon or the form of a modulation phenomenon [vi].

V. Case Study

The chosen workshop is the sulfuric one; its principal function is the production of sulfuric acid (H_2SO_4) by MONSANTO with double absorption, based on the liquid sulfur. It also generates the superheated vapor for the internal phosphoric office useful, which builds an important part in the phosphate industry and their derivatives. To ensure its annual production, this office disposes a set of workshops to assemble their goods and services that schematizes as follow:

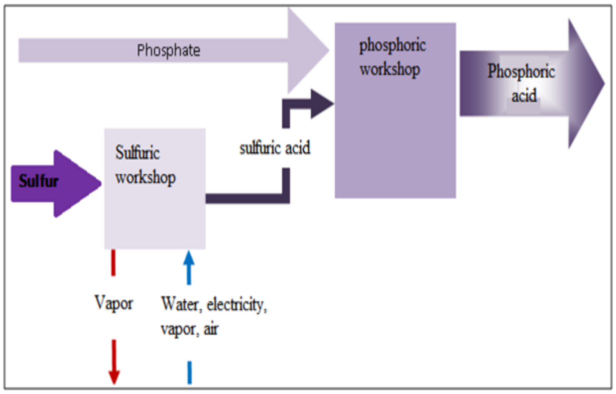

Figure7. Block schematic of the phosphoric office workshops

The Sulfuric workshop is divided into 5 process steps:

- Storage of the liquid sulfur;
- Combustion of the sulfur;
- Conversion;
- Sulfuric acid production;
- Sulfuric acid storage.

1. *Identification of critical equipment*

For the purpose to determine the critical equipments, a detailed analysis has made on the sulfuric workshop equipments. This analysis consists to use the Pareto analysis, using as criterias: the frequency and duration of breakdowns.

Based on these analysis, the turbofan is the most critical equipment in terms frequency and duration of breakdowns.

2. *Kinematic chain*

The following figure illustrates the various components (Turbine, Reducer and Fan) of strategic equipment: the turbofan

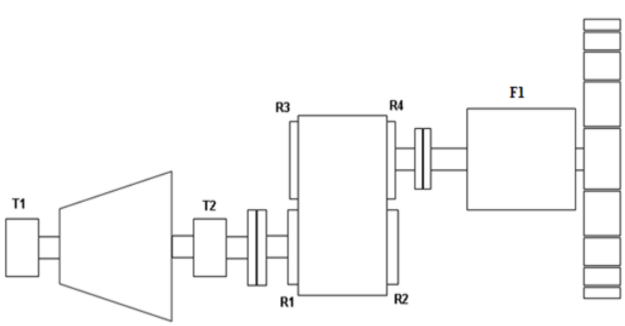

Figure8. The kinematic chain of the turbocharger

3. *Kinematic elements*

The tables below represent the technical sheet of the kinematic elements

Power	Nominal	5756 KW
	Maximum	7191 KW
Velocity		8746 rpm
Lubricating oil flow	Front bearing carrier	0,93 m3/h
	Rear bearing carrier	0,93 m3/h
	Thrust bearing	2,8 m3/h

Table 1. The technical sheet of the Turbine

Power	7191 KW
Velocity of entry	8746 Tr/min
Lubricating oil flow	12 m3/h

Table 2. The technical sheet of the Reducer

Power		6537 KW
Velocity		1354 - 2859 Tr/min
flow	Nominal	307,9 m3/h
	Rear bearing carrier	350000 m3/h

Table 3. The technical sheet of the Fan

4. *Vibratory Severity*

The Calculus of the equipment kinematics is necessary to define the vibration signature which constitutes the basic indicator for vibration monitoring. It defines the frequency of appearance of the abnormalities, and delimitsthe minimum and maximum thresholds for vibratory amplitudes of each organ.

The following values are taken when the turbine operates in a normal range for a rotational speed 7022 rpm :

	T1H	T1V	T1A	T2H	T2V	T2A
GL : Acceleration	2.84	1.67	1.13	0.18	0.476	0.609
GL : Vibratory velocity	0.510	0.456	1.89	0.393	0.464	1.88
GL : Rolling defect	6.36	5.37	4.21	3.67	2.87	3.31
Kurtosis	3.06	2.97	2.99	3.02	3.06	2.94
2-200Hz	0.018	0.018	0.050	0.019	0.012	0.068
2-2KHz	0.189	0.262	0.228	0.113	0.223	0.179
2K-20KHz	2.42	1.65	1.08	0.823	0.445	0.525

Table 4. Measurements of global level (acceleration, velocity, rolling defect) of the turbine

	R1	R2	R3	R4
GL : Acceleration	0.418	1.50	0.637	2.59
GL : Vibratory velocity	0.486	0.480	0.392	0.276
GL : Rolling defect	2.56	3.83	3.37	5.30
Kurtosis	2.60	1.80	2.80	1.81
2-200Hz	0.024	0.027	0.025	0.011
2-2KHz	0.175	0.231	0.114	0.325
2K-20KHz	0.384	1.45	0.576	2.28

International Journal of Engineering Research
Volume No.4, Issue No.8, pp : 450-455

ISSN:2319-6890)(online),2347-5013(print)
01 August 2015

Table 5. Measurements of global level (acceleration, velocity, rolling defect) of the Reducer

	F1H	F1V
GL : Acceleration	0.323	0.329
GL : Vibratory velocity	0.466	0.193
GL : Rolling defect	2.44	2.29
Kurtosis	3.04	2.90
2-200Hz	0.022	0.010
2-2KHz	0.133	0.133
2K-20KHz	0.362	0.292

Table 6. Measurements of global level (acceleration, velocity, rolling defect) of the Fan

The above tables clearly show the global levels of acceleration, velocity and rolling defect.

Constat

In normal working of turbine, and according to the E90-300 standard (Figure 9), the levied vibration severity on the different bearings is normal.

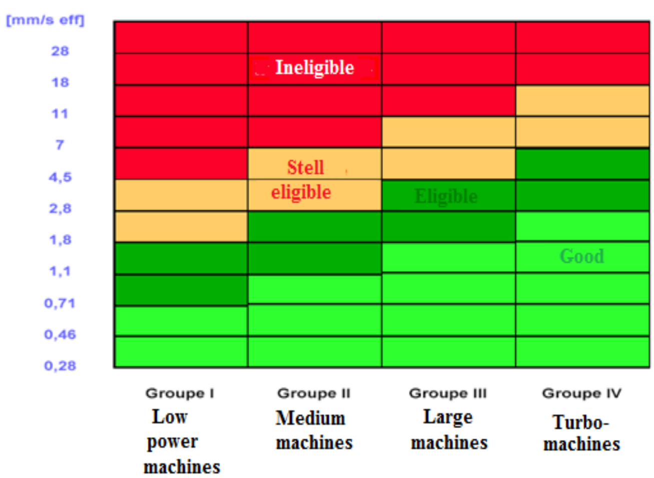

Figure9. Security Criteria Vibratory According to the Standard E90-300

5. Measure on ON-LINE surveillance system

In the case of the very strategic machines, which we are known to experiencing quite frequent failures, wewill choose stationary surveillance systems.The continued monitoring is also justified by security reasons. It all depends on the criticality of the machines.

The turbofan must be automatically stopped as soon as its vibratory levels exceed the eligibility threshold which is determined by the Standard E90-300.

This type of surveillance is used continuously in order to survey constantly the state of our machine,as well as it plays an important role in the efficient of the conduct of the enterprise. The surveillance On-line is mainly used to give the immediate warning of sudden change case in the status of the machine, thus triggering the alarm or produce alarm signals in the control room. So,for the appropriate measures can be taken before the disaster.

The table below shows the global levels of displacement rolling of turbines and reducers:

	P1	P2	P3	P4	P5	P6	P7	P8
GL : rolling displacement	6.04	5.53	5.17	5.61	8.97	10.7	26.5	22.7

Table 7. Measurements of GL of the rolling movement

knowing that:
T1 : P1 et P2 ;
T2 : P3 et P4 ;
R1 : P5 et P6 ;
R3 : P7 et P8.

5.1 Temporal signal measured on path 4

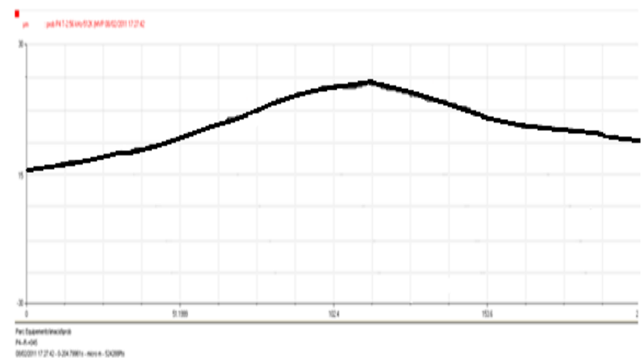

Figure10. Trend of the global level of rolling displacement on path 4

This measure shows an ascent/descent of the temporal vibrations on the path 4, which explains the turbine trip.

5.2 spectral Analysis

Measurement on path 4 when the displacement values are normal for a velocity of 7022 rev / min

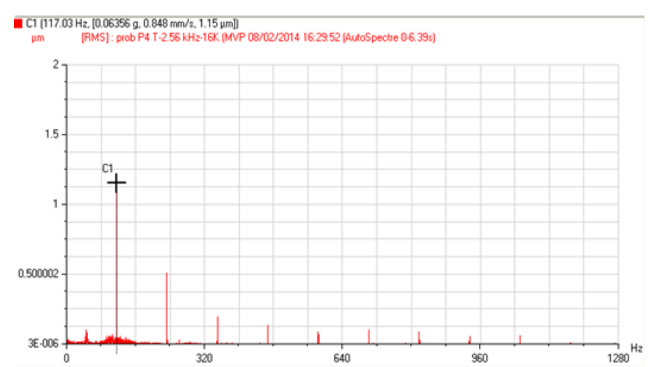

Figure11. Concatenated spectrum in linear scale of path 4

In this figure, no significant peak is observed, only a slight background noise is present. This confirms that the turbine is in good condition: it is no danger since once the value of rotational velocity 1x7022, is to 0.848 mm / s which is normal according te the standard E90-300 .

The following figure shows the measurement on path 4 during the ascent / descent of the amplitude for a velocity: 7022 r / min

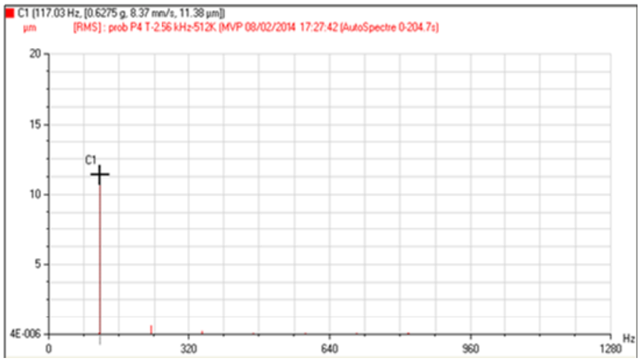

Figure12. Concatenated spectrum in linear scale of path 4 during the ascent/descent of the amplitude

On this spectrum, it is clear a peak corresponding to the presence of a defect on the path 4: once the value of rotational velocity 1x7022, is to 8.37 mm/s which is abnormal according te the standard E90-300 .

Findings and Recommendations

-The Mounted vibrations occurs with random periodicities.

-Measures which we have measured at Mounted vibrations confirm the high vibrations on the rack Bently.

-At The time of measurement on the rack, vibration observed on the bearing of the turbine by the device schenk (an agent of office phosphoric) showed a mounted from 0.3 to 6.8 mm / s.

-The temporal signal and the sampled spectrum on the rack (path 4) shows disturbance vibrations once the rotational velocity of the turbine,which lets thought the vibrations on the turbine are realand occur at the frequency of once rotation of the turbine.

-These Vibrations can be related to either:

- A random pumping phenomenon.
- A random unbalance phenomenon linked to impurities laid on the turbine or on the landing.
- A phenomenon whipping or bursting of the oil that benches functioning of the bearing and make it lose its lubricating properties so high vibrations.
- The system shuts down to protect the breakage of the rotor.
- He returned to office phosphoric to constitute a think tank to analyse the causes of effects proposed above by using methods such as: why why analysis, FMEA

VI. Conclusion

The objective of these studies was to provide the elements needed to monitor the vibration behavior of the equipment.The aim was to define the diagnosis process.

The introduction of anomalies such as gear defects and bearing defects changes the structure of the signals:General amplitude can increase and amplitude modulations and phase appear, the collected signals were observed in the field of spectral analysis.

The vibrations thus contain all the information about the state of the mechanical components of the machine. The difficulty lies in the analysis of vibration signals and identifying the components for the elements to be monitored.

References

i. Alain Boulenger, Christian Pachaud, DUNOD 2004 Vibration Analysis for maintenance.

ii. Jacques MOREL, Technique of ingénieur_R6 100 Vibration analysis and predictive maintenance.

iii. Alain Boulenger, Christian Pachaud, DUNOD 1998 Surveillance of machines by vibration analysis.

iv. John Heng DUNOD, paris, 2002 Practice of predictive maintenance.

v. Alain Boulenger, Christian Pachaud, DUNOD 1998 Vibration Diagnosis in preventive maintenance.

vi. Dynae, Vibration analysis for maintenance, Indicators of a reliable monitoring.