Mechanical Equipment - Course 230.1

GEARS AND GEARING

Whenever rotary motion must be transferred from one shaft to another, gears should be considered. A gear is a toothed wheel used to transmit positive and uniform rotary motion from one shaft to another.

Gear Types

Gears can be classified according to the position which the teeth occupy with respect to the axis of rotation of the gear body. The more common types of gears in use are Spur gears, Bevel gears, Helical gears, Herringbone gears, Spiral gears, Worm gears and Planetary gears. Specially shaped gears such as eleptical gears and square gears are designed for a special purpose and are not used nearly as much as the first group mentioned.

Spur gears as shown in Figure 1 are gears having straight teeth that are cut parallel with the axis of rotation of the gear body. Spur gears are used to transmit motion from one shaft to another parallel shaft.

Helical gears shown in Figure 2 are gears having their teeth cut on a cylinder and at an angle with the axis of rotation of the gear body. These are sometimes called spiral gears by mistake.

Herringbone gears shown in Figure 3 are gears having helical teeth which diverge from the centre of the gear towards the sides of the gear body.

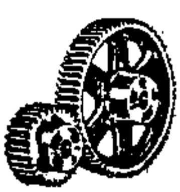


Figure 1

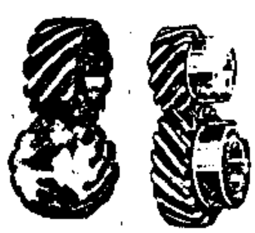


Figure 2

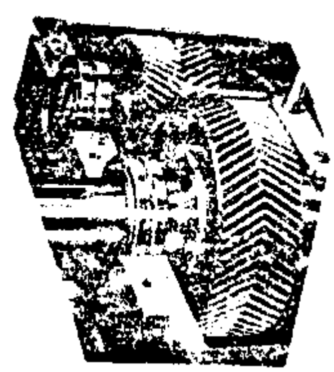


Figure 3

Spiral gears shown in Figure 4 are gears with teeth cut on a conical surface so that they curve continually away from or towards the apex of the cone upon which they are cut. These gears closely resemble bevel gears and are frequently called spiral bevel gears.

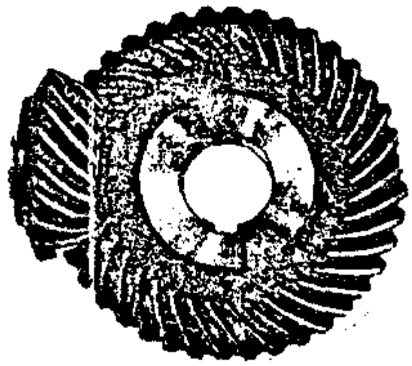


Figure 4

Bevel gears shown in Figure 5 are gears with their teeth cut on a conical surface so that the teeth radiate from the apex of the cone in a straight line. Miter gears are mating bevel gears having the same number of teeth and whose pitch cone angle is 45°. Miter gears are shown in Figure 5(a).

Figure 5

Figure 5(a)

A Worm gear, shown in Figure 6, is a gear having the the teeth cut angular to the axis of rotation and radially with the worm face. A worm gear is driven by a Worm, seen in Figure 6(a), which resembles a large screw thread.

Figure 6

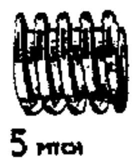


Figure 6(a)

Gear tooth profiles are commonly involute and this system has been developed from a basic rack. The rack as shown in Figure 7 and Figure 7(a) have straight sided teeth inclined at a standard pressue angle, usually 14 1/2° or 20°. This is an interchangeable system because all gears made to operate with this basic rack will operate with each other.

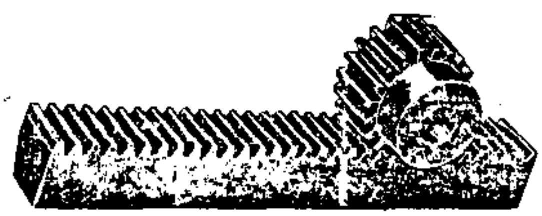


Figure 7

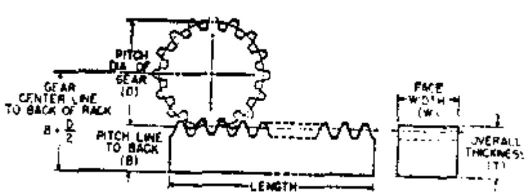


Figure 7(a)

To pressure angle is, as the name implies, the angle at which the tooth pressure is applied and distributed. In Figure 8, "Z" indicates the pressure angle.

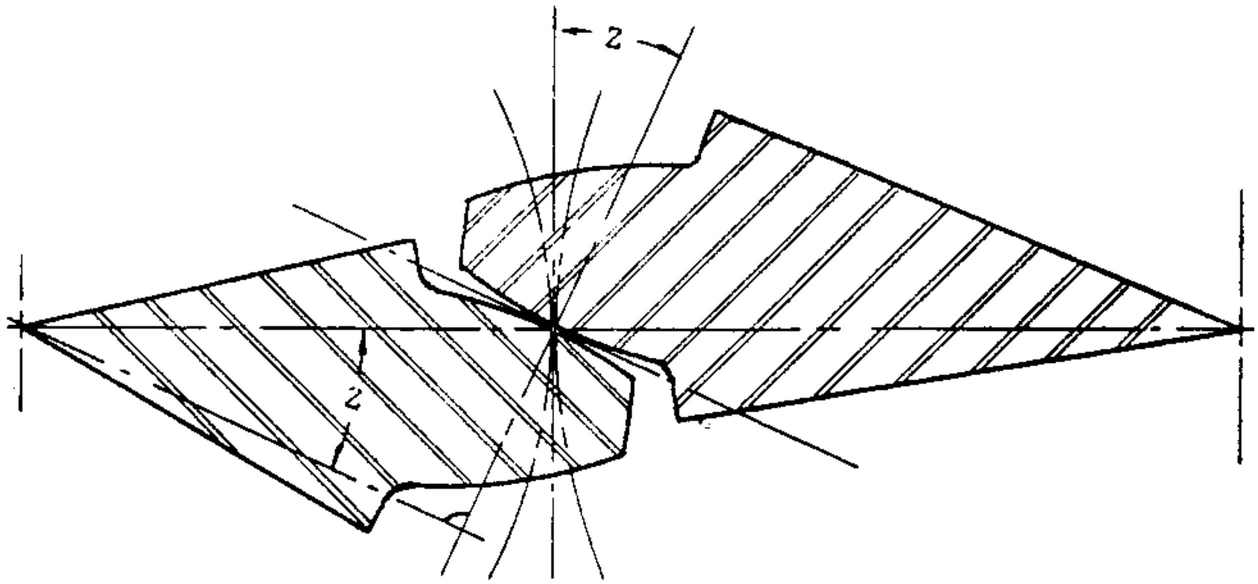


Figure 8

The 14 1/2° pressure angle gear has been used many years and remains useful for replacement or duplicate gears. The 20° pressure angle and more recently the 25° pressure angle have become standard for industry and the gear manufacturers. The gear designer's claim that the higher pressure angle (25°) permit the gears and the pinions to have fewer teeth without undercutting of the teeth.

Mating gears must have the same pressure angle or else they will not mesh properly.

Spur Gears

The gears shown in Figure 9 and the basic rack shown in Figure 10 give some of the terms used in calculating gear and tooth sizes.

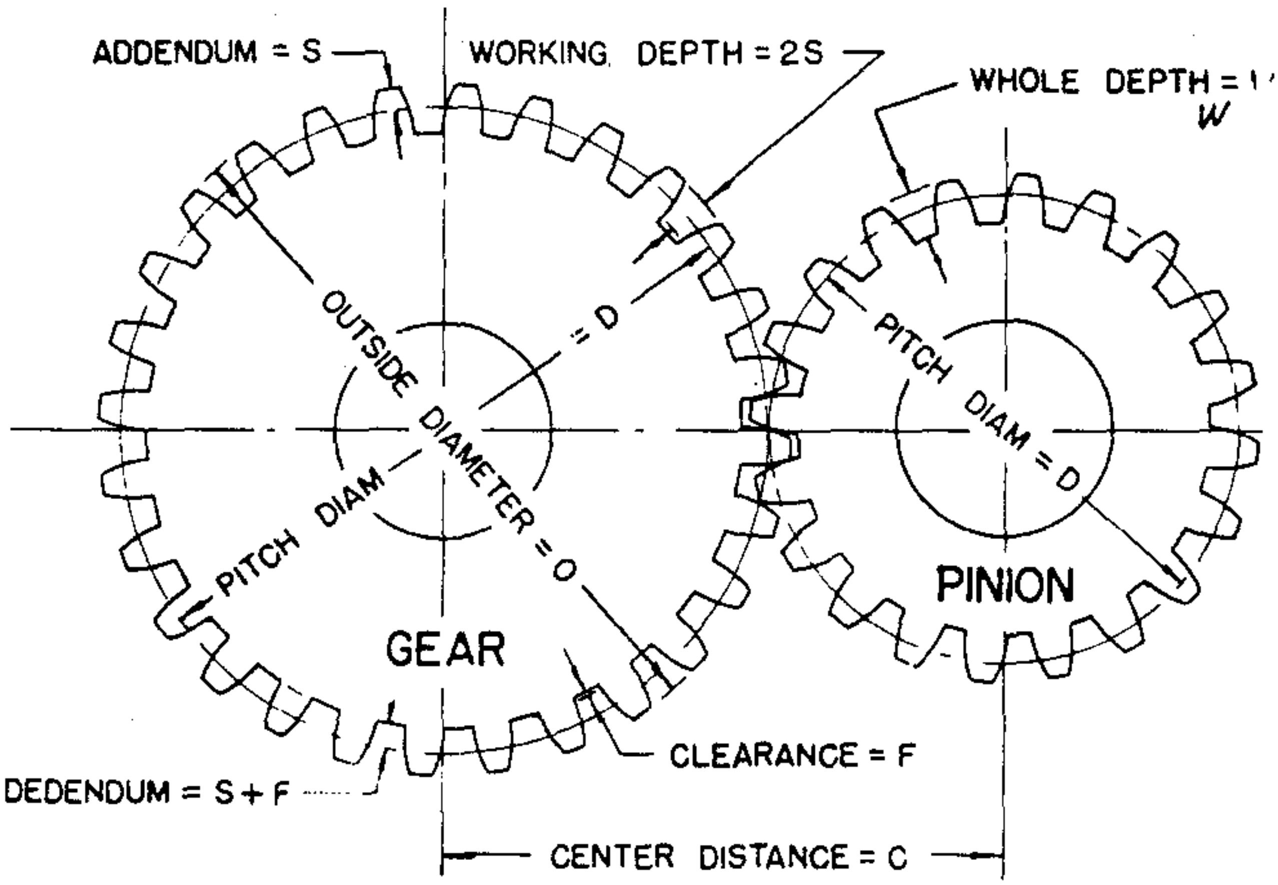
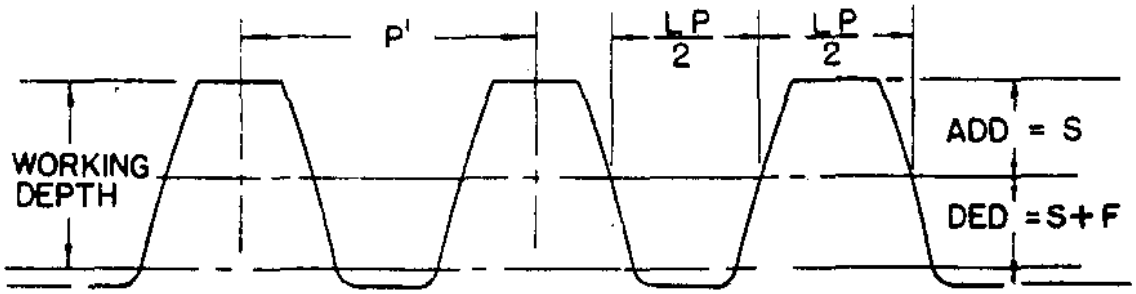

ADDENDUM = S
WORKING DEPTH = 2S
WHOLE DEPTH = W
OUTSIDE DIAMETER = O
= D
PITCH DIAM
PITCH DIAM = D
GEAR
PINION
CLEARANCE = F
DEDENDUM = S + F
CENTER DISTANCE = C

Figure 9



The Diametral Pitch (Pitch or P.) indicates the size of the tooth.

Addendum = $\frac{1}{P}$ Dedendum = $\frac{1.157}{P}$ Linear Pitch = $\frac{\Delta}{P}$

Working Depth = $\frac{2}{P}$ Whole Depth = $\frac{2.157}{P}$

Linear or Circular Pitch = P'

Rack Tooth

Figure 10

Pitch Circle: The pitch circle is an imaginary circle located about halfway down the gear tooth where both gears contact each other. Usually when a gear is spoken of as so many inches in diameter this is assumed to be the diameter of the pitch circle. The Pitch Diameter is the diameter of the pitch circle. See Figure 9.

Diametral Pitch (D.P.) is often abbreviated to "pitch" and the term pitch with respect to gears means "frequency". The pitch of a gear tooth is the number of teeth on the gear for each inch of pitch diameter. It is defined by the following equation:

$$P = \frac{N}{D}$$

Where P = Pitch
N = Number of Teeth
D = Pitch Diameter

Two gears must be of the same Diametral Pitch before they can mesh properly with each other, for example, two 8 D.P. gears will mesh properly but an 8 D.P. will not mesh with a 10 D.P.

Circular Pitch which is never abbreviated, is the sum of the tooth space plus the tooth width measured on the pitch circle, see Figure 9 and note that the circular pitch is a linear dimension and so must be measured in inches.

Addendum is the distance the tooth extends outside the pitch circle.

Dedendum is the distance from the pitch circle to the bottom of the gear bottom land and is equal to the addendum plus an allowance for clearance, or more simply, twice the addendum plust clearance.

Centre Distance is the sum of half the Pitch Diameter of one gear plus half the Pitch Diameter of the other gear, see Figure 9. The centre distance is very important because if the gears are correctly designed and manufactured they will mesh and operate freely and quietly, with the correct amount of backlash, at exactly that distance.

$$\text{eg, Standard C.D.} = \frac{\text{Pinion P.D.} + \text{gear P.D.}}{2}$$

It is most important that two mating gears must be of the same Diametral Pitch and the same Pressure Angle or they will not mesh properly.

Bevel and Miter Gears

Straight bevel gears can be used on shafts at any angle, though 90° is the most usual. Bevel and miter gears will provide smooth, quiet operation and long life when they are properly mounted and lubricated, however there are several important conditions to be met when assembling bevel gears:

Most standard bevel and ALL miter gears must be mounted on shafts that are at right angles (90°) to each other and as all bevel and miter gears develop radial and axial thrust loads these loads must be accommodated by use of suitable bearings. Figure 11 gives the various thrust directions for various combinations of gear sets.

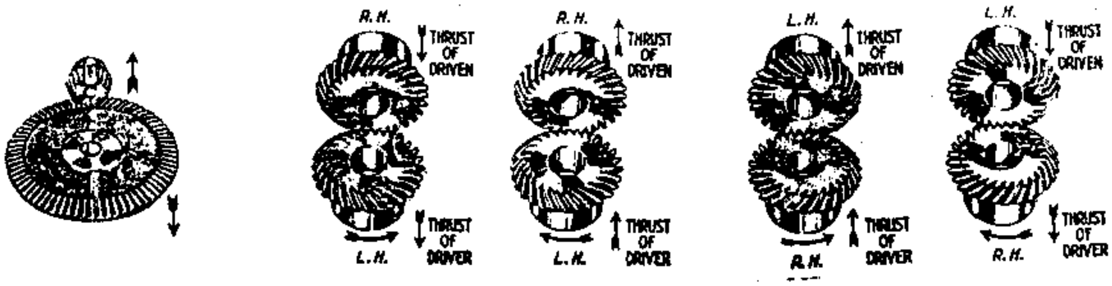


Figure 11

Helical Gears

Helical gears are used to transmit power or motion between non-intersecting shafts. The teeth of a helical gear may be cut with either a right or left hand helix. Two gears with teeth cut on the opposite hand operate on parallel shafts in much the same manner as spur gears. Figure 12 shows an opposite hand gear drive. This type of gear is recommened for high-speed and high torque applications. They will provide a stronger, smoother and quieter running drive than spur gears of the same pitch and size.

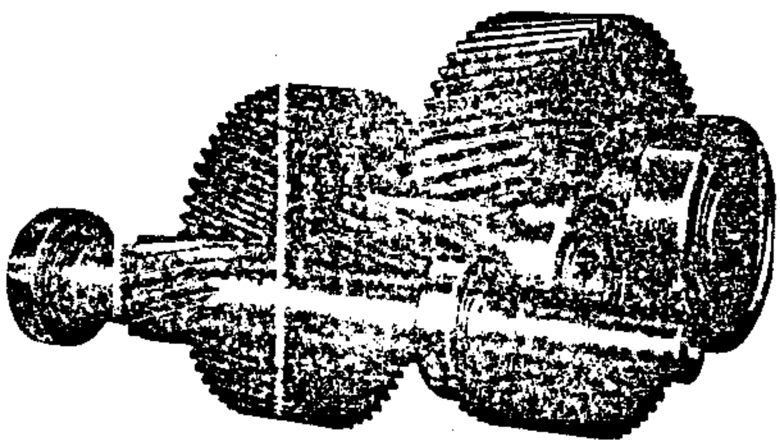


Figure 12

Figure 12(a)

Helical gears of the same hand as seen in Figure 12(a) operate on shafts that are 90° to each other. The load capacity of this type of drive is limited due to the reduction of tooth bearing area. Right angle shaft drives should be used for the transmisstion of motion only.

The rotation of helical gears generate an end thrust load and suitable bearings must be provided.

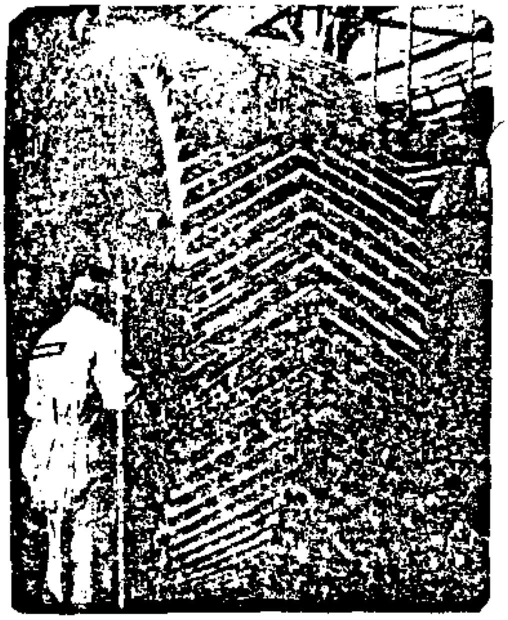


Figure 13

Herringbone Gears

Herringbone gears or double helical gears are used in a parallelled shaft transmission especially when a smooth continuous action is essential. The gear shown in Figure 13 is used in a speed increasing unit. This type of gear is used in marine reduction gears, in speed increasing units and in various tranmissions in connection with steam turbine and electric motor drives. Because of the double helix angle and the gear drive is self centering and large thrust bearings are not needed to take end thrust loads.

The failure of herringbone gears is rarely due to tooth breakage but is due to excess tooth wear or to sub-surface failure such as pitting or spalling.

Worm Gear Drive

A worm gear is essentially an endless screw wrapped around a cylinder. It has already been stated that a worm gear is driven by a worm. Figure 14 is an illustration of both a worm gear and a worm. The worm is manufactured with single, double, triple or quadruple starts on the worm screw. The worm gear and worm screw is used to convert rotary motion at high speed to rotary motion at low speed. The ratio or speed reduction equals the number of teeth cut on the worm wheel divided by the number of threads or starts on the worm screw. The ratios may range from 5:1 to 100:1.

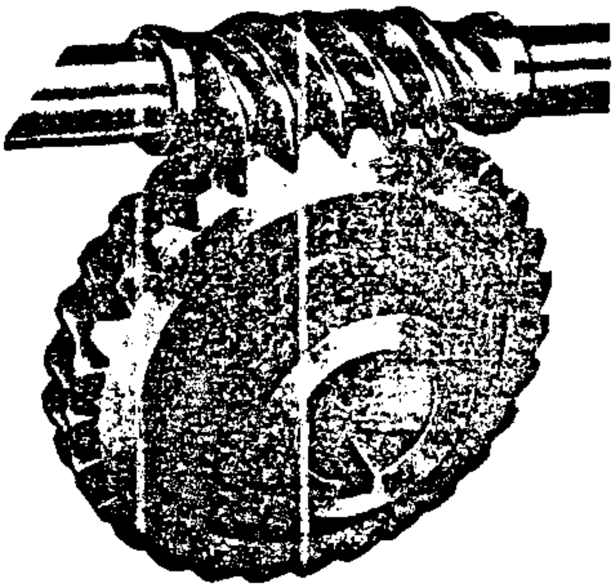
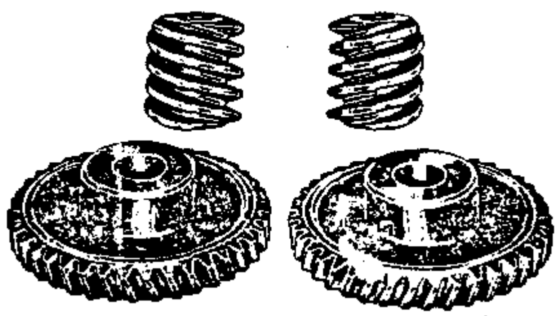


Figure 14



Left Hand Right Hand

Figure 15

The teeth of the worm gear and the threads of the worm may be cut left hand or right hand and are not interchangeable with each other. To tell which is which, stand them upright as in Figure 15. The threads on the left hand cut lean to the left and the threads on the right hand cut lean to the right.

Backlash

Backlash is lost motion between mating gear teeth. It is a function of the actual centre distance of the two gears and the actual tooth thickness of each other. Backlash is caused by the difference of the thickness of the gear tooth and the space into which it meshes. The purpose of backlash or clearance is to prevent the gears from jamming together and making contact with both sides of the gear tooth at the same time. Lack of backlash will cause noise, overloading, overheating, rapid wear and perhaps the seizing and breaking of the gear teeth. Too much clearance or backlash will also give noisy gears and overloading of the gear tooth because of lack of contact area which will result in rapid wear of the gear teeth.

The proper clearance required for the backlash is built into the gear tooth profile when the gear is designed and cut. The only control a maintainer has over the backlash is the centre to centre distance in the case of parallel shafts and the Mounting Distance in the case of bevel gear sets. Shafts that should be parallel must be parallel otherwise clearance at one edge of the gear tooth will be different from the clearance at the other edge of the gear tooth.

These are cases where backlash must be eliminated. In applications of "zero backlash" the gears and mountings have been designed for this consideration and anti-backlash devices have been provided.

The following is a table of approximate backlash figures for various pitch gears. The correct backlash allowance for a set of gears can be found in the gear manufacturer's handbook.

Diametral Pitch	Backlash	Diametral Pitch	Backlash
3	.013"	8-9	.005"
4	.010"	10-13	.004"
5	.008"	14-32	.003"
6	.007"	33-64	.0025
7	.006"		

An increase or decrease in the center distance will cause an increase or decrease in backlash. The approximate relationship is that for each .001" change in center distance the backlash will change approximately .0007".

The minimum backlash should be at least enough to accommodate a lubricating film of oil on the teeth.

Tooth Wear

During the initial run-in period of a set of gears the action of rolling and sliding will smooth the surface of the gear teeth. With proper operating conditions and lubrication the teeth will show little signs of wear and normal wear will occur. Initial pitting of the gear teeth may continue until the local high spots are worn down at which time the gears will perform satisfactorily. Progressive pitting may occur after the initial run-in, this is indicated by visual inspection where it will be seen that pieces of metal have been torn from the gear tooth leaving pits in the surface.

Abrasion is seen as fine scratches extending from the root to the tip of the teeth. Abrasion is caused by gritty material in the air or in the lubricating oil. Abrasion can be controlled by frequent cleaning of the gear teeth and frequent changing of the lube oil.

Galling removes metal from the tooth surface and is due to the failure of the oil film to carry the load. Sometimes the metal is dragged over the tooth edge, creating a feather--edged appearance. *Advance galling is indicated by a ridge* developing at the pitch line of the driven teeth and a groove at the pitch line of the driving teeth.

Spalling is the condition when large chips or flakes break away from the gear tooth. This condition starts at the root of the tooth. Often small flakes of metal will be visible in the coil.

H. Timmins
L. Laplante

ASSIGNMENT

1. List five types of gears.

2. What is meant by the pressure angle on a gear?

3. Define the following terms:

   (a) Pitch
   (b) Pitch Circle
   (c) Diametral Pitch

4. What two conditions must be met in order that two mating gears mesh?

5. Define what is meant by backlash in a gear.

6. Is backlash necessary in gear operations?

7. Describe three types of wear that will take place on a gear tooth.