A Quick Guide to Vibration Diagnostics of Rotating Machinery

1 ST STEP : DEFINING THE PROBLEM

Ask different peoples:

- The maintenance peoples
- The operators

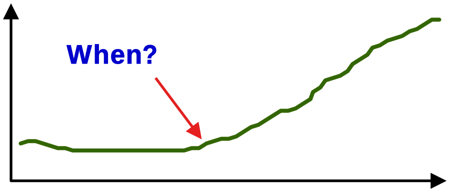
NOT JUST THE PLANT ENGINEER!

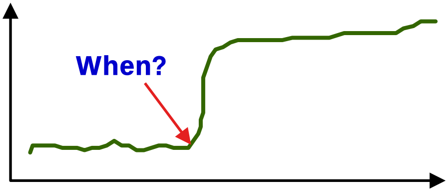
♣ PLEASE GATHERS MORE INFORMATION FROM VARIOUS SOURCES.

2ND STEP : THE MACHINE HISTORY

- When did the problem start?
- Was there a sudden or gradual increase in vibration?
- Has the machine always been running rough?
- Does it only run rough under certain conditions?
- Have there been any recent changes?

  New piping, structural changes, repairs, electrical changes, speed/load changes, performance changes.





3RD STEP : THE MACHINE DETAILS

- Make a sketch of the machine, showing the measurement points
- Try to get following data:
  - Bearing details (type, number of elements, bearing frequencies etc.)
  - Coupling maker and type
  - Input/output speed, rated power
  - Number of blades/vanes, gear details
  - Critical speeds
  - Background vibration sources

4TH STEP : VISUAL INSPECTION OF THE MACHINE

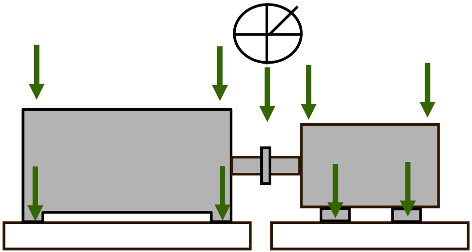
- Look for worn, loose, changed color or broken parts
- Leaking seals
- Foundation cracks
- Build up of deposits (e.g. on fan blades)
- Remember to use a stroboscope

See it, Feel it, Hear it!

5TH STEP : QUICK MACHINE ASSESSMENT

- Collect overall velocity levels at bearings

  Assume that the bearing with the highest level is nearest the area where the problem exists
- Collect overall velocity at foundation
- Check the following areas:
  - **Mounting feet and mounting bolts, piping, background vibration sources, across mounting interfaces**
  - **Use phase, make a clock-face drawing**



6TH STEP : EXAMINE THE RIGHT MEASUREMENTS

- Always take an 1~ 5X velocity spectrum
  at measurement points in the area of interest
- Take care of the 1X imbalance syndrome
- Look at waveform routinely
- Use high frequency acceleration spectra

7TH STEP : MAKE THE DIAGNOSIS

- **LOW FREQUENCIES**

  Unbalance, misalignment, bent shaft, eccentricity, looseness, cracks, shaft instabilities

- **MEDIUM FREQUENCIES**

  Gear faults, blade faults

- **HIGH FREQUENCIES**

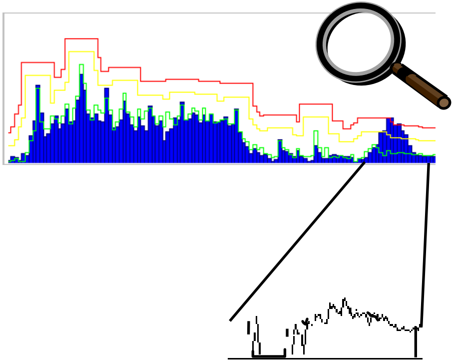
  Impacts, rubs, inadequate lubrication, flow turbulence, poor mechanical seal conditions, incipient bearing failures, high pressure leaks, pre-loads / improper interference fits

Vibration Analysis

Fault Analysis

- The main advantage of making vibration measurements on rotating machinery, is the possibility to detect faults, before they make the machine break-down.
- Thereby reduce economical losses, such as damaged equipment and production loss.
- The constant percentage band width spectrum has shown to be the most efficient.
- When a fault is detected, vibration analysis can be used to diagnose the fault.
- Making diagnosis using vibration analysis requires skill and experience.
- Additional measurements of FFT spectra and phase measurements is often required.

- In the following some simple rules for the most common machine faults are drawn up giving the fault type and a characteristic vibration measurements.
- The spectra in the examples are all made as drawings, in order to emphasize the typical feature of each fault.

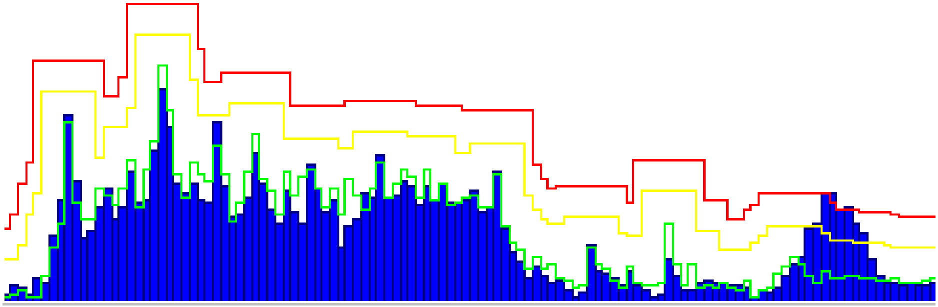


Fault Analysis Type

- Unbalance (imbalance)
- Misalignment
- Eccentricity
- Bent Shaft
- Shaft Crack
- Mechanical Looseness
- Journal Bearing Faults
- Rolling Element Bearing Faults
- Rotor Rub
- Cavitation
- Electrical Motor Problems
- Gear Faults
- Belt Faults

Fault Detection

- Constant percentage bandwidth spectra (CBP) is most efficient tool for fault detection
- The CBP spectra with its wide frequency range and adequate resolution in any frequency range, has proven to be the best tool there is for fault detection.



Mass Unbalance

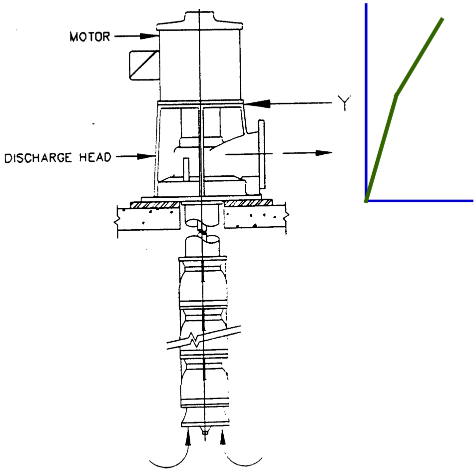
Unbalance (Imbalance)

- Unbalance is the most common fault associated with rotating shaft.
- Unbalance vibration is mainly radial.
- On overhung rotor axial components may be present as well.
- High 1X is often believed to be unbalance, however it can be misalignment, bent rotor or cracked shaft, and further investigation of what may cause the defect is often necessary.
- Often static unbalance and dynamic unbalance are seen together.
- The phase difference across the shaft therefore may vary.
- The tangential and radial 1X levels should be compared.
- The more nearly equal they are, the more likely that imbalance is the cause.
- In any case, the direction in which the machine has the least stiffness will be the direction of the highest 1X level.

Unbalance (Imbalance)

♣ Imbalance in Vertically Mounted Machines

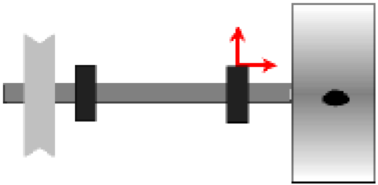
- Vertical machines, such as pumps, are usually cantilevered from their foundation, and they usually show maximum 1X levels at the free end of the motor regardless of where the vibration source is.



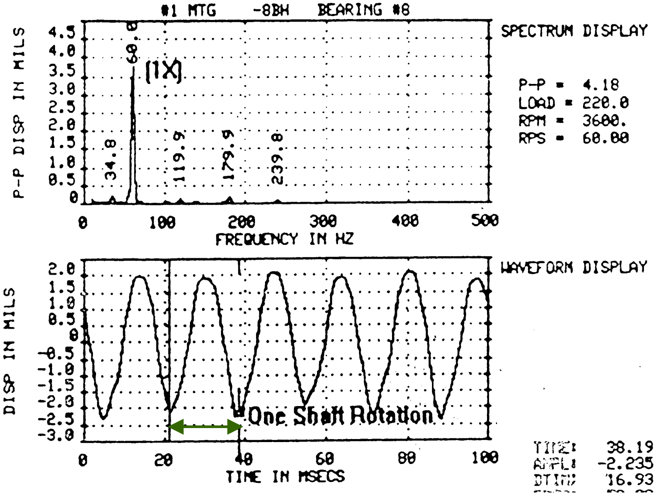
- To isolate motor imbalance from pump imbalance, it may be necessary to break the coupling and run the motor solo while measuring 1X.
- If the 1X level is still high the problem is the motor; otherwise it is the pump.

♣ Imbalance in Overhung Machines

- In a machine with an out of balance overhung, or cantilevered, rotor such as a fan will produce 1X vibration in the axial direction as well as some radial and tangential at the nearest bearing to the rotor.
- This is because the imbalance creates a bending moment on the shaft, causing the bearing housing to move axially.
- Examples of overhung rotors are close-coupled pumps, axial flow fans, and small turbines.
- The bearing closest to the overhung rotor will usually show the highest radial 1X-vibration levels.



Case History : Unbalance (Imbalance)



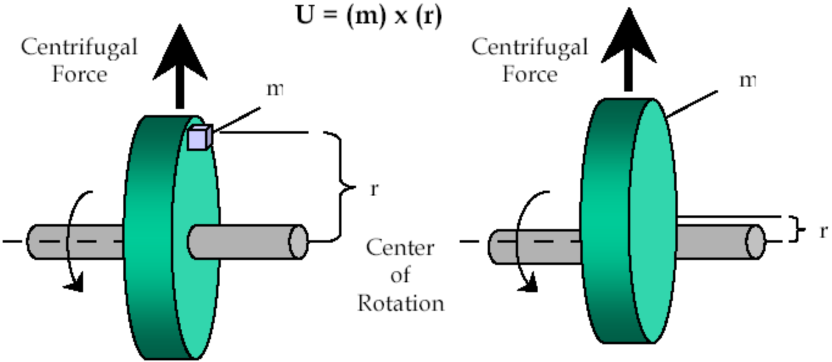
Unbalance vibration in electric motor

Definition of Unbalance

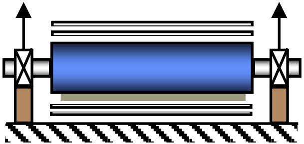
❖ **Unbalance**

- **That condition which exists in a rotor when vibratory forces or motion is imparted to its bearings as a result of centrifugal forces**
- **U = m x r (g·mm)**

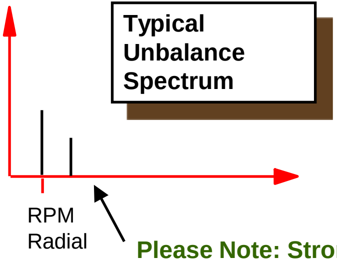
  m : unbalance mass (g)
  r : distance from unbalance mass to shaft/rotor centerline (mm)



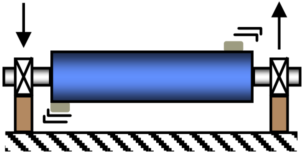
Types of Unbalance



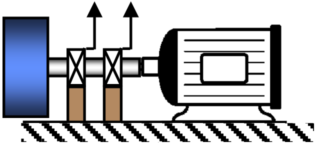
Static Unbalance
- Equal phase on each bearing
- Mainly radial vibration



Please Note: Strong unbalance cause harmonics



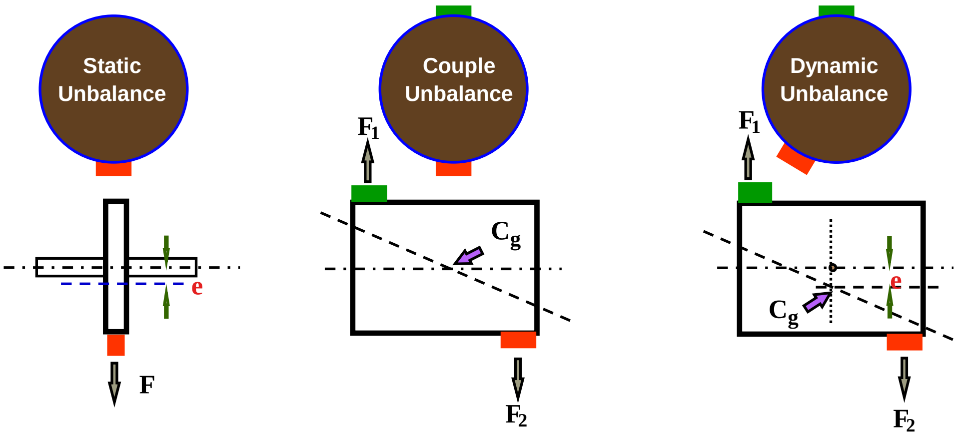
Coupled Unbalance
- Phase changes 180 ° across bearing
- Mainly radial vibration



Overhung Rotor Unbalance
- Both radial and horizontal vibration
- Often both static and dynamic unbalance are seen together

Types of Unbalance

- Static unbalance
- Couple unbalance
- Dynamic unbalance



Sources of Unbalance

❖ Manufacturing & Assembly Errors

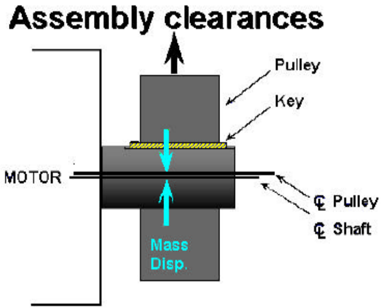
- Form error produced by welding and casting
- Clamping errors during machining, e.g. journal eccentric, inclined
- Permanent deformation caused by manufacturing, e.g. release of residual stresses, distortion during machining, deformation due to soldering, welding, shrink fits
- Deformation due to unequal tightening of bolts
- Variations in assembly components, e.g. different bolt length, different types of washers and nuts

❖ Material Faults

- Blow holes in castings
- Unequal material densities
- Unequal material thickness in welded assembly
- Run-out and clearance in ball bearings

❖ Design & Drawing Errors

- Parts do not have rotational symmetry
- Unmachined surfaces on rotor
- Run-out errors due to poor fits
- Key shorter than keyway
- Moving parts not mounted with rotational symmetry and wit



❖ Operation

- Corrosion, • Particle attachment

Sources of Unbalance

The following machine problems are among the conditions that will create imbalance:

- Uneven dirt accumulation on fan rotors
- Lack of homogeneity in cast parts, such as bubbles, blow-holes, porous sections
- Rotor eccentricity
- Roller deflection, especially in paper machines
- Machining errors
- Uneven mass distribution in electric motor rotor bars or windings
- Uneven erosion and corrosion of pump impellers
- Missing balance weights
- Bowed shaft

Severity of Imbalance

- The severity of imbalance depends on both the type and size of the machine as well as the vibration level.
- To assess imbalance severity, average 1X levels for healthy machines of the same type should be used as a comparison (reference level).
- If the second order peak is as large as the first order, you should suspect misalignment.
- The following levels are guidelines for general use in diagnosing imbalance for machines running at 1800 or 3600 RPM.
- Very high-speed machines have lower tolerance levels.

1X Vibration Level	Diagnosis	Repair Priority
< 3.58 mm/s	Slight Imbalance	No recommendation
3.58 ~ 7.16 mm/s	Moderate imbalance	Desirable
7.16 ~ 22.4 mm/s	Severe Imbalance	Important
> 22.4 mm/s	Extreme Imbalance	Mandatory

Severity of Imbalance

- The measured vibration level at 1X depends on the stiffness of the machine mounting as well as the amount of imbalance, with spring-mounted machines showing more 1X than solidly mounted machines for the same degree of imbalance.
- The overall size of the machine also affects the allowable 1X level as follows:

1X Vibration Level	Machine Type	Repair Priority
4.01mm/s	Small Single-stage Pump	Desirable
11.35 mm/s	Large Hydraulic Pump	Desirable
9.02 mm/s	Medium Sized Fan	Desirable

❖ Balance Quality Grade for Rigid Rotor

ISO 1940

Grade	Application
G 16	Drive shafts (propeller shafts) with special requirements. Parts of crushing machinery. Parts of agricultural machinery. Slurry or dredge pump impeller. Individual components of engines (gas or diesel) for cars, trucks and locomotives. Crankshaft drives of engines with six or more cylinders under special requirements.
G 6.3	Parts or process plant machines. Fans. Fly wheels. Pump impellers. Machine tool and general machinery parts. Normal electrical armatures. Individual components of engines under special requirements Marine main turbine gears (merchant service).
G 2.5	Gas & steam turbines, including marine main turbines. Rigid turbo-generator rotors. Turbo-compressors. Machine tool drives. Medium and large electrical armatures with special requirements. Small electrical armatures. Turbine driven pumps.
G 1	Grinding machine drives. Small electrical armatures with special requirements.
G 0.4	Spindles, disks and armatures of precision grinders.

Permissible Residual Specific Unbalance

❖ Balance Quality Grade for Rigid Rotor

- **ISO 1940**

  e_{per} N = constant

  e_{per} : permissible residual specific unbalance

  N : maximum speed (rpm)

- **API**

  U_{max} = 6350 W/N (g·mm)

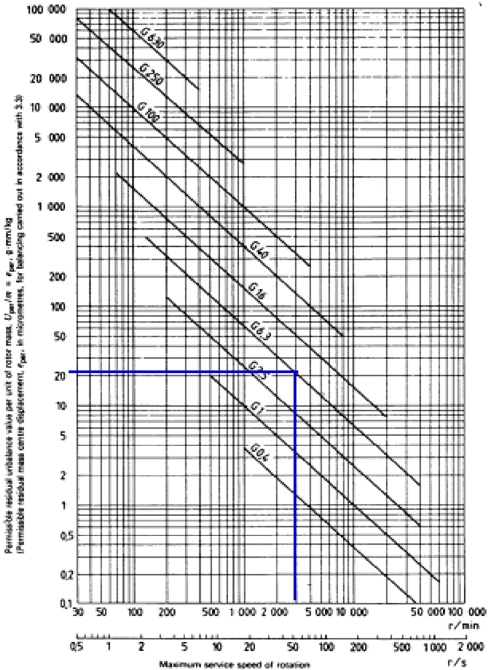
  W : journal static load (kg)

  N : maximum speed (rpm)

Example: N = 3000rpm, quality grade G 6.3

e_{per} ?

$e_{per} = V_{per} / \omega \approx 6.3 / 300 = 21\ \mu m$



Permissible Residual Unbalance

❖ Example for Turbine Rotor

- Rotor Weight 400 kg
- Max. Speed 10,000 rpm

❖ ISO 1940 G 2.5

U_{max} = 2.4 μm × 400 kg

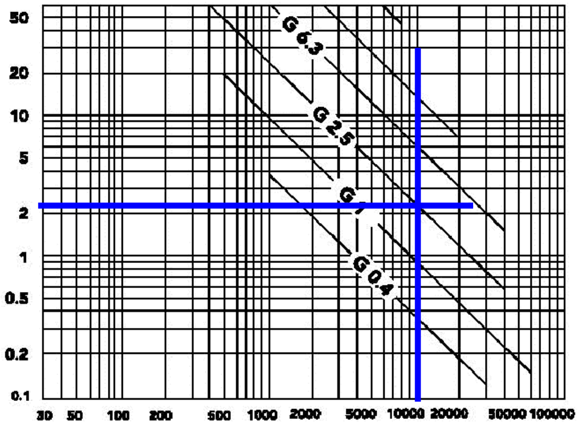
= 960.0 g·mm

❖ API

U_{max} = 6,350 × 200 kg/ 10,000 rpm

= 127.0 g·mm

(W = 400 kg/ 2 = 200kg)

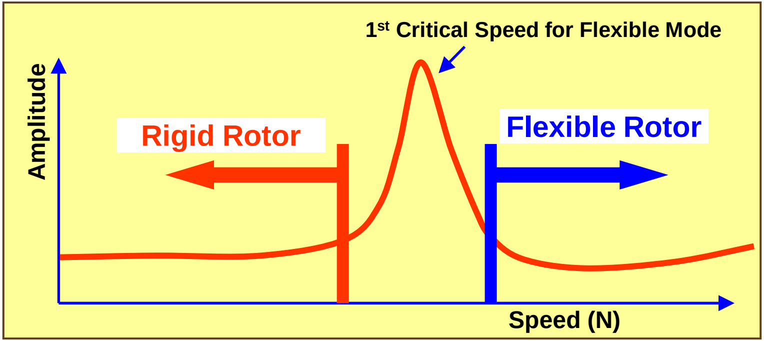


Balancing Machine

- Balancing
  - Shop Balancing
    - Low Speed Balancing Machine
      - Soft Mount Type
      - Hard Mount Type
    - High Speed Balancing Machine
      - Soft Mount Type
      - Hard Mount Type
  - Field Balancing

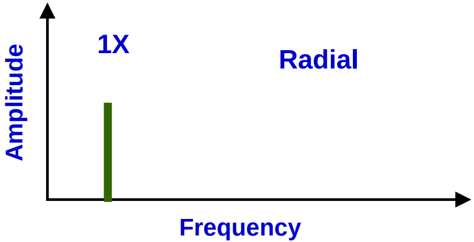
Definition of Rotors

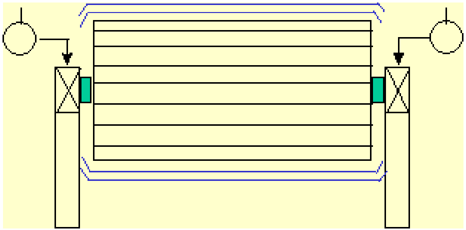
- **Rotor :** A body, capable of rotation, with journals which are supported by bearings
- **Rigid Rotor**
  - Condition of unbalance up to the service speed of the rotor does not change noticeably or at least by only an insignificant amount.
  - Can be corrected in any two (arbitrarily selected) planes
- **Flexible Rotor**
  - A rotor not satisfying the definition of a "rigid rotor"



Static Unbalance

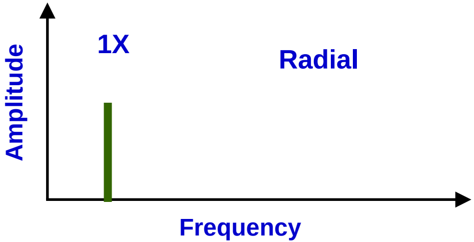
- Static unbalance (force unbalance) will be in-phase and steady.
- Amplitude due to unbalance will increase by the square of speed(Ω) (3 x speed increase = 9 x higher vibration). $F = me\Omega^2$
- 1x RPM always present and normally dominates the spectrum.
- Can be corrected by placement of only one balance weight in one plane at rotor center of gravity (CG).

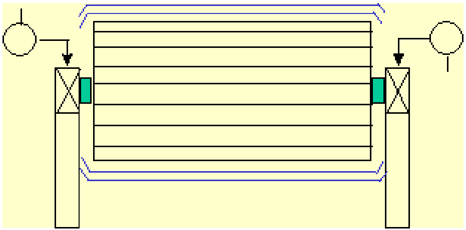




Couple Unbalance

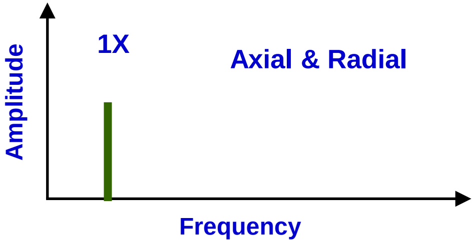
- Couple unbalance tends toward 180° out-of-phase on same shaft.
- 1x always present and normally dominates the spectrum.
- Amplitude varies with square of increasing speed.
- May cause high axial vibrations as well as radial.
- Correction requires placement of balance weights in at least 2 planes.
- Note that approx. 180° phase difference should exist between outboard and inboard horizontals as well as outboard and Inboard verticals.

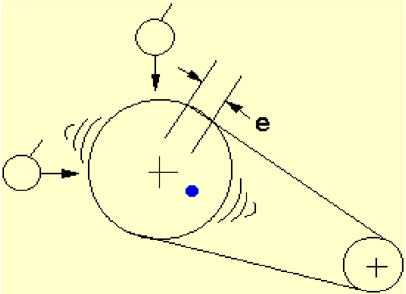




Overhung Rotor Unbalance

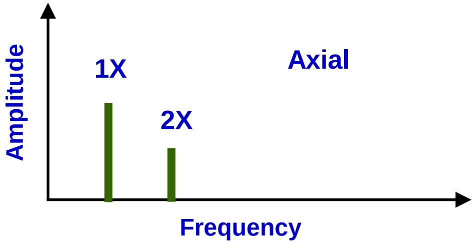
- Eccentricity occurs when the centre of rotation is offset from the geometric center line of a sheave, gear, bearing, motor armature, etc.
- The largest vibration occurs at 1x RPM of eccentric component in a direction through the centers of the two rotors.
- Comparative horizontal and vertical phase readings usually differ either by 0° or by 180° (each of which indicate straight line motion).
- Attempts to balance an eccentric rotor often results in reducing the vibration in one direction, but increasing it in the other radial direction (depending on the amount of eccentricity).

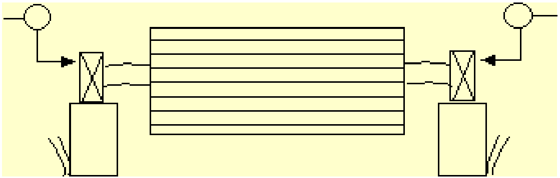




Bent Shaft

- Bent shaft problems cause high axial vibration with axial phase differences tending toward 180° on the same machine component.
- The dominant vibration ins normally at 1x if bent near the shaft centre, but at 2x if bent near the coupling.
- Be careful to account for the transducer orientation for each axial measurement if you reverse probe direction.

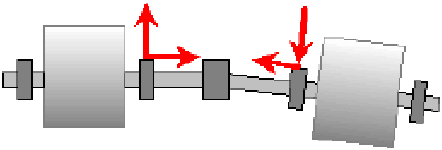




Misalignment

Definition of Misalignment

- Misalignment is a condition where the centerlines of coupled shafts do not coincide.
- If the misaligned shaft centerlines are parallel but not coincident, then the misalignment is said to be parallel misalignment.
- If the misaligned shafts meet at a point but are not parallel, then the misalignment is called angular misalignment.
- Almost all misalignment conditions of machines seen in practice are a combination of these two basic types.



Characteristics of Misalignment

- Misalignment is traditionally associated with a 2nd harmonic component, which according to some sources is due to to 2 times the stress reversal during one rotation.
- More probably the harmonic occurs due to distortion of the ideal sinusoidal vibration signal.
- It is quite common that misalignment occurs on the 1st harmonic only in the spectrum.
- An investigation of the phase relationship across the rotor and across the coupling should therefore always be carried out for distinguishing misalignment from unbalance.
- A misaligned rotor tend to wear in. That is after a while the bearing will get deformed after the misalignment.
- In the spectrum this is seen as the 2nd order component will decrease and the 3rd order will increase as wear develops.

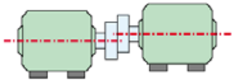
Misalignment Wear Process

- The 1X goes up
- The 1X and 2X goes up
- The 1X goes up, and the 2X goes down
- The 1X stays steady, 2X stays steady and the 3X goes up

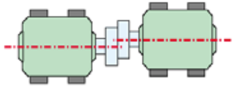
If rolling element bearings or gears are involved, the gear mesh and the bearing frequencies go up

Type of Misalignment

- **Parallel Misalignment**
  - **Vertical & Horizontal offset**

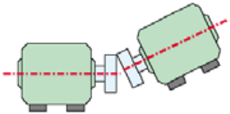


Vertical offset

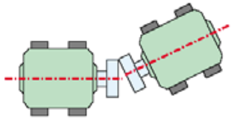


Horizontal offset

- **Angular Misalignment**
  - **Vertical & Horizontal Angularity**

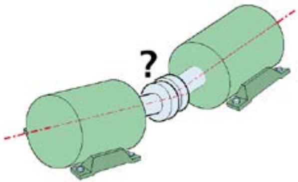


Vertical angularity



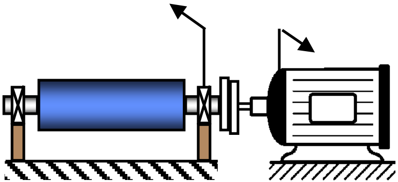
Horizontal angularity

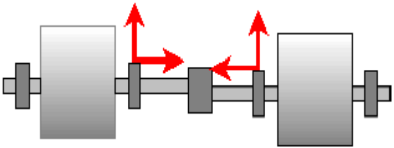
- **Combined Misalignment**
  - **Parallel Misalignment + Angular Misalignment**

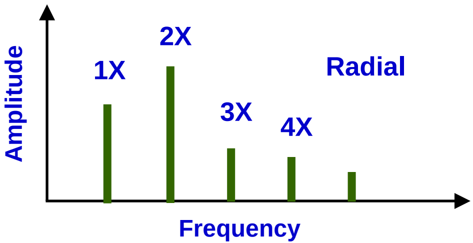


Parallel Misalignment

- Radial vibration approximately 180° phase shifted 2X often highest peak
- If the machine speed can be varied, the vibration due to imbalance will vary as the square of the speed.
- If the speed is doubled, the imbalance component will rise by a factor of four, while misalignment-induced vibration will not change in level
- Following is a typical vibration spectrum from a misaligned machine.

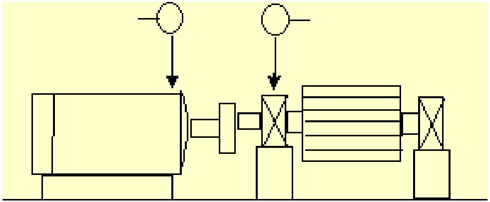






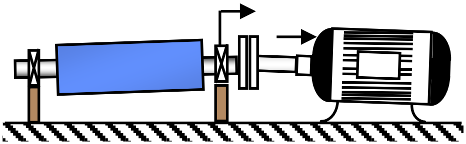
Parallel Misalignment

- Offset misalignment has similar vibration symptoms to angular, but shows high radial vibration which approaches 180° out-of-phase across the coupling
- 2x often larger than 1x, but its height relative to 1x is often dictated by coupling type and construction.
- When either angular or radial misalignment becomes sever, it can generate either high amplitude peaks at much higher harmonics (4x ~ 8x) or even a whole series of high frequency harmonics similar in appearance to mechanical looseness.
- Coupling construction will often greatly influence the shape of the spectrum when misalignment is severe.

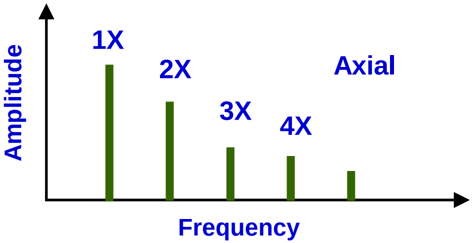


Angular Misalignment

- Axial vibration approximately 0° phase shifted 1X, 2X or 3X highest
- Angular misalignment produces a bending moment on each shaft, and this generates a strong vibration at 1X and some vibration at 2X in the axial direction at both bearings, and of the opposite phase.
- There will also be fairly strong radial and/or transverse 1X and 2X levels, but in phase.
- Misaligned couplings will usually produce fairly high axial 1X levels at the bearings on the other ends of the shafts as well!

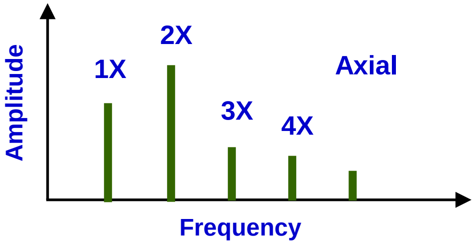


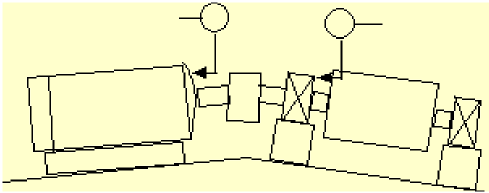
Please Note:
Misalignment often appears on 1X component only



Angular Misalignment

- Angular misalignment is characterized by high axial vibration, 180° out-of-phase across the coupling
- Typically will have high axial vibration with both 1x and 2x rpm. However, not unusual for either 1x, 2x or 3x to dominate.
- These symptoms may also indicate coupling problems as well.

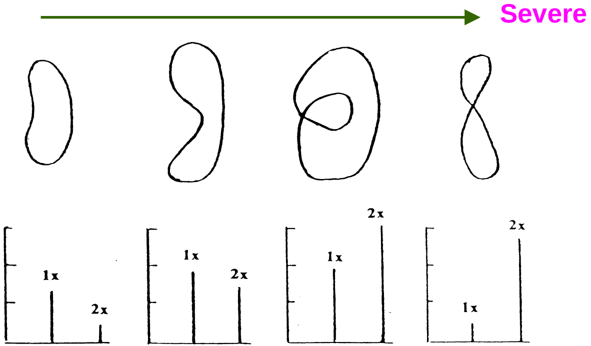




General Misalignment

- Most cases of misalignment are a combination of the two types
- Diagnosis is based on stronger 2X peaks than 1X peaks and the existence of 1X and 2X axial peaks.
- Take care that high axial 1X levels are not caused by imbalance in overhung rotors.
- Misalignment produces a variety of symptoms on different types of machines, and the average vibration signatures for healthy machines should be consulted to determine allowable 1X and 2X levels.

Orbit & spectrum



Temperature Effects on Alignment

- The best alignment of any machine will always occur at only one operating temperature
- Hopefully this will be its normal operating temperature.
- It is imperative that the vibration measurements for misalignment diagnosis be made with the machine at normal operating temperature.

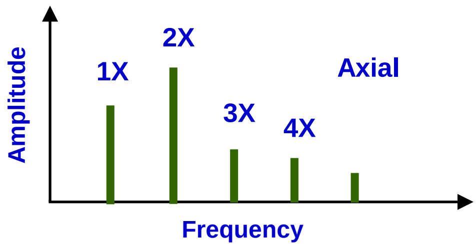
Causes of Misalignment

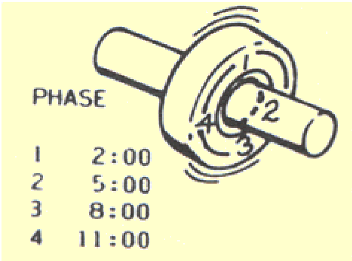
Misalignment is typically caused by the following conditions:

- Inaccurate assembly of components, such as motors, pumps, etc.
- Relative position of components shifting after assembly
- Distortion due to forces exerted by piping
- Distortion of flexible supports due to torque
- Temperature induced growth of machine structure
- Coupling face not perpendicular to the shaft axis
- Soft foot, where the machine shifts when hold down bolts are torqued

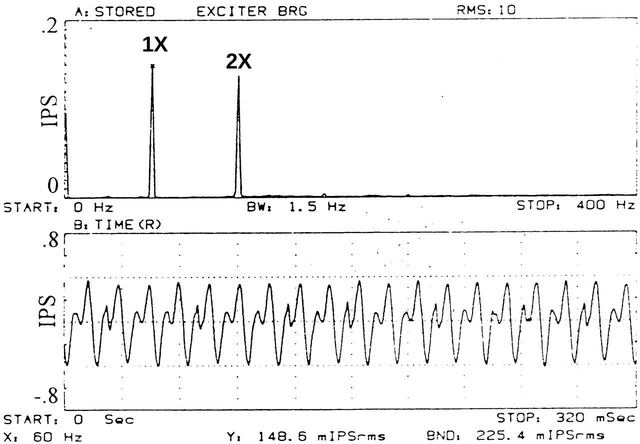
Misaligned Bearing Cocked On Shaft

- Cocked bearing will generate considerable axial vibration.
- Will cause twisting motion with approximately 180° phase shift top to bottom and/or side to side as measured in the axial direction of the same bearing housing.
- Attempts to align the coupling or balance the rotor will not alleviate the problem.
- The bearing must be removed and correctly installed.





Case History : Misalignment

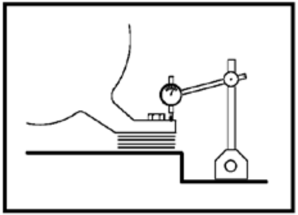


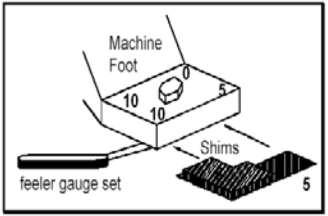
Misalignment vibration between generator and exciter

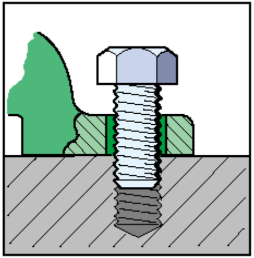
Alignment Procedure

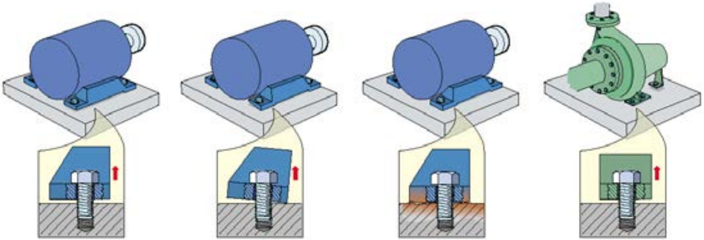
❖ Soft Foot Checks

- Dial Gage
- Feeler Gage









Parallel soft foot

Angular soft foot

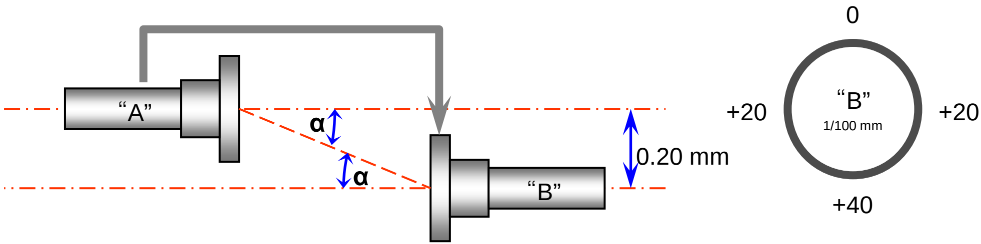
'Squishy foot' (corrosion)

Soft foot from external forces

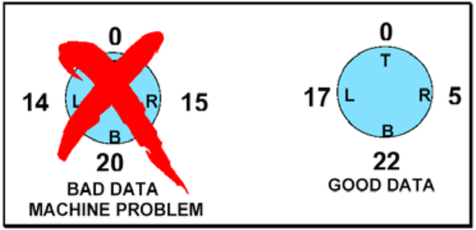
Alignment Procedure

❖ Indicator Readings

- Amount of offset = TIR/ 2, TIR : Total Indicator Readings



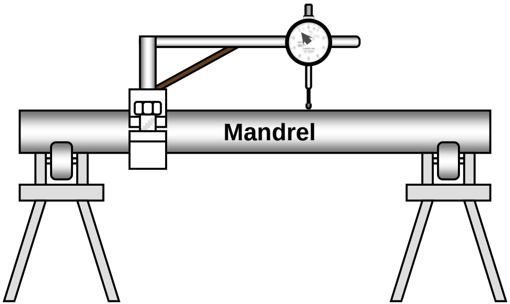
- Top + Bottom = Right + Left

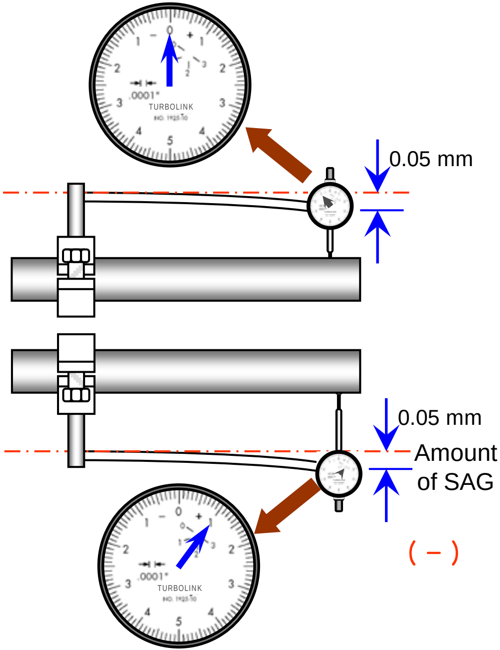


Alignment Procedure

❖ Bar SAG

SAG = TIR/ 2





Alignment Procedure

❖ Alignment Methods Using Indicator

- Rim & Face Shaft Alignment
- Reverse Shaft Alignment

❖ Applications

- **Rim & Face Shaft Alignment**

  Trains where one shaft can't be rotated during the alignment process.

- **Machines with coupling hubs that are axially close to each other.**

  Machines that have large diameter couplings.

  Small general purpose machines

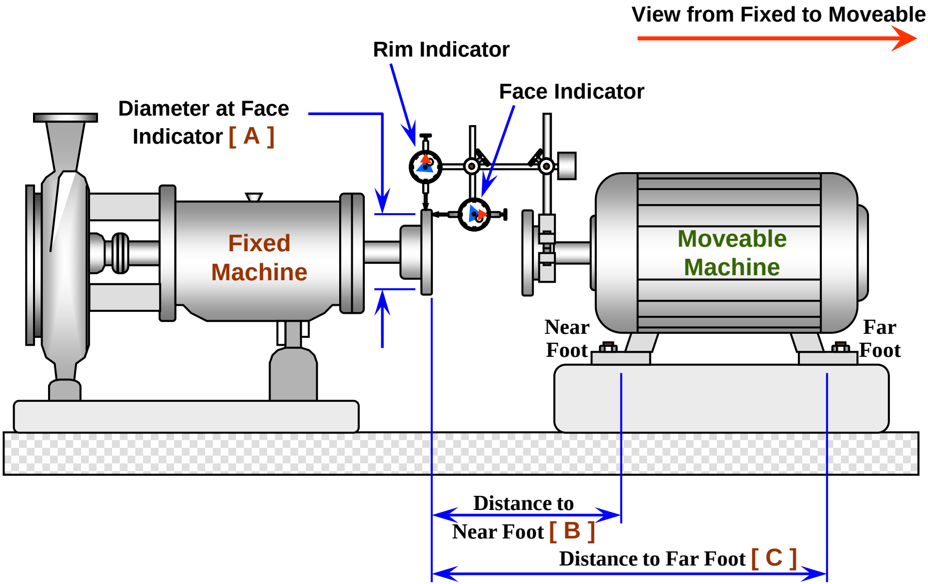
- **Reverse Shaft Alignment**

  Long span machines

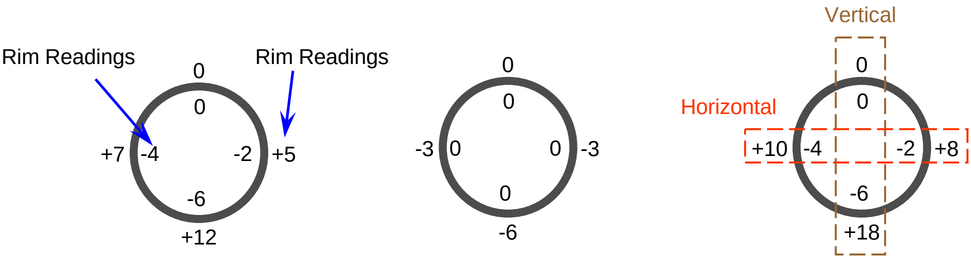
  Machines that require precision alignment.

Rim & Face Shaft Alignment

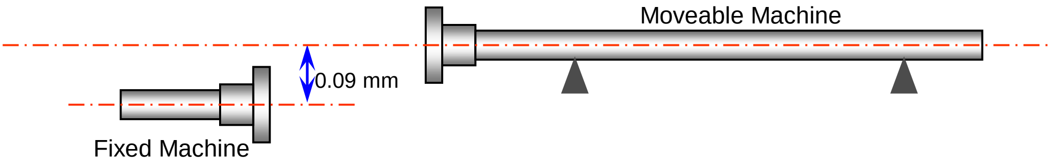
❖ Typical Set-up



❖ OFFSET MISALIGNMENT

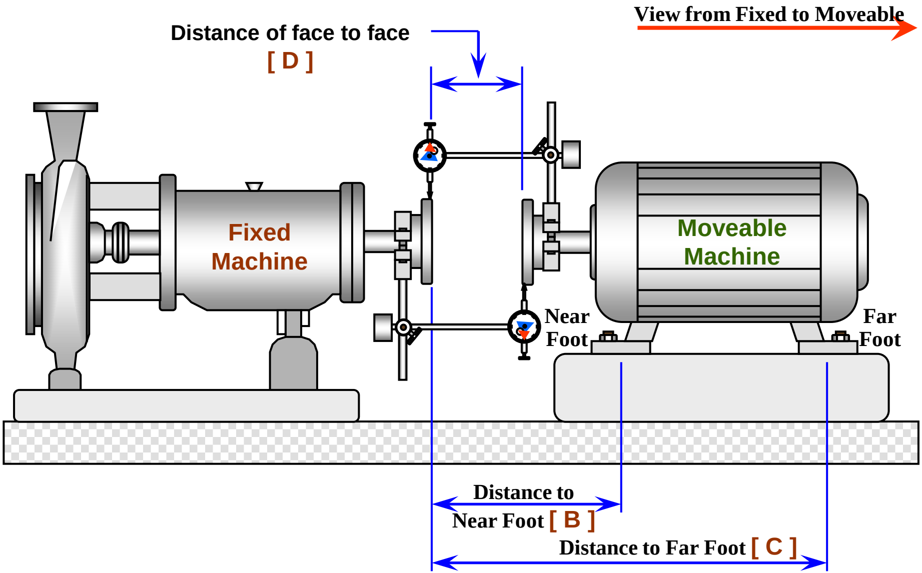


Measured Readings | **SAG Readings** | **Corrected Readings**



Vertical Offset (Side View)

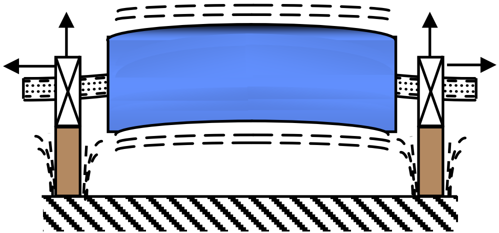
❖ Typical Set-up

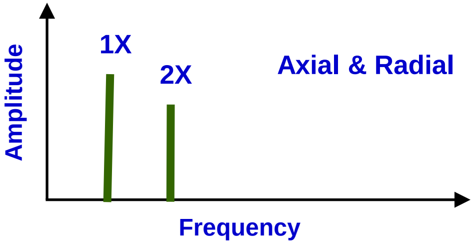


Bent Shaft

Bent Shaft

- A bent shaft is looking like a misalignment in the spectrum.
- A phase measurement for axial vibration across the shaft will distinguish between misalignment and bent shaft as the bent shaft will produce a 180 degrees phase shift.
- Axial and radial vibration
- 180° phase shift in axial vibration, 0° phase shift in radial vibration

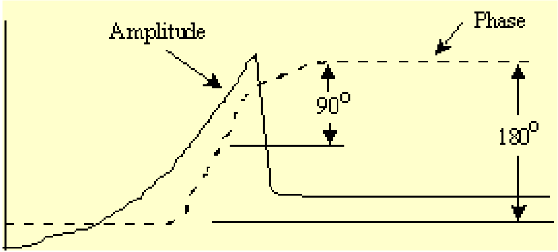


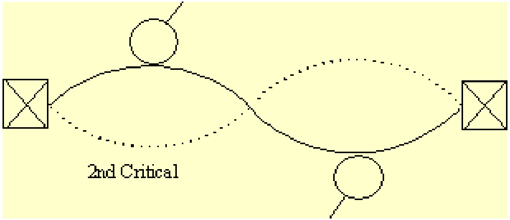


Resonance Problems

Resonance

- Resonance occurs when a forcing frequency coincides with a system natural frequency, and can cause dramatic amplitude amplification which can result in premature or even catastrophic failure.
- This may be a natural frequency of the rotor but can often originate from a support frame, foundation, gearbox or even drive belts.
- If a rotor is at or near resonance, it will be almost impossible to balance due to the great phase shift it experiences (90° at resonance; nearly 180° when it passes through).
- Often requires changing natural frequency location.
- Natural frequencies do not change with a change in speed, this helps facilitate their identification.

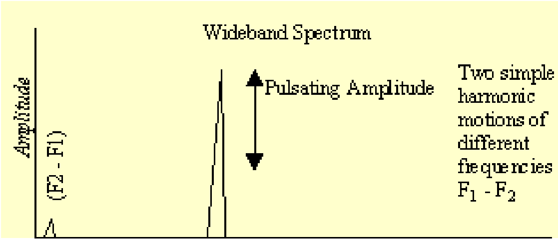


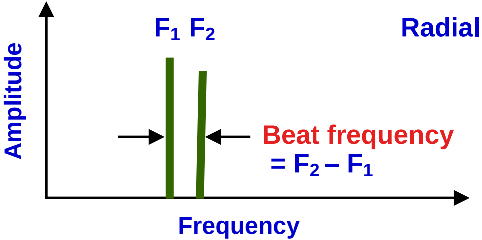


Beat Problems

Beat Vibration

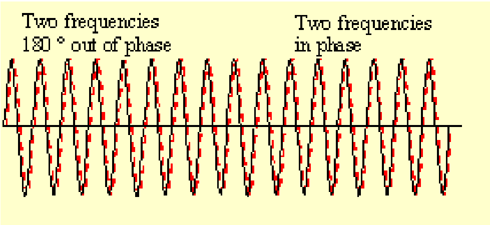
- A beat frequency is the result of two closely spaced frequencies going into and out of synchronization with one another.
- The wideband spectrum normally will show one peak pulsating up and down.
- When you zoom into this peak (lower spectrum), it actually shows two closely spaced peaks.
- The difference in these two peaks ($f_2 - f_1$) is the beat frequency which itself appears in the wideband spectrum.
- The beat frequency is not commonly seen in normal frequency range measurements since it is inherently low frequency.

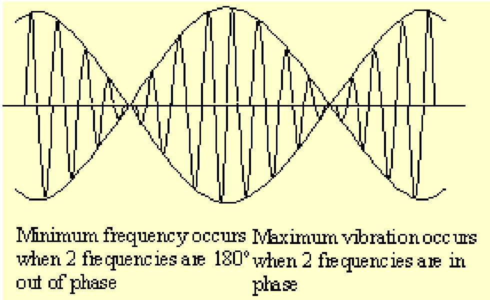




Beat Vibration

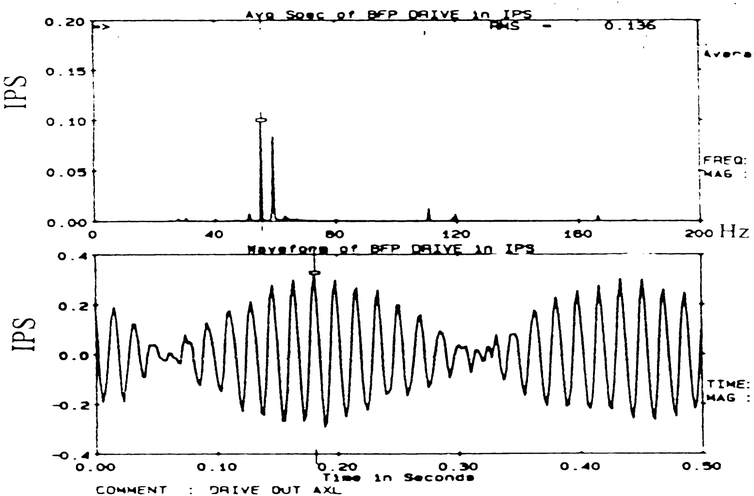
- Usually ranging from only approximately 5 ~100 CPM.
- Maximum vibration will result when the time waveform of one frequency (f_1) comes into phase with other frequency (f_2).
- Minimum vibration occurs when waveforms of these two frequencies line up 180° out of phase.





Case History : Beat Vibration

Operating speed (55Hz) & natural frequency



Beat vibration in boiler feed water pump

Looseness Problems

Mechanical Looseness

- Mechanical looseness produce a strongly distorted signal.
- The subharmonics (1/2X, 1/3X etc.) are attributable to the fact that the loose part bounces and thus does get excited every 2nd or 3rd revolution of the shaft.

- Mechanical looseness is indicated by either type A, B or C spectra.

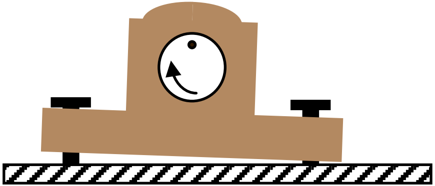
- Mechanical looseness is often highly directional and may cause noticeably different readings if you compare levels at 30° increments in the radial direction all the way around one bearing housing.

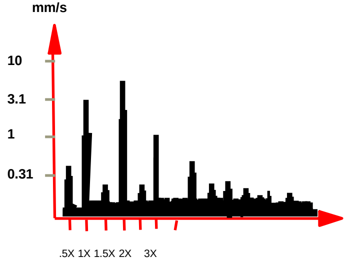
- Also note that looseness will often cause subharmonic multiples at exactly 1/2 or 1/3x rpm (0.5x, 1.5x, 2.5x etc.)

Looseness Problem

- **Loose Foundation**

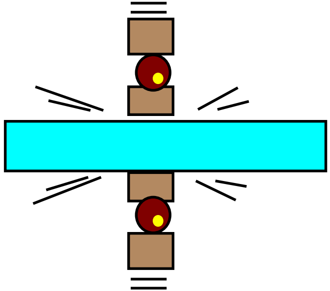
  2X often high sub-harmonics

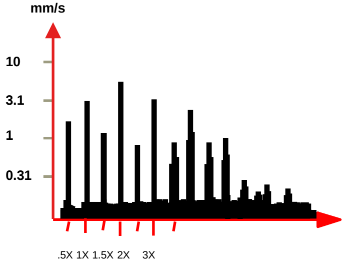




- **Loose shaft**

  Often series of sub harmonic components 1/2, 1/3, ... 1/n

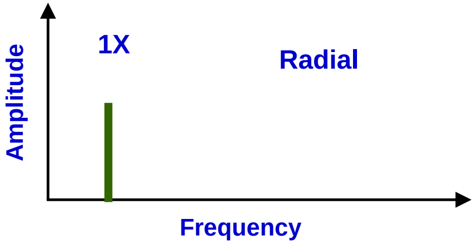


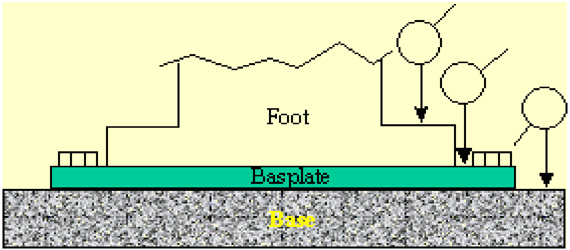


Mechanical Looseness

- Type A is caused by structural looseness/ weakness of machine feet, base plate or foundation, also by deteriorated grouting, loose hold-down bolts at the base and distortion of the frame or base (i.e. soft foot).

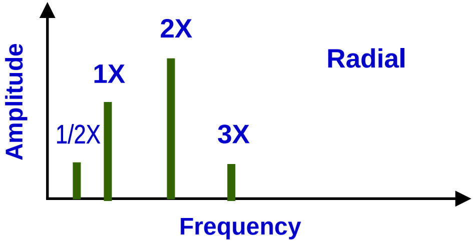
- Phase analysis may reveal approximately 180° phase difference between vertical measurements on the machine foot, base plate and base itself.

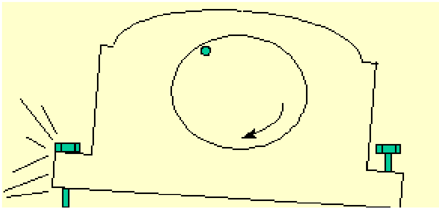




Mechanical Looseness

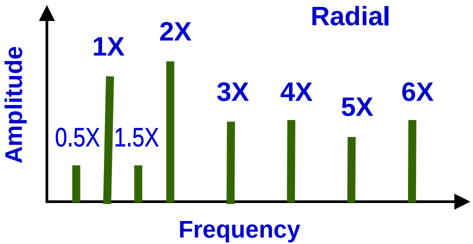
- Type 'B' is generally caused by loose pillow block bolts, cracks in the frame structure or bearing pedestal.

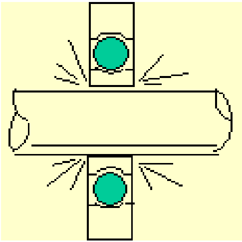




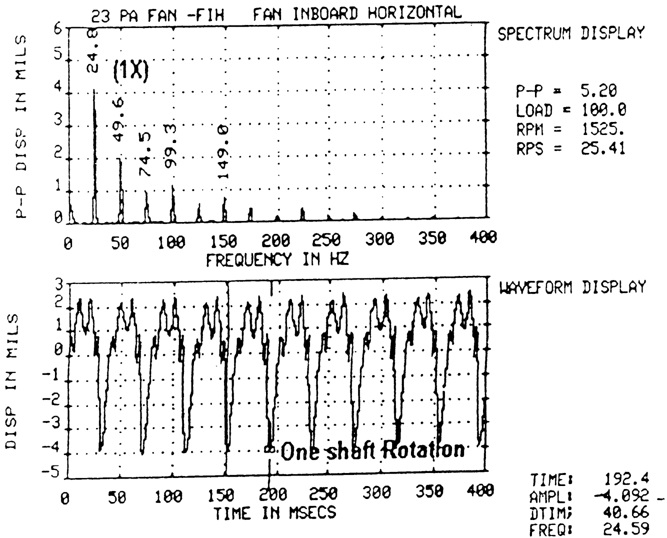
Mechanical Looseness

- Type C is normally generated by improper fit between component parts which will cause many harmonics due to non linear response of loose parts to dynamic forces from the rotor. Causes a truncation of time waveform.
- Type C is often caused by a bearing liner loose in its cap, excessive clearance in either a sleeve or rolling element bearing or a loose impeller on a shaft.
- Type C phase is often unstable and may vary widely from one measurement to the next, particularly if the rotor shifts position on the shaft from one start-up to the next.





Case History : Mechanical Looseness

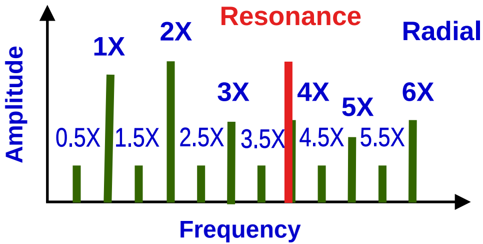


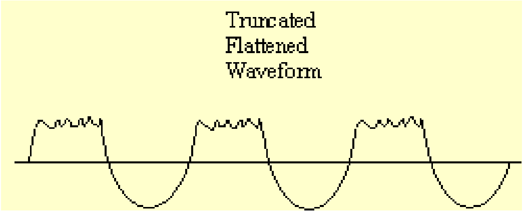
Mechanical looseness in fan journal bearing

Rotor Rubs

Rotor Rub

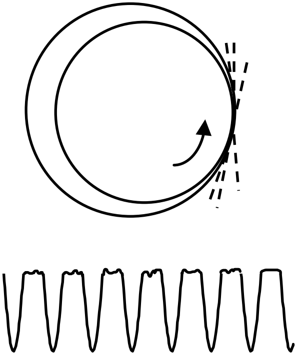
- Rotor rub produces similar spectra to mechanical looseness when rotating parts contact stationary components.
- Rub is either partial or throughout the whole revolution. Usually generates a series of frequencies, often exciting one or more resonance's.
  Often excites integer fraction subharmonics of running speed (1/2, 1/3, 1/4, 1/5, ...1/n), depending on location of rotor natural frequencies.
- Rotor rub can excite many higher frequencies (similar to wide-band noise when chalk is drug along a blackboard). It can be very serious and of short duration if caused by shaft contacting bearing babbitt; but less serious when the shaft is rubbing a seal, an agitator blade rubbing the wall of a vessel, or a coupling guard pressing against a shaft.





Rotor Rub

- Symptoms same as Mechanical Looseness
- Subharmonics 1/2X ,1/3X etc.
- Strong harmonic pattern caused by truncation



Truncated Wave form