PROTECTING BEARINGS FROM DUST AND WATER.

ABSTRACT
Protecting bearing from dust and water. Protection methods like labyrinth rings, rubber seals, felt seals and shaft mechanical seals are described. Choice of the appropriate shaft seal and seal configurations to protect against dust and water ingress is critical. Numerous shaft seal designs suited to contaminated conditions are reviewed. Keywords: Particles, contamination, bearing, shaft, grease barrier, breather.

Dusty surroundings are one of the most difficult environments for bearings. In equipment handling powders or in processes generating dust the protection of bearings against contamination by fine particles requires special consideration.

BEARING HOUSINGS
Bearings are contained within a housing from which a shaft extends. The shaft entry into the housing offers opportunity for dust (and moisture) to enter the bearing. The shaft seal performs sealing of the gap between the housing and shaft. Choice of the appropriate shaft seal and seal configurations to protect against dust ingress is critical.

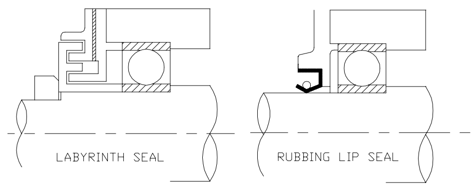


Figure No. 1. Shaft Bearing Housing Seals

Bearing housing seals for dusty environments may be either a labyrinth type or a rubbing seal type. The labyrinth type requires a straight shaft running true. Rubbing seals are the more common and allow for some flexing of the shaft. The sketches below are conceptual examples of each type of seal. When setting a lip seal into place to prevent dust ingress insure the sealing lip faces outward.
In situations of high dust contamination there may be a need to redesign the shaft seal arrangement for better dust protection than provided in standard housings. Some ideas which can reduce dust ingress into bearing housings are to :

i. provide two or more seals in parallel. Bearing housings can usually be purchased with combination seals as standard.

ii. retain the housing shaft seals but change from a greased bearing in the housing to one which is sealed and greased for life. If contamination were to get past the shaft seals, the bearing's internal seals would protect it.

iii. stand the bearing off the equipment to create a gap between the end of the equipment and the bearing housing while sealing the shaft at the equipment.

iv. put in a felt seal wipe between the housing and the wall of the equipment to rub the shaft clean. Install of a mechanical seal in very harsh environments.

v. install a grease barrier chamber sandwiched between two seals. This barrier is separate to the bearing housing and acts as the primary seal for the bearing. Grease pumped into the chamber will flush out past the seals.

vi. replace the grease barrier chamber instead with an air pressurised chamber.

vii. shield the bearing housing from dust with use of a specially fabricated rubber shroud encapsulating the housing and wiping the shaft or fit a rubber screen with a hole wiping the shaft over the opening emitting the dust.

viii. flush the bearing with grease by pumping excess grease into the housing and allowing the grease to be forced past the shaft seals or through a purposely drilled 15mm hole in the housing. The hole must be on the opposite side of the bearing to the grease nipple, at the bottom of the bearing housing when in service and between the bearing and seal.

ix. Mechanical seals can be fitted to the shaft with the stationary seal sitting toward the machine and the rotating seal mounted back along the shaft. Combinations of other seals and wipers can also be used in conjunction with the mechanical seal. Mount the auxiliary seals so they see the dust/water first and keep the mechanical seal as the last line of protection.

Some conceptual examples are shown in Figure No. 2.

Vibration and out-of-balance equipment

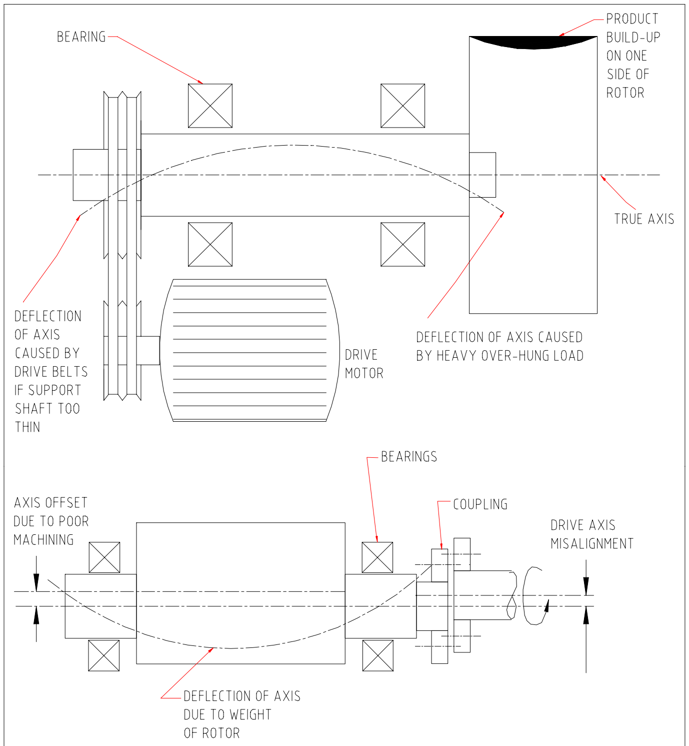
ABSTRACT
When spinning equipment is out of balance. Vibration from out-of -balance rotating equipment can be frightening. The ground shakes, machines jump about, hold down bolts come loose and parts break. An unbalanced rotating body will produce forces on its bearings and transmit them throughout its structure and into the foundations. Keywords: rotor, centrifugal forces, balance quality.

CAUSES OF OUT-OF-BALANCE

The table below lists some common causes for unbalance.

a)	Bent or bowed between support bearings
b)	Overhung weight bends shaft under gravity
c)	Unevenly distributed solid or liquid inside rotor
d)	Loose parts on the rotor
e)	Eccentrically manufactured diameters on the rotor
f)	Misalignment of the drive train to the rotor axis
g)	Loose drive couplings flop about
h)	Loose tolerances between assembled parts on rotor
i)	Shoulders on rotor manufactured out-of-square to axis
j)	Voids or cavities within the rotor
k)	Misalignment of bearings force shaft to bow

The drawings below provide examples of some of the problems listed in the table above.



TYPICAL OUT-OF-BALANCE CAUSES

REDUCING OUT-OF-BALANCE PROBLEMS

Minimising vibration involves minimising out-of-balance forces. The following table indicates simple actions to take to reduce the problems of out-of-balance.

i)	Make the rotor with all diameters on the same axis
ii)	Machine the rotor from one piece of material
iii)	Machine the rotor complete without altering the initial machining set-up
iv)	Finish machine multiple part rotors when fully assembled on the shaft
v)	Reduce lengths of unsupported sections and overhangs
vi)	Keep tolerances tight on parts assembled on the rotor

Vibration and its control

ABSTRACT
Vibration and its control. Vibration in equipment is the result of unbalanced forces. Out-of-balance is corrected by adding or removing material so that when the equipment is operating the unbalance is controlled to an acceptable level. Keywords: spring stiffness, damping, center of rotation, center of mass, natural frequency, isolation mount, counter balance, out-of-phase.

The transference of unbalanced forces through equipment into neighbouring structures causing them to shake is vibration. The motion of a body is limited by what connects it to a machine and the walls in which it moves. Every time there is a change of direction unbalanced forces produce a shock. This shock travels throughout the machine and is transmitted to all connected items.

Mostly a spring is used to isolate vibration movement or a damper is used to absorb the movement. A full explanation of vibration control requires calculus and is beyond the scope of this article. The spring-mass-damper system of Figure No. 1 below is a simplified representation of a vibration control system.

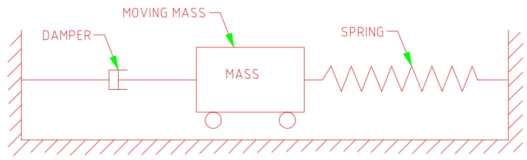


Figure No. 1 A spring-mass damper system.

Spring force and damper pressure control the mass' movement. The damper piston moves and so absorbs the vibration. Where as the spring flexes and isolates the movement from its attachment.

The rate of vibration is called the frequency. It is measured in cycles per second and has the units Hertz. A four-pole electric motor rotates at about 1500 RPM. This is 25 cycles per second or 25 Hertz. Vibration caused by an external applied force is known as a forced vibration because the mass oscillates at the frequency of the external force. An example is the shake produced by the moving pistons and crankshaft in a car engine.

The equation for the natural frequency of an undamped spring-mass system moving in one direction is

$$f_n = ½ \pi \sqrt{(K/M)}$$

Where K is the spring stiffness and M the mass.

This equation lets us find the resonance frequency for a mass–spring system. Such a system can be represented in the drawing above by removing the damper.

Wild gyrations develop when the forced frequency nears the system natural frequency. Every system has a natural frequency and will shake to destruction if it is forced to move at that rate. This phenomenon is known as resonance. An example would be the shattered wineglass caused by an opera singer's voice or vibrations in long, thin shafts that start and then stop as the shaft speed goes through its natural frequency speed.

The four methods of vibration control are listed below.

Reduce or eliminate the exciting force by balance or removal.
Use sufficient damping to limit amplitude.
Isolate the vibration source from the surrounds by using spring mounts of appropriate stiffness.
Introduce a counterbalancing force opposite in phase to the exciting force.

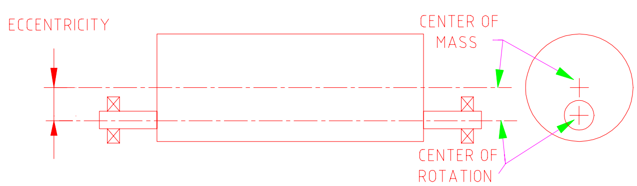


Figure No. 2 Eccentricity between center of mass and center of rotation.

Most importantly every moving mass must be balanced about its center of rotation. The topic of rotary machine balancing was introduced in FEED FORWARD UP-TIME articles 141 "Vibration ands out of balance equipment". The article indicated that rotating masses must be balanced to an acceptable standard. Out–of-balance rotors cause vibration because the center of mass of

IMPORTANCE OF FIT, TOLERANCE AND CLEARANCE

ABSTRACT
Importance of fit, tolerance and clearance. Many equipment breakdowns and stoppages occur because of improper sizing between holes and shafts. The shaft is too tight in the hole; the hole is off-center; one part is loose on another and slips out of place or does not seal as it should. Keywords: size range, engineering drawings, dimensions.

CLEARANCE
Equipment is designed so that parts have either a gap between them so they can move separately to each other or they are firmly in contact and do not move relative to each other. The gap or lack of it, between the hole and shaft is called the clearance. Clearance is determined by the size difference between the parts. Fits and tolerances are used to specify the size range of parts.

FIT
The types of fits have been given names. They range from an interference fit, where the parts are purposely made to be forced together. This fit can be further described as heavy through to light interference. Whereas a clearance fit is for parts made to have a space between them. This fit can be further described as tight through to loose. Between these two fits is the transition fit where interference may or may not occur. The amount of interference or clearance is achieved by specifying the tolerance range for the parts possible sizes.

TOLERANCE
Because of gradual cutting tool wear and minute changes in the machine tool internals due to temperature changes and wear/movement of internal parts, machined items can not all be made perfectly to the same dimension. It is permitted to make the part to within a range of sizes. That range is called the tolerance on the dimension.

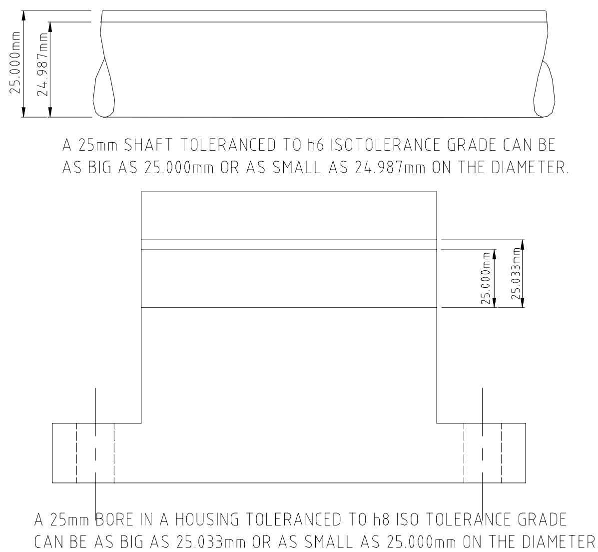


Figure 1. A dimensioned and toleranced shaft and hole.

Figure 1 shows a dimensioned shaft and a dimensioned hole in a block with tolerances to provide a transition fit when assembled. At the largest sized shaft and the smallest sized hole they would contact. This tolerance is too tight for a shaft that had to move through the hole but might be suitable for the outer race of a bearing fitted in a bearing housing of a rotating shaft. In such a case the bearing race must not move on the shaft (spin) as it will wear the shaft, so an interference fit might be suitable. If the load on the bearing was large, or there was a lot of vibration or the shaft was spinning very fast it would be better to make it a light interference fit. If the shaft were large and rotating at low speed and repairs had to be done by the tradesman while in-the-field without access to bearing removal and installation equipment, it might be better if it was a tight clearance fit.

Selection of tolerances for a part is made after considering -
- the speed at which the part moves
- the applied loads and forces it must withstand
- the amount of vibration permitted
- whether grease or oil lubrication is used
- ease of assembly
- changes in size due to thermal expansion.

Engineering drawings follow a recognised standard for displaying the dimensions and tolerances required for a machined part. The Figure 2 shows two acceptable ways to dimension and tolerance a part.

B r o n z e – U s e t h e r i g h t o n e i n t h e r i g h t p l a c e .

By Richard Lang of Abonnel Precision Engineering (Web www.makers.com.au)

ABSTRACT
Bronze – use the right one for the right job. This quarter we will talk a little about bronzes, their properties and applications. Occasionally people refer to a brass bush when in fact they want a bronze bush and could we write something on this. Keywords: plain bearing, brass, gun metal, phosphor bronze, aluminium bronze, copper alloy, cast, wrought, machining properties.

Lets also look at the range of materials one may come across:

Leaded Gun Metal (LG2)	**Phosphor Bronze (PB1)**
Aluminium Bronze	**Manganese bronze**
High tensile brass	**Brass**

The factors that will effect performance in your application of any plain bearing material will be:

- compatibility or the anti-weld and anti-scoring characteristics. A good bearing material will have a low propensity for the microscopic high spots to weld to the shaft material.
- conformability is the ability to compensate for misalignment and manufacturing imperfections. A soft relatively pliable material (low modulus of elasticity) is good.
- embeddability or the ability to absorb dirt and metal particles without scoring and wear. In metals this is the same as conformability but not so in plastics.
- fatigue resistance is of note when the load changes direction- look for cracks at right angles to the surface, flaking surface. A soft material over say steel can be used to counter this.
- corrosion resistance is important in salt water, acids and oxidised oils.
- load capacity is a function of tensile strength and hardness. Higher hardness and strength give greater load carrying capacity but give poorer anti-scoring, conformability and embeddability properties. Where high loads dictate hard bearings, make sure that; the shaft is harder; both have high finish; free of dirt e.g. oil filtration; constant oil film (oil pump interlocked at start up); high standards of alignment (bearing location design and checking procedures). Where there are high loads the bearing material may need to be backed with say steel, which can prevent deflection within the allowable misalignment limits for the bearing.
- high thermal conductivity is required to remove heat and the expansion characteristics should match the shaft and surrounding components.

Lets now focus on a range of brasses and bronzes which are available in Australia. The first thing to realise is that there are wrought standards AS2738.2 and cast standards AS2738.3. Wrought products are factory produced by rolling and mechanical working, while bearing bronze castings are usually by one of the following techniques:

. sand cast . centrifugal . continuous cast

In the case of bronze the continuous cast material has all of the advantages of the wrought products in other materials i.e. uniformity, greater density, better mechanical properties and economy of mass production in limited complexity of shapes such as round and hollow bar.

There are numerous copper alloys but there are four groups:

. copper-lead (20-40% lead)
. leaded bronze (4-25% lead, 4-10% tin)
. tin bronze (8-20% tin)
. aluminium bronze

Brasses have a high zinc component while in the bronze range zinc is low and tin is the major addition to the copper. Copper- lead and leaded bronze have the best bearing properties such as compatibility, conformability and embeddability. The addition of tin, aluminium and iron increase the mechanical properties. Manganese increases strength and corrosion resistance while silicon increases strength, hardness and machinability. Zinc and lead improve machinability. For an acid resistant zinc-free bronze the zinc needs to be less than 0.05% and phosphorous up to 0.15% as in AS 2738.3 C90250 or C90710 is also close.

Applications

Copper- lead alloys

They are the simplest metallurgical and act like white metal. Hardness is similar to white metal at room temperature but the copper- lead alloys are harder when the operating temperature is around 150^{0}C. They are used in a sandwich construction with steel backing and white metal lining. The lead does not dissolve fully in the copper and can act as a smearing lubricant. Used in combustion engines for main and connecting rod bearings and for moderate loads and speeds in electric motors, and turbines. Good fatigue strength and high load capacity.

Electric Motor Current Protection Saves Your Plant.

ABSTRACT
Electric motor current protection saves your plant. A lot of equipment failure results from just simple, plain mistakes, sometimes from unintentional forgetfulness, sometimes from 'short-cut' taking and sometimes because of ignorance of the consequences. The result is plant destroyed at great cost and inconvenience. But for plant being driven by an electric motor use of under and over current protection is something that can be done very cheaply to protect it from being run outside of its design 'envelope'. A current transformer is placed around the electrical cables leading to the motor. The transformer is connected to a monitoring device that alarms when the current is outside preset limits. Keywords: motor load, overload, motor characteristic.

ELECTRIC MOTOR CURRENT DRAW

The power required to operate a 3-phase induction electric motor depends on the torque load on the motor. Low load means a low power draw and causes a low current draw, high load leads to a high power draw and a high current draw. Low load means the motor is turning near full speed and doing little work while drawing little power, high load means the motor is turning at lesser speed and working hard while causing a greater power draw. Overload means the motor has too much load and cannot turn at all. Figure No. 1 shows a 3-phase induction motor performance characteristics.

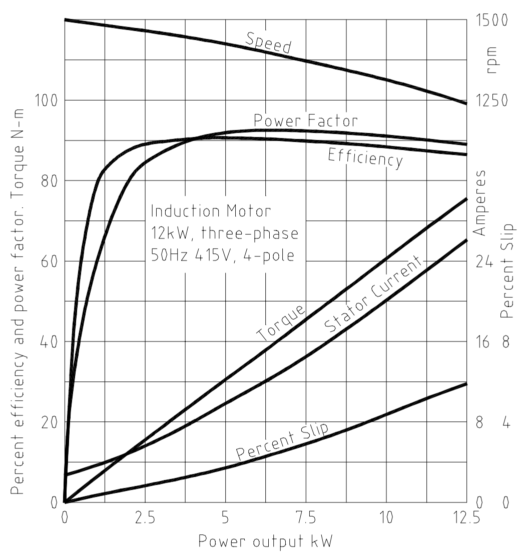


Figure No 1. Electric motor characteristics

The stator current draw characteristic is a good variable to monitor and use for a decision to stop the motor before it gets damaged. Anything attached to the motor will also stop. In this fashion the equipment is protected from any condition that produces a low power draw or any condition that causes a high power draw.

DETECTING CHANGING ELECTRIC CURRENT

When an electric current flows through a wire it produces a magnetic field around the wire. The greater the current, the stronger the magnetic field. The magnetic field will induce electrical fields and cause current to flow in neighbouring wires. This phenomenon causes problems for process logic computer (PLC) equipment and field equipment communications because the electrical fields can interrupt signals sent between equipment and computer. In this case communication cabling is specially shielded away from power cabling. However the phenomenon is useful as a means of monitoring electric power draw.

By installing a current transformer onto a power cable the transformer develops its own current which is proportional to the current in the cable being monitored. Using a current transformer means there no wires to cut, the transformer is low cost, readily available and installation is quick. When coupled with a metering relay and a timer it is possible to turn off the power to a motor when the current goes outside set limits for a given period of time. If the limits are set to the current draw at maximum and minimum working situations and the motor is turned off when the limits are passed then the motor is protected from abnormal load conditions.

The use of a current transformer is but one way to detect the presence of an electrical current. Other methods are also available to detect electrical current and involve installing the monitoring device into the electrical circuit.

UNDER-CURRENT SITUATIONS

When a motor is freewheeling, or it is very lightly loaded, the current required to just turn the motor is only a small portion of the full load current. If such a situation develops when a motor in operation it is probably because something abnormal has occurred.

The Big Bang – starting and stopping equipment under load.

ABSTRACT
The Big Bang – starting and stopping equipment under load. When a machine starts-up its parts move from zero speed to operating speed in a short time (the reverse when stopping). During this short period the biggest forces that the machine experiences act on its components. If during the start-up or slow-down the product or process loads are added to the machines own self-loads the forces acting on the machine's parts are horribly magnified. If these impulse forces exceed the machine's design allowance, or cause gradual fatigue, then the stressed parts will shatter without warning.
Key words: inertia, kinetic energy, momentum, torque

What is Inertia?
In engineering terms inertia is the tendency for a body with mass to want to remain in its current state of motion (Newton's first law of motion). Try pushing the kitchen table across the floor. To start it moving requires more force than to keep it moving. Part of the initial force was to overcome its inertia (the other part was to overcome starting friction, which is higher than moving friction).

If instead the kitchen table were piled high with a wedding feast it would require a greater force to start it moving. The additional load would add a greater inertia component. A sufficiently heavy load forced to jerk forward quickly could stress the table legs at start-up to a point they snapped off. Now that would really ruin the wedding feast!

Another example of the effect of inertia is the pressure you feel on your back when you are pushed into the seat as a car, bus or train accelerates from stop. All moving machines behave the same as your kitchen table or the bus and train. Due to inertia, more force is required to get it up to speed than when it is at operating speed.

The size of the inertia force depends on :

- The weight of the object.
- The acceleration of the object.
- And for rotating parts - the position of the object's mass in relation to the position of its center of rotation.

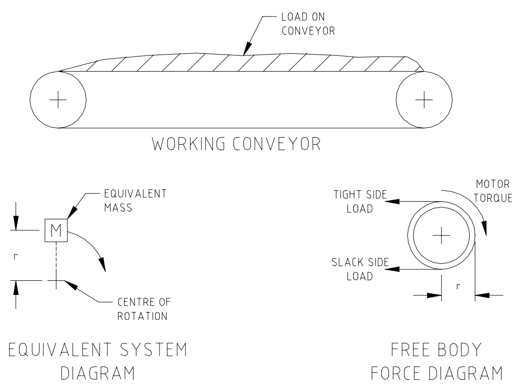


Figure No. 1 Conveyor Inertia

Figure No. 1 shows a loaded conveyor at the top and below it the head pulley free-body force diagram. The free body diagram is a representation of the forces acting on the pulley at a point in time. Its use simplifies the engineering analysis.

The load, the pulley drum and the belt mass act at the edge of the head pulley. Suddenly starting the conveyor fully loaded will place a surge inertia load on the head pulley drive and parts. If you see gearboxes rocking at start-up or when stopping, then they are experiencing inertia forces.

The Effect on Starting and Stopping Torque
To bring a machine up to full speed from rest requires a force to be applied (Newton's second law of motion). For rotating machinery the force is applied as a torque. Torque is a linear force acting at a certain distance from the center of rotation. The free-body diagram in Figure No. 1 shows the inertia force acting at the head pulley drum. The motor that drives the conveyor will need to generate slightly more matching torque if the conveyor is to move.

The size of the torque depends on the acceleration, the mass being moved and the location of the mass from the center of rotation. The greater the mass and the further from its rotational center it lies, the greater the required torque to start it moving. As the need for more torque rises there is a proportional increase in the required power to deliver the torque.

The formula for the power of a rotating mass is:

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