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Mechanical Vibration of rotating and static equipment

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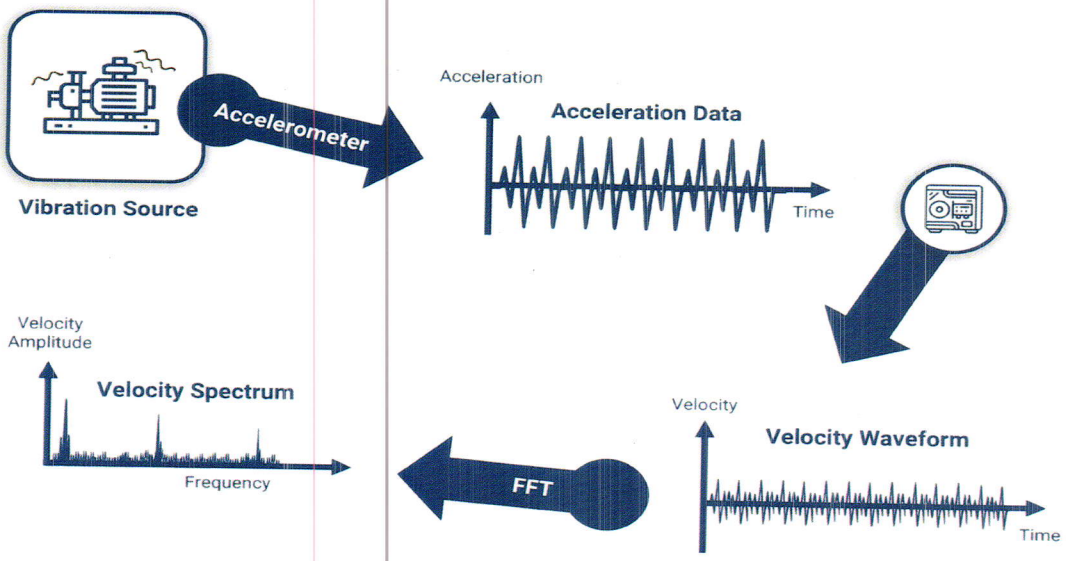

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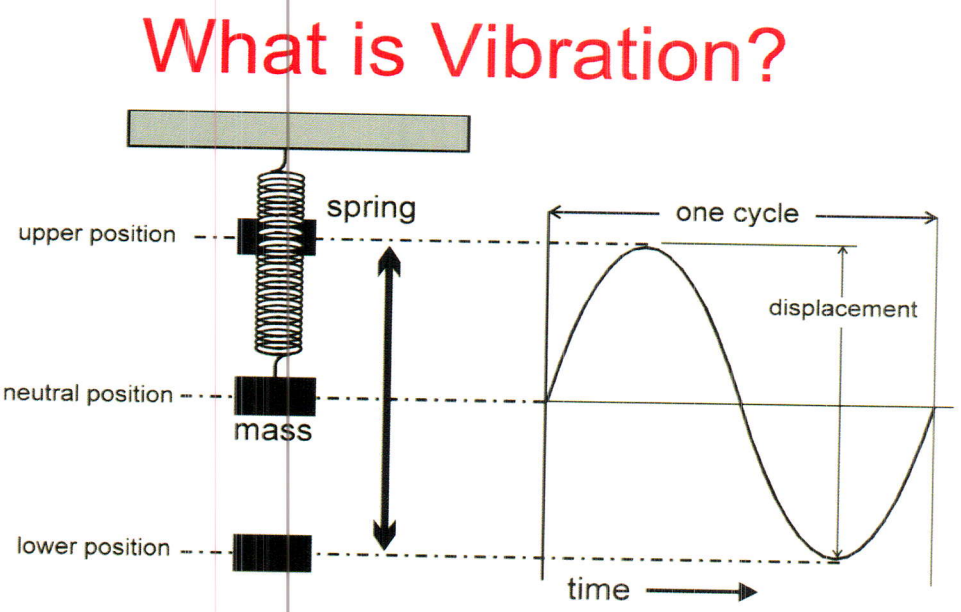
☑ Introduction

I. Vibration analysis description:

Vibration is a physical phenomenon that presents itself in operational rotating machineries and moving structures, regardless of the condition of their health. Vibration can be induced by various sources, including rotating shafts, meshing gear-teeth, rolling bearing elements, rotating electric field, fluid flows, combustion events, structural resonance and angular rotations.

Vibration means the state of object that moves repetitively back/forward, right/ left or up/down and is generally expressed by Frequency, Displacement, Velocity, and Acceleration. These 4 elements are generally denoted as f, D, V, A

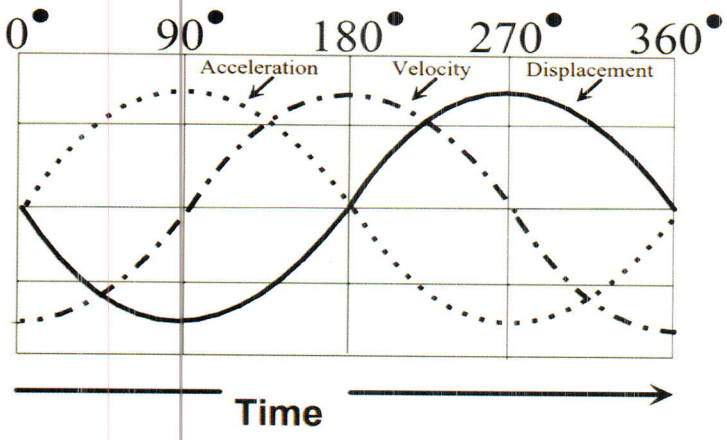


Vibration is the movement of a body about its reference position.
Vibration occurs because of an excitation force that causes motion.

Vibration- Measurable Characteristics

Velocity is the first derivative of displacement as a function of time, it is the rate of change in displacement (the speed of the vibration).

Acceleration is the second derivative of displacement, it is the rate of change of velocity (the change in speed of the vibration).



Measurements & Units

Displacement (Distance)

mils or micrometer, mm

Velocity (Speed - Rate of change of displcmt)

in/sec or mm/sec

Acceleration (Rate of change of velocity)

G's or in/sec^2 or mm/sec^2

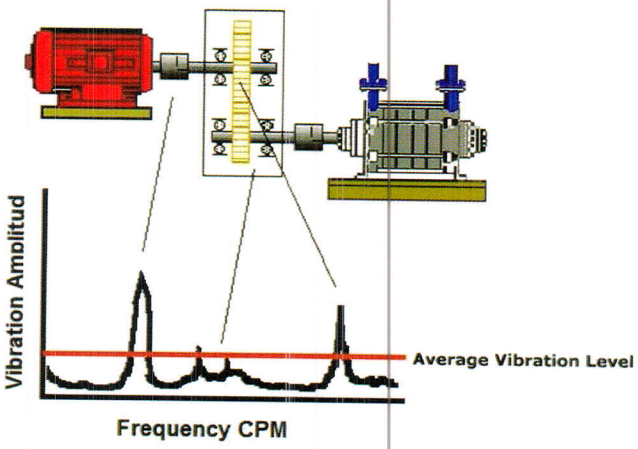
Vibration analysis is one strategy of CBM implemented at site and plants which is a major component of predictive maintenance PDM, it is a process that monitors the levels and patterns of vibration signals within a component, machinery or structure, to detect abnormal vibration events and to evaluate the overall condition of the test object and also to identify potential failure of components before the components have actually failed.

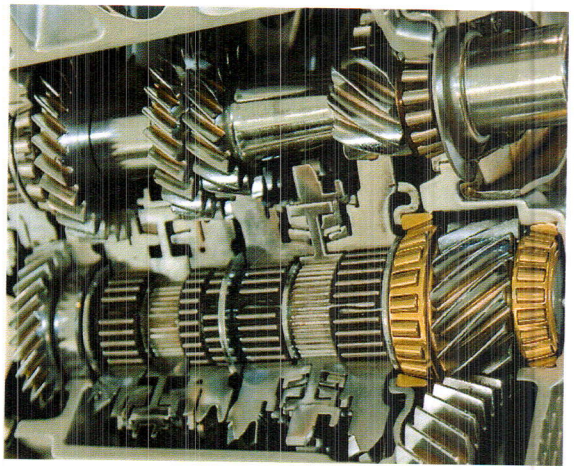
Vibration analysis is the most prevalent method used for monitoring, detecting and analyzing the equipment condition.

Maintenance activities based on asset condition, rather than on a pre-set interval, has the potential to progress maintenance activities to a new level of efficiency.

the use of effective condition monitoring allows maintenance to be scheduled, or other actions to be taken to prevent failure and avoid its consequences.

Most of the results arising due to vibration lead to failures, damage of equipment and in worst cases loss of life. Knowing more about vibration helps us to control damage and take preventive measures from damages to occur.





☑ Safety Measures:

The precautions below apply to all vibration data gathering on rotating and static assets.

- Grant safe permit to work and follow the steps, risks associated and control measures.
- PPE: Follow site rules for the proper kind of safety shoes, hats, goggles, glasses, gloves, do not wear loose or torn clothing that can be caught in moving parts of a machine and wear long sleeves in the vicinity of hot surfaces.
- Take extra care for those machines which are in operation during vibration data collection.
- Hand Tools: Take special care when using hand tools. Use the right tool for the job
- Do not remove a safety guard, if require to remove it while the equipment is in operation then extra care to be taken and follow the RA procedure.
- Machine Guards: Guards on belt or chain drives, open gears, couplings etc., should be removed only after the machine is shutdown.
- Only qualified personnel should perform the tasks
- Ensure the vibration analyzer (device) is explosion proof if used in natural gas area.

☑ **Purpose:**

The purpose of this document is to define the processes required to perform a successful vibration analysis program of rotating and static equipment, to identify a basis for the implementation of appropriate test, diagnostic and monitoring equipment and techniques. The provision of such features is central for achieving a maintenance philosophy based on the use of predictive maintenance and condition monitoring techniques.

This document provides guidance on the process for developing an optimum vibration analysis strategy for rotating machinery and static assets, it also discusses the selection of tools and techniques for its effective implementation.

☑ Application Guidelines of Vibration Analysis

I. Why need to monitor vibrations

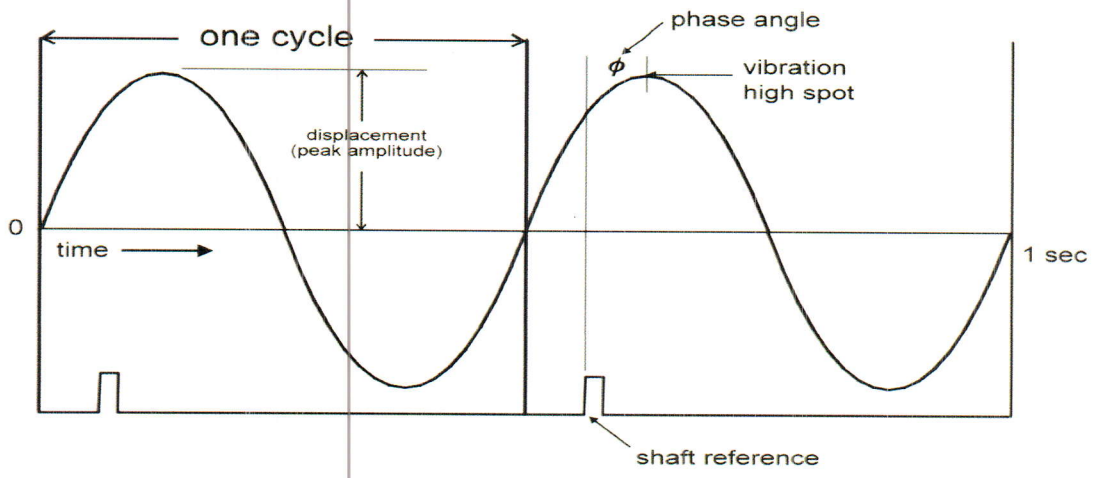
Any business that uses heavy equipment in their daily operations can benefit from monitoring vibrations. The advantages of doing so include the following:

- Understand causes of damage
- Monitor repair needs
- Keep an overall health check on equipment

Vibration sensors are an excellent way to monitor the health of key assets. They provide precise information on how individual pieces of equipment are doing, and the data they provide can help you anticipate when future maintenance needs may occur. The end result is a more streamlined maintenance process and improved machine health.

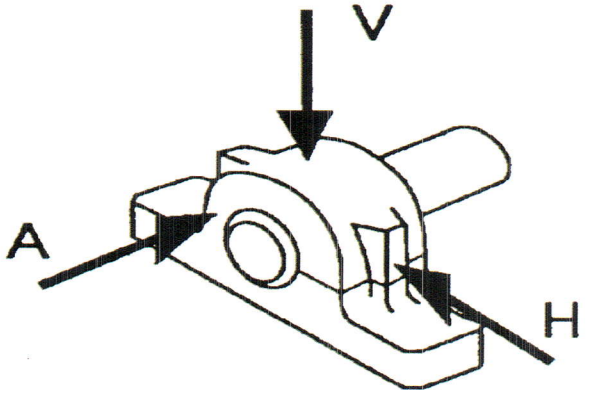
During the pandemic, critical industries such as energy and power, chemicals, food and beverages, and healthcare continue to witness an increased demand for vibration sensors to ensure safe and efficient operations of machinery. Currently, online vibration monitoring is a preferred monitoring process as it is more advanced than portable condition monitoring and provides real-time machine data to plant operators.

Vibration Terms



Measurement Planes

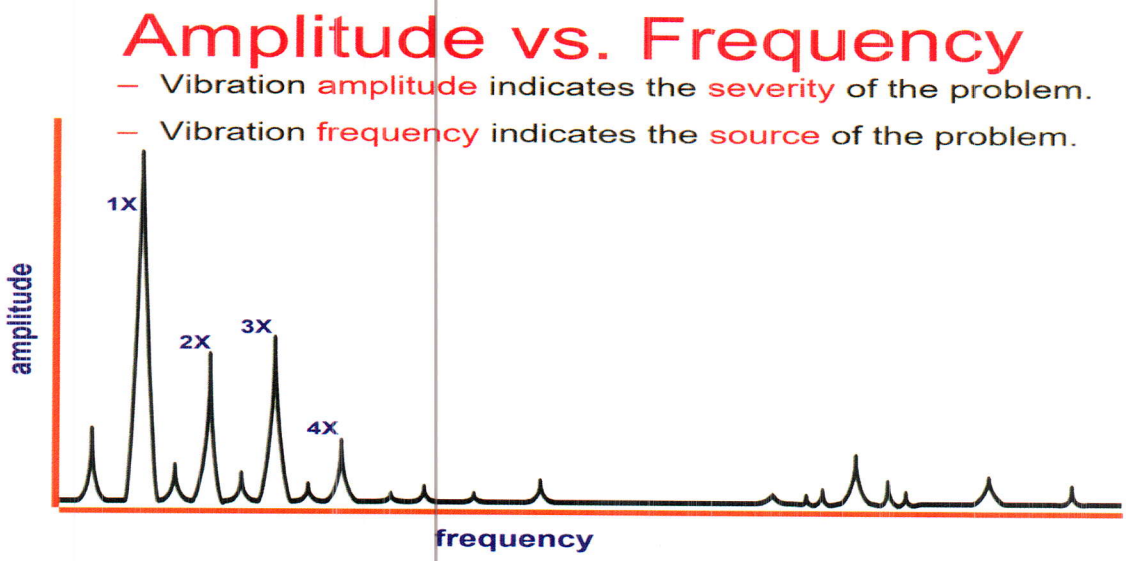
- radial
  - vertical
  - horizontal
- axial



- In the context of vibration monitoring, 1 x rpm means a vibration frequency that is the same as the rotation speed (one vibration oscillation per revolution of the rotor), 2 x rpm means a frequency 2 x the rpm (two oscillations per revolution), etc.

- Because of nonlinear effects in the mechanical system, vibrations can be excited at different multiples of the rotation speed (1x, 2x, 3x, etc) and even at fractional multiples (for example 0.5x). However, the "synchronous" vibration at 1x RPM usually has the biggest amplitude.

Below table is an ISO standard which is use to evaluate the severity of machine vibration in order to guide with the existing condition of the machine.



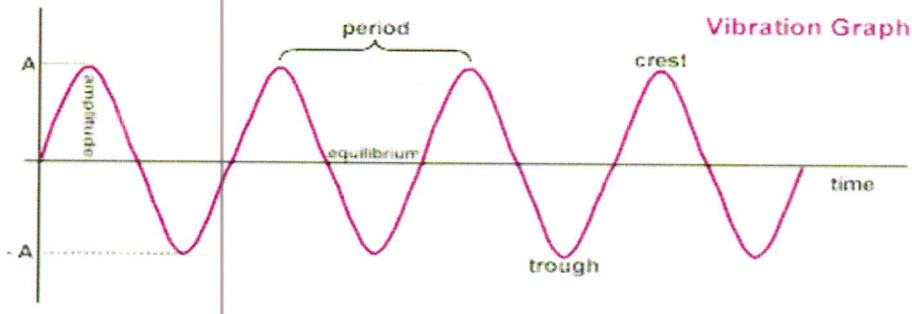
Amplitude-The maximum distance to which the object of a vibrating pendulum goes from its central position is called Amplitude of Vibration.

Time period-One complete to and fro movement of the object about mean position is called one vibration or one oscillation.

The time taken by the object to complete one vibration or one oscillation is called the Time period of pendulum.

Frequency-The number of vibrations or oscillations made in one second is called the frequency of vibration

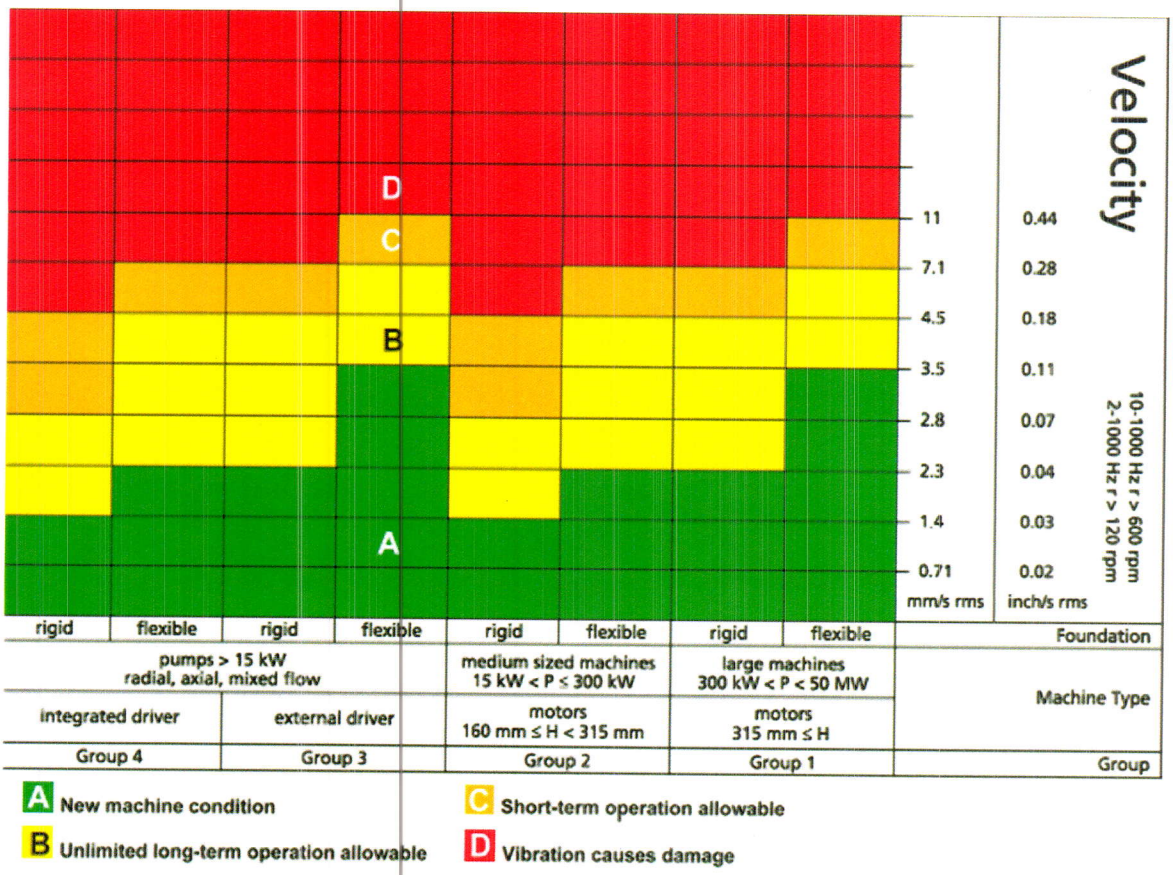
Time period=1/Frequency



- In fact, some faults in mechanical bearings can excite vibrations at a frequency which doesn't have any "obvious" relation to the rotor speed - for example problems with the bearing lubrication system can excite so-called "oil whip" vibrations at about 0.9 x the rotor speed.

II. Vibration reading severity ISO Standard 10816-3

Below table is an ISO standard which is use to evaluate the severity of machine vibration in order to guide with the existing condition of the machine.



Group 2 Machines: electric motors and driven machines between 20 and 402 hp.

Group 1 machines: electric motors and driven machines above 402 hp.

You will notice in the graph that Group 1 machines can tolerate slightly higher vibration levels than Group 2 machines. This is because larger machines have a larger mass, a wider stance and can generally tolerate slightly higher overall vibration levels.

Each of these two groups is also separated into rigid and flexible mounts. Machines mounted on a flexible base, such as isolator springs or neoprene pads, can tolerate slightly higher vibration levels, as the movements of these machines are damped or damped by the isolator or pad.

Let's take as an example a 150 hp electric motor, driving a pump, at 1765 rpm, on a rigid base, and use the ISO 10816-3 table.

Recommended vibration levels in speed (mm per second/peak):

Newly commissioned machinery: this is assumed to be a new, unworn motor and pump, operating at "best case". A general vibration level of 0.08 in/sec (pk) or 1.4 mm/sec (rms) or less would be expected.

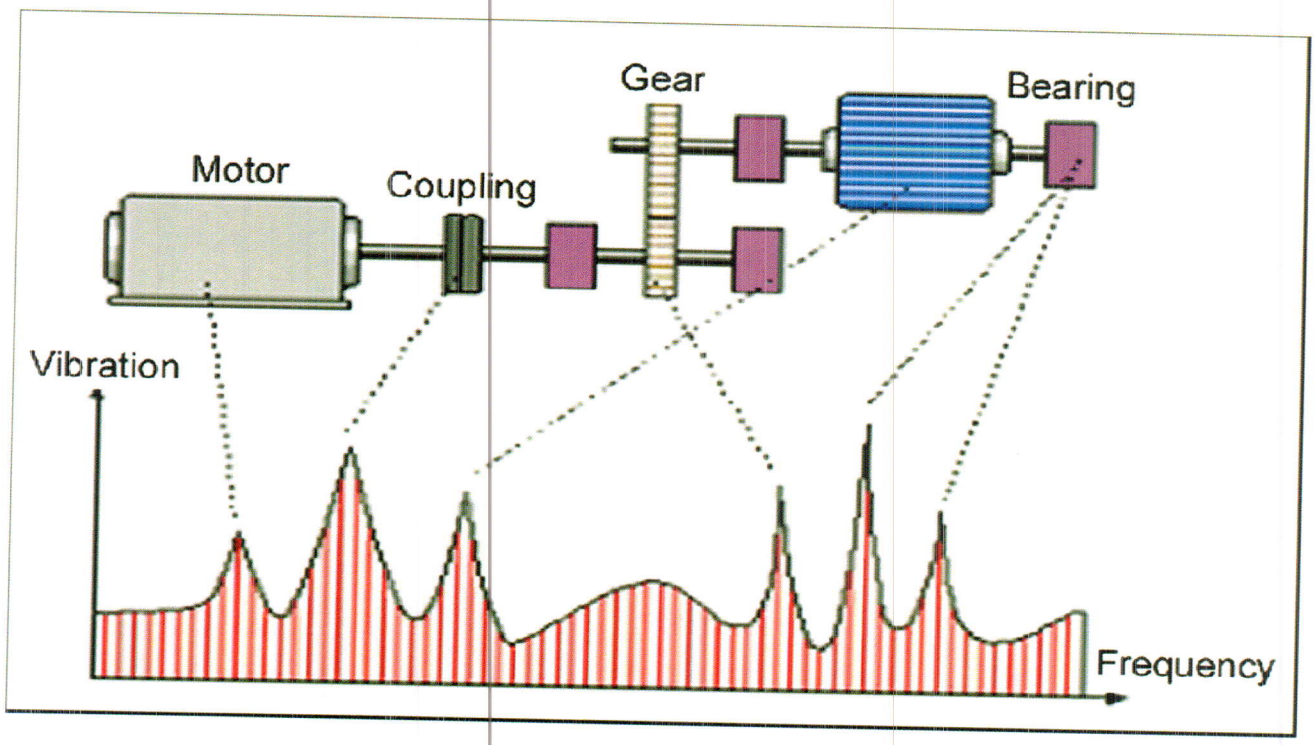
Unrestricted operation: this assumes a motor/pump that has been in operation beyond the original start-up. An acceptable vibration level would be less than 0.16 in/sec (pk) or 2.8 mm/sec (rms).

Restricted operation: the same motor/pump operating at vibration levels between 0.16 and 0.25 in/sec (pk) or 2.8-4.5 mm/sec (rms) should be considered to have a problem causing excessive vibration, such as unbalance or misalignment. This machine could be operated as needed; however, maintenance should be scheduled to reduce vibration.

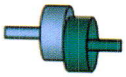
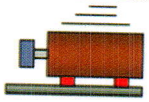
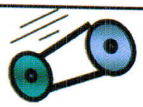
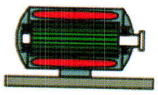
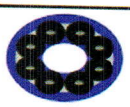
Damage occurs: vibration levels in the motor/pump above 0.25 in/sec (pk) or 4.5 mm/sec (rms) could cause additional damage to machine components, such as bearings. This machine should be taken out of service as soon as possible and corrective action taken to reduce vibration.

Note that the ISO 10816-3 table is for "advised" levels of vibration quality. Some common sense should also be used. For example, a machine tool would need to operate at a lower vibration level to maintain the quality of the machining finish. A hammer mill may operate at a higher vibration level while in use.

However, for typical industrial machinery, the ISO 10816-3 table is a good benchmark for vibration quality.



III. A Guide to Fault / Frequency Relationships

Typical Fault & Dominant Frequency	Details	Comments
 **x 1** **IMBALANCE**	Imbalance occurs at rotational frequency equal to 1 x rpm of the out of balance part. Usually radial (horizontal or vertical) Sometimes dynamic (axial)	Amplitude is direct indication of degree of imbalance
 **x 2** **MISALIGNMENT**	Typically angular and/or offset problems in couplings Radial + Axial	In both radial and axial directions also apparent at x1rpm because of imbalance inherent to misalignment
 **X 2 Natural 1 X** **LOOSENESS**	Mechanical - caused by loose rotating parts or excessive play in machine mountings	Typically a machine will vibrate as it hits a natural resonant frequency during run up or run down - once the associated rpm is passed vibration amplitude decreases
 **X 1 and (x1)x(No of blades/vanes)** **PASSING**	Usually cause a x1 frequency component and a multiple related to the number of vanes/blades	Also referred to as blade pass frequency
 **No. of teeth x rotational frequency of associated gear** **MESHING**	Defects cause low amplitude high frequency vibration and show imbalance, misalignment and tooth damage associated with Gear Mesh Frequencies	Gear Mesh Frequency = output gear rpm x No. teeth in output gear. e.g. 32 tooth gear operating at 300 rpm [300/60 =5Hz] GMF = 32x5 = 160Hz
 **Related to rotational speed and multiples of rotational speed** **BELTS**	Vibration analysis will identify rubbing and misalignment	Use strobe techniques to identify slipping belts
 **At supply frequency and multiple of** **ELECTRICAL**	50Hz(UK)	Vibration will stop when power is turned off!
 **3-10 x rpm & Higher** **BEARINGS**	Bearings indicate problems at high frequency 2- 60KHz (in the early stages of deterioration) and at low amplitude	Range of techniques available with bearing cabability

IV. Application of Vibration Analysis:

Vibration can be induced by various sources, including rotating shafts, meshing gear-teeth, rolling bearing elements, rotating electric field, fluid flows, combustion events, structural resonance and pipe strains.

Common applications of vibration analysis are detecting and assessing rotational and structural issues,

- Misalignment
- Imbalance
- Bearing wear
- Gearbox wear
- Mechanical looseness
- Structure looseness
- Soft foot
- Pipe strain
- Bent shafts
- Resonance
- Electrical issues including windings, rotor bars, and VFD tuning
- Cavitation/flow related.

☑ Tools Required:

- Vibration analyzer, probe
- Hand tools

☑ Routine date collection and analysis:

- Regular PM and PDM on defined intervals and condition-based monitoring.
- All data need to be recorded for future comparison, analysis and history.

☑ **Reference:**

- Vibration technical institute
- ISO 10816-8:2014(en), Mechanical vibration
- ASTM D3580 Standard Test Methods for Vibration