Lifetime Reliability • Solutions

Phone: +61 (0) 402 731 563
Fax: +61 8 9457 8642
Email: info@lifetime-reliability.com
Website: www.lifetime-reliability.com

The Lifetime Reliability Solutions
Certificate Course in Maintenance and Reliability
Module 1 – Introduction to Principles of Reliability and Precision Maintenance

Session 3
Principal Causes of Failure in Machinery

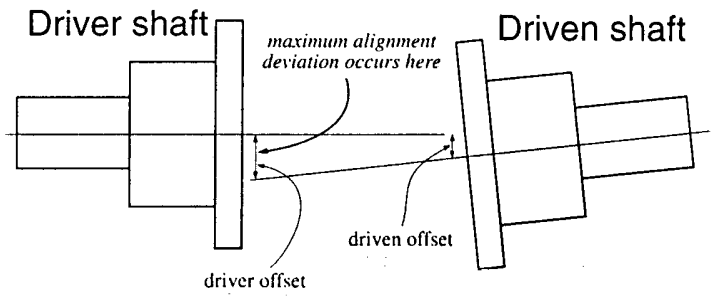
Many causes of failure in machinery exist and their predominance will vary to some degree from industry to industry. However, the most common causes, in order, are,

- Misalignment
- Unbalance
- Resonance
- Bearings
- Looseness
- Flow-related problems
- Electrical
- Bent Shaft
- Gear Mesh

It may be argued that Bearing failure is the most common cause but it is appropriate to look at the root cause for the bearing failure and work with that. Accordingly, the most common causes, in order, are misalignment, unbalance and bearings. Most of these faults show characteristics that are identifiable with vibration analysis. Others may show better through oil analysis or thermography.

Misalignment

Misalignment is universally recognised as the leading contributor to machinery failure. For the same level of vibration it is much more serious than unbalance for its effect in reducing bearing life, largely because of the parasitic axial thrust.



Misalignment exists when the centre lines of two adjacent machines deviate from each other. Alignment related problems include soft foot, pipe strain, inadequate bases etc.

Principal Causes of Misalignment

- Lack of appropriate Standards and Specifications
- Poor Tolerances and Poor Methods
- Good Methods, but bad practices
- Lack of understanding of precision process

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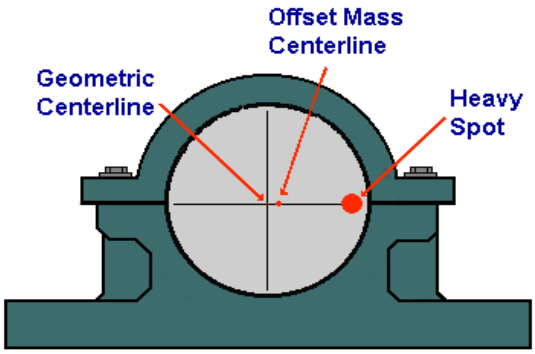
- Dynamic movement (thermal growth, pipe strain etc.)
- Mis-diagnosis with Unbalance or Looseness

Unbalance

Unbalance is arguably the next most significant contributor to premature machine failure.

Unbalance exists when the mass centre line of a rotor is not coincident with the geometric centre line. The resultant orbital motion has a severe impact on the life of bearings and on seals.



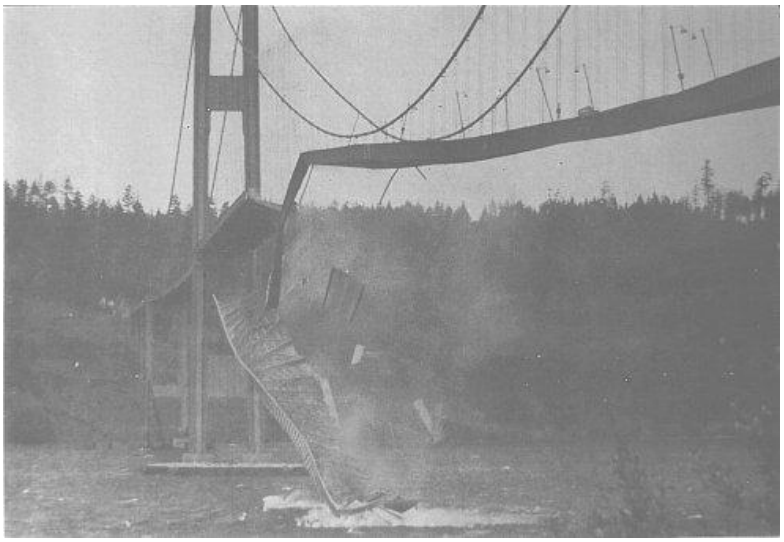
Principal Causes of Unbalance

- Accumulation of assembly tolerances
- Poor attention to assembly
- Inappropriate use of standards
- Non-homogeneous materials (casting blow holes)
- Operational – uneven build up of product
- Erosion of rotor material

Resonance

Resonance is a condition which occurs when a machine **forcing frequency** (related to rotational speed) becomes coincident with, or close to, the **natural frequency** of a machine component or appendage. The problem is most often seen in the supporting structure or attached pipe work.

> The condition is like that of a mechanical amplifier and can result in a very severe vibration at that frequency when the forcing vibration is already too high. The results can be quite destructive, like pictured in the Tacoma Bridge disaster in Washington State many years ago.



Thus, resonance may be seen as a condition that aggravates the whole range of other problems. It is somewhat more common than it is given credit for and complicates the diagnosis and correction of the root problem.

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Resonance is not necessarily a problem in itself. It is a condition which, when present with any of the other problems, can lead to excessive vibration

Bearing Failure

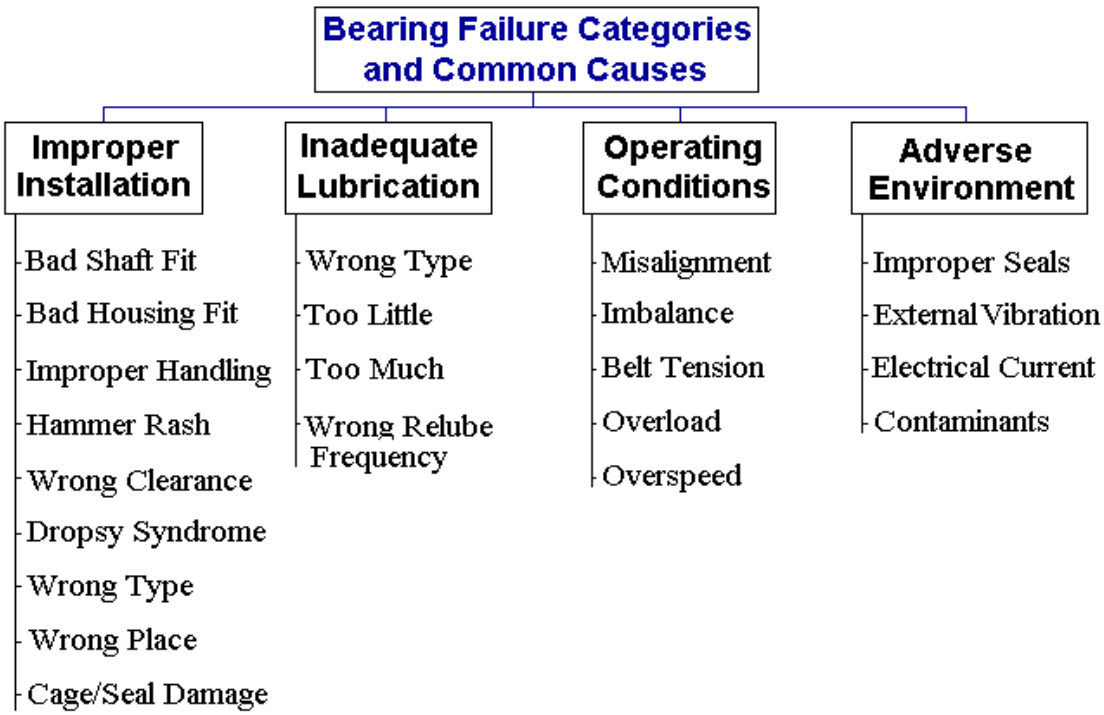
Bearing failure itself is not a significant source of vibration until quite advanced stages of failure are reached. However, with appropriate signal conditioning the information relating to the early stages of failure is available in the vibration signal.

The design life of a bearing is very dependant upon the service it is in. In some industries it appears that fewer than 5% of bearings achieve their design life.

Primary Causes of Premature Bearing Failure

The most common cause of bearing failure is probably loss or contamination of the lubricant. However, assuming lubrication is adequate, mechanical defects such as misalignment and unbalance have a severe impact upon bearing life. Indeed, there is a cubic relationship between fatigue (vibration velocity) and bearing life; thus a halving of vibration velocity can theoretically give 8X the bearing life.

With the advance in modern manufacturing technology there is not the same problem with "cheapie" bearings as there used to be. There is a greater range of manufacturers supplying bearings of satisfactory quality and the competitiveness now revolves more around the supportive and technical services that are provided.



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Looseness

Looseness may be considered as being where parts are not fitted tightly together. Typically this fits into three categories;

- Structural looseness/weakness of machine feet, baseplate or foundation. Also by deteriorated grouting, loose hold-down bolts at the base and distortion of the frame or base. This may be seen as Soft Foot.
- Loose plummer block bolts, cracks in frame structure or bearing pedestal.
- Improper fit between component parts, e.g. excessive clearance in a sleeve or rolling element bearing, impeller loose on its shaft.

The one thing that is a certainty with looseness is that the situation will only get worse; looseness should always be dealt with promptly with a view to limiting the damage.

Flow Related Problems

Flow related problems such as cavitation and recirculation are caused by pumps operating outside of their design parameters.

When a centrifugal pump is operated below its design capacity, or with extreme suction conditions, it is likely to experience cavitation. Cavitation occurs when vapour bubbles are formed in the pump low pressure regions and then collapse in a higher pressure region; the collapse leads to erosion of the impeller, and sometimes the casing.

Another common problem with centrifugal pumps is recirculation. Liquid returns from the impeller discharge either externally to the impeller suction through worn wear rings, or may return internally, and impacts on the impeller vanes. The problem is worse when the discharge is throttled or when the impeller is axially displaced so that it does not align with the pump discharge. The result is increased vibration at vane passing frequency and there may be a significant temperature increase. The reverse flow in the pump and mixing of the liquid results in a random vibration not unlike cavitation and can lead to erosion of the impeller.

Electrical Problems

Electrical problems which can result in vibration include;

- Soft foot
- Uneven air gap
- Cracked or broken rotor bars
- Eccentric rotors
- Loose phase connections

Of these, Soft Foot would be the most common and potentially the most serious. It leads to a distortion of the motor stator causing an uneven air gap, but also giving an effective misalignment condition.

Bent Shaft

Another potential source of machine vibration is a bent shaft.

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Shafts may become bent by being subject to an excessive force from unbalance, seizure or thermal distortion. This may also occur through poor assembly from cocked bearings, incorrectly torqued Taper Lock bushings, or tapered distance pieces.

Gear Meshing

When faults occur in gearboxes they will often express as vibrations related to gear meshing frequency. These faults may include;

- Misalignment of the gearbox internally or externally
- Soft foot
- Poorly manufactured gears
- Bent shaft

What causes most of the problems ?