Journal of Engineering and Applied Sciences 11 (9): 2094-2104, 2016
ISSN: 1816-949X

Analysis and Diagnosis of Different Defects by Vibratory Analysis on Test Bench

[1]Amal Boukili, [1]Mohammed El Hammoumi, [2]Bachir El Kihel and [1]Said Haouache
[1]Industrial Techniques Laboratory (LTI), Faculty of Sciences and Techniques (FST), Sidi Mohammed Ben Abdellah University, BP. 2202, Fez, Morocco
[2]Laboratoire de Genie Industriel et Production Mecanique, Ecole Nationale des Sciences Appliquees, Universite Mohamed Premier, Oujda, Maroc

Abstract: Maintenance has become a real source of productivity for businesses. 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 become 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. There are numerous techniques required to be used in a maintenance plan 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 programmers. The present study consists in a first step, to provide a precise description of the characteristics of vibration, of vibration sensors, advantages and limitations of each family of indicators: scalars, spectral, vectors, temporal as well as vibration monitoring strategy. Then to make a vibration analysis of vibration signals from a set of organs of the vibratory bench to studies in the technological platform industrial engineering of ENSAO in order to detect the presence of defects by presenting and interpreting, if possible, the measurement results obtained.

Key words: Predictive maintenance, vibratory analysis, vibration sensors, vibration monitoring, spectral analysis

INTRODUCTION

All machines in operation produce vibrations, imagery of dynamic forces generated by the moving parts. Thus, a new machine in excellent working condition produces very little vibrations. The deterioration in the operation usually leads to an increase in vibratory levels. By observing the evolution of this level, it is therefore, possible to obtain valuable information about the state of the machine. These vibrations have a special place among the parameters to be considered for diagnosis (Eason *et al*., 1955; Pachaud *et al*., 1997).

The modification of the vibration of a machine constitutes usually the earliest manifestation a physical abnormality, potential cause of damage, or even failures. These features make monitoring by vibration analysis, an indispensable tool for modern maintenance since, it allows by screening or diagnosis of faults, to avoid breakage and to intervene on a machine at that good time and during scheduled shutdowns of production.

Generalities on the vibration

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

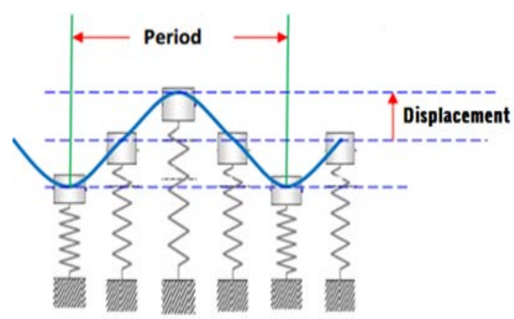

Fig. 1: Movement of a mass suspended to a spring

A mechanical system is in vibration, if it is animated by a movement of back and forth around an average position, called position of equilibrium. If we observe the movement of a mass suspended to a spring (Fig. 1), researchers discover that is reflected by:

Corresponding Author: Amal Boukili, Industrial Techniques Laboratory (LTI), Sidi Mohammed Ben Abdellah University, Faculty of Sciences and Techniques (FST), BP. 2202, Fez, Morocco

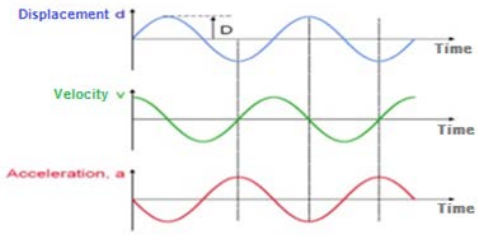

Fig. 2: Representation of the movement of a simple system

- A displacement; the position of the mass varies on either side of the equilibrium point
- A velocity; displacement variation with respect to time
- An acceleration; velocity variation with respect to time

The vibration of a machine subjected to a periodic force can be described in terms of displacement, velocity or acceleration (Fig. 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.

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

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

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

Nature of vibration: Any rotating machine in operation generates vibrations that can be classified as follows:

- The periodic vibrations sinusoidal type simple (Fig. 3a) or sinusoidal type complex (Fig. 3b) 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)
- The periodic vibrations impulse type: (Fig. 3c) 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 spalling of bearings or defect on gears, excessive play
- The random vibration impulse type: (Fig. 3d) can for example, be generated by a lack of lubrication on a rolling, the cavitations of a pump

Choice of physical quantities to be measured: To monitor a machine, one has to choose the physical quantity to measure. This quantity is called setting or surveillance indicator.

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: $F \leq 100$ 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: $F \leq 100$ 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: $0 \leq F \leq 20000$ Hz (Fig. 4)

To find a defect, researchers measure the vibration amplitude in mode of displacement, velocity or acceleration, according to the frequency of the dominant vibratory component is induced 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.

Vibration sensors: The obtaining of a vibration reading consists to convert the mechanical vibration produced by a machine into an equivalent electrical signal. This operation is performed by means of vibration sensors. These represent the critical element of the measurement chain.

Among the most commonly used sensors we find: the proximeter to measure the displacement, the velocimeter to measure the speed and the accelerometer to measure the acceleration (Harris and Piersol, 2002). A vibration sensor is mainly characterised by:

- Its bandwidth (usage range); frequency range within which the amplitude measured by the sensor does not exceed a margin of error fixed by the manufacturer
- Its dynamic range (amplitude measurement range) range between the smallest and the largest amplitude accepted by the sensor

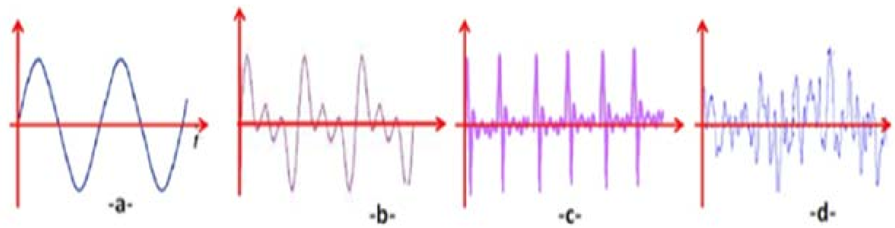

Fig. 3: The nature of a vibration

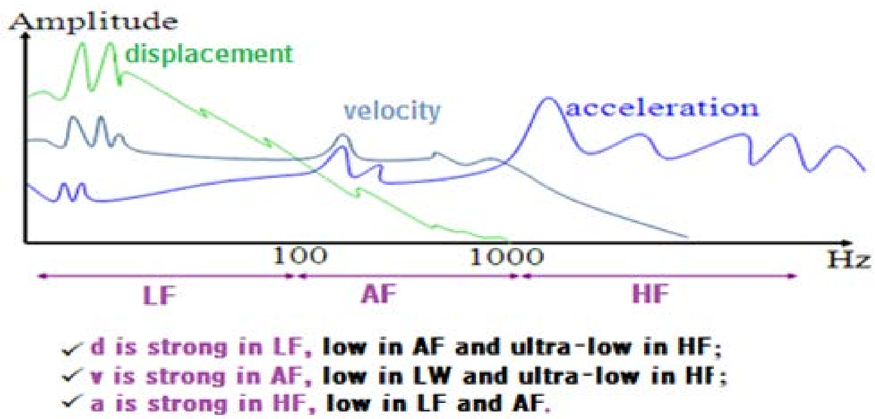

Fig. 4: Choice of physical quantities to be measured depending on the nature of defects sought

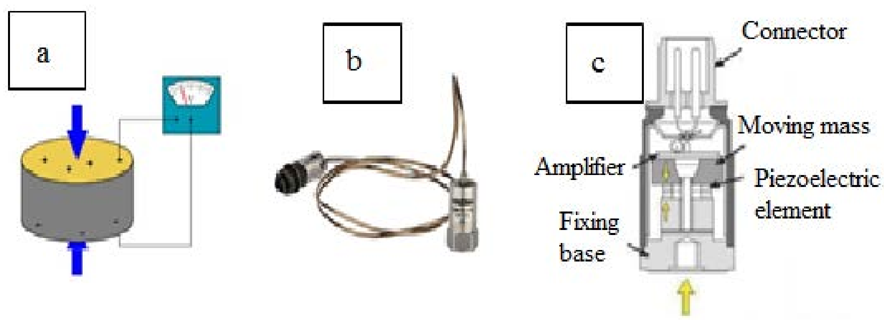

Fig. 5: The behavior and the components of a piezoelectric

- Its sensitivity: relationship between the electrical variable delivered to the sensor output and the amplitude of the mechanical movement that gives it birth. It is given by the manufacturer of the sensor

The most used in vibratory analysis sensors are accelerometers. The principle of operation of the accelerometer is based on the property possessed by the piezoelectric materials to electrically polarize under the influence of a force, where charges appear on crystal surfaces.

An accelerometer is constituted by a disk made of piezoelectric material which acts as a spring on which rests a mass. Thereof moves under the effect of an acceleration, it exerts on the piezoelectric disc efforts inducing an electric charge proportional to the acceleration. The accelerometers are highly appreciated because they have many properties:

- Usable over very large frequency ranges
- Excellent linearity over a wide dynamic range (typically 140 dB)
- The acceleration signal can be electronically integrated to give the displacement and the speed
- Vibration measurements can be made under a variety of environmental conditions while maintaining excellent precision (typically 250, -400, -700°C for special models)

- It is charge generator, so it is independent of any external power supply
- No mobile component, therefore extremely durable

Extremely compact and has a good price/quality ratio

Vibratory indicators

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 its development, formulating a diagnosis need to appeal to numerous indicators and criteria. There are four types (Pachaud *et al*., 1997): scalar indicators, spectral indicators, vector indicators and time indicators.

According of their parameters, these indicators can be grouped into two main categories: 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 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 (DYNAE).

The scalar indicators: A scalar indicator associated with a raw signal or having been the subject of prior treatment (filtering, demodulation) a characteristic of the 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) (Pachaud *et al*., 1997).

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) (DYNAE).

The spectral indicators: A spectral indicator associated with a signal a spectral representation of the latter (spectrum, zoom, cepstrum, spectrum modulation function, transfer function).

These indicators present a greater interest in being sensitive as well to developments in the form of a signal well as to those of its energy and therefore are insensitive to masking effects, provided that the resolutions of analysis chosen for elaborate are in line with the repetition frequencies of the sought phenomena. They thus offer extremely interesting prospects in the context of machine monitoring. They moreover 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 (DYNAE; Pachaud *et al*., 1997).

The vector indicators: A vector indicator combines the 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 distorted or overall 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 (DYNAE).

The time indicators: A time indicator associates to a signal 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 shucked teeth, the duration of a periodic impulse phenomenon or the form of a modulation phenomenon (DYNAE; Alfredson and Mathew, 1985).

Fields of applications: Numerous types of industrial equipment and machines can be monitored by vibratory analysis methods. Their list is provided in Table 1.

Table 1: Fields Of applications currants of vibratory analysis

Centrifugal machines	Continual process	Alternative movement
Pump	Continuously cast	Pumps
Compressors	Band trains, in hot	Compressors
Fans	or in cold	Diesel engines
Blowers		Petrol engines
Motor-generators	Circuit lines	Machine tools
Ball mill	Plating lines	Grinding machines
Refrigerators	Stationery machinery	Tools for boring
Mixers	Manufacturing lines of	Milling
Speed of boxes	boxes of conserve	Machining centers
Centrifuges	Stripping lines	Dippers
Transmissions	Impression	Processing machines
Turbines	Dyeing and finishing	of metal
Dryers tournants	Chemical plants	
Electric motors	Refineries	Grinding machines

MATERIALS AND METHODS

Strategies for vibration monotoring

Global analysis: Global analysis aims to monitor the machine health status (control without diagnostics), based on the measurement of vibration signals in the radial and axial directions (Fig. 6) (Tandon and Choudury, 1999).

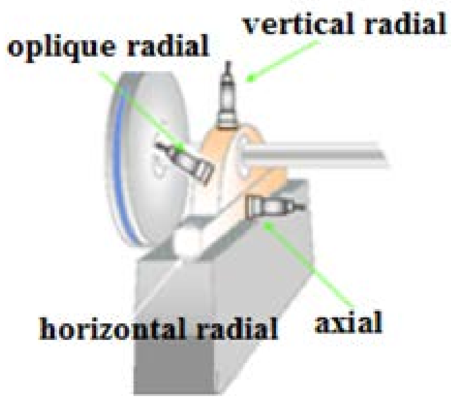

Fig. 6: Illustrative diagram of different radial and axial directions

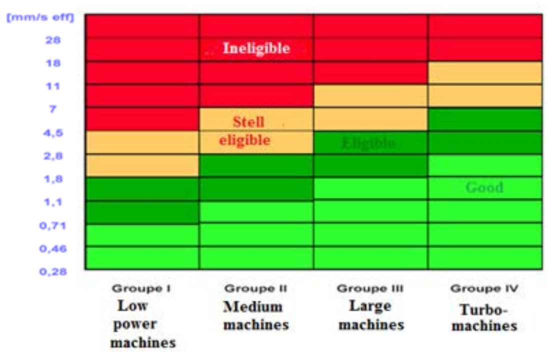

Fig. 7: Security criteria vibratory according to the standard E90-300 (Norm)

This type of measurement is easy to use and effective for the detection of fault level. The value generally used is the vibratory amplitude which makes it possible to locate the defect compared to a level of alarm but does not inform about the origin of the problem.

Consequently, the global analysis consists in measuring the effective value of the vibratory signal and to compare it with thresholds defined by the standards which depend on the power of the machine and the industrial sector.

Spectral analysis: The temporal signals are often random signals and thus difficult to analyze, on the other hand their spectra are very simple and easy to exploit. The spectral analysis is a study of the variations of amplitudes of the vibratory signal of frequential representation (Tandon and Choudury, 1999). This technique makes it possible to recognize the anomalies being able to exist in the machine. Indeed, starting from the frequencies to which the anomalies appear, it is possible to detect the origin of a defect and to follow of it the evolution thanks to the spectral signatures of each defect.

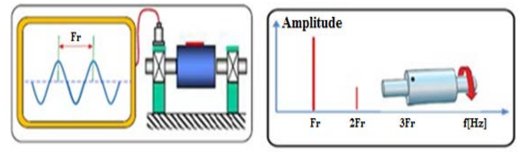

Fig. 8: Temporal signal of an unbalance and its theoretical spectrum

Defect of imbalance: When the axis of rotation of the tree does not coincide with its axis of inertia, there would be appearance of a centrifugal force which deforms the rotor: it is said that the rotor presents an unbalance.

If we measure the amplitude of the vibratory signal using a sensor placed on the bearing supporting an unbalanced rotor, the spectrum of the measured signal present a peak at the rotational frequency of the shaft and his harmonics. The vibratory signal generated by an unbalance and its spectral signature are shown in the Fig. 8.

Misalignment: Researchers talk about misalignment when the axes of the two shafts are not confused on the level of a coupling or when the two bearings supporting a shaft are not well aligned.

The radial misalignment is distinguished for which the two axes are parallel but eccentric, of the angular misalignment for which the two axes form a certain angle between them (Sahraoui *et al*., 2008). On the spectrum, we see the presence of components 2.3 or even 4 times the rotational frequency with amplitudes higher than those of the component of order 1 (Fig. 9).

Defect of belts: The principal defect encountered on belts is related to a localised deterioration: torn off part or defect of joint. This defect is directional. Its privileged direction is that of the tension of the belts. Thus, the signal corresponding to the defect of belts, if there exists, will be stronger in the horizontal direction than in the vertical direction. Figure 10 shows frequencies characteristic of a defect of belt (Sidahmed, 1991). Where, N_1 and N_2, respectively represent the rotational speeds of the wheels n^{o1} and n^{o2}. Frequencies of the defect of belt. For the wheel n^{o1}:

$$F_{b1} = Fr \times \frac{\pi \times D_1}{1} \tag{1}$$

For the wheel n^{o2}:

$$F_{b2} = Fr \times \frac{\pi \times D_2}{1} \tag{2}$$

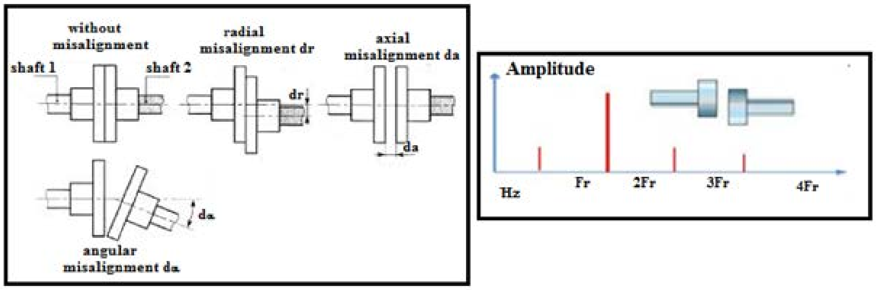

Fig. 9: Spectrum characteristic of a misalignment of shafts

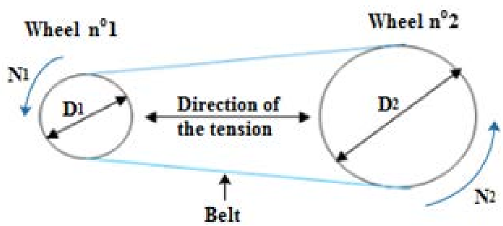

Fig. 10: Frequencies characteristic of a defect of belt

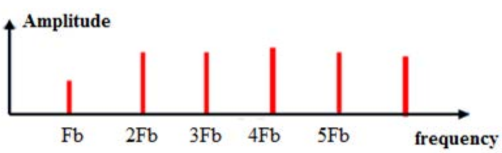

Fig. 11: Spectrum of a defect localised of belt

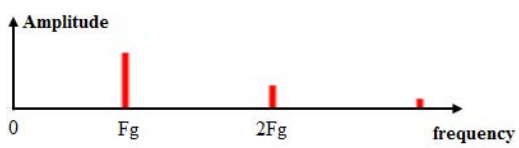

Fig. 12: Spectrum of the healthy gearing

The vibratory image gives a peak of important amplitude to the frequency of passage of belts F_b and its harmonics (Fig. 11).

Defect of the gearing: Gears composed of two cogwheels 1 and 2, representing z_1 and z_2 teeth respectively and turning at the frequencies F_1 and F_2. Even if gears are healthy, each time a tooth of wheel 1 engages in wheel 2, it occurs a catch of load. The spectrum thus contains a peak at the frequency of gearing F_g and its harmonics (Fig. 12). Such as:

$$F_g = F_1 \times z_1 = F_2 \times z_2 \quad (3)$$

If one of wheels presents a deteriorated tooth, it occurs a hard shock, at each tower of the wheel. The spectrum corresponding (Fig.13) shows a comb whose step corresponds to the rotational frequency of the deteriorated wheel and being itself until the high frequencies.

Fig. 13: Spectrum of gears presenting a deteriorated tooth
Bearings defects

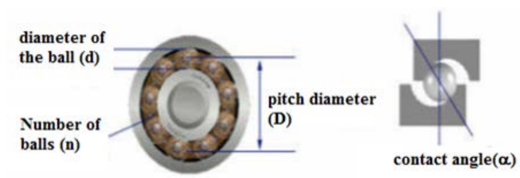

Fig. 14: Characteristics of a Bearing

Bearing defect: The bearings are among the most requested components of the machines and represent a source of frequent breakdowns. The defects which we can be encountered are kind of chipping, galling, corrosion, etc. (Benbouaza *et al*., 2013)

In most case, degradation results in chipping of one of the tracks or a rolling element (Stack *et al*., 2005), producing a shock at each passage. The defective bearings generate vibrations of frequencies equal to the rotational speeds of each part of bearing (Stack *et al*., 2005). It is thus possible to locate the defect and thus to know if it is located on the inner ring, on the outer ring, on the cage or on the rolling elements. The characteristics of a bearing are shown in Fig. 14. Indeed, each organ of the bearing, presents a characteristic frequency. The frequency of the outer ring is given by:

$$F_{Rout} = 0.5 \times F_r \times n(1 - (\frac{d}{D} \times \cos(\alpha)) \quad (4)$$

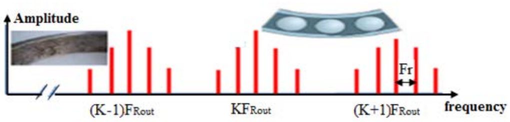

Fig. 15: Spectrum of a defect of type chipping on the outer ring

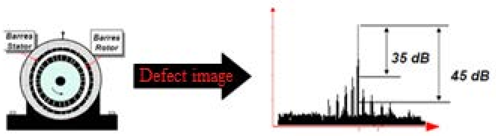

Fig. 16: Spectrum of a defect of crack on rotor bars

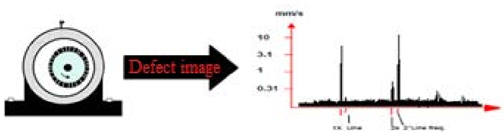

Fig. 17: Spectrum of a defect of crack on stator bars 6

The frequency of the inner ring is giving by:

$$F_{Rout} = 0.5 \times F_r \times n(1 + (\frac{d}{D} \times \cos(\alpha)) \tag{5}$$

The frequency of the rolling elements is giving by:

$$F_{ball} = 0.5 \times F_r \times \frac{d}{D \times (1 - (\frac{d \cos \alpha}{D})^2)} \tag{6}$$

The frequency of the cage is giving by:

$$F_{cage} = 0.5 \times F_r \times (1 - (\frac{d}{D} \cos(\alpha)) \tag{7}$$

Where:

n = The number of rolling elements (balls, rollers or needles)
D = The pitch diameter
d = The diameter of rolling elements
a = Contact angle
Fr = Rotational frequency of the inner ring (the outer ring being supposed fixed)

Thus, for example a defect of type chipping affecting the ring of an outer ring has as a vibratory image a comb of lines, whose step corresponds to the frequency of F_{Rout}. At each component of this comb, is associated a pair of lateral bands spaced with the rotational frequency (Fig. 15).

A defect of type chipping affecting the inner ring has as a vibratory image a comb of lines centered on F_{rinn}. At each component of this comb are associated several pairs of lateral bands spaced with the rotational frequency (Fig. 16 and 17).

Fig. 18: The Vibratory Bench of Studies

Electric defect: Among the defects of electric origin, there are:

- Rotor defect (Bonnett and Soukup, 1992)
  - Bars rotor broken
  - Open electrical circuit
  - Eccentric or curved rotor
- Stator defect
  - Short-circuit open in the coil
  - Ovalisation of the stator

RESULTS AND DISCUSSION

Experiments at the laboratory

Objective: This part aims to illustrate in a real case the spectral analysis. The study will be based on vibratory measures carried out on the Vibratory Bench of Studies of the technological laboratory platform 2M located at the National school of Sciences Applied-Oujda (ENSA). This test bench (Fig. 18) makes it possible to introduce the various defects and to acquire measurements relative to these various defects. These measurements were carried out using device "AVIBROTEST 60" (Fig. 19), it is a device of type (analyzer/collector) which measures the vibration in various strategic locations. Where:

- Command box
- Device of load of bearing
- Engine with two shaft ends
- Multiplier
- Srvo protection cover
- Pump centrifuges monocellulaire
- Circuit of repression
- Circuit of aspiration
- Reservoir

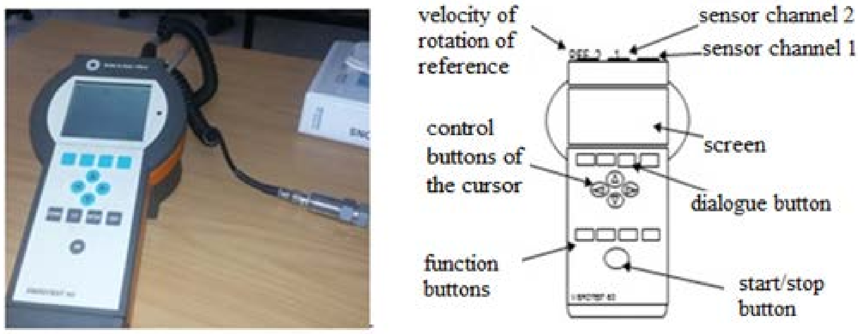

Fig. 19: VIBROTEST 60 and its schematic description

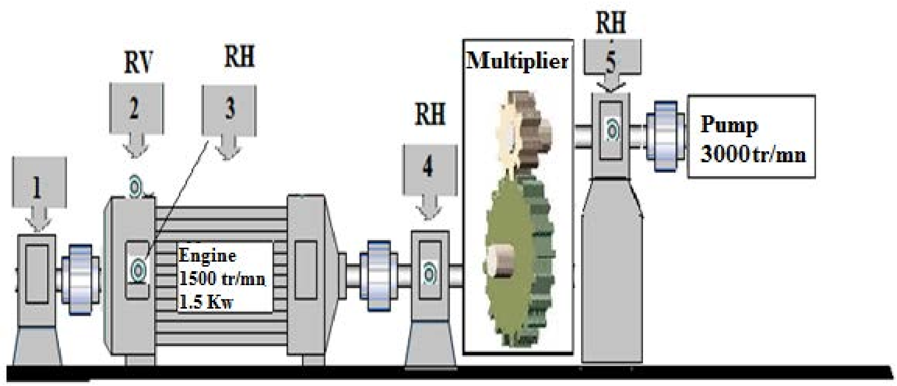

Fig. 20: The kinematic chain of the vibratory bench of studies

- Equipment of measurement of the vibrations
- Laser system of shaft alignment

Description of the measuring equipment: The acquisition of the vibratory signals was ensured by an analyzer named VIBROTEST 60 connected to a piezoelectric accelerometer as shown in the Fig. 19. The VIBROTEST 60 is a device of type analyzer/data collector. It makes it possible to acquire the vibratory signal and to treat it in real time (analyzer mode) as it can record the measured signals. It is constituted mainly by:

- Two numbered connectors 1 and 2 for the connection of the sensors
- A connector named "REF" for the connection of the photoelectric sonde
- A screen which visualizes the signal measured as well as the various parameters
- The dialogue buttons for the select and the adjustment of the parameters
- The control buttons for the displacement of the cursor on the visualized signal
- The function buttons for the recording of the results and the modification of the system configuration
- A start/stop button

Kinematic chain: The following figure represents the kinematic chain of the vibratory bench of studies as well as the points of measurement on which is disposed VIBROTEST 60 for measurement. The latter are indicated by numbers on the following figure: Where:

- RV means a measurement point into Radial Vertical
- RH represents a measurement point into Radial Horizontal

Spectral analysis of the vibratory bench of studies: The organs of the test bench which we controlled are: the bearing, the engine, the gearing and the pump.

Bearing control: Researchers conducted an axial measurement in the frequency band (0-200 Hz). The rotational frequency of the shaft was fixed at F_r = 10 Hz. The defects of the bearing generally appear around these frequencies: the frequency of outer ring F_{rout} = 194 Hz; the frequency of inner ring F_{rinn} = 274 Hz and the frequency of cage F_{cage} = 20 Hz.

In order to check the health status of the bearing, researchers took a radial horizontal measure in the range of (0-200 Hz). The spectrum obtained is visualized on the following Fig. 21:

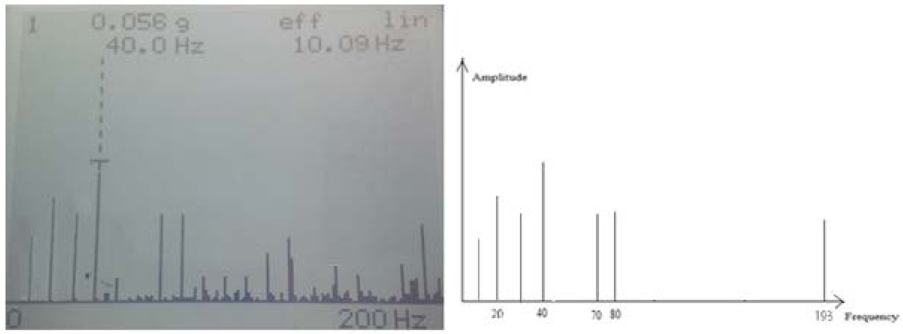

Fig. 21: Spectrum of the bearing on (0, 200 Hz)

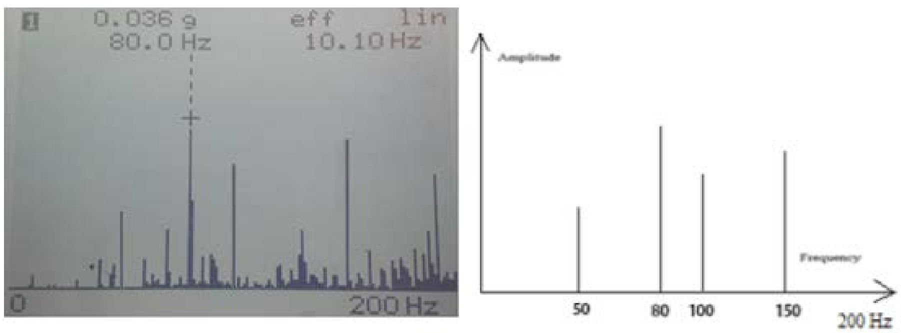

Fig. 22: Spectrum of the engine at direction radial vertical on (0, 200 Hz)

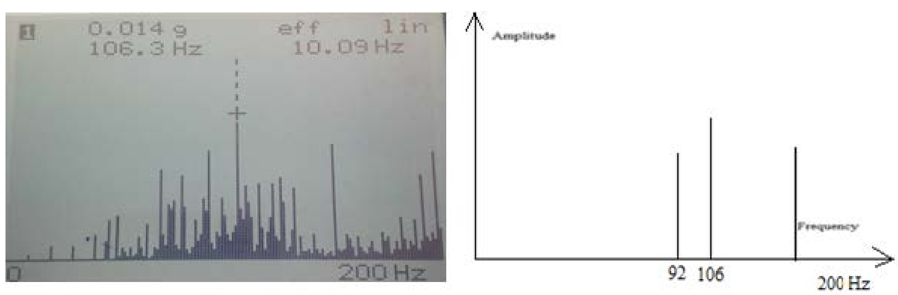

Fig. 23: Spectrum of the engine at direction radial horizontal on (0, 200 Hz)

Engine control: The electrical engine is composed by a rotor and a stator. The control of these two organs can be done in low frequencies, as it can be done on average frequency, around the frequency of notch. The measure at direction radial vertical in low frequencies (0-200Hz) gave rise to the spectrum visualized on the following Fig. 22. The measure at direction radial horizontal in low frequencies (0-200 Hz) gave rise to the spectrum visualized on the following Fig. 23:

Gearing control: The defects of gearing generally appear around the frequency of gearing Fg and its harmonics. The F_g is given by:

$$F_g = z_1 \times Fr_1 = z_2 \times Fr_2$$

Where:

z_1 = The number of teeth of the first wheel
z_2 = The number of teeth of the second wheel
z_1 = 53 teeth
z_2 = 53 teeth

For a rotational frequency of the engine F_{r1} = 10 Hz; the frequency of the gearing F_g = 530 Hz and F_{r1} = 20.3 Hz. So, in order to check the health status of the gearing, we took a radial horizontal measure in the range of (0-2000 Hz). The spectrum obtained is visualized on the following Fig. 25.

Pump control: A measure into radial horizontal was taken on the pump with a rotational frequency of 10 Hz in a range of 2 kHz is shown in the following Fig. 24 and 25:

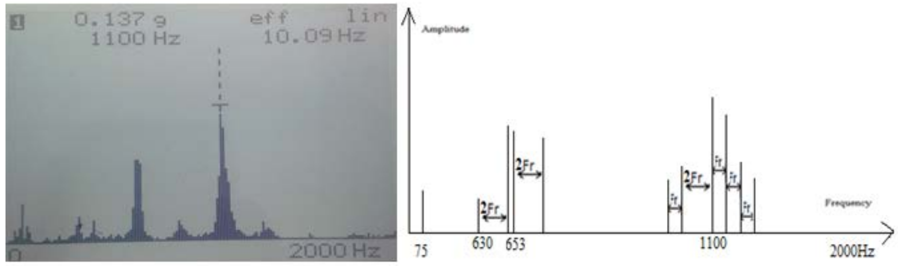

Fig. 24: Spectrum of the gearing at direction radial horizontal on (0, 2000 Hz)

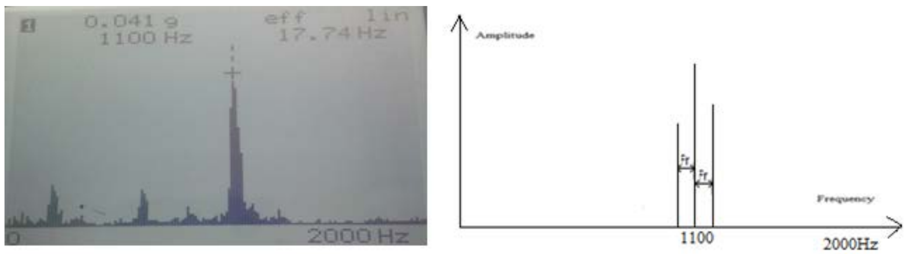

Fig. 25: Spectrum of the pump at the direction radial horizontal on (0, 2000 Hz)

- In Fig. 21, we note the presence of fundamental Fr = 10 Kz and its harmonics: 2, 3 and 4 Fr which suggests that it is about an angular misalignment

Researchers notice also the presence of the frequency 20 Hz which represents F_{cage} as well as its multiple 40 Hz which lets say that it is a defect of cage. The presence of the frequency F = 193 Hz which is close to the frequency F_{rout} = 194 Hz, leads us to conclude that it is a defect on the outer ring. These vibrations can be caused by:

- A random phenomenon of unbalance related to the impurities posed on the bearing
- A phenomenon of whipping or bursting of the oil which puts except game operation of the bearing and to make him to lose its lubricity so high vibrations

In Fig. 22, we notice the presence of the frequency 80 Hz which represents a dental defect of coupling. And also the presence of the supply frequency Fc = 50 Hz as well as its harmonics with a maximum of amplitude for the peak 150 Hz which is 3 Fc. there is probably an electric defect, this problem can be caused by:

- Bar rotor broken
- Unequal air-gap (static eccentricity or dynamics)
- Stator problems (iron which moves)
- Imbalance of the phases or defect of unbalance of the rotor

The peaks which researchers considered interesting in Fig. 23 are found on the frequency F_1 = 92 Hz and F_1 = 106 Hz are not represent a defect since their amplitudes do not exceed the threshold defined by the standard.

In Fig. 24, researchers notice that there is an amplitude modulation around the frequency 663Hz and another modulation around the frequency 1100 Hz. Researchers did not find the link between these frequencies and the frequencies characteristic of the machine. It is perhaps about a resonance or the characteristics of the gearing provided by the manufacturers contain errors.

The spectrum of Fig. 25 contains a rise in level vibratory around frequency 1100 Hz which could be at the origin of a defect of cavitation or a random phenomenon of pumping.

CONCLUSION

The early detection of the defects of the machines remains a topical field of research essentially for news aiming the development of reliable and practical methods. Indeed, in several bibliographical studies, the spectral analysis was presented as being a technique of vibratory monitoring reliable and practical for the detection of the defects, this technique makes it possible to recognize the anomalies may exist in the machine. Indeed, starting from the characteristics of a monitored machine and frequencies at which the anomalies appear, it is possible, to detect the origin of a defect and to follow of it the evolution through the spectral signatures of each defect. The aim was to initially provide a precise description on the characteristics of a vibration, the vibration sensors, the interest and the limits of each family of indicators: scalars, spectral, vector, temporal and vibratory strategy of monitoring as well as to control a set of organs of the Vibratory Bench to Studies available in the technological platform Industrial Engineering of the National school of Sciences Applied-Oujda ENSAO by using the spectral analysis, in order to detect the presence of defects. According to the tests conducted we concluded that:

- The spectral analysis makes it possible to detect the defects of electric, misalignment, gearing, bearing and cavitation
- In spite of the small failures, the organs should not be changed if their amplitudes do not exceed the threshold defined by the standard E90-300
- When there is a defect of misalignment, there is appearance of the peak of the rotational Frequency (Fr) and its harmonics
- When we have rotating shaft installation
- When there is a defect on the inner ring, there is appearance of the peak frequency of these defects and a big number of lateral bands, because are submitted to modulation of the shaft rotation speed
- When there is a defect on the outer ring or in the cage of bearing, there is appearance of the peak frequency of these defects and his multiples

ACKNOWLEDGEMENTS

The researchers are pleased to acknowledge the partial support of the Industrial techniques laboratory (LTI), Sidi Mohammed Ben Abdellah University, Faculty of Sciences and Techniques. Also, we are gratefully acknowledged the technological platform PFT2M, Industrial Engineering Laboratory and Mechanical Production of the ENSA-Department of Industrial and LDOM in Oujda for giving us permission to use their facilities for the research.

REFERENCES

Alfredson, R.J. and J. Mathew, 1985. Frequency domain methods for monitoring the condition of rolling element bearings. Trans. Inst. Eng. Aust. Mech. Eng., 10: 108-112.

Benbouaza, A., B. Elkihel and F. Delaunois, 2013. Analysis and diagnosis of the different defects of asynchronous machines by vibration analysis. Intl. J. Comput. Sci. Eng., 5: 258-269.

Bonnett, A.H. and G.C. Soukup, 1992. Cause and analysis of stator and rotor failures in three-phase squirrel cage induction motors. IEEE Trans. Ind. Appl., 28: 921-937.

Eason, G., B. Noble and I.N. Sneddon, 1955. On certain integrals of Lipschitz-Hankel type involving products of Bessel functions. Philos. Trans. R. Soc. London, 247: 529-551.

Harris, C.M. and A.G. Piersol, 2002. Harris Shock and Vibration Handbook. McGraw-Hill, New York, USA.,.

Pachaud, C., R. Salvetat and C. Fray, 1997. Crest factor and kurtosis contributions to identify defects inducing periodical impulsive forces. Mech. Syst. Signal Process., 11: 903-916.

Sahraoui, M., A. Ghoggal, S.E. Zouzou and M.E. Benbouzid, 2008. Dynamic eccentricity in squirrel cage induction motors-Simulation and analytical study of its spectral signatures on stator currents. Simul. Modell. Pract. Theory, 16: 1503-1513.

Sidahmed, M., 1991. Detection de defauts dans les engrenages. Cetim Inf., 124: 71-74.

Stack, J.R., T.G. Habetler and R.G. Harley, 2005. Experimentally generating faults in rolling element bearings via shaft current. IEEE. Trans. Ind. Appl., 41: 25-29.

Tandon, N. and A. Choudhury, 1999. A review of vibration and acoustic measurement methods for the detection of defects in rolling element bearings. Tribol. Intl., 32: 469-480.