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THE PROCESS CONTROLLER's GUIDE TO

MECHANICAL TRANSMISSION OF POWER

This is number 7 in the Process Controller Guide series of documents

Number 1	Pollution Control.
Number 2	Water Sources and Water Treatment**.**
Number 3	Wastewater Treatment
Number 4	Phosphorus Removal from Wastewater.
Number 5	Electricity and Electric Motors.
Number 6	Pumps, Blowers and their Operation.
Number 7	**Mechanical Transmission of Power**

This guide is NOT intended to be a comprehensive manual on the mechanical transmission of power. Nor is it intended as a definitive guide of what type of equipment to be chosen for use on a water or wastewater treatment works.

This guide is intended to give Process Controllers an overview of the different types of couplings, bearing and gearboxes that are found on a water or wastewater treatment works and to give them a better understanding of these items of equipment.

It is intended that this document be a useful reference and training manual guide to all persons involved in the Water and Wastewater Industry.

These documents are dedicated to the thousands of men and women (both present and past) who are involved in the life critical profession of Water and Wastewater Treatment.

NOTE:

Credits: some information was obtained via Google. Where original authors/owners could be determined, this is indicated.

THE PROCESS CONTROLLER's GUIDE TO

THE MECHANICAL TRANSMISSION OF POWER

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THE MECHANICAL TRANSMISSION OF POWER.

PART 1.

BACKGROUND.

1.1 INTRODUCTION.

The Process Controller's Guide no. 5 (Electricity and Electric Motors) covered what electricity is, how it is distributed to the point of use and how electric motors worked.

The Process Controller's guide no. 6 (Pumps, Blowers and their Operation) covered how pumps and blowers converted the input power into useful work.

This Process Controller's Guide covers the equipment that fits in between the electric motor and the pumps or blowers and other items of equipment associated with the mechanical transmission of this power.

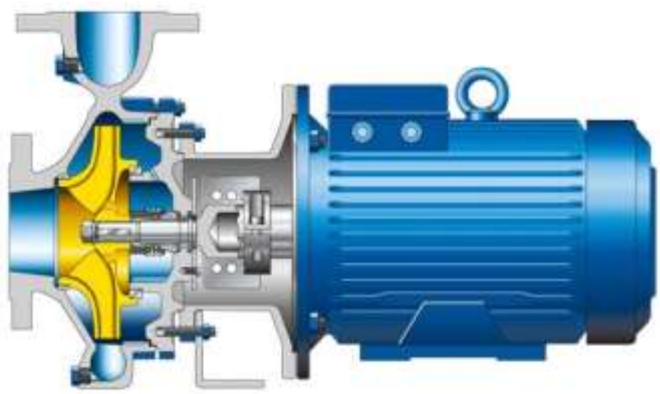
1.2 DRIVING and DRIVEN EQUIPMENT.

The electric motor will produce its power in the form of a rotating shaft to transmit the torque and the power produced by the motor. This will be referred to as the "driving unit".

The equipment receiving the torque and the power may continue to use this rotating motion or may convert it into a reciprocating motion for certain uses. This will be referred to as the "driven unit".

1.3 CLOSE COUPLED MOTORS AND PUMPS OR BLOWERS.

Close-coupled pumps use a single shaft that extends from the motor to the pump body through an opening in the cover plate. Usually the pump impeller is mounted directly to the electric motor shaft. The advantage of close-coupled pumps and blowers is that they do not require couplings. This makes them cheaper than the frame mounted counterparts. They are smaller in size and do not need alignment. An example of a close coupled pump is shown in figure 1 below:



KSB pumps

Figure 1 – AN EXAMPLE OF A CLOSE-COUPLED PUMP.

It may be seen that there are no bearing in the pump, therefore the motor bearings must be capable of handling the radial and axial loads of the unit. The subject of radial and axial loads will be covered in part 5 that covers bearings. This type of layout is usually limited to about 5kW of motor power.

1.4 FRAME MOUNTED MOTORS, PUMPS AND BLOWERS.

By far the largest number of driving units and driven units are mounted next each other on a common baseplate. Here the driving unit shaft and the driven unit shaft are connected by a flexible coupling. Both units will have bearings to support the rotating shaft.

An example of a typical layout is shown in figure 2 below:

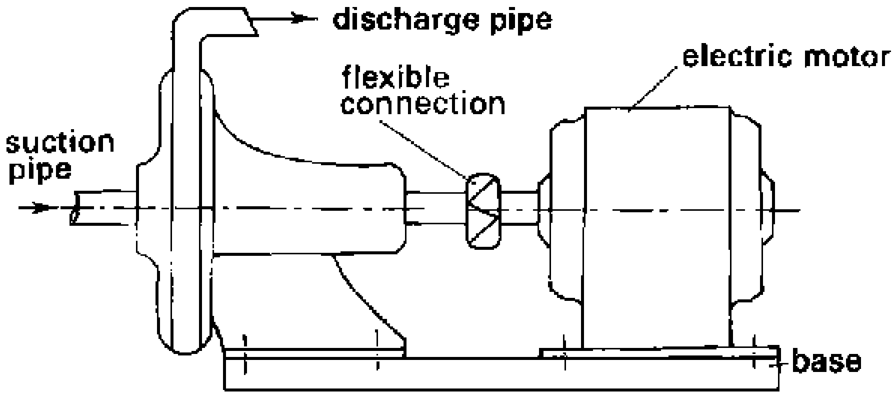


Figure 2 – AN EXAMPLE OF A TYPICAL MOTOR – PUMP LAYOUT.

1.5 VARIOUS METHODS FOR THE MECHANICAL TRANSMISSION OF POWER.

There are three main methods for the mechanical transmission of power from the electric motor to pumps, blowers etc.

1. via a rotating shaft as shown in figure 2 above;
2. via a belt or chain drive;
3. via hydraulic power.

It may be seen in figure 2 above, that a shaft coupling is required to transmit the power from the motor output shaft to the pump input shaft. The subject of couplings will be covered in part 2.

Part 3 will cover the various types of belt drive.

Part 4 will cover the use of hydraulic power.

Part 5 will cover gearboxes as these are required whenever it is necessary to change the speed of rotation of the pump or blower – either slower or faster than the electric motor speed.

Part 6 will cover bearings and bushes. These are required to support the rotating shaft within the fixed part of the pump, blower etc.

THE MECHANICAL TRANSMISSION OF POWER

PART 2.

SHAFT COUPLINGS.

2.1 INTRODUCTION.

As seen earlier, shaft couplings are required to “connect” the driving unit output shaft to the driven unit input shaft in order to transmit the power of the electric motor to the item being driven.

Besides being able to transmit the required power and torque, the shaft coupling must be flexible enough to handle small amounts of misalignment between the two shafts. This is necessary to prevent unnecessary wear of the bearings on both the driving unit and the driven unit. The shaft coupling will reduce vibration between the two units.

2.2 TYPES OF MISALIGNMENT.

1. axial misalignment;
2. radial misalignment – also called off-set misalignment, or parallel misalignment;
3. angular misalignment.

It is possible to have any 2 types (and even all 3 types at the same time).

These three types are shown in figure 3 below. In the figure below, each shaft is fitted with a flange to make it easier to explain the types of misalignment:

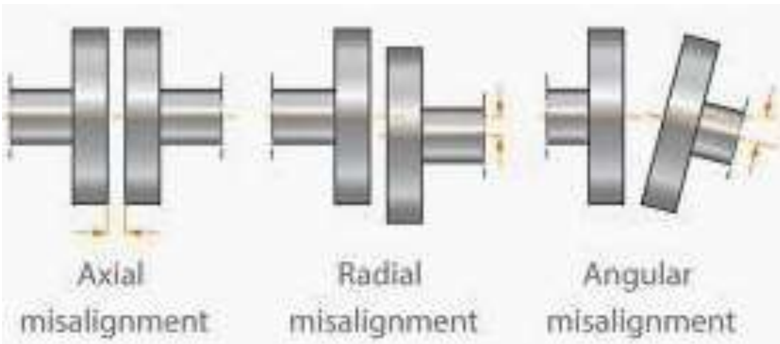


Figure 3 – SHOWING THE THREE TYPES OF MISALIGNMENT.

2.2.1 Axial Misalignment.

As metal heats up, it expands; it therefore necessary that there be some clearance between the 2 parts of the coupling. This is to prevent one shaft pushing against the other shaft and putting extra load onto the bearings of both the driving unit and the driven unit. There will also be some axial movement of each shaft due to the clearance in the bearings. This is known as “float”. This is shown in figure 4 below:

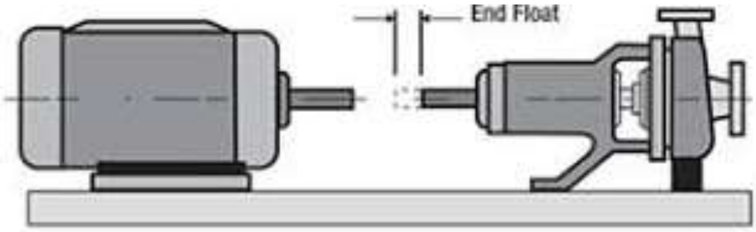


Figure 4 – SHOWING END FLOAT.

The amount of clearance required depends on the type of shaft coupling used.

2.2.2 Radial or Off-Set or Parallel Misalignment.

This can be in the horizontal plane or the vertical plane or both. This will put excessive load on the bearings of both the driving and the driven unit. The amount of misalignment that can be tolerated depends on the type of shaft coupling.

2.2.3 Angular Misalignment.

This will also put excessive load on the bearings of both the driving and the driven unit. Again the amount of misalignment that can be tolerated depends on the type of shaft coupling.

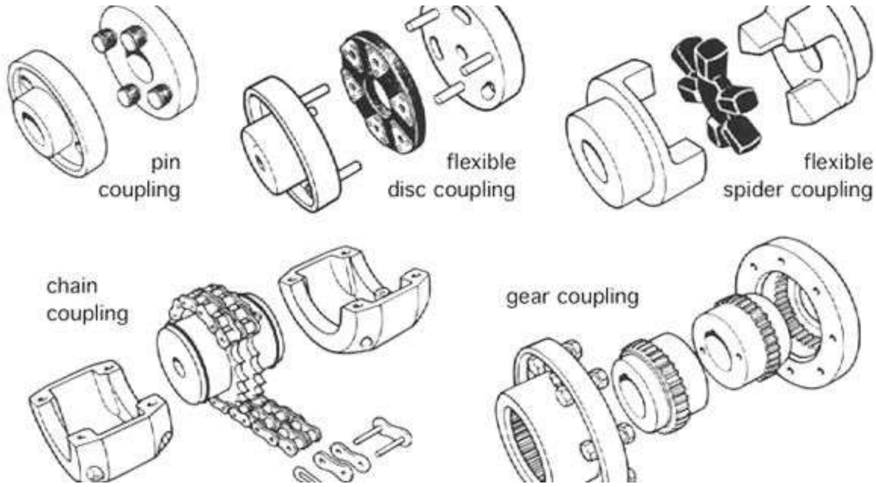
2.2.4 Correction of Misalignment.

This function will be carried out by the maintenance unit as special tools are required to do the work.

2.3 TYPES OF SHAFT COUPLINGS.

There are many types of shaft couplings. Each has their own advantages and disadvantages. The choice of which one to use will be the responsibility of the design team. This section is intended to give the Process Controller an idea of what the various couplings look like.

In terms of the safety requirements, each coupling must be covered by a suitable shield so that contact with the shaft coupling by hand is not possible. There will be no maintenance jobs that the Process Controller will be required to do. Examples of various types of couplings are shown in figure 5 below:



pinterest

Figure 5 – SHOWING VARIOUS TYPES OF SHAFT COUPLINGS.

One common type of shaft coupling not shown above is the rubber tyre coupling as shown in figure 6 below:

egana group.com

Figure 6 – THE RUBBER TYRE SHAFT COUPLING.

2.4 FIXING THE SHAFT COUPLING TO THE SHAFT.

There are two ways of fixing a shaft coupling onto a shaft:

1. shrink-fit;
2. interference fit;
3. using a key and a keyway;
4 using a set screw or grub screw.

Depending on the type of shaft coupling, it may be fitted directly on the shafts, or to a flange that in turn is fitted to the shaft.

2.4.1 Shrink-fit.

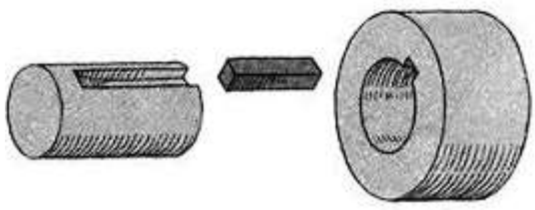
This method uses the advantage that metals expand when heated and contract when cooled. The process would involve either heating the item (shaft coupling or flange) to the fitted to the shaft OR cooling the shaft so that the item slides on easily. In both cases, when both parts return to room temperature then the item grips the shaft very firmly. To remove the item, the process is reversed. It is necessary for the designer to calculate the amount of expansion (or contraction) required to ensure a firm fit.

2.4.2 Interference fit.

This method requires the use of a hydraulic press to press the unit over the shaft. Again the designer must calculate the diameter of the shaft and the diameter of the unit being fitted to ensure that the unit firmly grips the shaft.

2.4.3 Using a Key and a Keyway.

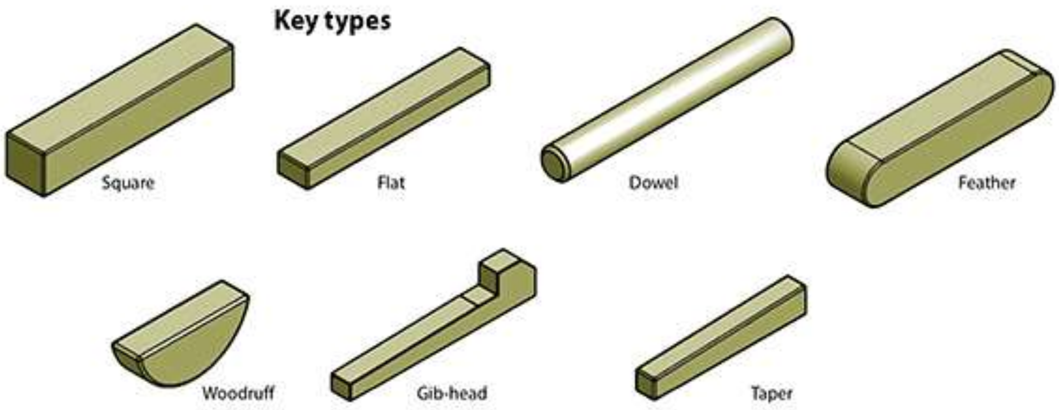
A key is an accurately sized piece of metal that fits into a keyway that is cut into the shaft and the unit being connected to the shaft. This prevents any movement between the shaft transmitting the power and the attached component. An example is given in figure 7 below:



linearmotiontips.com

Figure 7 – SHOWING A KEY AND A KEYWAY.

Keys (and keyways) are made in different shapes. Some examples are given in figure 8 below:

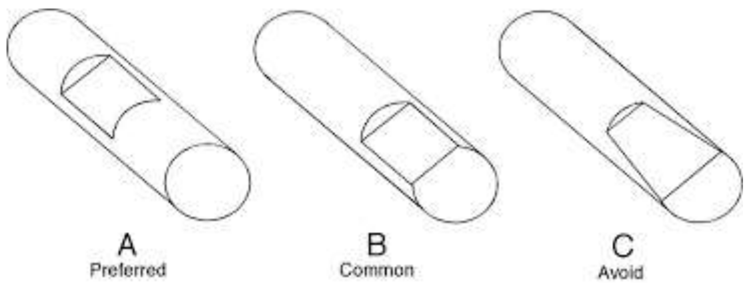


Machinedesign.com

Figure 8 – SHOWING DIFFERENT TYPES OF KEYS.

2.4.4 <u>Using a Set Screw or Grub Screw.</u>

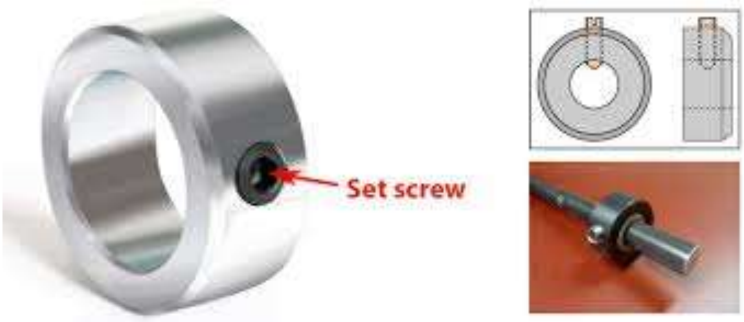
For small power items, a set screw or grub screw may be used. This will usually be a flat spot machined in the shaft into which the set screw (grub screw) is tightened. The shaft would look like the example shown in figure 9 below:



newscrewdriver.com

Figure 9 – SHOWING AN EXAMPLE OF A FLAT SPOT MACHINED ONTI A SHAFT TO TAKE A SET SCREW.

An example of a set screw assembly in shown in figure 10 below:



ltp.nyu.edu

Figure 10 – SHOWING A TYPICAL SET SCREW ASSEMBLY.

In very small units, the flat spot may be omitted and the unit would then rely on friction between the set screw and the shaft to prevent the latter from moving independently of the shaft.

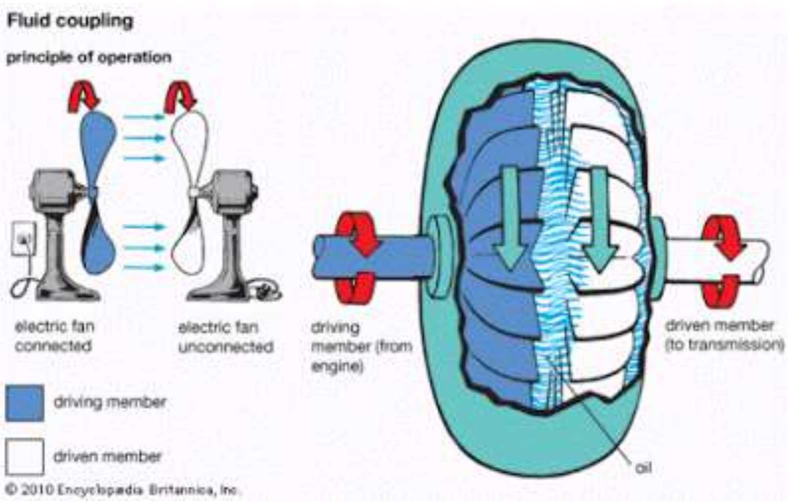
The fixing methods covered above in 2.4 will be used in the items covered in parts 3, 4 and 5.

2.5 FLUID (HYDRAULIC) COUPLINGS.

In the Process Controllers Guide 5 on Electricity and Electric Motors it was shown in figure 38 on page 32 that on starting an electric motor; the current drawn rises quickly to a high value and then fairly quickly drops down again to the normal operating current.

If the electric motor is used to operate a machine with a significant mass such as a centrifuge, then the current will take much longer before it drops. This is because the electric motor must accelerate a much larger mass to its operating rotation speed. One way to reduce the starting current and especially to reduce the time that the electric motor is drawing a high current; is to install a fluid coupling between the electric motor and the centrifuge.

The fluid coupling consists of a pump impeller on the input shaft and a runner or turbine on the output shaft. When the motor starts, the impeller pumps the oil towards the runner. As the speed of the impeller increases so the runner (that is connected to the centrifuge) starts to rotate. Over a period of 30 to 60 seconds, the runner speeds up until it is running at nearly the same speed as the input shaft. There is usually about a 3% loss in speed. This method reduces the period of high starting current on the electric motor. The principle of operation is shown in figure 11 below:



. encyclopaedia brittanica

Figure 11 – SHOWING THE PRINCIPLE OF A FLUID COUPLING.

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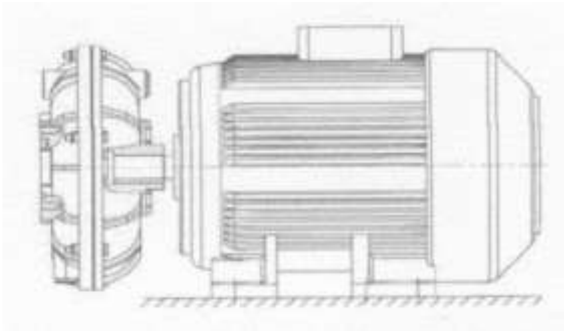
Figure 12 shows a typical fluid coupling fitted to an electric motor.



Morskate

Figure 12 – SHOWING A TYPICAL LAYOUT OF AN ELECTRIC MOTOR WITH A FLUID COUPLING.

2.6 COUPLING GUARDS.

The Driven Machinery Regulations that form part Occupational Health and Safety Act (Act 85 of 1993), prescribes the guarding of certain items of equipment. The following extract from the Regulations apply:

Occupational Health and Safety Act, 1993

Driven Machinery Regulations, 1988

2. Revolving Machinery.

Unless moving or revolving components of machinery are in such a position or of such construction that they are as safe as they would be if they were securely fenced or guarded, the user shall cause –

a. every shaft, pulley, wheel, gear, sprocket, coupling, collar, clutch, friction drum or similar object to be securely fenced or guarded;

b. every set screw, key or bolt on revolving shafts, couplings, collars, friction drums, clutches, wheels, pulleys, gears and the like to be countersunk, enclosed or otherwise guarded;

c. every square projecting shaft or spindle end and every other shaft or spindle end which projects for more than a quarter of its diameter to be guarded by a cap or shroud;

d. every driving belt, rope or chain to be guarded; and

e. the underside of every overhead driving belt, rope or chain above passages or workplaces to be so guarded as to prevent a broken belt, rope or chain from falling and so injuring persons:

Provided that the provisions of this paragraph shall not apply where in the opinion of an inspector, no danger exists in the case of light belts due to the nature thereof and the speed of operation.

Figure 13 shows an example of a suitable coupling guard. The small holes in the upper part are a good idea as they allow for any heat to escape.

Altramotion.co.za

Figure 13 - SHOWING AN EXAMPLE OF A SUITABLE COUPLING GUARD.

THE MECHANICAL TRANSMISSION OF POWER.

PART 3.

BELT AND CHAIN DRIVE SYSTEMS.

3.1 INTRODUCTION.

The shaft couplings covered in part 2 are used where the two shafts are in-line with each other and the one unit is mounted in front of the other.

Belt or chain drives would be used when the two units are mounted next to each other. This difference is shown in figure 14 below:

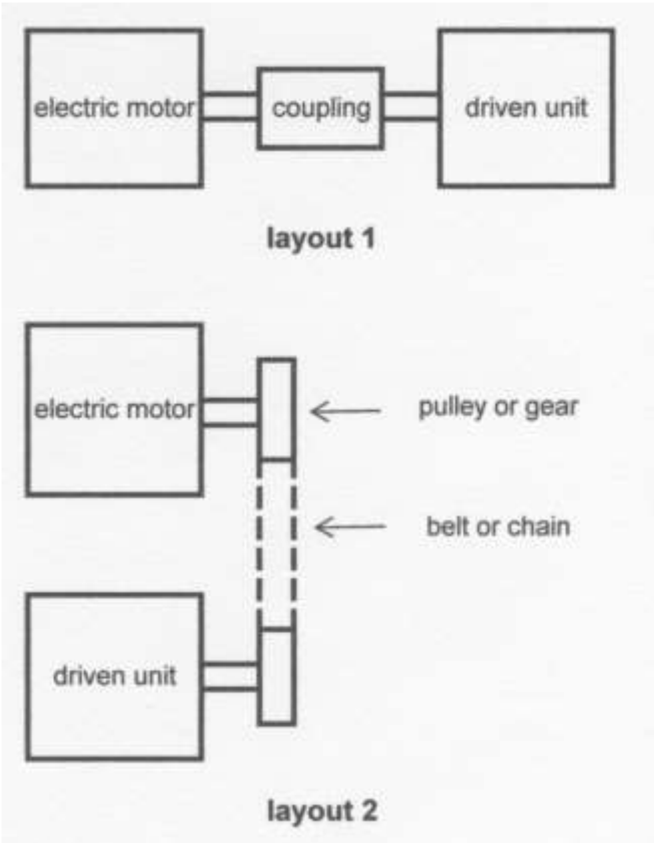


Figure 14 – SHOWING TWO MOTOR / DRIVEN UNIT LAYOUTS.

There are two types of belts:

1. friction drive;

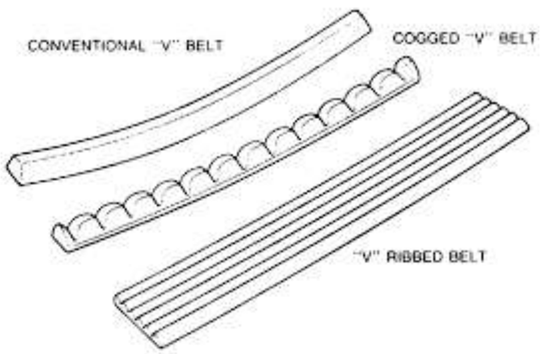
2. positive drive.

3.2 **FRICTION DRIVE BELTS.**

These may in turn be subdivided into:

1. conventional V-belt;
2. cogged V-belt;
3. V ribbed belt;
4 flat belt. This is the original type of friction belt drive and is very rarely used these days.

The first 3 types are shown in figure 15 below:



mazdabg.com

Figure 15– SHOWING DIFFERENT TYPES OF FRICTION DRIVE BELTS.

3.2.1 Conventional V-belt

The conventional V-belt is the most commonly used type. Depending on the power transmission requirement 0ne or more belts may be used. An example of a drive with 3 belts is shown in figure 16 below:

machinedesign.com

Figure 16 – SHOWING THE V-BELTS AND THE GROOVED PULLEY.

V-belts are widely used in industry because of its power transmitting capacity. As the load increases, the wedge shape of the belt grips the edges of the pulley (or sheave) thereby increasing more friction which makes it able to carry the extra power without slipping. This is providing the belt(s) are correctly tensioned.

Figure 17 shows the detail of the V-belt and the grooved pulley.

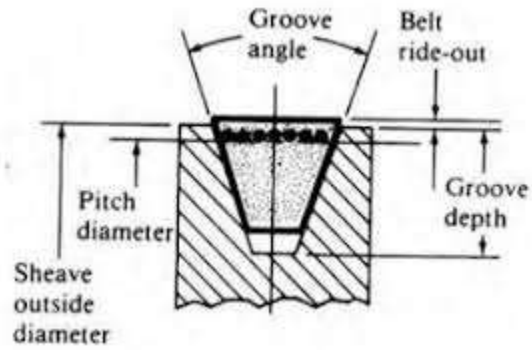
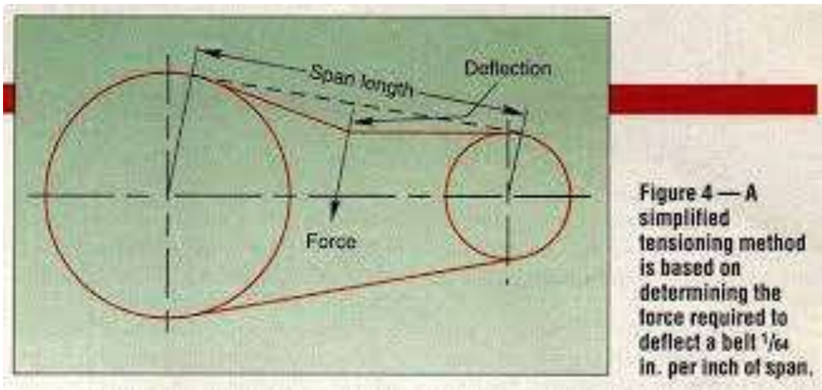


Figure 17 - SHOWING THE DETAIL OF THE V-BELT AND THE GROOVED PULLEY.

Here more than one V-belt is used, it is very important that a “matched set” of belts be used. That is, the belts must be the same length to a high degree of accuracy. For example, Gates® new standard is 8mm difference in length for a belt with a total length of 2.5 metres. This is a tolerance of ± 0.16%. If one belt is longer than the other(s), then it will do less work and the so the other belt(s) will do more work than they were designed to do. This will shorten their life.

It is also important that the v-belts be correctly tensioned. If they are too loose then they will slip and this will generate heat and shorten the life of the belt. If they are too tight then the belt will put unnecessary load of the bearings of both the driving shaft and the driven shaft. The deflection should be 1/64 of an inch per inch of span length – that is 1/64 of the span length. For a span length of 750mm, this would be a deflection of 11.mm. The deflection is shown in figure 18 below:



Gates.com

Figure 18 – SHOWING DEFLECTION OF A V-BELT FOR TENSIONING PURPOSES.

The tension of a new belt should be checked after about 24 hours of operation.

3.2.2 Cogged V-Belt.

The cogged type has certain advantages:

1. it can transmit more power for a certain width of belt;

2 they run a bit cooler and so have a longer life;

3. they are slightly more efficient;

4. slightly smaller pulley may be used as the belt can bend around a sharper curve.

The disadvantage is that they are more expensive.

Both conventional V-belt and cogged V-belt can run on the same type of pulley and require the same tension. For a span length of 750mm, this would be a deflection of 11mm.

3.2.3 V-Ribbed Belt.

The V-ribbed concept employs what is essentially a flat belt with a series of V-shaped ribs running the length of the belt on the driving surface. These thin belts operate efficiently and can run at high speed. The belt ribs bottom completely on the pulley, so there is no wedging action.

To make up for the lack of wedging action, the belts must be tightened to a higher tension. This is usually about 20% higher than a V-belt. For a span length of 750mm, this would be a deflection of 9mm.

An advantage of the V-ribbed belt is being a single unit. This eliminates the need for a matched set of belts.

An example of a typical V-ribbed belt installation is shown in figure 19 below:

Figure 19 – SHOWING A TYPICAL V-RIBBED BELT INSTALLATION.

3.3 POSITIVE DRIVE BELTS.

These are required when a constant speed ratio between the driving pulley and the driven pulley is essential. An example is the cam shaft belt drive on an engine. Here the cam shaft must turn at exactly half the speed of the crankshaft. The positive drive belt acts in a similar fashion to a chain drive in this respect.

These belts have teeth across the belt that mesh with grooves on both the driving pulley and the driven pulley. A close up view is shown in figure 20 below:

sitspa.com

Figure 20 – SHOWING A CLOSEUP VIEW OF POSITIVE DRIVE BELT AND PULLEY.

Alignment of the driving and driven pulleys (sheaves) is very important to prevent damage to belts and to bearings in the driving and driven units. The various types of misalignment are shown in figure 21 below:

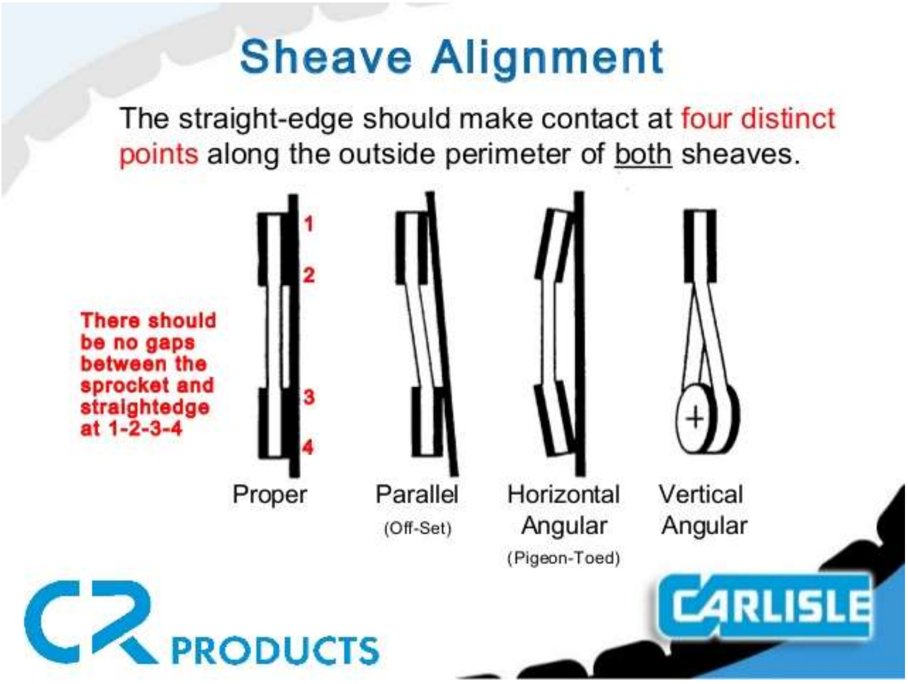


Figure 21 – SHOWING VARIOUS TYPES OF PULLEY MISALIGNMENT.

It may be seen that these forms of misalignment are similar to those covered in the section 2.2 on couplings. Ideally the centre of the pulley on the driving unit should be at the same height as the centre of the pulley on the driven unit, but this is not essential – some difference is permitted.

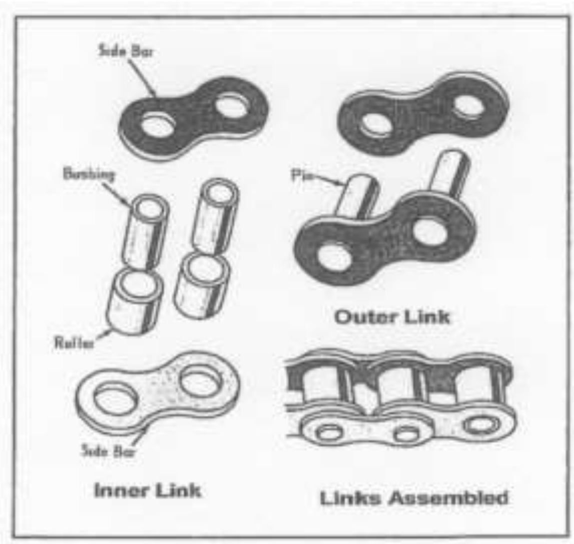
3.4 ROLLER CHAIN DRIVES.

The roller chain drive is similar to the positive drive type belt covered above in 3.3 in that there is no slip between the driving pulley and the driven pulley. A typical roller chain assembly is shown in figure 22 below:

theengineerspost.com

Figure 22 – A TYPICAL CHAIN DRIVE ASSEMBLY.

The roller chain drive consists of a number of links. Each link is made up of a number of components. These are shown in figure 23 below:



techav.co.za

Figure 23 – SHOWING THE COMPONENTS OF A ROLLER CHAIN DRIVE.

Amongst the advantages of a roller chain drive are:

1. there is no slip between the driving shaft and the driven shaft;

2. it has a higher driving efficiency than the friction (belt) drives;

Chain drives may be used outside as they are less affected by the weather. They must still be covered by a suitable guard and must be lubricated frequently.

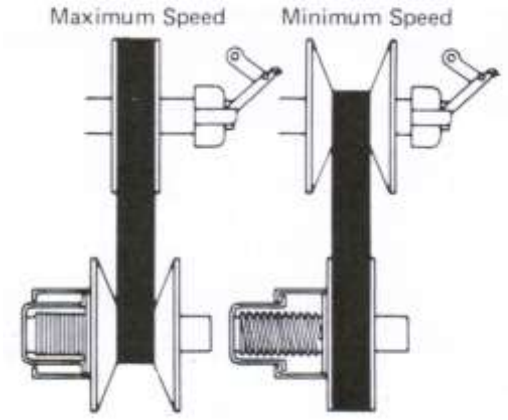
3.5 VARIABLE SPEED BELT DRIVE.

All the various types of belts covered above transmit the power at a constant speed. If a variable speed is required then the electric motor speed may be varied. Later in section 6.8, variable speed gearboxes will be covered.

By using special pulleys, a variable speed drive is possible. This works on the principle that the closer to the centre of the pulley that the belt grips the shorter the distance that a point on the belt moved for each revolution of the pulley. In the same way, the further away from the centre that the belt grips, the longer the distance that a point on the belt moved for each revolution of the pulley.

This change in the position where the belt grips the pulley is made possible by moving the two parts of the pulley closer together or further apart.

The driving pulley at the top is adjusted as required. The driven pulley at the bottom is spring loaded and keeps the tension on the belt. Only special Vee belts can be used in this system. The layout is shown in figure 24 below:



all torque transmissions

Figure 24 – SHOWING THE PRINCIPLE OF A VARIABLE SPEED BELT DRIVE.

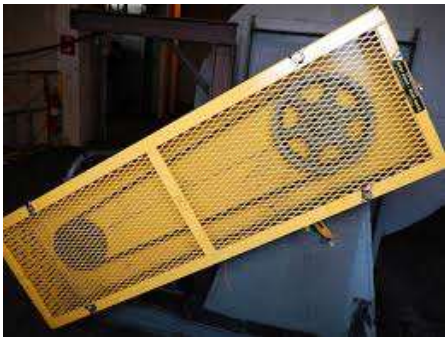
USEFUL OPERATING TIPS

1. ADJUST THE SPEED **ONLY** WHEN THE MOTOR ASSEMBLY IS TURNING TO AVOID DAMAGE TO THE ADJUSTING MECHANISM;

2. DO NOT OPERATE THE UNIT CONTINUOUSLY FOR MORE THAN 24 HOURS WITHOUT MAKING A SLIGHT SPEED ADJUSTMENT TO AVOID EXCESS WEAR AT ONE POINT ON THE PULLEYS

3.6 BELT AND CHAIN GUARDS.

The requirement to have belt guards was covered in section 3.5. The example given below in figure 25 shows a good design. When a belt is nearing the end of its life, it usually starts losing small particles of rubber. With a mesh covering, one will be able to see this more easily and so arrangements may be made in time to replace the belt(s) before they break. Also the mesh covering allows heat to escape. This will lengthen the operational life of the belt(s).



Conveyorguarding.com

Figure 25 –SHOWING A SUITABLE GUARD FOR A BELT DRIVE

THE MECHANICAL TRANSMISSION OF POWER.

PART 4.

USING HYDRAULIC POWER.

4.1 INTRODUCTION.

The hydraulic transmission of power uses a liquid to transfer the linear or rotary motion and linear or turning force (torque). There are two main types of hydraulic power transmission:

1. hydrokinetic;

2. hydrostatic.

4.2 HYDROKINETIC POWER TRANSMISSION.

The Fluid Coupling covered in section 2.5 is a good example of the use of hydrokinetic power transmission. As was seen, this method accelerates the driven unit to its operational speed over a longer period than a direct coupling. This is advantageous for both the driving unit and the driven unit. This system also does not transmit vibration from the input shaft to the output shaft.

The working principle where the hydraulic pump and the hydraulic motor are away from each other is shown in figure 26 below. The hydraulic pump may be rotary or piston type. The hydraulic motor may be gear, piston or vane type. The output would be a rotating shaft.

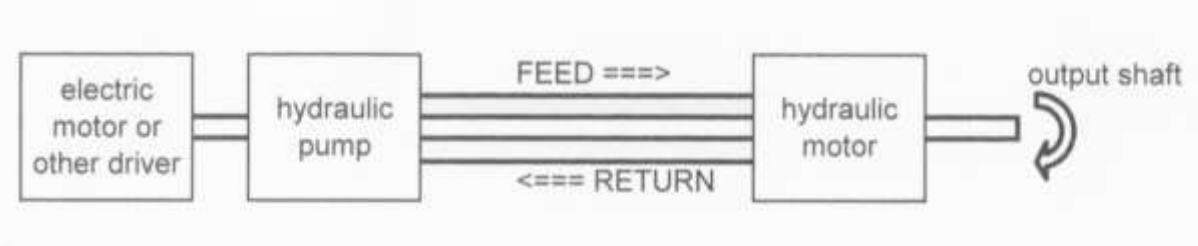


Figure 26 – EXAMPLE OF A HYDRAULIC PUMP DRIVING A REMOTE HYDRAULIC MOTOR.

Among the advantages of this system are:

1. the hydraulic motor could be designed to run either faster or slower than the electric motor;

2. the system may be made variable speed;

3. the hydraulic motor could be located in an explosive atmosphere for example close to an anaerobic digester while the electric motor is located in a safe place.

A disadvantage would be a slight loss in energy efficiency.

4.2 HYDROSTATIC POWER TRANSMISSION.

This system would also use a hydraulic pump. The pressurized oil would be used to drive a piston in a linear (straight line) motion. The basic system is shown in figure 27 below:

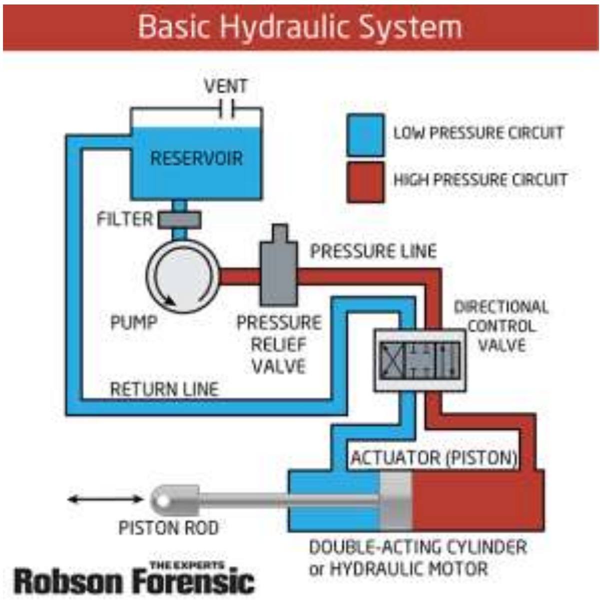


Figure 27 – EXAMPLE OF A BASIC HYDROSTATIC SYSTEM.

The linear action of the piston road may be used for a number of purposes. Examples are:

1. adjusting the tension of belts in a belt press and ensuring correct tracking of the belts;
2. operating certain types of screens;
3. operating certain types of valves;
4. operating the bucket of a front end loader.

THE MECHANICAL TRANSMISSION OF POWER

PART 5.

BEARINGS.

5.1 INTRODUCTION.

All the items of equipment covered in Process Controller's Guide no. 5 (Electricity and Electric Motors) and 6 (Pumps and Blowers) have shafts that are rotating. These shafts need to be held in place in such a manner that there is limited movement (except rotation) and minimal friction between the moving parts and the fixed body of the motor, pump or blower. As seen with the transmission of electricity and the movement of water in a pipe, there is friction to the movement of electricity or water. This friction causes energy loss and is usually in the form of heat.

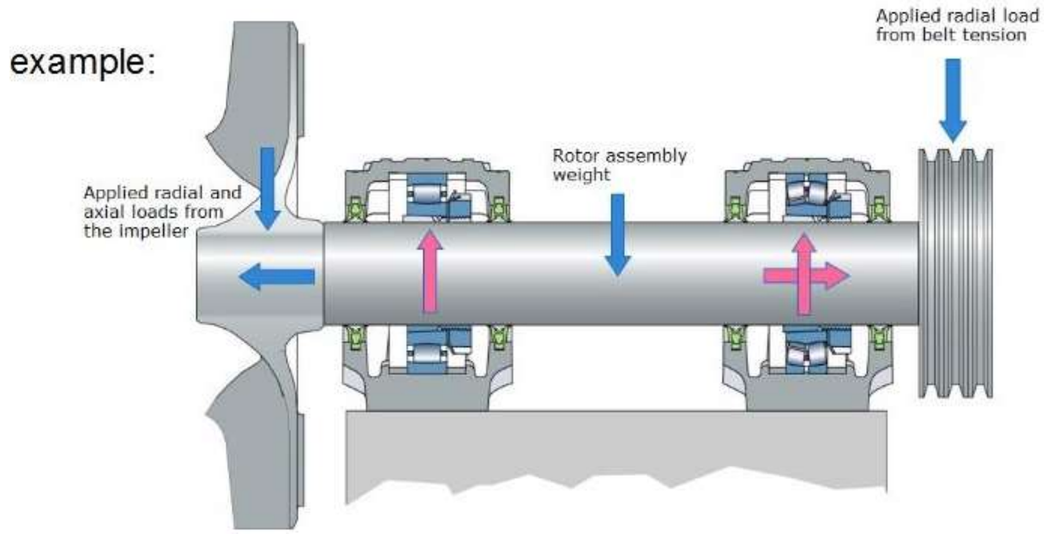
The friction between the moving part and the fixed part will generate heat and this will cause damage to both parts and can lead to the two parts seizing up due to expansion. It is the job of the bearings to support the shaft and to minimize the friction between the moving part and the fixed part.

There are two types of loading on a bearing:

1. radial loading;

2. axial loading.

These are shown in figure 28 below:



bearingtips.com

Figure 28 – SHOWING RADIAL AND AXIAL LOAD ON A ROTATING SHAFT.

In this case the bearing at the pulley end is absorbing the axial load from the impeller.

Usually there will be both radial and axial load on the bearing. How much axial loading depends what work the rotating shaft is doing. The axial load may be in one direction only. In most instances, there are both radial and axial loads on a bearing. The axial loading may be very small or it could be a major factor. The type of bearing chosen will depend on these factors.

5.2 RADIAL LOADING ON BEARINGS.

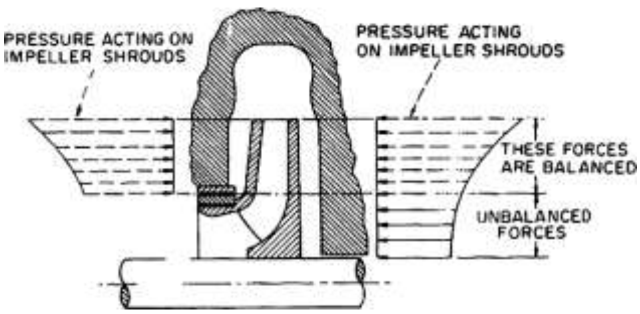
This acts at right angles to the axis of rotation of the shaft. The radial loading will include the weight of the shaft (when mounted horizontally) and additional radial loading such as that from a belt drive as shown in figure 26.

The ability of the bearing of absorb radial loading depends on the construction of the bearing. This will be covered later when some of the common types of bearings are discussed.

5.3 AXIAL LOADING ON BEARINGS.

This acts along the axis of the shaft. There will be either a “pulling” effect or a “pushing” effect depending what is causing the axial load.

In a single stage centrifugal pump the pressure on the suction side of the impeller is lower than the pressure on the back (input shaft) side of the impeller. This is why the liquid being pumped is drawn into the pump. This also results in the net thrust being towards the impeller. The forces on the impeller are shown in figure 29 below. The unbalanced force is the axial thrust on the pump shaft.



Sciencedirect.com

Figure 29 – SHOWING THE FORCES ACTING ON A CENTRIFUGAL PUMP IMPELLER.

A similar set of forces would act on a centrifugal air blower. In the case of the two stage centrifugal water pump or a two stage air blower, the two stages can be mounted back to back so that the axial load from the second stage helps to reduce the axial load from the first stage.

A very high axial loading will be put onto the top bearing of an Archimedes screw pump. This top bearing must support the weight of the screw plus the weight of the water being conveyed up the screw.

5.4 THE PARTS OF A BEARING.

A bearing has 4 basic working parts:

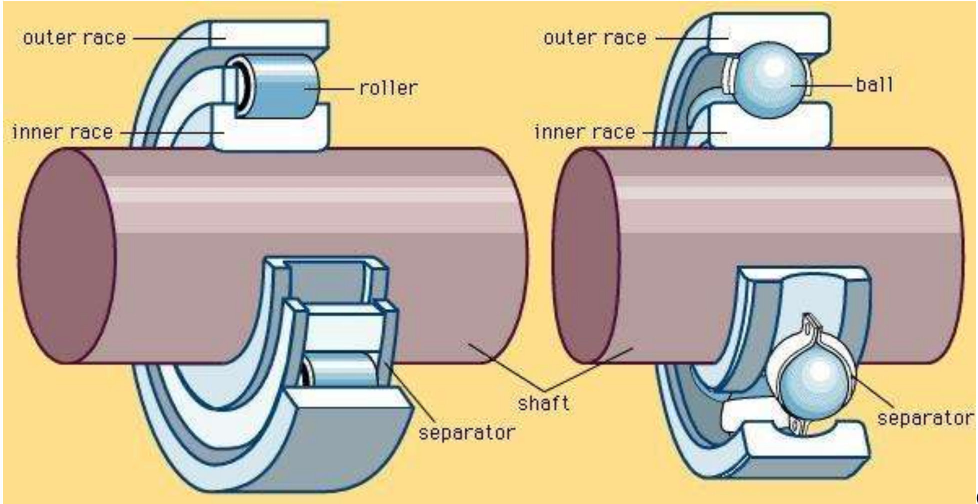
1. the outer race (also called outer ring or cup);

2. the inner race (also inner ring or cone);

3. the rolling elements (either balls or rollers);

4. the separator (also called cage or retainer).

These parts are shown in figure 30 below:



engineering360

Figure 30 – SHOWING THE 4 BASIC PARTS OF A BEARING.

All the different types of bearings covered in this guide will be a variation of these two basic types. There are a number of variations of these two basic types, each has advantages and disadvantages and variation in its ability to handle radial thrust, axial thrust or the combination of the two, called angular thrust.

5.5 THE CONCEPT OF POINT LOAD.

If one has an item weighing 10kg and it is supported on a base with an area of 1 cm², then the loading on the item upon which the base is standing is 10kg/cm². If the base has an area of 1 mm² (0.01 cm²); then the loading is 1 000kg/cm². This is illustrated in figure 31 below:

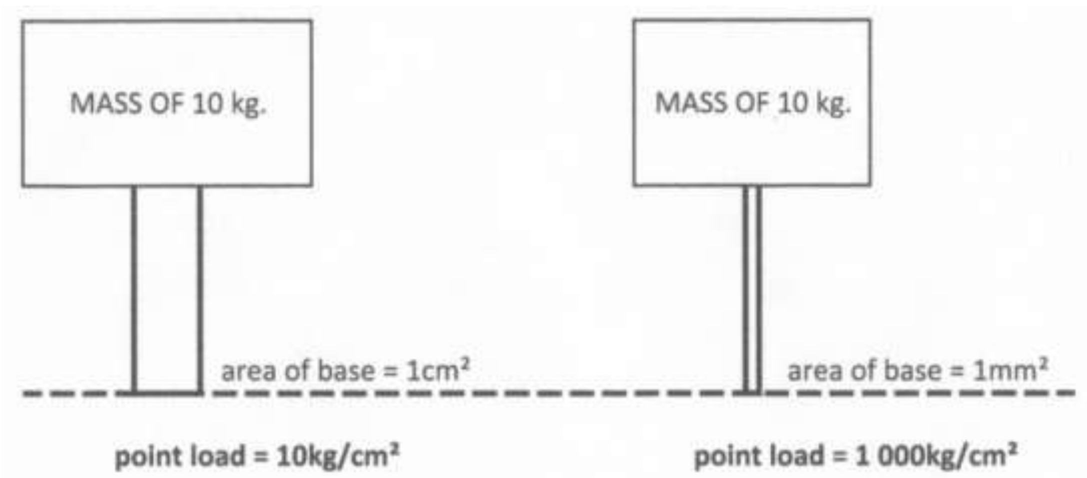


Figure 31 – SHOWING THE CONCEPT OF POINT LOADING.

In a ball bearing, the area of contact between the ball and the inner and outer race is very small. Therefore the point loading is high. In contrast, in the roller, the area of contact extends along the length of the roller and therefore the point loading is lower. In general, a roller bearing is able to handle a larger radial load than a ball bearing.

5.6 BALL BEARINGS.

The types of ball bearings that will be covered below are:

1. deep groove;

2. double row;

3. angular contact;

4. self aligning;

5. thrust.

5.6.1 Deep Groove Ball Bearing.

An example was shown in figure 30. This is the most versatile and probably the commonly used type of ball bearing. They may be rated as “normal” in their ability to handle radial load and axial load. These bearings can handle the axial thrust in either direction. With the proper separator it is suitable for high speed operation: > 5 000 rpm.

5.6.2 Double Row Ball Bearing.

In order to increase the loading capacity of a deep groove ball bearing, it is possible to have two races installed in one cage. These bearings will have an increase in their ability to handle radial load, but no increase in their ability to handle an axial load. An example is shown in figure 32 below:

indiamart.com

Figure 32 – AN EXAMPLE OF A DOUBLE ROW BALL BEARING.

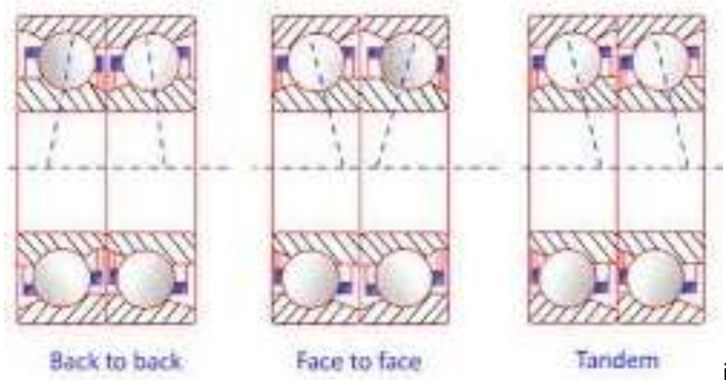
5.6.3 Angular Contact Ball Bearing.

It was In order to increase the axial load handling capability; the inner and outer race may be made with a step against which the ball bearing may press. This increases it ability to handle an increase in axial loading BUT ONLY IN THE ONE DIRECTION. This is shown in figure 33 below:

skf.com

Figure 33 – AN EXAMPLE OF AN ANGULAR CONTACT BALL BEARING.

To overcome the disadvantage of this bearing being able to handle axial load in one direction only, it is possible to use two bearings to handle axial loading in both directions. These may be mounted back to back OR face to face. This is shown in figure 34 below. If the two bearings are mounted in tandem, then they can handle twice the axial loading in one direction but none in the opposite direction.

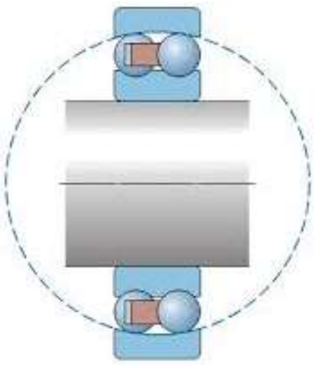


jctxbearing.com

Figure 34 – SHOWING DIFFERENT WAYS OF INSTALLING TWO ANGULAR CONTACT BALL BEARINGS.

5.6.4 Self Aligning Ball Bearing.

The above bearings must be accurately aligned otherwise excessive wear will take place and the life of the bearing will be significantly shortened. It is possible for a bearing manufactured so as to be able to handle a small amount of misalignment. If the outer race internal face is manufacturer to the shape of a circle as shown in figure 35 below, then the balls and the separator are able to move slightly along this arc to absorb the misalignment. There must be two sets of balls in the bearing.

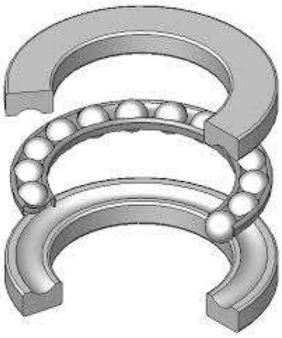


skf.com

Figure 35 – SHOWING THE PRINCIPLE OF A SELF ALIGNING BALL BEARING.

5.6.5 Thrust Ball Bearing.

These bearings are specifically designed to handle axial thrust. They cannot handle any radial thrust. An example is shown in figure 36 below:



Wikipedia

Figure 36 – SHOWING A TRUST BALL BEARING.

5.7 ROLLER BEARINGS.

The types of roller bearings that will be covered below are:

1. cylindrical roller;
2. spherical roller;
3. tapered roller;
4. needle roller;
5. thrust.

5.7.1 Cylindrical Roller Bearing.

In section 5.5, the concept of point loading was introduced. It was also indicated that the point of contact between the ball and the inner and outer races was very small leading to high point loading. The roller bearing overcomes this problem by having a larger area of contact that runs along the length of the roller. This is known as a linear contact area. This means that in general a roller bearing can handle a higher radial load than a ball bearing. They are still limited in the amount of axial load that they can handle. A typical example is shown in figure 37 below:

machinemfg.com

Figure 37 – EXAMPLE OF A TYPICAL ROLLER BEARING

5.7.2 Spherical Roller Bearing.

The cylindrical rollers are, as their name suggests, shaped like a cylinder with straight parallel sides. As indicated above they have a poor axial loading capability. To improve the axial loading capability, the rollers are made with a crowned shape. This is shown in figure 38 below:

wikipedia

Figure 38 – EXAMPLE OF A SPHERICAL ROLLER BEARING.

They are usually constructed with two sets of rollers. The improved axial loading capability operates in both directions.

5.7.3 Tapered Roller Bearing.

These rollers are mounted at an angle to the shaft that it being supported by the bearing. This means that they handle the axial load very well when the load is pressing the inner race further into the outer race. If the loading was in the other direction, the inner race would tend to pull away from the outer race. This would result in the bearing collapsing. The construction of the bearing is shown in figure 39 below:

indiamart.com

Figure 39 – SHOWING THE CONSTRUCTION OF A TAPERED ROLLER BEARING.

5.7.4 Needle Roller Bearing.

Needle Roller Bearings are a type of cylindrical roller bearing where the length of the roller is much larger than then the diameter. Needle roller bearings are designed for radial load applications where a low profile is desired.

They can handle high radial low axial, very little axial loading. An example is given in figure 40 below:

indiamart.com

Figure 40 – SHOWING THE CONSTRUCTION OF A NEEDLE ROLLER BEARING.

5.7.5 Thrust Bearings.

These are designed to take axial thrust. They cannot handle any radial thrust. They may be of the roller type, ball type or needle type. Examples are shown in figures 41 and 42 below:

.  Timken.com

Figure 41 – EXAMPLE OF A ROLLER THRUST BEARING.

indiamart.com

Figure 42 – EXAMPLE OF A BALL THRUST BEARING.

5.8 "WHITE" METAL BEARINGS.

An alternative type of bearing that can be used in engines and large blower installations is the so-called "white" metal bearing. This requires a continuous supply of oil to provide lubrication between the bearing material and the rotating shaft. The "white" metal is usually a mixture of tin and lead and small quantities of antimony and other materials. As this metal is very soft, it is mounted onto a steel backing plate. The holes and the groove in the centre are to allow oil to go between the bearing and the rotating shaft. This may be seen in figure 43 below:

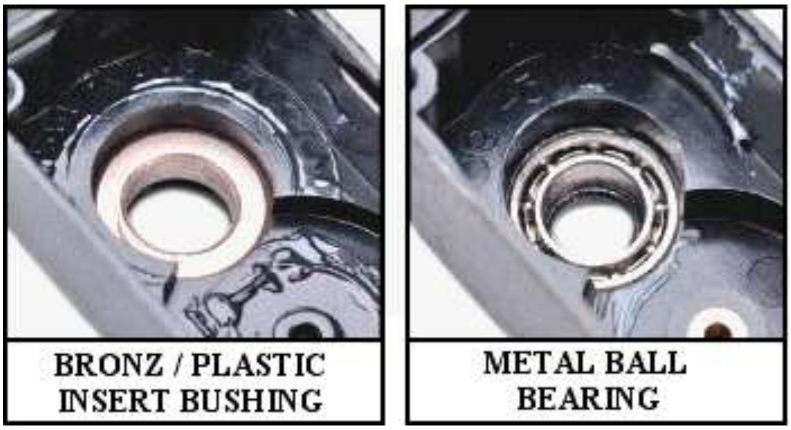
enginepartsuk.net

Figure 43 – A TYPICAL "WHITE" METAL BEARING LINER.

This type of bearing is also used in motor car and truck engines.

5.9 <u>BUSHINGS.</u>

In certain small applications such as a desk fans and computer components, a very small type of bearing is required due to space limitations. Here a bushing (or bush), may be used to reduce the friction between the rotating shaft and the stationary support frame. This is a tube or sleeve of a suitable material that allows the rotating shaft to turn with little friction. A bushing is comparted with a bearing in figure 44 below:



blue point engineering

Figure 44 – SHOWING THE DIFFERENCE BETWEEN A BUSHING AND A BEARING.

The bushing may be made of a soft metal such as phosphor bronze or a plastic material such as nylon or Vesconite®. The former will require lubrication either on initial installation or ongoing. The latter usually do not need lubricating.

There are installations where a bushing may be for large pieces of equipment. An example is on the Archimedes screw. Here a large roller thrust bearing at the top of the unit supports the weight of the screw and the water being pumped up the flights. The bottom bearing being continuously under water is usually a phosphor bronze bushing with a continuous supply of grease as a lubricant. The continuous supply of lubricant ensures that water; sand etc. does not enter the bushing.

A common mistake made by contractors is to install a 6mm grease line from the grease pump to the bushing. The friction of the long length of small diameter piping often results in the failure of the grease pump due to high pressure. The grease line should have a minimum diameter of 10mm and even 12mm in the chase of a large installation to ensure that grease reaches the bottom bush.

In the case of a screw conveyor, for example of a grit classifier, the lower bearing can be fitted outside the unit. Here a standard ball bearing may be used.

5.10 LINEAR BEARING SURFACES.

The bearing types covered above all involve a rotating part and a fixed part. There are times when one part moves past another part in a linear motion – that is a straight line. One example is the slides on an inclined screen. Here the rake assembly would move up and down between two guide channels. A typical layout is shown in figure 45 below.

The up and down movement of the rake assembly inside the support channel will cause wearing of each part even if grease in used. When used in wastewater containing sand, the wear rate will be even faster. Replacement of the rake assembly or the support channels would be expensive and would result in the item of equipment being out of use for some time – of the order of weeks.

It would makes sense to fit special wearing plates at each end of the rake and if necessary inside the support channel. These would be made of a softer material so that these would wear first and would be replaced when necessary. The usual material would be phosphor-bronze. This does not rust and has excellent lubrication properties that are improved further when greased. These wearing strips would be fitted with machine screws. When needed, the worn plates would be removed and new ones fitted. This job would take only a few hours,

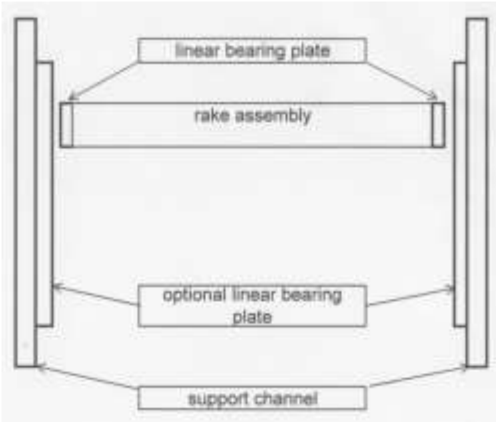


Figure 45 – AN EXAMPLE OF LINEAR BEARING PLATES USED ON A RAKE ASSEMBLY.

5.11 LUBRICATION OF BEARINGS.

Bearing lubrication plays a vital role in the performance and life of bearings. The most important task of the lubricant is to separate parts moving relative to one another (balls or rollers and raceways) in order to minimize friction and prevent wear. A lubricant that is designed for specific operating conditions will provide a load bearing wear protective film. The ideal condition is when the friction surfaces are separated by this film. In addition to providing this load bearing film, the lubricant should also allow for the dissipation of frictional heat thus preventing overheating of the bearing and deterioration of the lubricant and provide protection from corrosion, moisture, and the ingress of contaminants.

Too much grease volume (over greasing) in a bearing cavity will cause the rotating bearing elements to begin churning the grease, pushing it out of the way, resulting in energy loss and rising temperatures. .This can result in accelerated wear of the rolling elements and then component failure.

Grease is applied to a bearing using a grease gun that is attached to a grease nipple. These come in different shapes as shown in figure 46 below:

YBW forum

Figure 46 – SHOWING VARIOUS TYPES OF GREASE NIPPLE

In certain high rotational speed situations, oil may be used instead of grease. This will usually be when there is much heat generated by the bearing. Oil would be pumped from a holding tank, through a heat exchange, through the bearing and then draining back to the holding tank.

5.11.1 Important Matters Relating to Greasing of Bearings.

Besides the need to avoid over-greasing a bearing, there are other important matters to note:

1. The need to use the correct grade of grease as specified by the bearing manufacturer;

2. the need to keep the grease nipple clear by not painting over it;

3. the need to clean the nipple before applying the grease gun to avoid pumping any dirt etc. into the bearing;

4. the need to wipe away any excess grease on the grease nipple;

5. the need to keep the grease gun discharge point clean to avoid contaminating the grease to be pumped into the grease nipple.

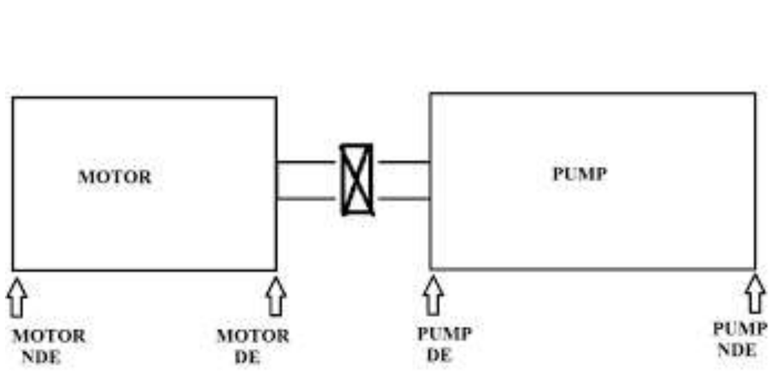
5.11.2 Sealed for Life Bearings.

When grease is applied to a bearing with a grease gun, the old grease is pushed out of the bearing. This grease has to go somewhere. In many cases, for example a Totally Enclosed Fan Cooled (TEFC), there would be nowhere for the grease to go except into the space between the stator and the rotor. This is clearly undesirable. In these cases, a "sealed for life" bearing that does not need greasing after installation is used.

IT IS IMPORTANT TO NOTE THAT "SEALED FOR LIFE" DOES NOT MEAN **FOR EVER**. The bearing would need to be replaced at intervals as part of a preventative maintenance program – this could be every 3 years, depending on the running hours of the unit.

5.12 DRIVE END (DE) and NON-DRIVE END (NDE) OF SHAFTS.

The **drive** end of an electric motor is the end of the shaft that turns a coupling or pulley etc. – in other words the power output end. The **non-drive** end is the other end. In the pump, blower etc. being driven, the end at which the coupling or pulley etc. is fitted is the drive end. These are shown in figure 47 below:



content.sciendo.com

Figure 47 – SHOWING THE DRIVE END AND NON-DRIVE END OF A DRIVING AND DRIVEN UNIT.

In many cases, different types of bearings are used for the drive end and the non-drive end of the motor or pump shaft.

5.13 BRINELLING OF BEARINGS.

Brinelling can be caused by a heavy load resting on a stationary bearing for an extended length of time. The result is a permanent dent or "brinell mark". The brinell marks will often appear in evenly spaced patterns along the bearing races, resembling the primary elements of the bearing, such as rows of indented lines for needle or roller bearings or rounded indentations in ball bearings. It is a common cause of ball and roller bearing failures.

If a motor, pump or blower is going to stand for a long time (greater than 3 months); the shaft should be turned a few times every 3 months to move the grease around in the bearing, and also to ensure that the shaft does not stay in exactly the same position for a very long time. If the area where this equipment is stored has any vibration, then the shaft should be turned more frequently.

THE MECHANICAL TRANSMISSION OF POWER

PART 6.

GEARBOXES.

6.1 INTRODUCTION.

In *Process Controller Guide 5 section 4.8,* it was shown that the most common electric motor speeds were:

1. about 3 000 rpm – 2 pole motor

2. about 1 500 rpm – 4 pole motor

3. about 1 000 rpm – 6 pole motor

The word “about” is used as there is between 2 and 5% slip and so the motors runs a little bit slower than the speeds given above.

It is quite rare that one of these speeds is the speed that one wants to run a particular item of equipment - this where a gearbox is used. They may be speed increasing gearboxes where the output shaft turns faster than the input shaft OR they may be speed reducing gearboxes where the output shaft turns more slowly than the input shaft.

Both speed increasing and speed decreasing gearboxes may be split into 3 layouts:

1. where the input shaft and the output shaft are parallel to each other, but not necessarily in line;

2. where the single output shaft is at 90 degrees to the input shaft;

3. where the two output shafts are at 90 degrees to the input shaft.

These layouts are shown in figure 48 below:

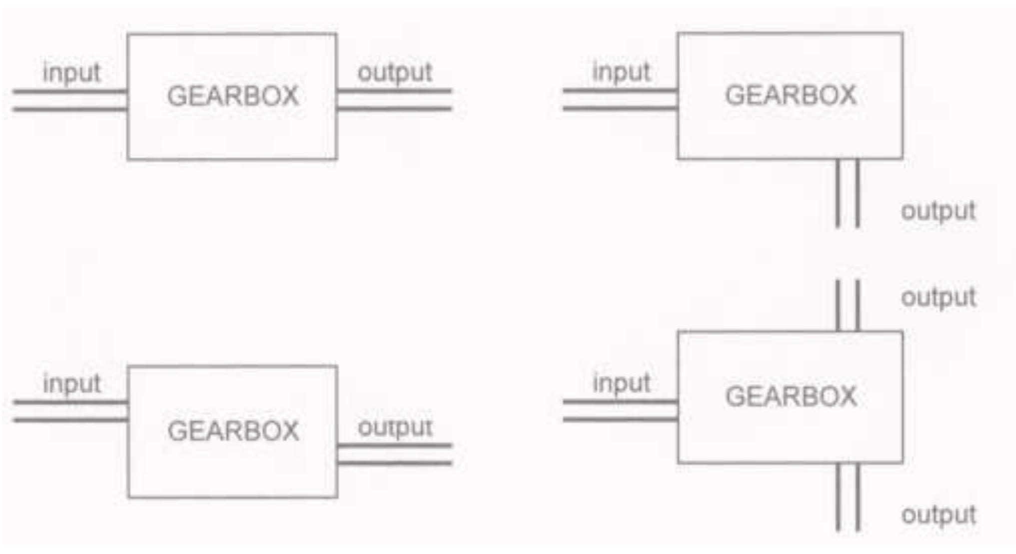


Figure 48 – SHOWING DIFFERENT GEARBOX LAYOUTS.

6.2 GEARBOXES WHERE INPUT AND OUTPUT SHAFTS ARE PARALLEL TO EACH OTHER.

As seen in figure 48, the input and output shafts may be in-line or off-set depending on the gear box construction. If there is a large difference between input and output speed, them the output shaft will almost certainly be off set from the input shaft. An example of an in-line (Co-axial) gearbox and motor unit is shown in figure 49 below:

dpaonbthenet.net

Figure 49 – AN EXAMPLE OF AN IN-LINE GEARBOX AND MOTOR UNIT.

This layout will usually only be used for the smaller (less powerful) units.

For a larger gearbox, a typical internal layout is shown in figure 50 below:

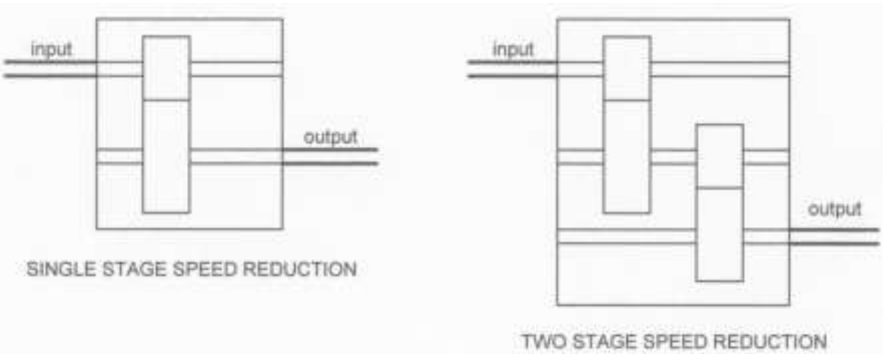


Figure 50 – SHOWING A SINGLE STAGE AND A TWO STAGE SPEED REDUCTION GEARBOX.

It can be seen that the two stage gearbox has an intermediate shaft.

It may be seen from the above figure that a smaller gear is turning a larger gear. If the smaller gear has say 20 teeth and the larger gear say 60 teeth; then the smaller gear will need to rotate 3 times to make the larger gear rotate once. If the input shaft rotated at 1 500 rpm; then the output shaft would rotate at one third of this speed namely 500 rpm.

In gearboxes with parallel input and output shafts, there is a limit to how small the smaller gear can be. If the ratio between the input shaft speed and the output shaft speed is say 10:1; then the larger gear would have to be very large to achieve a 10:1 (OR 1:10) ratio. The gearbox designer would probably choose to use a two stage speed layout as shown in figure 49 and the right hand layout in figure 50.

6.3 TYPES OF GEARS USED IN PARALLEL SHAFT GEARBOXES.

There are a number of gear types than can be used here. Each type has advantages and disadvantages. Among the types are:

1. spur gear (also known as a straight cut gear);

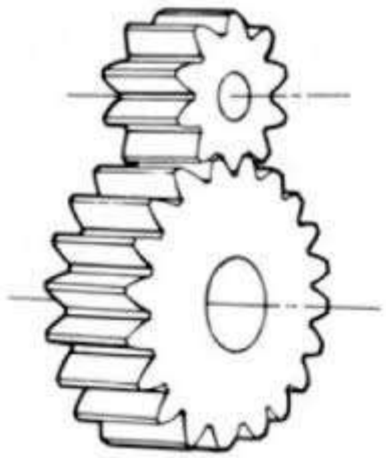
2. helical gears;

3. double helical gear;

4. herringbone gear.

6.3.1 Spur Gears.

The teeth of the spur gears are parallel to the shaft axis. This causes the gears to produce radial reaction loads on the shaft, but not axial loads. Spur gears tend to be noisy because they operate with a single line of contact between teeth. While the teeth are rolling through mesh, they roll off of contact with one tooth and accelerate to contact with the next tooth. This means that the transmission of torque is not uniform, but varies slightly. This is usually not a problem. An example of a set of spur gears is shown in figure 51 below:



khkgears.net

Figure 51 – SHOWING A SET OF SPUR GEARS.

6.3.2 Helical Gears.

Helical gears have teeth that are oriented at an angle to the shaft. This means that more than one tooth of each gear is in contact with each other during operation and helical gears are capable of carrying more load than spur gears. Due to the load sharing between teeth, this arrangement also allows helical gears to operate smoother and quieter than spur gears.

During operation there is a significant axial thrust on the gear shafts. The bearings locating the shaft must allow for this. The thrust would be in one direction only.

This is the most commonly used gear type in parallel shaft gearboxes.

An example is shown in figure 52 below:

indiamart.com

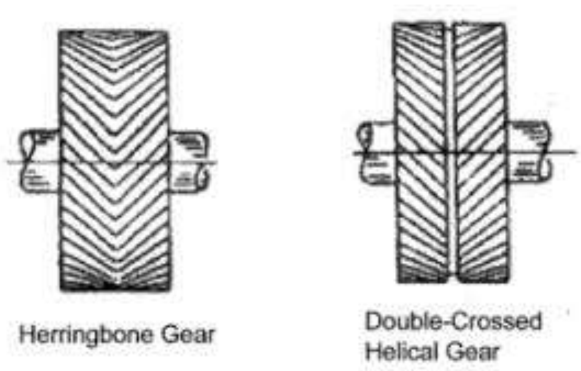
Figure 52 – SHOWING A SET OF HELICAL GEARS.

6.3.3 Double Helical Gears.

To eliminate the axial thrust load mentioned above, a double helical gear may be used. Here the two helical faces are placed next to each other with a gap separating them. Each face has identical, but opposite, helix angles. This arrangement gives even greater tooth overlap and thus a smoother operation. Like the helical gear, double helical gears are commonly used in enclosed gear drives.

6.3.4 Herringbone Gears.

Herringbone gears are very similar to the double helical gear, but they do not have a gap separating the two helical faces. Herringbone gears are typically smaller than the comparable double helical, and are ideally suited for high shock and vibration applications. Herringbone gearing is not used very often due to their manufacturing difficulties and high cost. The two latter types are shown in figure 53 below:



motioncontroltips.com

Figure 53 – SHOWING A HERRINGBONE AND A DOUBLE HELICAL GEAR.

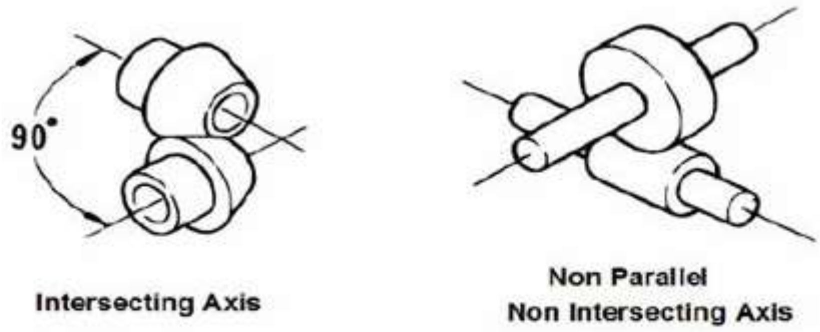
6.4 GEAR BOXES WHERE INPUT AND OUTPUT SHAFTS ARE AT RIGHT ANGLES TO EACH OTHER.

There are two basic types of these gearboxes:

1. intersecting axes;

2. non-Intersecting axes.

These are shown in figure 54 below:



quest10.com

Figure 54 – SHOWING THE LAYOUT OF INTERSECTING AND NON-INTERSECTING AXES.

6.5 TYPES OF GEARS USED WITH INTERSECTING AXES.

These are known as bevel gears. They have a cone as its pitch surface and its teeth are cut along the cone. The smaller gear is known as the “pinion”. The larger gear is sometimes called the “crown” because of its shape. One would hear the phrase “crown and pinion”.

There are different types of bevel gear:

1. straight bevel gear;

2. helical bevel gear;

3. miter gear.

6.5.1 Straight Bevel Gear.

These are the most common and simplest type of bevel gear. As their name suggests, they have straight teeth and in this regard resemble the spur gear covered in section 6.3.1. The teeth shape and tooth engagement is similar to that of a spur gear. They do not exert any axial thrust. They are also relatively noisy. An example is shown in figure 55 below:


aliexpress.com

Figure 55 – SHOWING A TYPICAL STRAIGHT BEVEL GEAR.

6.5.2 Helical Bevel Gear.

These are bevel gears are bevel gears with curved tooth lines. Due to higher tooth contact ratio, they are superior to straight bevel gears in efficiency, strength, vibration and noise. On the other hand, they are more difficult to produce. Also, because the teeth are curved, they cause thrust forces in the axial direction. An example is shown in figure 56 below:


thomasnet.com

Figure 56 – AN EXAMPLE OF A HELICAL BEVEL GEAR.

6.5.3 Miter Bevel Gear.

These are straight bevel gear where both gears are the same size. The output speed is the same as the input speed. An example is given in figure 57 below:


kggear.co.jp

.Figure 57 – AN EXAMPLE OF A MITER BEVEL GEAR.

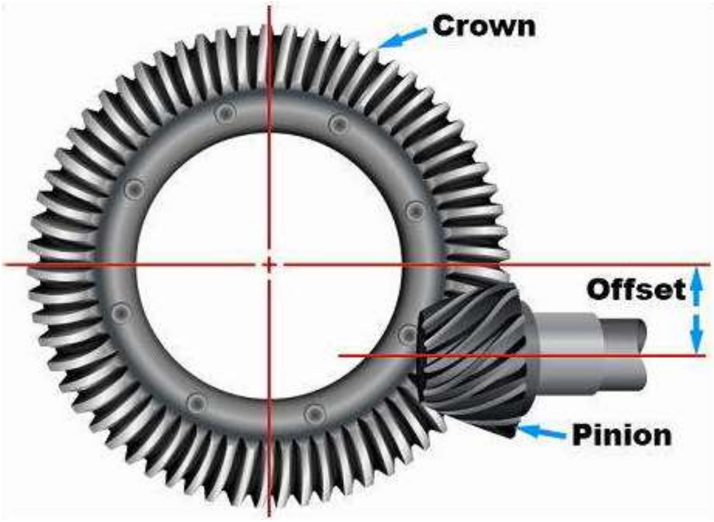
6.6 TYPES OF GEARS USED WITH NON-INTERSECTING AXES.

Included here are:

1. hypoid gear;
;
2. screw gear;
3. worm gear;
4. rack and pinion gear.

6.6.1 Hypoid Gear.

In a hypoid gearbox, the spiral angle of the pinion causes some sliding along the teeth, but the sliding is uniform, both in the direction of the tooth profile and longitudinally. This gives hypoid gearboxes very smooth running properties and quiet operation. But it also requires special EP (extreme pressure) gear oil in order to maintain effective lubrication, due to the pressure between the teeth. Since the shafts of hypoid gears don't intersect, bearings can be used on both sides of the gear to provide extra rigidity. An example of a hypoid gear is shown in figure 58 below:



motioncontroltips.com

Figure 58 – AN EXAMPLE OF A HYPOID GEAR.

6.6.2 Screw Gear.

Screw gears are a pair of same hand helical gears with the twist angle of 45° on non-parallel, non-intersecting shafts. Because the tooth contact is a point, their load carrying capacity is low and they are not suitable for large power transmission. Power is transmitted by the sliding of the tooth surfaces, it is necessary to pay attention to lubrication when using screw gears. There are no restrictions as far as the combinations of number of teeth. An example is shown in figure 59 below:

khkgears.net

Figure 59 – AN EXAMPLE OF A SCREW GEAR SET.

6.6.3 Worm Gear.

A screw shape cut on a shaft is the worm, the mating gear is the worm wheel, and together on non-intersecting shafts is called a worm gear. The worm is the driving gear while the worm wheel is the driven gear. This type is generally only used when a large reduction in rotational speed is required. There is a large increase in torque in the output shaft. In contrast to all the other types of gear assemblies covered above; due to friction, it is virtually impossible for the unit to run in reverse – that is for the worm wheel to drive the worm. This may be an advantage.

Lubrication of the wearing surfaces can be a problem. Even though the efficiency is low due to the sliding contact, the rotation is smooth and quiet.

The worm will have significant axial thrust. As seen in the figure 60 below; there are thrust bearings at each end of the shaft upon which the worm is mounted.

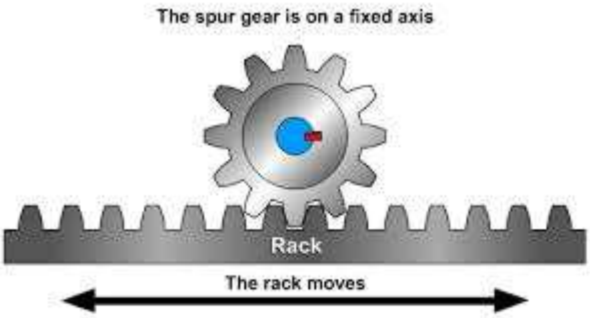
indiamart.com

Figure 60 – AN EXAMPLE OF A WORK GEAR ASSEMBLY.

6.6.4 Rack and Pinion Gear.

All the types of gears covered above have a rotational output. The rack and pinion system has the usual rotational input but has a linear output – that is the output component moves in a straight line backwards and forwards.

This system can be used to operate gates, steering on a car etc. An example is shown in figure 61 below:

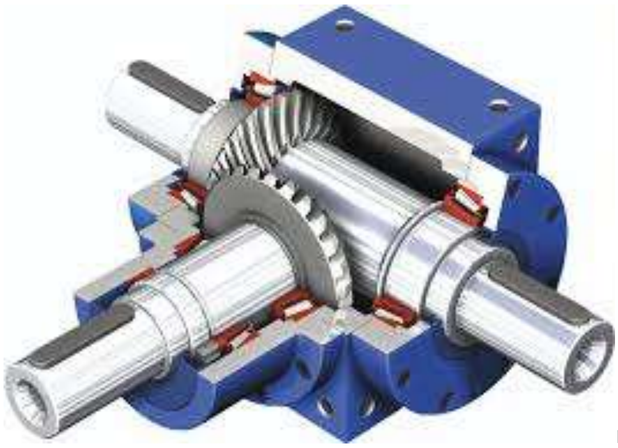


notesandsketches.co.uk

Figure 61 – EXAMPLE OF A RACK AND PINION DRIVE

6.7 GEARBOXES WITH TWIN OUTPUT SHAFTS.

The various gearboxes covered above have a single output shaft. There are operating systems that require two driving points. An example would be the moving bridge on a square or rectangular sedimentation tank. If there was an electric motor on each end of the bridge they would have to run at exactly the same speed at all times to prevent the bridge from "crabbing" or one side moving ahead of the other side and causing the bridge to jam. A typical gearbox is shown in figure 62 below:



motionusa.com

Figure 62 – SHOWING A TYPICAL DUAL OUTPUT SHAFT GEARBOX.

An example of the use of a dual output gearbox on a moving bridge is shown in figure 63 below:

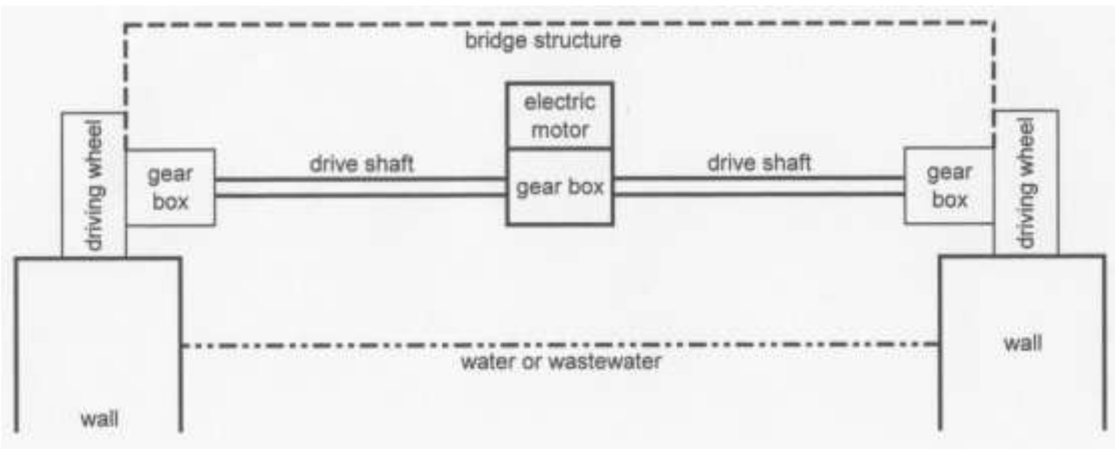
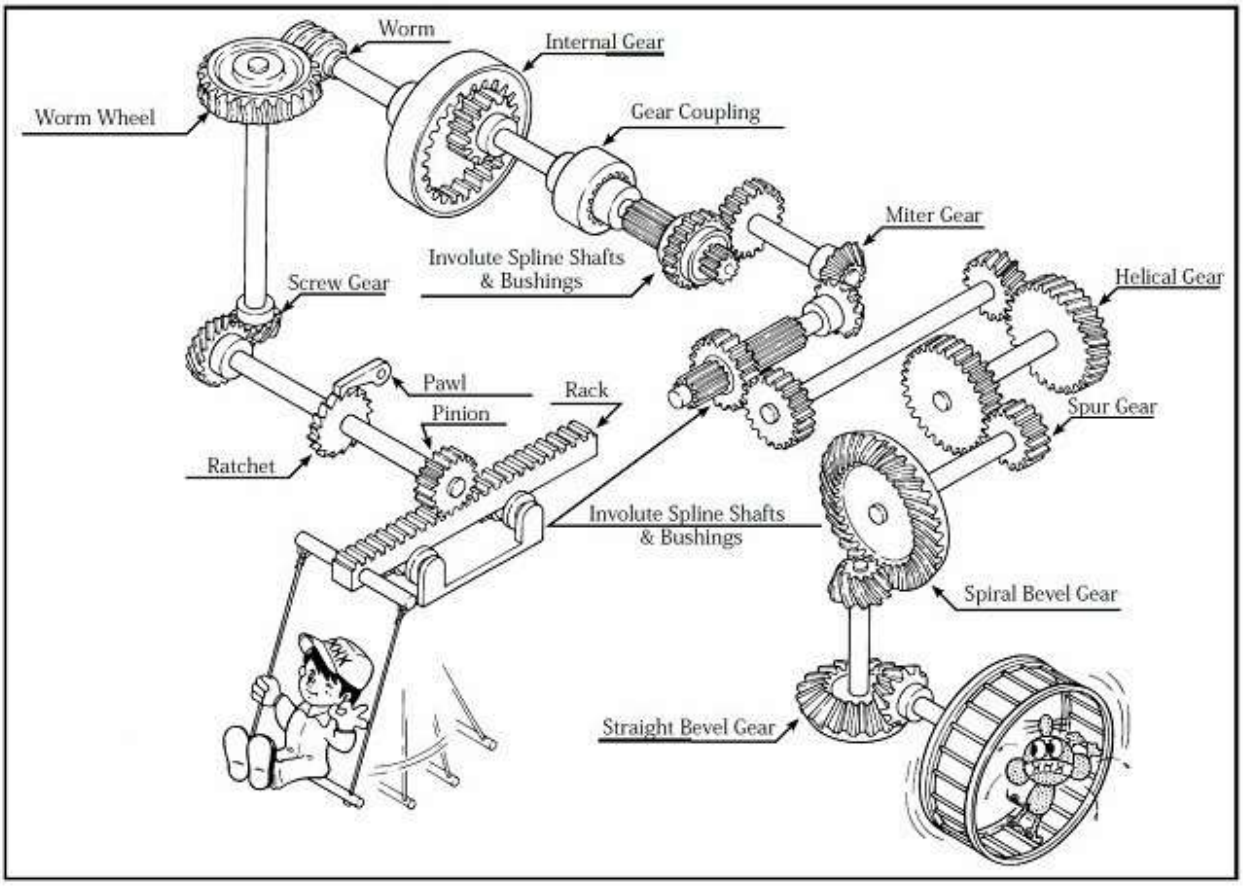


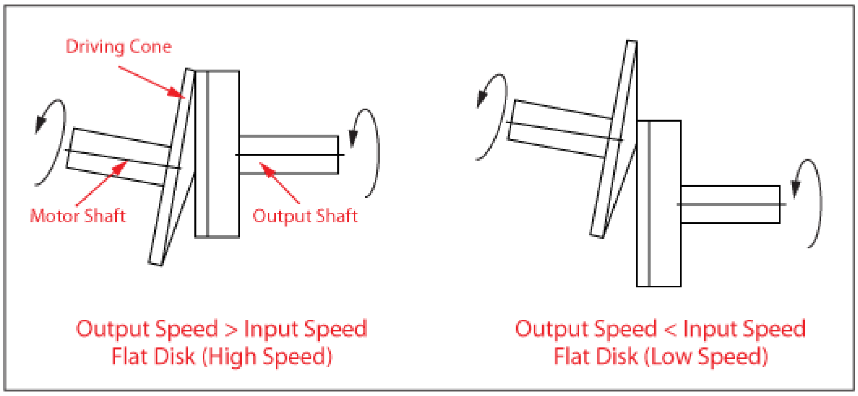
Figure 63 – SHOWING A USE OF A DUAL OUTPUT GEARBOX.



Thanks to Khkgears.net

6.8 VARIABLE SPEED GEARBOXES.

The variable speed belt drive was covered in section 3.5. Due to various factors, it may be preferable to have a variable speed gearbox. One example would be where the gearbox is required to be close coupled to the motor, i.e. bolted directly onto the motor. An example of how one type of variable speed gearbox works is shown below in figure 64:



isccompanies.com

Figure 64 – SHOWING THE OPERATING PRINCIPLE OF ONE TYPE OF VARIABLE SPEED GEARBOX.

(The movement of the motor shaft has been exaggerated to show the principle of operation).

An example of an actual unit is shown in figure 65 below:

+bonfiglioli

Figure 65 – SHOWING AN EXAMPLE OF A VARIABLE SPEEED GEARBOX.

Such a unit would have a turn down ratio of about 6:1 – the maximum speed is 6 times the minimum speed.

USEFUL OPERATING TIPS

1. ADJUST THE SPEED **ONLY** WHEN THE MOTOR ASSEMBLY IS TURNING TO AVOID DAMAGE TO THE ADJUSTING MECHANISM;

2. DO NOT OPERATE THE UNIT CONTINUOUSLY FOR MORE THAN 24 HOURS WITHOUT MAKING A SLIGHT SPEED ADJUSTMENT TO AVOID EXCESS WEAR AT ONE POINT ON THE DISCS.

6.9 LUBRICATION OF GEARBOXES.

Suitable lubrication of the gears in a gearbox is of prime importance. This serves two main purposes:

1. to provide a lubricating layer between the two gears to reduce friction;

2. to remove the heat from the rolling and sliding friction between the two gears.

It is very important that the correct grade of oil be used in each gearbox to avoid unnecessary wear on the various components.

ONE TYPE FITS ALL DOES NOT APPLY.

There are three main types of gear lubrication:

1. grease lubrication;

2. splash lubrication;

3. forced oil circulation.

6.9.1 Grease Lubrication.

This would generally be used for low speeds and low power input. It would generally not be used for continuous operation due to heat build-up .Over-greasing would contribute to the unit heating up due to power losses caused by additional friction. Here the grease would lubricate the bearings and the gears.

6.9.2 Splash Lubrication.

Helical, spur, and bevel gearboxes are typically lubricated using splash lubrication. During splash lubrication, the gears or another component within the gearbox dip into an oil bath. Through rotation these components begin "splashing" the oil into necessary chambers and crevices that may contain additional gears or bearings in need of lubricant. It is necessary to ensure that the gearbox is not under-filled so that the gear teeth are not fully immersed in the bath. If the oil level is too high then excessive losses will result due to the oil being churned up by the rotating gear. A typical layout is shown in figure 66 below:

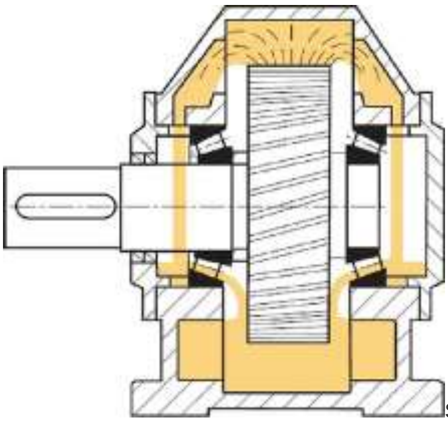

springerlink.com

Figure 66 – SHOWING THE PRINCIPLE OF SPLASH LUBRICATION.

6.9.3 Forced Oil Lubrication.

High speed and high power industrial gearboxes are lubricated through forced oil lubrication. These units often have spray lubrication provided through the use of nozzles, with oil circulating at a pressure of about 0.7 bar. Extra care must be taken to ensure the oil reaches the contacting surfaces. This process can become difficult as centrifugal forces deflect the stream of oil. An example of a simple system with an integral oil sump is shown in figure 67 below:

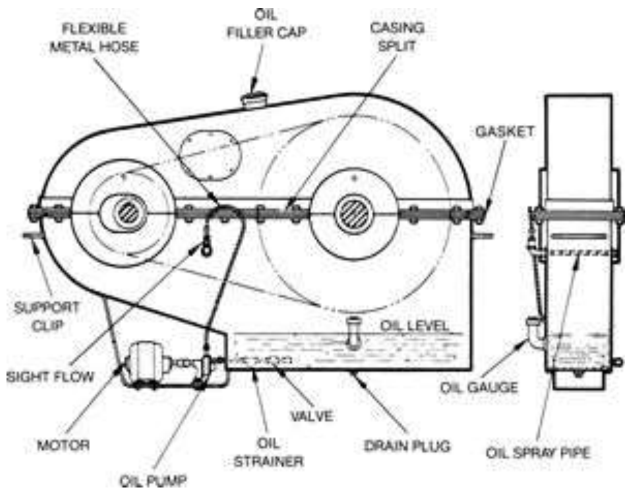


Figure 67 – SHOWING A SIMPLE FORCED OIL LUBRICATION SYSTEM.

A more complex system with a separate oil storage tank, oil fed bearings on the blower and an oil/water heat exchanger for cooling the oil is shown in figure 68 below:

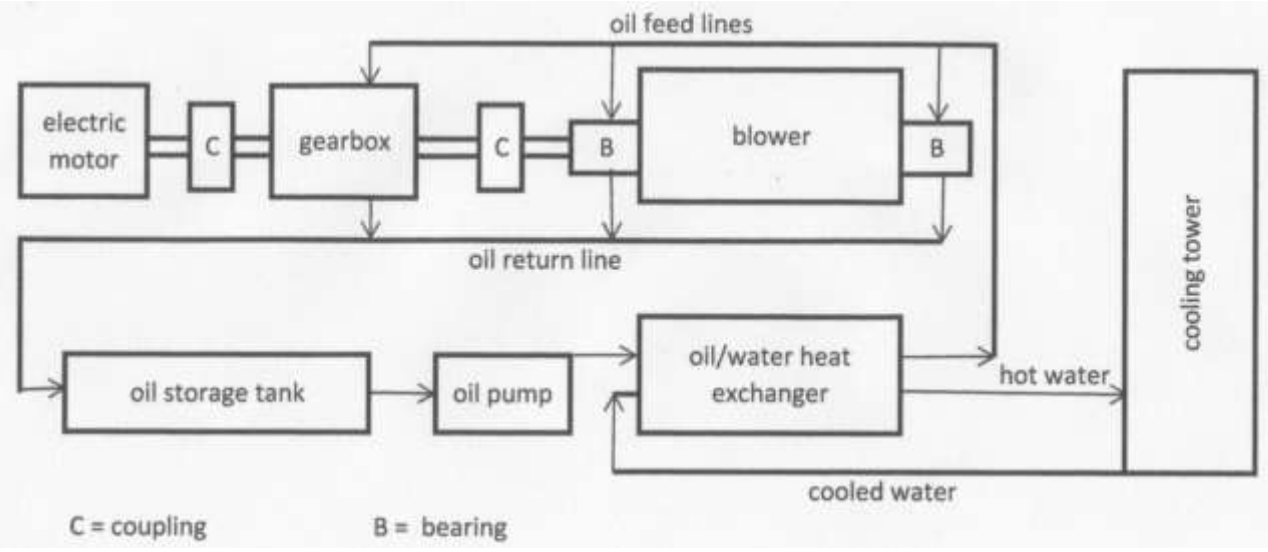


Figure 68 – SHOWING A COMPLEX FORCED OIL LUBRICATION FOR GEARBOX AND BEARINGS.

Generally a higher oil pressure is needed in the above case.

PART 7.

SHAFT SEALS AND VALVE PACKING.

7.1 INTRODUCTION.

In the mechanical transmission of power there will be a rotating shaft inside a fixed body that is supported by bearing or in some cases, a bushing. Some bearings are sealed to prevent loss of the lubricating grease. Many bearings are not sealed and therefore grease (or oil) may be lost and dirt etc. may enter the bearing.

In the case of a water pump, a seal is required on the input shaft. An air blower would also require a seal on input shaft to prevent loss of air.

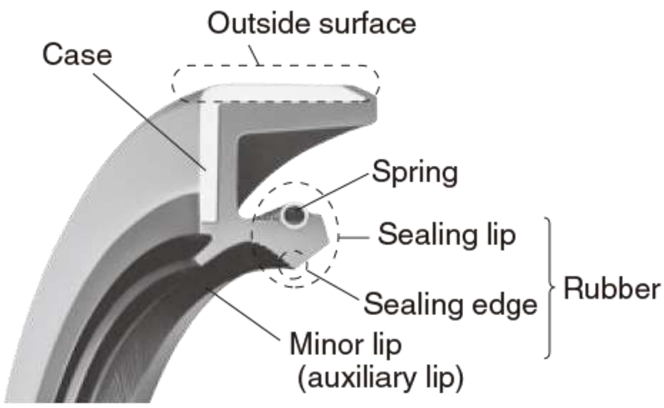
Similarly, a valve stem would leak without some kind of seal.

7.2 RADIAL SHAFT SEAL.

Radial shaft seals are located between the stationary and rotating components. They typically consist of two parts:

1. the cylindrical outer covering that is held firmly against equipment body;
2. the sealing lip that presses against the rotating component with a defined loading usually provided by a spring.

Rotary shaft seals provide sealing and wiping functionality for rotating movements under **low pressure and high velocity**. They perform two essential functions: the primary function is to retain the bearing or system lubricant in the system to avoid leakage, and the secondary function is to preclude any contamination of the system by external particles or other environmental impacts. The construction of a typical lip seal is shown in figure 69 below:



koyo.jtekt.co.jp

Figure 69 – SHOWING THE CONSTRUCTION OF A TYPICAL LIP SEAL

These types of seals would be used on the input and output shafts of a gearbox.

7.3 WATER PUMP MECHANICAL SEALS.

As indicated above, the lip seals are used in low pressure situations. In a water pump, for example, the seal around the input shaft must be capable of containing the water pressure inside the pump. Here a completely different type of seal is required. The mechanical seal consists of two parts:

1. the part that is stationary and fixed to the body of the pump etc;

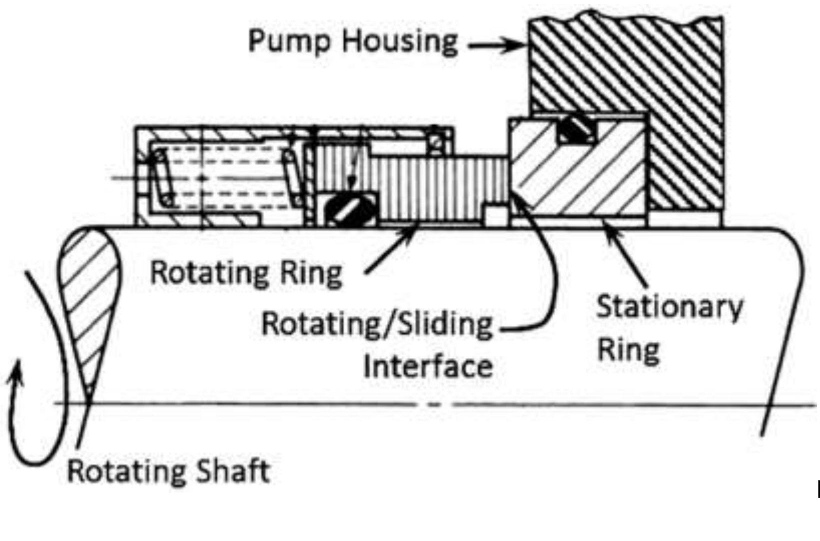
2. the part that rotates.

The various parts of a mechanical seal are shown in figure 70 below:

pump products

Figure 70 – SHOWING THE PARTS OF A MECHANICAL SEAL.

The layout of a mechanical seal installation is shown in figure 71 below:

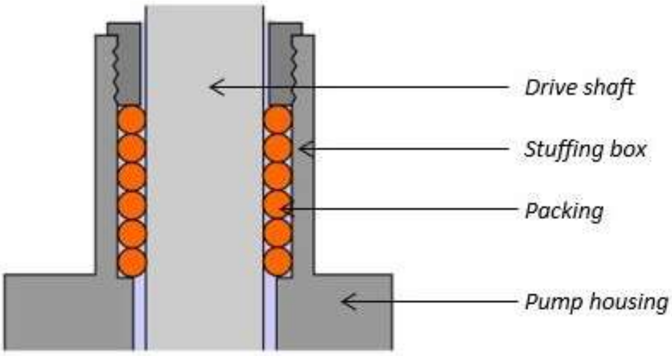


pumpsandsystems.com

Figure 71 –SHOWING THW LAYOUTOF A MECHANICAL SEAL INSTALLATION

The rotating/sliding interface between the stationary part and the sliding part is identified

Another type of seal used in water pumps using what is known as a stuffing box. This uses removable packing. The main advantage of this type of packing is that it can be replaced without dismantling the pump. If there is leakage at the drive shaft, the packing may be tightened. One must be careful not to over-tighten as this will increase friction and therefore heat generation that will damage the packing material. Although the illustration shows a vertical assembly, it can be used just as easily in the horizontal layout. A typical stuffing box shaft seal is shown below in figure 72 below:



Michael smith engineers

Figure 72 – SHOWING A TYPICAL STUFFING BOX SHAFT SEAL LAYOUT.

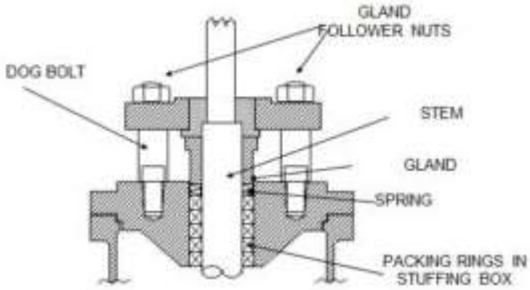
A variety of materials may be used for the packing. A typical type of packing is “square” rope as shown in figure 73 below:

global sources

Figure 73 – SHOWING A TYPICAL PACKING MATERIAL.

7.4 VALVE STEM SEALS.

Valve stem seals are often of the stuffing box type as covered above. Again the advantage is that the packing may be tightened and can be replaced without dismantling the valve. A typical layout is shown in figure 74 below:



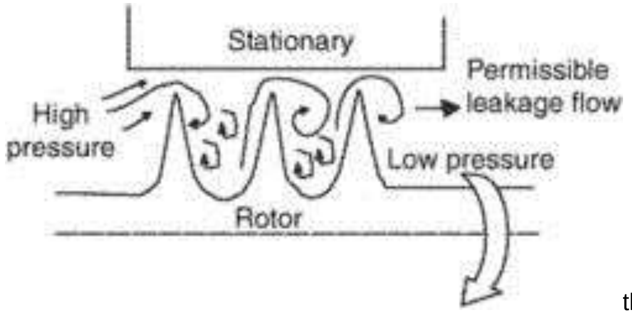
instrumentation and control engineering

Figure 74 – SHOWING THE TYPICAL VALVE STEM PACKING LAYOUT.

7.5 AIR BLOWER SEALS.

As mentioned in PC Guide no. 6 in section 3.3, positive displacement Roots type blowers usually operate at between 1 000 and 2 000 rpm. The pressure produced by the blower does normally not exceed 65 kPa. Here a lip type seal may be used.

Centrifugal blowers, in comparison, operate at much higher rotational speeds – about 10 000 rpm for single stage blowers and at about 5 000 rpm for 2 stage centrifugal blowers. The above types of seals cannot be used on a blower at these speeds. A commonly used type of seal is the labyrinth seal. The concept of which is shown in figure 75 below:



the free dictionary.com

Fig 75 - SHOWING THE CONCEPT OF A LABYRINTH SEAL.

In practice there would be many more segments in the seal to minimize air loss. The seal does not prevent air loss; it merely insures that there is sufficient pressure loss across each segment so that by the time the leaking air reaches the last segment, the air pressure is only slightly above the atmospheric pressure outside the blower.

THE MECHANICAL TRANSMISSION OF POWER

PART 8.

OBSERVATIONS BY PROCESS CONTROLLERS.

8.1 INTRODUCTION.

Usually much of the maintenance work will be performed by a dedicated maintenance team or external contractor, the Process Controller team will often be required to perform routine oiling and greasing of certain components. The Process Controller in a position to detect many indications of future mechanical malfunction by using their senses. These are covered below.

8.2.1 USING ONE's SIGHT.

Things one should look out for include:

1. **oil leaks**. This will often indicate that an oil seal is failing. If ignored, the oil will make a mess, can make a floor slippery and can result in a low oil level that will cause unnecessary wear on bearings and gears;

2. **movement of equipment.** If holding down bolts loosen with time, then equipment can start moving on its base or whatever it is fixed to. This can cause misalignment of shafts that could put extra load on couplings and bearings. This can lead to failure of these components;

3. **darkening of electrical wires.** Where there is a poor electrical contact between a wire and an electrical item such as a contactor, heat will be generated. Most electrical wires are PVC covered, The PVC will darken in colour when excess heat is generated at the contact point. This will be possible to see in an electrical board with clear (polycarbonate) covers, but will not be possible to see in a steel electrical cabinet. In the latter case, one is referred to 8.2.2 below;

4. **particles of rubber from drive belts.** Under normal operating conditions, there should be no particles of rubber coming off a belt drive. If the tension of the belt(s) is too low or the belt(s) are worn, then they will begin to slip on the pulleys and heat up. This can cause pieces of rubber to break off from the belt(s). This is an early indication of the impending failure of one or more of the belts.

8.2.2 USING ONE's SENSE OF SMELL.

As seen earlier, oil and grease are often used as a lubricant to reduce friction between a moving part and a stationery part. Friction produces heat, so a lack of lubrication will increase friction and will therefore produce extra heat.

Things one should look out for include:

1. **oil and grease giving off strong odour.** Under normal operating conditions, equipment containing oil as a lubricant will give off a slight smell. This would become stronger if the oil

becomes hotter than usual. This is where the Process Controller needs to know their works so that they know what is a normal odour and what is an abnormal odour;

2. **electrical panel giving off an odour.** Under normal operating conditions, there should be no odour given off by an electrical panel. If there is a poor electrical contact, this will generate heat and a distinctive odour will be given off as the PVC covering the electrical wires heats up;

3. **belt drives giving off an odour.** Under normal operating conditions, there should be no odour given off by a belt drive. If the tension of the belt(s) is too low or the belt(s) are worn, then they will begin to slip on the pulleys. This will generate heat that in turn will give off an odour. This is an early indication of the impending failure of one or more of the belts.

8 2.3 USING ONE's SENSE OF HEARING.

All operating electrical and mechanical equipment will generate noise while running.

Things one should look out for include:

1. **unusual or excessive noise.** When bearings become worn, there will be an increase in the amount of noise generated. This is where the Process Controller needs to know their works so that they know what is a normal level of noise from an item of equipment and what is an abnormal level of noise;

2. **noisy pump**. As mentioned PC Guide no. 6 section 2.10, cavitation in a centrifugal pump is noisy and can cause damage to the impeller of the pump.

8.2.4 USING ONE's SENSE OF TOUCH.

All operating electrical and mechanical equipment will have some vibration when running.

Things one should look out for include:

1. **unusual or excessive vibration**. When bearings become worn, there will be an increase in the amount of vibration generated. This is where the Process Controller needs to know their works so that they know what is a normal level of vibration from an item of equipment and what is an abnormal level of vibration. To check - gently touch the motor body, gearbox or blower with tips of the fingers.

DO NOT TRY TO TOUCH ANY MOVING OR VERY HOT ITEMS OF EQUIPMENT.

Centrifugal pumps partially blocked or cavitating will also show an increased level of vibration.

8.3 IN CONCLUSION.

Get to know your plant and look out for things that are not normal. Early detection of problems is far better than waiting for something to break before doing something about it.

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