Mechanical Vibrations Analysis

Iby del Rosario Márquez Ambriz[1], Ubaldo Sánchez Grajeda[2], Clemente Torres Ibarra[3], José Antonio Vázquez Vences[4], José Luis Hernández Corona[5], Ernesto Mendoza Vázquez[6]

[1-6]Ingeniería en Mantenimiento Industrial, Universidad Tecnológica de Tlaxcala, El Carmen Xalpatlahuaya Huamantla, Tlaxcala, Mexico..

---***---

Abstract – Vibration measurement and analysis is the main technique used for monitoring the condition of machines. *This allows us to know in depth the behavior of the equipment while it is in operation and help us to detect as many mechanical problems in the equipment of an industry. By measuring and analysing vibrations in machines and industrial equipment, point failures are detected which avoid unnecessary dismantling, emergencies are minimised, the whole life span of the machine components is used, the extent of damage is prevented and scheduled stops are made. This reduces the cost of maintenance in all industrial plants by a large percentage. Predictive maintenance uses several discipline. The most important of these is a periodic vibration analysis. There are commercial vibration analysis systems, so it is essential to know the techniques used to identify and predict mechanical anomalies in industrial machinery, measuring the vibration and identifying the frequencies involved.* In this document we present the vibration recorded *by an ADXL335 speedometer that send electrical signs of the vibration acceleration through arduino UNO and the data is processed in LabVIEW software as a spectrum analyzer.*

Key Words: Speedometer, Arduino, failure, spectrum.

1. INTRODUCTION

In this research the authors compiled notes for the analysis of mechanical vibration versus other general maintenance methods to reduce costs and increase reliability of equipment performance. In the evolution of mechanical vibrations, the developments in methodology and mathematics needed to establish the framework that systematizes knowledge must be considered. This approach allows us to put together in our brains the complex puzzle that represents the evolution of human knowledge in any area. Cultural circumstances related to date and place of birth, education, wars, plagues, etc., are creating the conditions for every step to be taken. This text presents a possible reading of this history by classifying the evolution of vibration inn stages of development and records. It is possible to group, in a first period that we call "origins", the events and people who laid the conceptual foundations of the field of vibrations. This period goes from antiquity to the Renaissance, that is, approximately from 3000 B.C to 1500 of our era.

They can be recognized in this period as main lines:

- Music and musical instruments
- The emerge of the basic concepts of the scientific methodology.
- The basic principles of vibration such as: movement, natural frequency, resonance, energy, isolation, measurement.

A second period to be considered is that from the Renaissance to the mid- 19th century, which we will call "formalization". At this time there is a great mathematical and conceptual development that consolidates the theoretical body of vibrations, as well as progress in instrumentation. Once the theoretical framework was established, the determination factor in the consolidation of the engineering approach to vibrations was the development of high speed machinery, which developed under the pressure of industrialisation. We will call this stage from approximately 1850 to 1950 "applications". During this dynamic period, the engineering concepts and applications required by machinery such as: locomotives, cars and airplanes are made, ranging from the steam engines to turbines. Of course, the above-mentioned implies the development of modern methods of analysis and design, and also the publication of the books, text and consultation,that allowed the diffusion of this area of knowledge. Vibration engineering continues to develop, but it was considered appropriate to stop at this point.

Mechanical Vibrations

The development of predictive systems such as Mechanical Vibration being those that are intended to measure after a time interval, measuring the vibration or oscillation and identifying the frequencies involved. The swinging of a pendulum and the movement of a plucked string are references of vibration. The theory of vibration has to do with the study of the oscillatory movements of bodies and forces associated with them [1].

A vibratory system typically includes a means to store potential energy (spring or elasticity), a means to conserve energy (mass or inertia), and a means by which energy is gradually lost (damping).

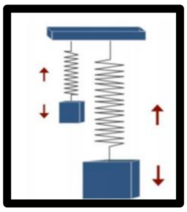


Fig -1: Mass-spring Experiment

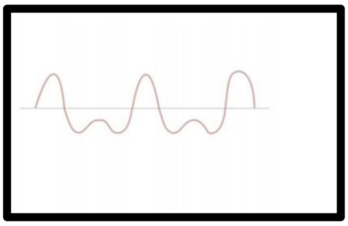


Fig -2: Time-dependent displacement

The vibration of a system involves the transformation of its potential energy into kinetic energy and from this into potential energy in an alternating manner. If the system is damped, some of its energy is dissipated in each vibration cycle and must be replaced by an external source to maintain stable vibration state.

Characteristics of vibration measurement and its characteristic equation, are:

- Displacement (amplitude): It is the distance between the position of the particle that vibrations and its position of rest. We generally refer to the maximum amplitude. Unit: m

Ec. 1 $\Delta x = x_f - x_0$

- Speed: It is the speed that animates the particle. It is equivalent to that derived from displacement with respect to the time. Unit: m/seg.

Ec. 2 $V = k\,[A]^x\,[B]^y$

- Aceleración: Es la variación de la velocidad por unidad de tiempo y equivale a la segunda derivada del desplazamiento con respecto al tiempo. Unidad: m/seg2

Ec. 3 $$a = \frac{v - v_0}{t}$$

- System´s own frequency: This is the frequency at which the system would oscillate taken out of its equilibrium state. It is a function of the mass and elasticity of all the systems that make it up. Unit: Hz.

Ec. 4 $$f = \frac{1}{\tau}$$

- Resonance: When a system is excited by an external harmonic force, whose frequency is equal to the natural frequency of the system, the amplitude of the vibration increases and the system is said to be in resonance (3).

Ec. 5 $$\beta = \frac{\Omega}{\omega} = 1$$

- Damping: Any influence that extracts energy from a vibrating system is known as damping. The definitions given have informative and clarification value only, and are not fixed by ISO 10816 (2).

Ec. 6 $F = mx'' + cx' + kx$

1.2 Components

The applied components to this measurement system are the next.

A cycle evaluates the distance the start and end point of a wave. From the distribution of the intensities of a radiation as a function of wavelength, energy, frequency, mass or any other related magnitude are attributed to the spectrum.

The bearing has a hole inside it for the shaft to rest. The shaft turns the parts that make up the machine, which without transmitting any torsional force turns the gearbox that has a mechanism used to transmit mechanical power from one component to another. One of the parts that make up a machine and serve to reduce the friction between a shaft and the parts connected to it, is the bearing that provides support and facilitates its movement.

2. Methodology

2.1 Vibration analysis

This module will allow us to develop vibration analysis [4] for dynamic broken systems, through a transmission system that is a motor, a belt and a disc with different perforations, this allows us to place different counterweights and evaluate different types of levels of unbalance. However, when any of its components fail, the characteristics of these vibration change allowing under a detailed study to identify the place and type of failure that is occurring, thus facilitating its rapid repair repair and maintenance. Vibration analysis is based on the interpretation of the vibration signals with reference to the tolerance level indicated by the manufacturer or by technical standards.

2.2 Vibration measurement

The instrument proposed for this research is to determine the vibrations by means of the acceleration sensor **ADXL335**. This sensor is placed directly on the machine at those points that are susceptible to failure. rectly on the machine at those points that are susceptible to failure.

In general, the shafts are one of the most frequently damaged parts. For this reason, a good place to place the sensor is on the bearing supports since vibrations are transmitted through them.

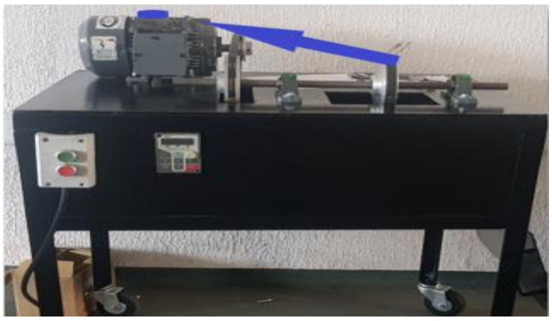
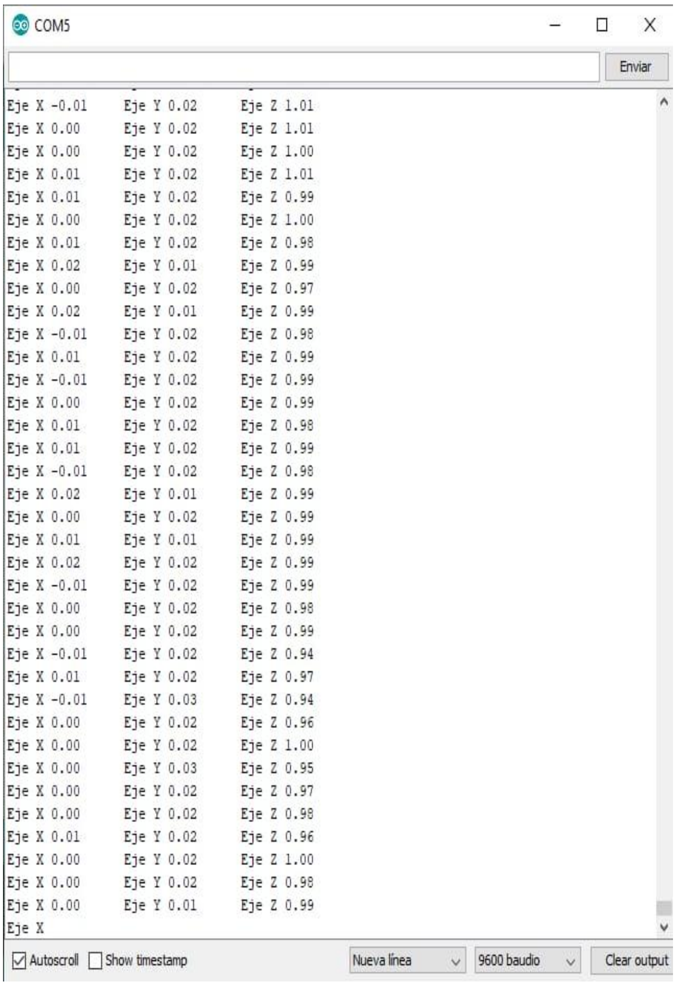


Fig -3: Sensor position

One factor that influences the quality of the measurements is the connection of the sensor in such a way that makes it good contact with the structure of the machine so that it can take readings in the 3 axes, two radial: vertical and horizontal and one axial. Readings must be taken while maintaining the same machine operating conditions, the location of the sensor and the time between measurements so that the data obtained can be compared. The following table shows the results of the measurements obtained by the ADXL335 acceleration (in G´s)and prints out on the serial monitor the value of each axis. The Z axis shows a 1 or 0.99 which is the acceleration of gravity. Depending on how we accommodate the sensor that value changes.

Table-1: Sensor reading results



COM5

Enviar

Eje X -0.01	Eje Y 0.02	Eje Z 1.01
Eje X 0.00	Eje Y 0.02	Eje Z 1.01
Eje X 0.00	Eje Y 0.02	Eje Z 1.00
Eje X 0.01	Eje Y 0.02	Eje Z 1.01
Eje X 0.01	Eje Y 0.02	Eje Z 0.99
Eje X 0.00	Eje Y 0.02	Eje Z 1.00
Eje X 0.01	Eje Y 0.02	Eje Z 0.98
Eje X 0.02	Eje Y 0.01	Eje Z 0.99
Eje X 0.00	Eje Y 0.02	Eje Z 0.97
Eje X 0.02	Eje Y 0.01	Eje Z 0.99
Eje X -0.01	Eje Y 0.02	Eje Z 0.98
Eje X 0.01	Eje Y 0.02	Eje Z 0.99
Eje X -0.01	Eje Y 0.02	Eje Z 0.99
Eje X 0.00	Eje Y 0.02	Eje Z 0.99
Eje X 0.01	Eje Y 0.02	Eje Z 0.98
Eje X 0.01	Eje Y 0.02	Eje Z 0.99
Eje X -0.01	Eje Y 0.02	Eje Z 0.98
Eje X 0.02	Eje Y 0.01	Eje Z 0.99
Eje X 0.00	Eje Y 0.02	Eje Z 0.99
Eje X 0.01	Eje Y 0.01	Eje Z 0.99
Eje X 0.02	Eje Y 0.02	Eje Z 0.99
Eje X -0.01	Eje Y 0.02	Eje Z 0.99
Eje X 0.00	Eje Y 0.02	Eje Z 0.98
Eje X 0.00	Eje Y 0.02	Eje Z 0.99
Eje X -0.01	Eje Y 0.02	Eje Z 0.94
Eje X 0.01	Eje Y 0.02	Eje Z 0.97
Eje X -0.01	Eje Y 0.03	Eje Z 0.94
Eje X 0.00	Eje Y 0.02	Eje Z 0.96
Eje X 0.00	Eje Y 0.02	Eje Z 1.00
Eje X 0.00	Eje Y 0.03	Eje Z 0.95
Eje X 0.00	Eje Y 0.02	Eje Z 0.97
Eje X 0.00	Eje Y 0.02	Eje Z 0.98
Eje X 0.01	Eje Y 0.02	Eje Z 0.96
Eje X 0.00	Eje Y 0.02	Eje Z 1.00
Eje X 0.00	Eje Y 0.02	Eje Z 0.98
Eje X 0.00	Eje Y 0.01	Eje Z 0.99
Eje X		

Autoscroll Show timestamp Nueva línea 9600 baudio Clear output

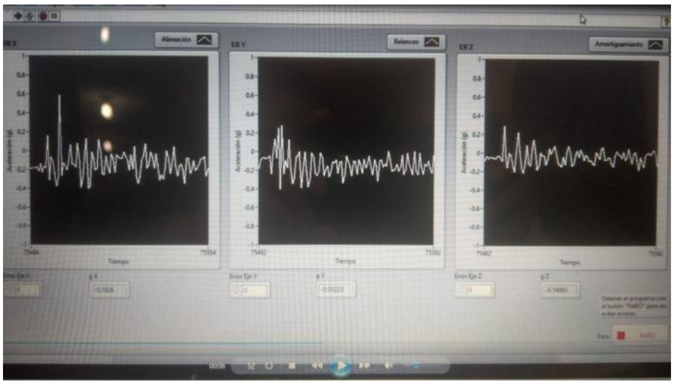


Fig -4: ADXL335 sensor result waves

2.3 Interpretation of Results

With the readings obtained from the measurements, the interpretation is made using analysis techniques that allows us to know the state of the machines. The basic techniques that are most commonly used are:

- **Frequency analysis:** The analysis of the shape of the graph is fundamental to understanding many of the vibration phenomena that affect the engine in this study, it will allow us to diagnose results that cannot be diagnosed by the vibration spectrum alone, particularly it is important in the analysis of gearboxes and bearings [5].

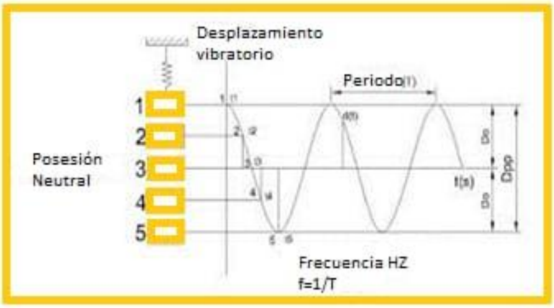


Fig -5: Frequency waves

To carry out this study, the following steps are followed:

a) The frequency bands of those measurement points that are important are defined.

b) Any of the evaluation criteria are applied to determine the site and size of the failure if they exist.

c) The faults that are occuring are indicated on the basis of knowledge of their vibrations and their frequency band.

- **Time analysis:** this analysis is a complement to the frequency analysis since it serves to confirm diagnoses in those failures that have similar spectrum, these problems can be, unbalance, misalignment and slack [6].

2.4 Failure by vibration analysis.

The faults that can be identified in the machines by means of the vibrations are the following::

- Unbalance

Unbalance can be defined as a measure that quantifies the distance the centerline of a mass of the rotor moves from the centerline of rotation [7]. The unbalance is synchronous with the rotation speed of the machine, and its direction is mainly radial. Therefore, in the vibration spectrum the vibration amplitudes associated with this fault are recorded in the 1X component (first harmonic). ISO 1925 classifies the types of unbalance according to the distribution of unbalancing masses.

a) Static unbalance, when the main axis of inertia is parallel to the axis of rotation.

b) Unbalance by even forces, when the main axis of inertia intercepts the axis of rotation at the center of gravity of the rotor.

c) Quasi-static unbalance, when the main axis of inertia intercepts the axis of rotation at a point other than the center of gravity of the rotor.

d) Dynamic unbalance, when the main axis of inertia does not intercepts the axis of rotation.

- Misalignment

Angular. Angular misalignment occurs when the centerlines of two shafts are cut at an angle. The presence of strong axial vibration at 1x rpm characterizes this type of misalignment, which may be accompanied by harmonics of the shaft speed at low amplitudes. .

Symptoms:

a) Strong axial vibration at 1x rpm possibly with harmonics at 2x and 3x.

b) The harmonic 2x rpm in the axial direction can reach a value equal to or even higher than 1x.

c) Vibration in the radial direction, probably of lesser amplitude than in the axial direction, at 1x, 2x and 3x.

d) The axial phase measurements on both sides of coupling are offset by 180°.

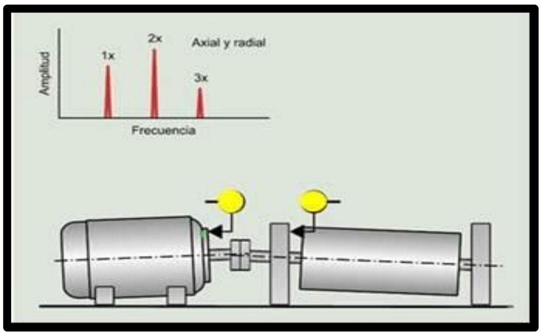


Fig -6: Angular misalignment

- Parallel misalignment. Two axes are misaligned in parallel when the axes are parallel and separated by a certain distance. The misalignment can be vertical or horizontal and is manifestation spectrally with a strong radial vibration at 1x and 2x shaft rpm, and may have higher harmonics of lower amplitude..

Symptoms:

a) Strong radial vibration at 1x rpm with harmonics at 2x and 3x.

b) The harmonic 2x rpm in the radial direction can reach a value equal to or even higher than 1x.

c) The radial phase measurements on both sides of the coupling are 180° off.

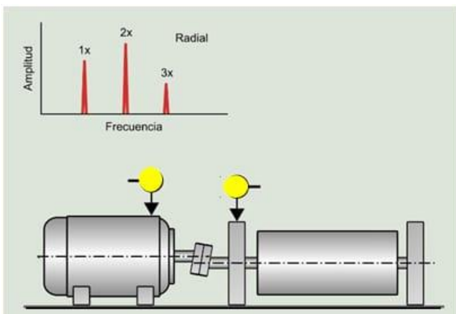


Fig -7: Parallel misalignment

- Misalignment in Bearings and Bearings. Regardless of whether there is good alignment in the coupling, there may be misalignment between the shaft and the bearing. Misalignment can be caused by deformation in the machine or by improper assembly. If one of the legs of the machine is not in the same plane as the others or if the bed is not flat, tightening the anchor bolts will generate a deformation and consequently a misalignment. Another example of bearing misalignment occurs in large fans where the bearing housings are mounted on the metal structure of the fan. If the metal structure is not rigid enough, it will deform under load conditions and cause misalignment. Generally, the biggest deformation is in the bearing next to the impeller, causing an axial misalignment.
-
- Misaligned ball or roller bearings are characterized by axial vibration regardless of the unbalanced condition. Vibration can occur at 1x, 2x, 3x rpm or at the number of balls or rollers in the bearing due to the speed of rotation.

- Anti-friction bearing misalignment presents radial and axial vibration, usually at 1x and 2x rpm of the rotational speed. Bearing misalignment is often accompanied by rotor imbalance, so rotor balancing will reduce radial and axial vibration.

Symptoms:

a) Strong axial vibration at 1x rpm possibly with harmonics at 2x and 3x.

b) The harmonic 2x rpm in the axial direction can reach a value equal to or even higher than 1x rpm.

c) The axial phase readings at the bottom, left, top and right of the bearing are off by 90°.

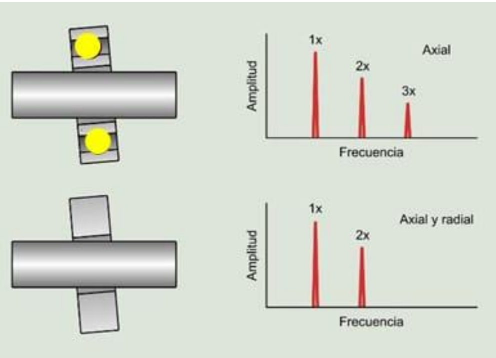


Fig -8: Bearing misalignment

- Damping:

a) Fluid damping. It is produced by the resistance of a fluid to the movement of a solid, being this viscous or turbulent.

b) Hysteresis damping. It is caused by internal molecular friction or hysteresis, when a solid body is deformed.

c) Dry friction damping. It is caused by kinetic friction between dry sliding surfaces.

3. CONCLUSIONS

Due to the technological advances in the world of vibrations, several options have been found when it comes to detecting some failures caused by vibrations of components that make up the much used rotary equipment in industrial tasks. We have the interpretation of vibration spectra or the analysis of waves in time, which can be detected or interpreted more effectively in the data obtained by our sensor and thus be able to give a viable and accurate solution to the failure or anomaly present in the equipment, some of these cases may be, turbulence in blocks and pumps, lubrication problems or metal to metal contact as the case may be. The results of these vibration analyses serve us to control and monitor the rotating machines and thus to make a good maintenance schedule without putting at risk its components, the machine and the production.

ACKNOWLEDGEMENT

We do not have enough words of thanks to express to them what their teachings meant to us. We learned more from you than you expected. Thank you, Dr. Corona and Dr. Mendoza.

REFERENCES

[1] EMPLEO, consejería de educación y empleo. Vibraciones mecánicas. 2005.

[2] Norma ISO 10816. Primera Edición 15/05/18. Vibración Mecánica.

[3] IDEARA S. Vibraciones mecánicas. Factores relacionados con la fuente y medidas de control. Confederación de empresarios de Pontevedra (CEP) y la Fundación para la prevención de riesgos laborales. 2014. P. 11.

[4] García P. J. Mantenimiento Predictivo en la Industria. 2000.

[5] Vibraciones Mecanicas. Mantenimiento Predictivo y las Vibraciones Mecanicas. Citado el 18 de junio de 2020.

[6] Incrementando la Confiabilidad de su Analisis de Vibración. citado 16 de junio de 2020.

[7] Introducción al analisis de vibraciones. Citado el 22 de junio de 2020.

BIOGRAPHIES

José Luis Hernández Corona Candidate for a Doctor from the Autonomous University of Tlaxcala, Research Professor at the Technological University of Tlaxcala in the Department of Mechanical Engineering, responsible for the Academic Body of Industrial Maintenance

Ernesto Mendoza Vazquez teacher researcher of time complete in the Technological University of Tlaxcala, Desirable Profile before the PROMEP as well as academic corps in industrial maintenance, with a master's degree in advanced manufacturing

Iby del Rosario Marquez Ambriz graduated from T. S. U. in Industrial Area Maintenance at the Universidad Tecnológica de Tlaxcala in 2018. works in the company of Petróleos Mexicanos in the area of Corrosion as an Assistant Operator. He is currently studying Industrial Maintenance Engineering at the Technological University of Tlaxcala.

Ubaldo Sánchez Grajeda graduated from T. S. U. in Industrial Area Maintenance at the Technological University of Tlaxcala in 2018. works in the company "Petróleos Mexicanos" in the area of Industrial Safety and Environmental Protection as a Firefighting Assistant. He is currently studying Industrial Maintenance Engineering at the Technological University of Tlaxcala.

Clemente Torres Ibarra graduated from T. S. U. in Industrial Area Maintenance at the Technological University of Tlaxcala in 2018. works in the company "Petróleos Mexicanos" in the area of Civil Works as a General Worker. He is currently studying Industrial Maintenance Engineering at the Technological University of Tlaxcala.

José Antonio Vázquez Vences graduated from T. S. U. in Industrial Area Maintenance at the Universidad Tecnológica de Tlaxcala in 2018. works in the company "Petróleos Mexicanos" in the area of Coordination of Uses and Rights of Way as Administrative Manager Real Estate Branch. He is currently studying Industrial Maintenance Engineering at the Technological University of Tlaxcala.