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Standards for Vibration Analysis

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Abstract: *This paper discusses about the various standards available and provides the information to decide about the severity of the vibration problem. Mechanical Vibration of machines with Operais to establish realistic guidelines for acceptable vibration levels with respect to reliability, safety, and human perception. The most important aspects of this international standard are vibration velocity has been selected as the significant parameter for characterizing the severity of machine vibration and second one is the root mean square (RMS)value of the oscillating velocity is used to measure vibration severity.*

INTRODUCTION

Condition monitoring by expectations are as follows:

- AE is GO/NO GO reading for immediate bearing fault detection.
- No need for plant machinery asset register or bearing details.
- Expert analysis is undertaken when ascertaining machine service extension.
- Acoustic emission brings down the cost of condition monitoring.

Vibration Based Condition Monitoring

Table: 1 VBCM with a wide spread use of variable speed machinery and processes

CONDITIONS	OPERATIONS
Constant speed machines	Continuous
Runs at constant speeds as required	Periodic Continuous
Short running speeds as required	Periodic Intermittent
No fixed speed period, linked with process needs	Variable Speeds Broad Range
Variable between say 200 RPM	Variable Speeds Narrow Range

Traditional vibration data collection is effective with continuous constant speed machinery but introduce any variables then the data becomes more complex and perhaps confusing. This leads to incorrect maintenance decisions that can impact on the confidence of a VBCM programme

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Primary conditions	Secondary conditions	Orientation/ Plane
Un balance	Alignment, Looseness, Gear meshing	Horizontal-90
Looseness	Unbalance, Alignment	Vertical – 0 to 180
Alignment	Unbalance, Gear meshing	Axial
Unbalance, shaft position	Looseness, Alignment, Oil whirl	Dual sensors
Bearing & lubricant condition	None-Unbalance, Misalignment, Looseness etc. impose stresses on bearings. Distress is the key indication	Acoustic Emission – Any position ,seek highest signal

The VBCM Management Challenge

Often misunderstood, the best vibration measurements are often constant speed machinery, generally over 600 rpm .In fact the higher the speed the better and if anti-friction bearings are involved then readings taken from the outer bearing case are relatively easy to analyse

Table: 1 Let us look at rotor speeds related to traditional vibration monitoring:

Rotor Speed RPM	Degree of Measurement Difficulty	Method/Solutions
>600	Not difficult	Traditional vibrations frequency domain for detailed analysis well established
<600	Becomes more difficult	Use low frequency sensor to measure in displacement
<100	Very difficult	Long data collection time with time synchronous averaging to get clear signal
<50	Special technique needed	Set up requires considerable care, data may be confusing
<5	Not practical	Use Acoustic emission, simple process and effective

Off- Line Vibrations Protection Systems Comparison

Understanding the benefits and limits of any system will set the expectation realistically; the table below identifies the main strengths and weaknesses of off-line vibration data collection:

Strengths	Weaknesses
Portability	Taking the correct reading (prone to error)
Unlimited readings	Limited diagnostics with critical machines
Non invasive	Focused mainly on mechanical faults
On the spot visual faults can be noted	Hand held sensor readings limits detection range
Data collection is relatively simple	Difficult to take shaft relative readings
Powerful mechanical analysis capability	Labour intensive, especially data analysis
Basic training takes 5 days	False alarms can be due to process variables

On- Line Vibration Protection System Comparison

The strengths and weaknesses with On-Line Vibration System are far from exhaustive but the main issues need to be appreciated as they influence the selection and investment decision.

Strengths	weaknesses
Undertakes machine protection duties	Generally only overall vibration readings measured
Continuous, constant data acquisition	High initial investment
Instant alarms of impending machine faults	Limited to installed sensors
Communicates with distributed control system	Eddy current probes are invasive, needs shutdown
Data visible to operations	Set to detect only mechanical faults

MCM – Success and Applications

The technology has been successfully deployed in a wide range of industries, some of which have applied condition monitoring for many years. They have found MCM very complementary to existing systems, particularly for remote or inaccessible machinery prone to electrical faults. MCM has also been especially successful in industries that have been traditional users of condition monitoring.

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Examples of this include the food and beverage, building services, water treatment, automotive, marine and general manufacturing sectors. New applications for MCM are being adopted daily. Wind turbines are an obvious one where existing condition monitoring consists of an array sensors, wiring etc all adding to the cost of the installation. MCM is an ideal single instrument that also learns the process variables inevitable with a wind turbine. For, Hydro turbines, especially older units that did not appear to justify on-line diagnostic systems yet experience more electrical winding failures than over designed mechanical elements; the MCM Provides a dual role monitoring system at minimal cost and no intrusion to the rotating machinery.

Vibration of Machine Life

Obviously, once a machine is started and brought into service, it will not run indefinitely. In time, machine will fail due to the wear and ultimate failure of one or more of critical components.

$$\mathrm{L}\ (HOURS) = \frac{16{,}000}{RPM} * \left(\frac{RATE}{LOAD}\right)^3$$

Where,

RPM = Machine rotating speed in revolutions per minute
RATE= The rated load capacity of the bearing (lbs)
LOAD= The actual load to which the bearing is subjected. The includes not only the static load due to the weight of the rotor, but the dynamic load due to forces of unbalance, misalignment, etc;

Characteristics of Vibration

Vibration was defined earlier as simply "the cyclic or oscillating motion of a machine component from its position of rest or its neutral position." Whenever vibration occurs, there are actually four forces involved that determine the characteristics of the vibration. These forces are:

1. The exciting force, such as unbalance or misalignment
2. The mass of the vibrating system, denoted by the symbol (M)
3. 3.The stiffness of the vibrating system, denoted by the symbol (K)
4. The damping characteristics of the vibrating system, denoted by the symbol (C)

The exciting force is trying to cause vibration, whereas the stiffness, mass and damping forces are trying to oppose the exciting force and control or minimize the vibration.

The characteristics needed to define the vibration include:

1. Frequency
2. Displacement
3. Velocity
4. Acceleration

Vibration Frequencies and the Likely Causes

Table: 1

Frequency in terms of RPM	Most Likely causes	Other possible causes & Remarks
1* RPM	Unbalance	1.Eccentric journals, gears or pulleys 2.Misalignment or bent shaft –if high axial vibration 3.Bad belts if RPM of belt 4.Resonance 5.Reciprocating forces 6.Electrical problems
2* RPM	Mechanical Looseness	1.Misalinment if high axial vibration 2.Reciprocating forces 3.Resonance 4. Bad belts if 2* RPM of belt

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3* RPM	Misalignment	Usually a combination of misalignment and excessive axial clearances (looseness)
Less than 1* RPM	Oil whirl(less than ½ RPM	1.bad drive belts 2.background vibration 3.sub-harmonic resonance 4."beat" vibration
Synchronous(A.C.Line frequency)	Electrical problems	Common electrical problems include broken rotor bars, eccentric rotor, unbalanced phases in poly-phase system, unequal air gap
2 * synch. frequency	Torque pulse	Rare as a problem unless resonance is excited
Many times RPM (harmonically related freq.)	Bad gears Aerodynamic forces Hydraulic forces Mechanical looseness Reciprocating forces	Gear teeth times RPM of bad gear Number of fan blades times RPM Number of impeller vanes times RPM May occur at 2,3,4 and sometimes higher harmonics if severe looseness
High frequency (not harmonic cally related)	Bad anti-friction bearings	1.bearing vibrations may be unsteady-amplitude and frequency 2.cavitation,recirculation and flow turbulence cause random, high frequency vibration 3.improper lubrication of journal bearings(friction excited vibration) 4.rubbing

Machinery Vibration Severity Chart

The severity chart used for diagnosing is used in many processes industries and the chart is shown in Figure 1. The various parameters used in the chart are as follows

Very Rough

Unsafe vibration with huge potential one, and severe vibration, potentially unsafe. Make immediate detailed vibration analysis to identify trouble. Excessive vibrations may cause oil-film breakdown. Consider shutdown to avoid in-service failure.

Rough

Potentially damaging vibration. Make detailed vibration analysis to identify trouble. Rapid wear expected. Make more frequent periodic checks. Schedule for repair.

Slightly Rough

Faults likely. Make detailed vibration analysis. Continue periodic checks. Schedule repair as necessary.

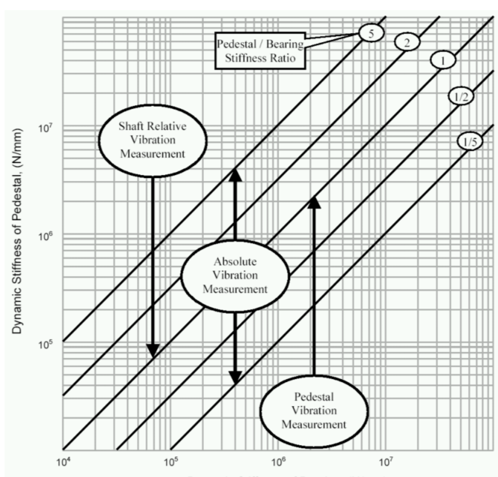

Figure:1 Machinery vibration severity chart

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Average

Minor faults. Continue routine periodic checks. Watch for increase.

Smooth

Well balanced. Typical of well balanced, well aligned equipment. Make routine periodic checks.

Very Smooth

Exceptional. Extremely well balanced, well aligned equipment. Make routine periodic checks.

Good

Machines with overall vibration velocity levels in the GOOD range may have minor problems. However, at this level, the problems are not normally severe enough to warrant shutting the machines down for further corrections. A “baseline” vibration frequency analysis should be performed on these machines to identify their normal vibration characteristics. This information will prove invaluable in pinpointing the cause when problems do develop.

Fair

Machines with overall vibration velocity levels in the FAIR range have somewhat more severe problems, but generally, not severe enough to warrant an immediate shutdown for correction. Since machine deterioration usually progresses more rapidly at these vibration levels, periodic vibration checks should be made 2 to 3 times more frequently than the normal check interval. In other words, if a monthly check is scheduled for machines with vibration levels in the GOOD range, machines in the FAIR range should be checked at least 2 to 3 times a month to avoid catastrophic failure.

Alarm

Lacking any past history, the ALARM levels given in the table serve as realistic starting points for a predictive maintenance program. Machines that fall in this category should be thoroughly analyzed to pinpoint the cause or causes of vibration and a shutdown scheduled for correction at the earliest opportunity. As one vibration technician once said, “the worse things get, the quicker they get worse.”

Severity Standards

Table: 1

ISO 7919 Series	Mechanical vibration of non reciprocating machines-Measurement on rotating shafts and evaluation criteria
7919-1:1996	Part1:General guide lines
7919-2:2001	Part2:Land based steam turbines and generator in excess of 50MW with normal operating speeds of 1500 r/min, 3000 r/min, and 3600 r/min
7919-3:1996	Part3:Coupled industrial machines
7919-4:1996	Part4:Gas turbine sets
7919-5:1997	Part5:Machines set in hydraulic power generating and pumping plants

ISO 10816 Series	Mechanical vibration- Evaluation of machine vibration by measurements on non- rotating parts
10816-1:1995	Part1:General Guidelines
10816-2:2001	Part2:Land based steam turbines and generators in excess of 50MW with normal operating speeds of 1500 r/min, 1800 r/min,3000 r/min and 3600 r/min
10816-3:1998	Part3:Industrial machines with normal power above 15Kw and nominal speeds between 120 r/min and 15000 r/min when measured in situ
10816-4:1998	
	Part4:Gas turbine sets excluding aircraft derivatives
10816-	Part5:Machines set in hydraulic power generating and pumping plants

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5:2000	
10816-6:1995	Part6:Reciprocating machines with power ratings above 100Kw

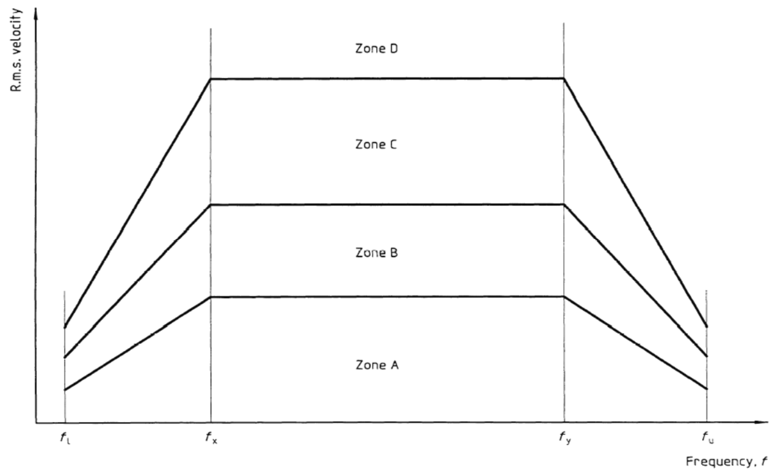

Figure: 1 RMS velocity and frequency

R.M.S Vibration Velocity Calculation

<table>
<tr><th>R.M.S vibration velocity mm/sec</th><th>Up to 15 kW class I</th><th>15 to 75 kW class II</th><th>>75 kW (rigid) class III</th><th>>75 kW (soft) class IV</th></tr>
<tr><td>0,28</td><td rowspan="3">A</td><td rowspan="4">A</td><td rowspan="5">A</td><td rowspan="6">A</td></tr>
<tr><td>0,45</td></tr>
<tr><td>0,71</td></tr>
<tr><td>1,12</td><td rowspan="2">B</td></tr>
<tr><td>1,8</td><td rowspan="2">B</td></tr>
<tr><td>2,8</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>4,5</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>7,1</td><td rowspan="5">D</td><td rowspan="2">C</td></tr>
<tr><td>11,2</td><td rowspan="4">D</td><td rowspan="2">C</td></tr>
<tr><td>18</td><td rowspan="3">D</td></tr>
<tr><td>28</td><td rowspan="2">D</td></tr>
<tr><td>45</td></tr>
</table>

Conclusion

Vibration severity of machinery is defined in terms of the rms value of the vibration velocity. The ISO definition identifies 15 vibration severity for four classes of machines: 1) small, 2) medium, 3) large, 4) turbo machine. The vibration severity of class 3 machine, including large prime movers. ISO gives the vibration severity for whole building vibration under blasting and steady-state vibration.

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