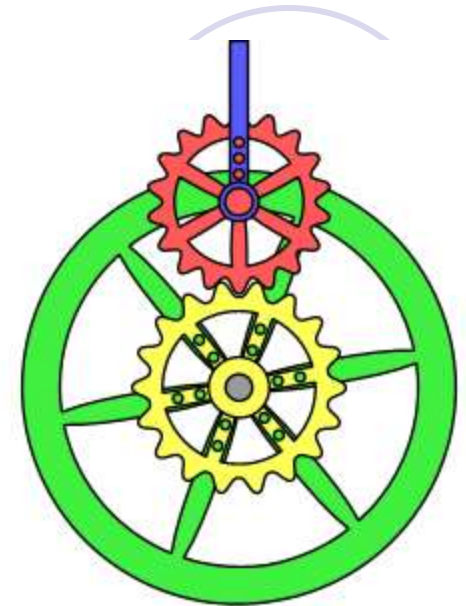




# Mechanical Design II ME 352

By S.G.Khan

Chapter 13...





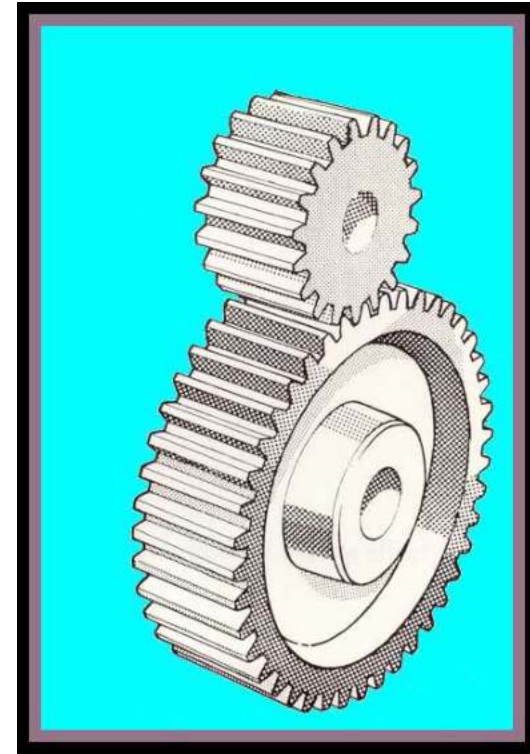
*A 17-tooth spur pinion has a diametral pitch of 8, runs at 1120 rev/min, and drives a gear at a speed of 544 rev/min. Find the number of teeth on the gear and the theoretical center-to-center distance.*

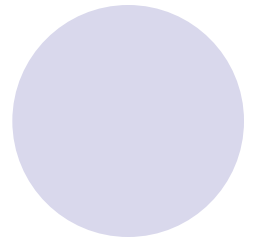
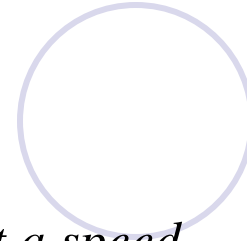
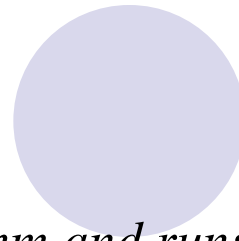
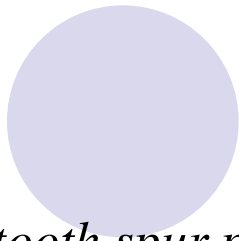
$$d_P = \frac{17}{8} = 2.125 \text{ in}$$

$$d_G = \frac{N_2}{N_3} d_P = \frac{1120}{544} (2.125) = 4.375 \text{ in}$$

$$N_G = Pd_G = 8(4.375) = 35 \text{ teeth}$$

$$C = (2.125 + 4.375) / 2 = 3.25 \text{ in}$$



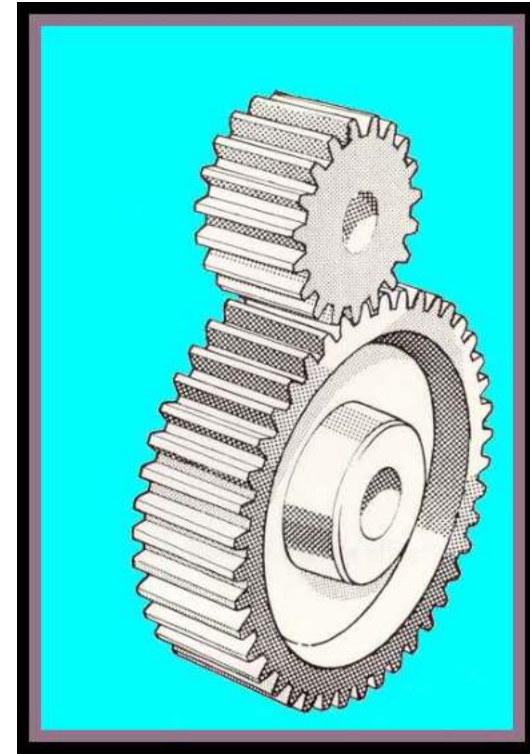


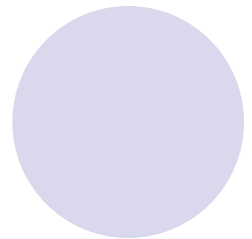
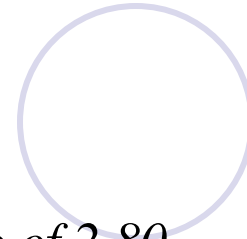
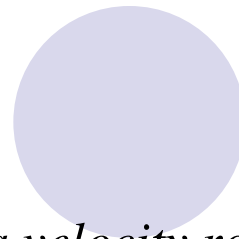
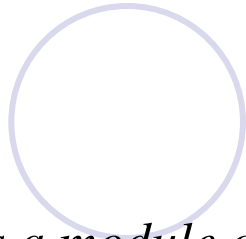
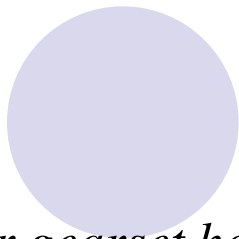
● A 15-tooth spur pinion has a module of 3 mm and runs at a speed of 1600 rev/min. The driven gear has 60 teeth. Find the speed of the driven gear, the circular pitch, and the theoretical center-to-center distance.

$$n_G = 1600(15/60) = 400 \text{ rev/min} \quad \text{Ans.}$$

$$p = \pi m = 3\pi \text{ mm} \quad \text{Ans.}$$

$$C = [3(15 + 60)]/2 = 112.5 \text{ mm} \quad \text{Ans.}$$





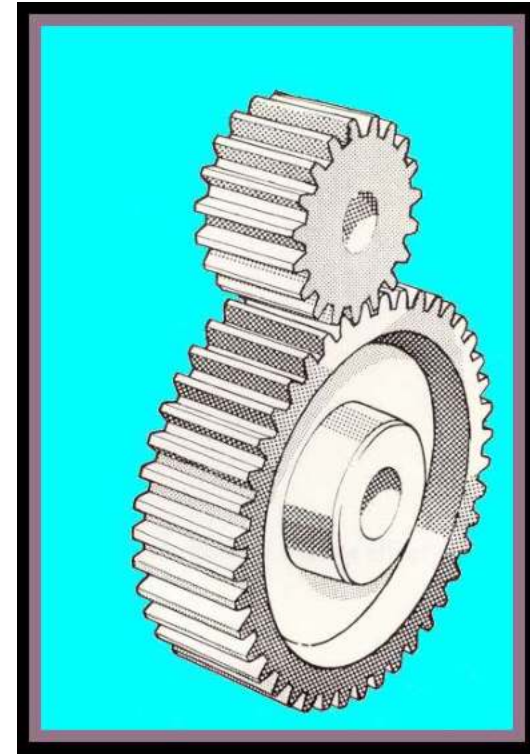
• A spur gearset has a module of 4 mm and a velocity ratio of 2.80. The pinion has 20 teeth. Find the number of teeth on the driven gear, the pitch diameters, and the theoretical center-to-center distance.

$$N_G = 20(2.80) = 56 \text{ teeth} \quad \text{Ans.}$$

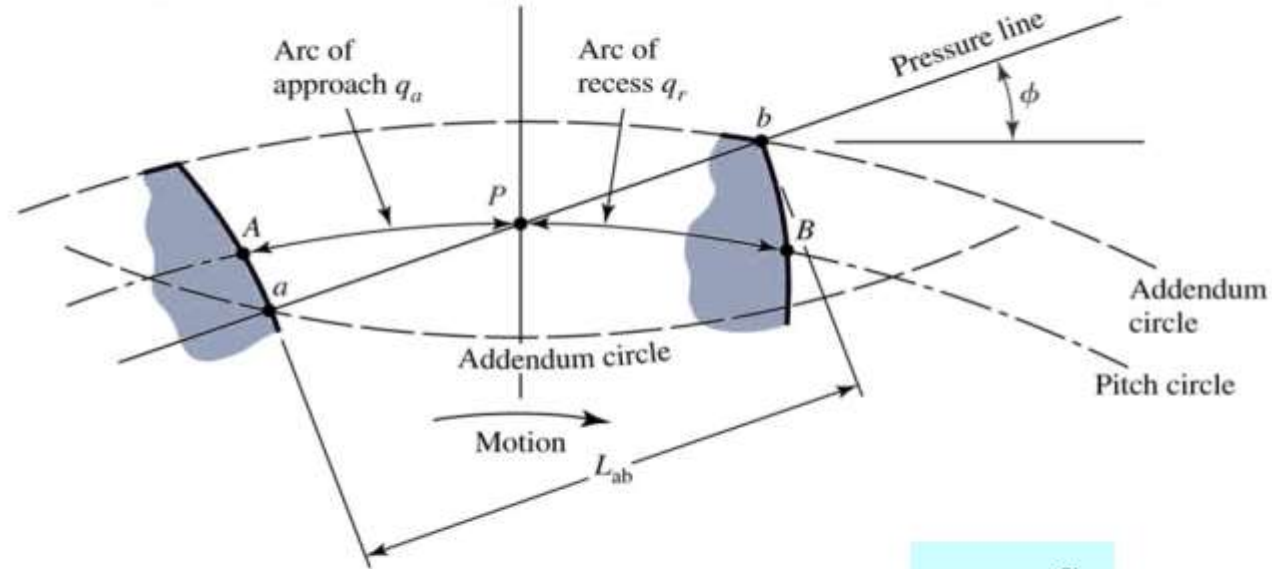
$$d_G = N_G m = 56(4) = 224 \text{ mm} \quad \text{Ans.}$$

$$d_P = N_P m = 20(4) = 80 \text{ mm} \quad \text{Ans.}$$

$$C = (224 + 80)/2 = 152 \text{ mm} \quad \text{Ans.}$$



# Contact Ratio



The zone of action of meshing gear teeth is shown in Fig. 3–16. We recall that tooth contact begins and ends at the intersections of the two addendum circles with the pressure line. In Fig. 13–16 initial contact occurs at  $a$  and final contact at  $b$ . Tooth profiles drawn through these points intersect the pitch circle at  $A$  and  $B$ , respectively. As shown, the distance  $AP$  is called the *arc of approach*  $q_a$ , and the distance  $PB$ , the *arc of recess*  $q_r$ . The sum of these is the *arc of action*  $q_t$ .

**Arc of Action  $q_t = \text{Arc of Approach} + \text{Recess} = AB$**

$$m_c = q_t / p$$

**Contact ratio,  $m_c$**

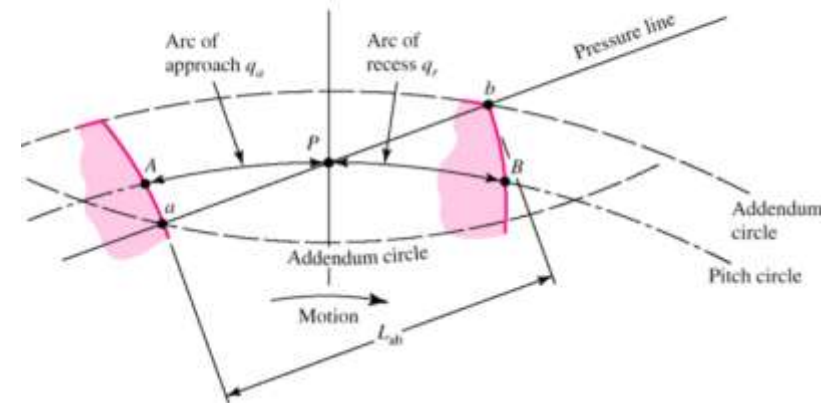
**Average number of pairs in contact**

this ratio is also equal to the length of the path of contact divided by the base pitch.

# Contact Ratio....

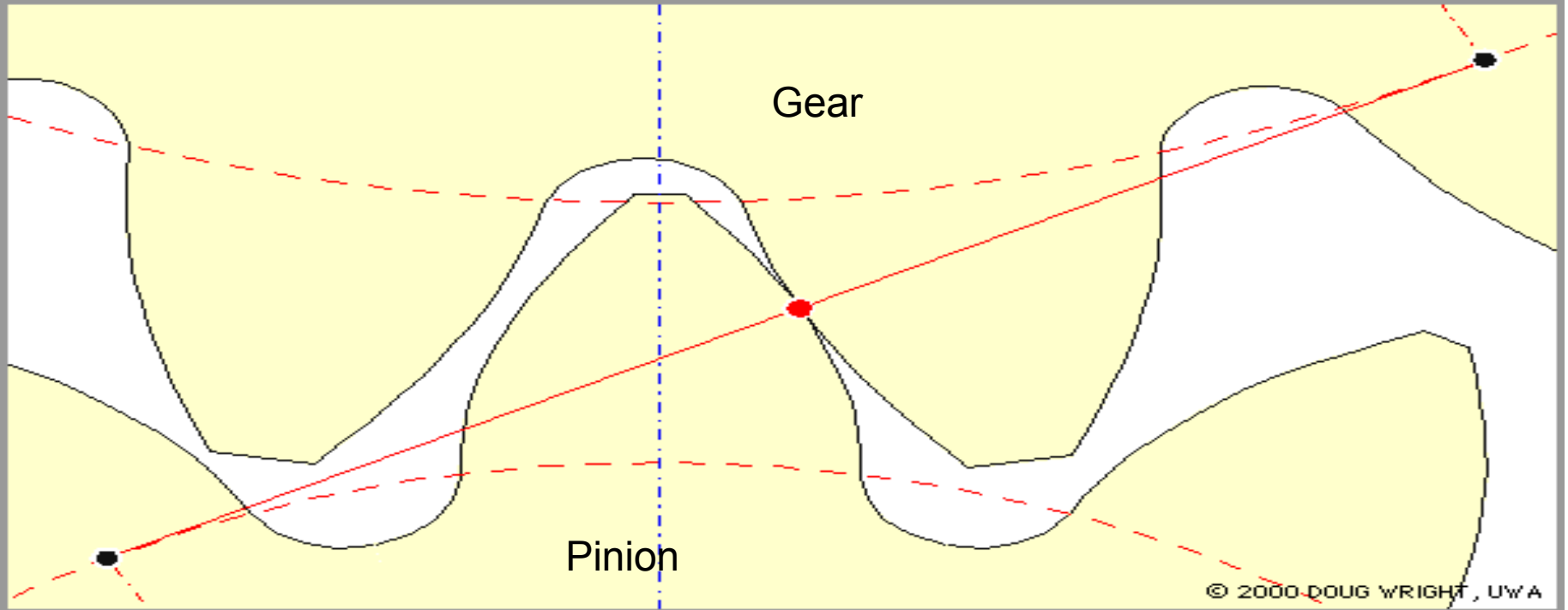
consider a situation in which the arc of action is exactly equal to the circular pitch, that is,  $q_t = p$ . This means that one tooth and its space will occupy the entire arc  $AB$ . In other words, when a tooth is just beginning contact at  $a$ , the previous tooth is simultaneously ending its contact at  $b$ . Therefore, during the tooth action from  $a$  to  $b$ , there will be exactly one pair of teeth in contact.

Gears



Next, consider a situation in which the arc of action is greater than the circular pitch, but not very much greater, say,  $q_t \approx 1.2p$ . This means that when one pair of teeth is just entering contact at  $a$ , another pair, already in contact, will not yet have reached  $b$ . Thus, for a short period of time, there will be two teeth in contact, one in the vicinity of  $A$  and another near  $B$ . As the meshing proceeds, the pair near  $B$  must cease contact, leaving only a single pair of contacting teeth, until the procedure repeats itself.

$$m_c = \frac{L_{ab}}{p \cos \phi}$$



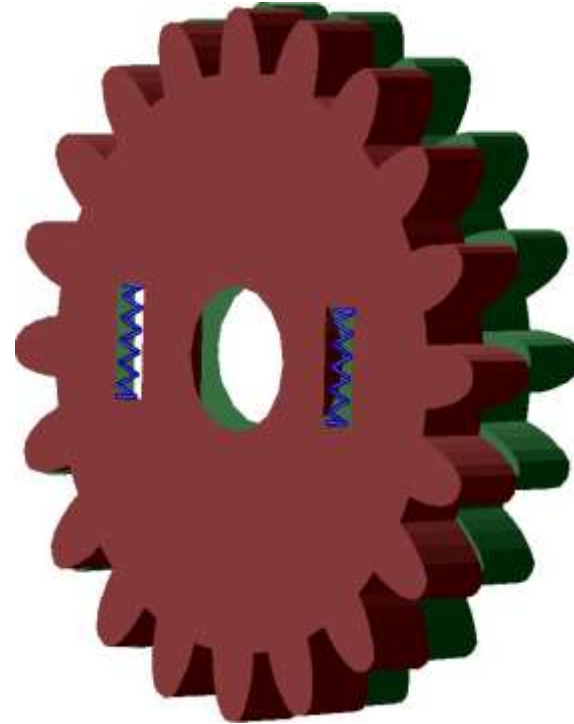
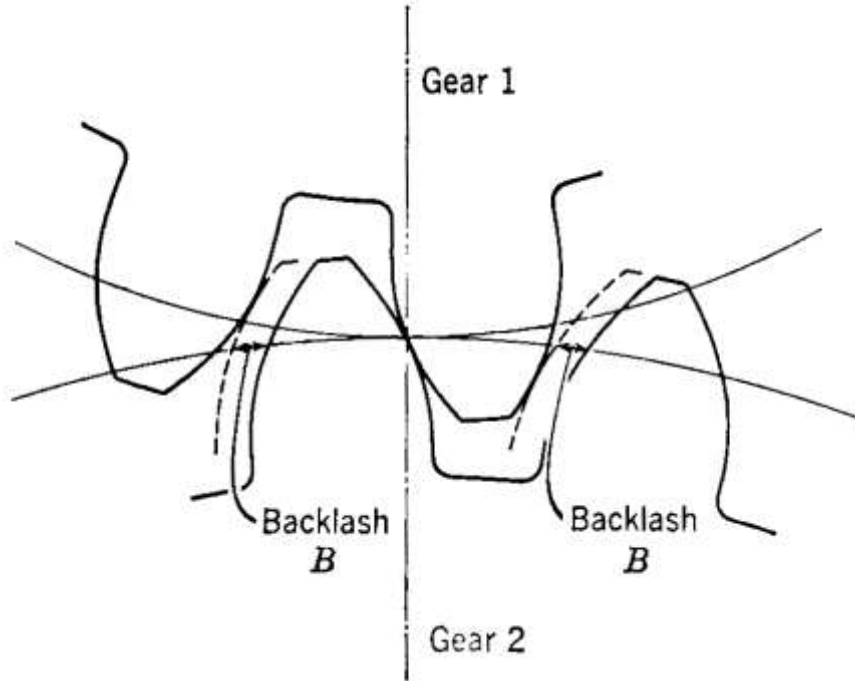
- The animation shows clearly :
- the contact point marching along the line of action
  - the path of contact bounded by the two addenda
  - the orthogonality between line of action and involute tooth flanks at the contact point
  - how load is transferred from one pair of contacting teeth to the next as rotation proceeds
  - relative sliding between the teeth - particularly noticeable at the beginning and end of contact
  - guaranteed tooth tip clearance due to the dedendum exceeding the addendum
  - a significant gap between the non-drive face of a pinion tooth and the adjacent wheel tooth

# Backlash



- The clearance between mating teeth measured at the pitch circle
- Whenever torque changes sign, teeth will move from one side of contact to another
- Can cause an error in position
- Backlash increases with increase in centre distance
- Can have anti-backlash gears (two gears, back to back)

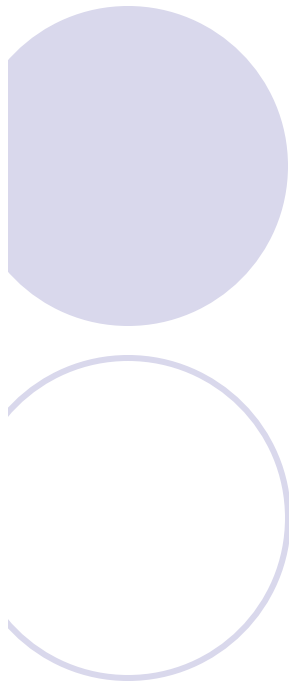
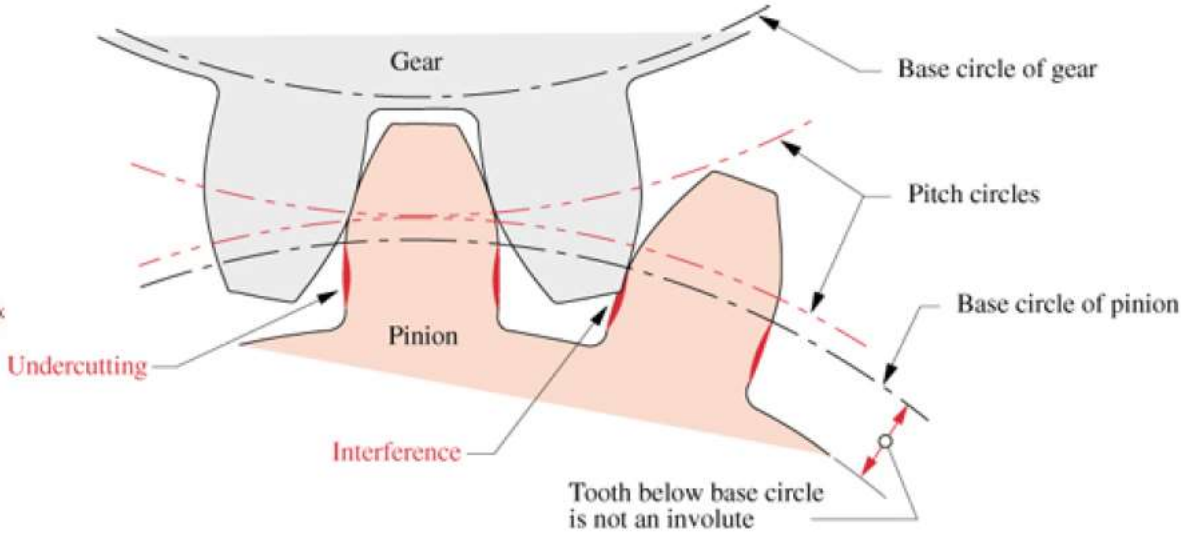
# Backlash



# Interference and Undercutting

- Interference – The region where the motion is not conjugate.
- Undercutting – part of the pinion tooth is removed in the manufacturing process

For no undercutting	
$\phi$ (deg)	Min # teeth
14.5	32
20	18
25	12



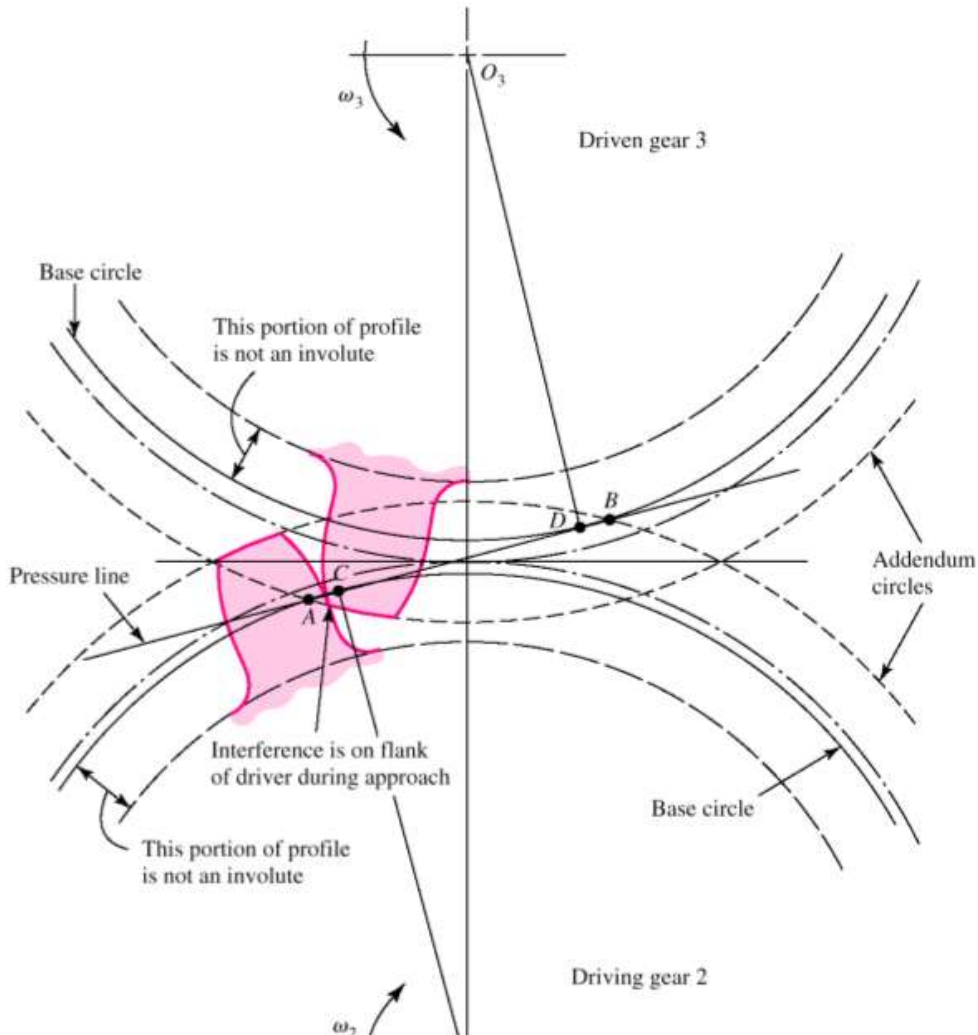
The contact of portions of tooth profiles which are not conjugate is called *interference*.

# Interference

The title 'Interference' is positioned to the left of a row of five circles. The first circle is solid light purple, the second is a light purple outline, the third is solid light purple, the fourth is a light purple outline, and the fifth is solid light purple.

- Normally, contact begins when the tip of the driven tool contacts the flank of the driving tooth
- But in case of interference, the flank of the driving tooth first makes contact with the driven tooth at a point, which is before the involute portion of the driving tooth comes within the range
- In other words, contact is occurring below the base circle of gear 2 on the non-involute portion of the flank
- The actual effect is that the involute tip of face of the driven gear tends to dig out the non involute flank of the driver

# Interference in action of gear teeth



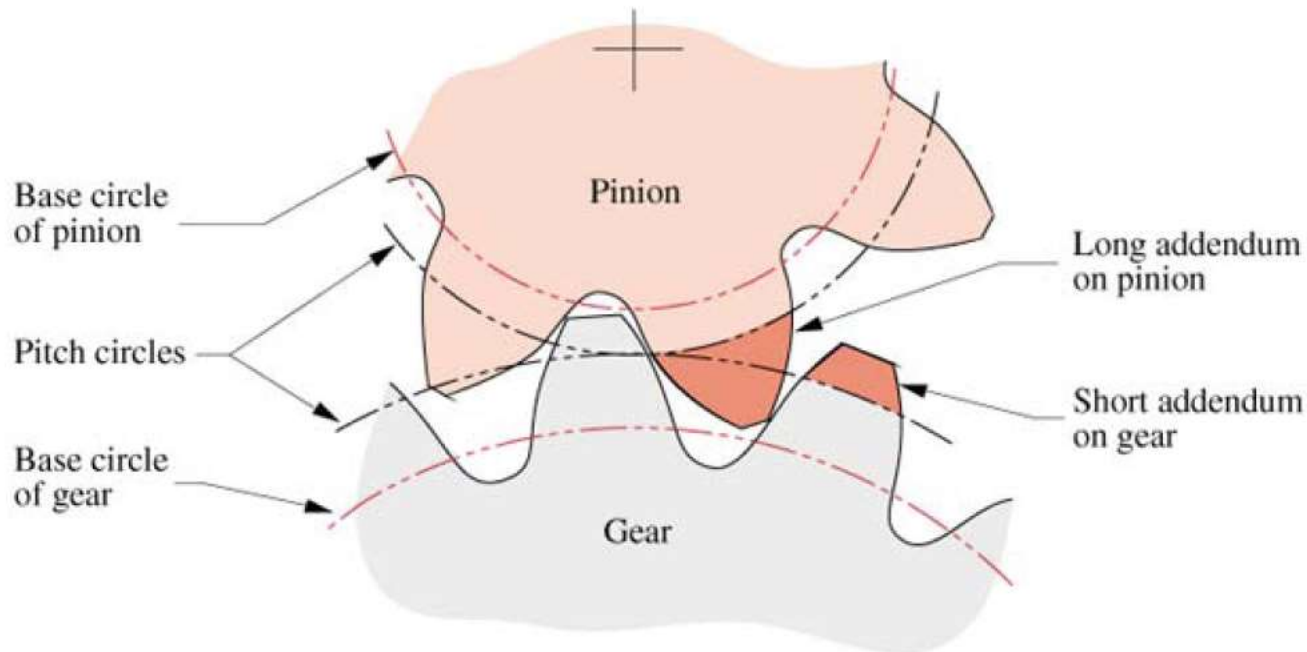
# Undercutting



- When gear teeth are produced by generation process, interference is automatically eliminated because the cutting tool removes the interfering portion of the flank
- This effect is called undercutting
- The undercut tooth is considerably weakened
- Thus the effect of eliminating interference by a generation process is merely to substitute another problem for the original one

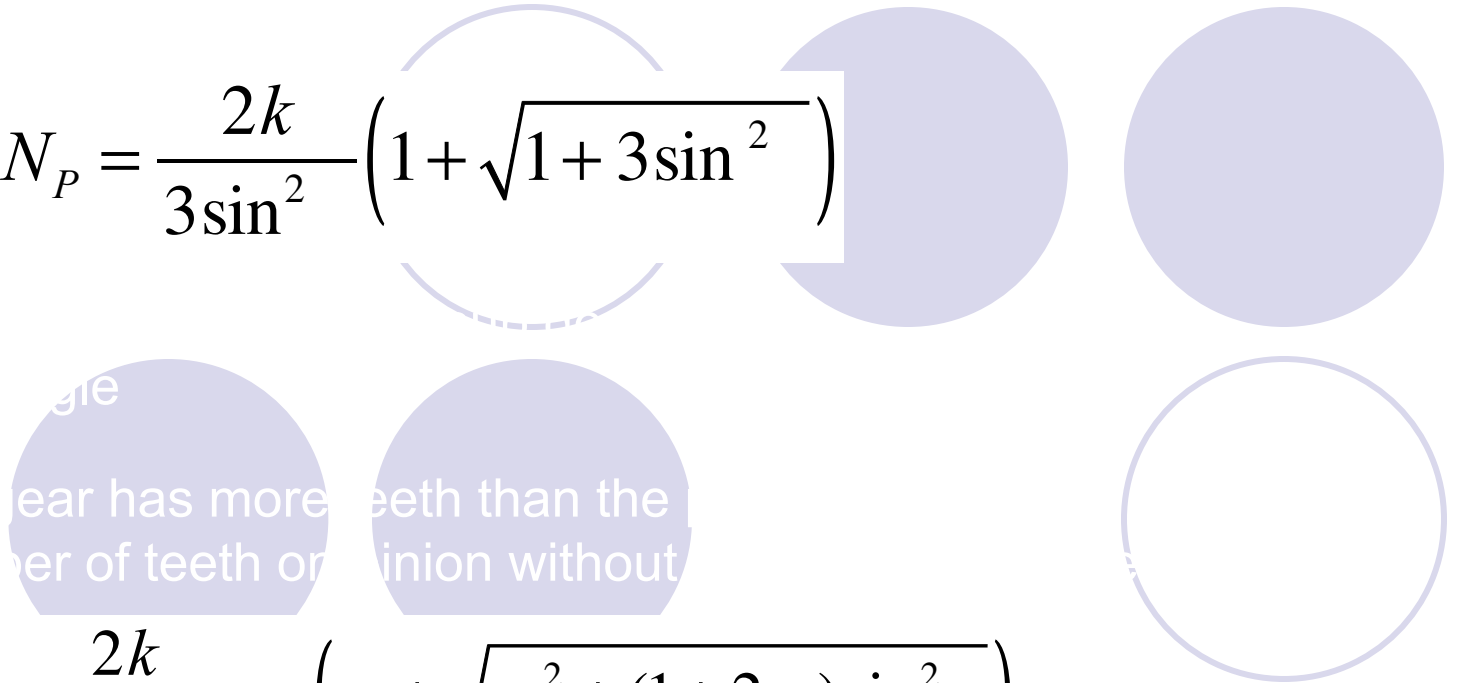
# Undercutting: Profile Shifted Teeth

- Another option to avoid undercutting is the addendum can be increased on pinion and decreased on gear to avoid undercutting



# To avoid undercutting

$$N_P = \frac{2k}{3\sin^2} \left( 1 + \sqrt{1 + 3\sin^2} \right)$$



$$N_P = \frac{2k}{(1 + 2m)\sin^2} \left( m + \sqrt{m^2 + (1 + 2m)\sin^2} \right)$$

$$m = \frac{N_G}{N_P}$$

# Forming of Gear teeth



- Gear teeth can be formed with large number of ways
  - Sand casting
  - Shell molding
  - Investment casting
  - Centrifugal casting
  - Permanent-mold casting
- Teeth can also be formed using powder metallurgy process
- Or by using extrusion
- Gears that carry large loads in comparison with their sizes are usually made of steel and are cut with either form cutters or generating cutters



# Form and generating cutting

- In form cutting, a tooth space takes the exact form of the cutter
- In generating cutting, a tool having a shape different from tooth profile is moved relative to the gear blank so as to obtain the proper tooth shape

# Cold forming or Cold rolling



- One of the newest and most promising methods
- Dies are rolled against steel blanks to form the teeth
- The mechanical properties of the metal are greatly improved by the rolling process, and a high quality generated profile is obtained at the same time

# Machining and Molding

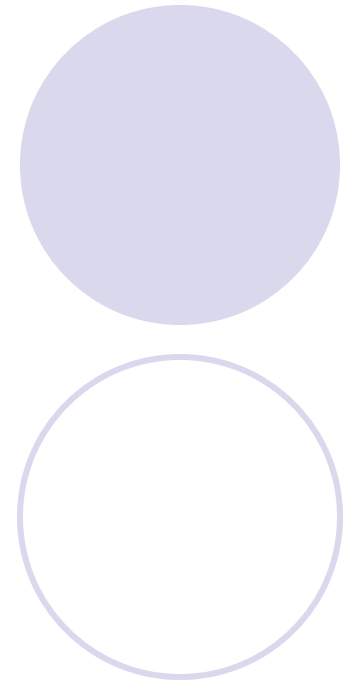
- Gear teeth may be machined by milling, shaping or hobbing, they may be finish by shaving, burnishing, grinding or lapping
- Gears made of thermoplastics such as nylon, polycarbonate, acetal are quite popular and are easily manufactured by injection molding: these gears are of low to moderate precision, low in cost for high production quantities, and capable of light loads, and can run without lubricant



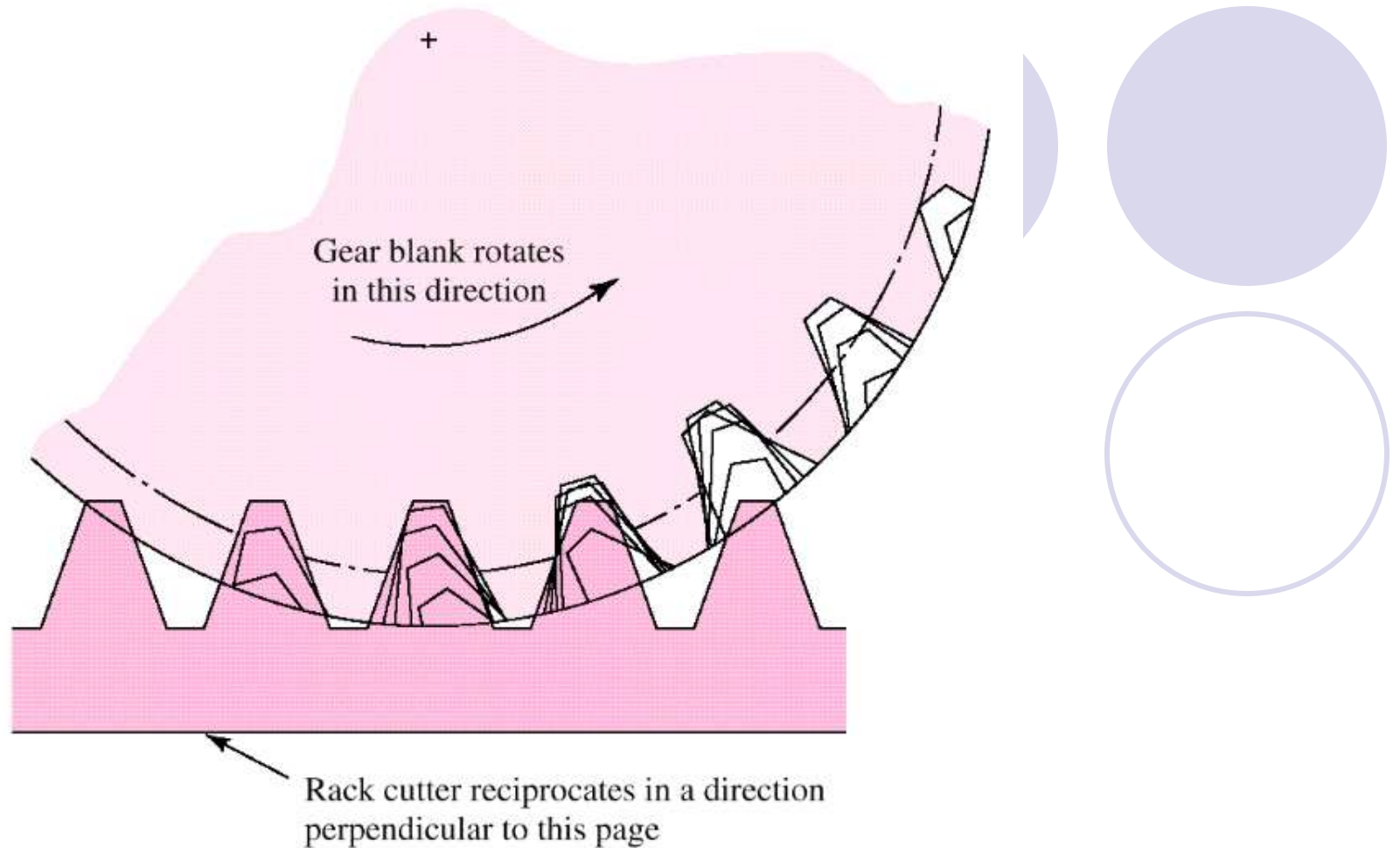
# Making of Gear



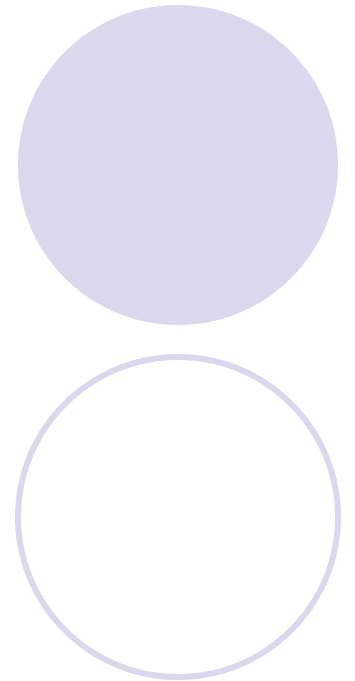
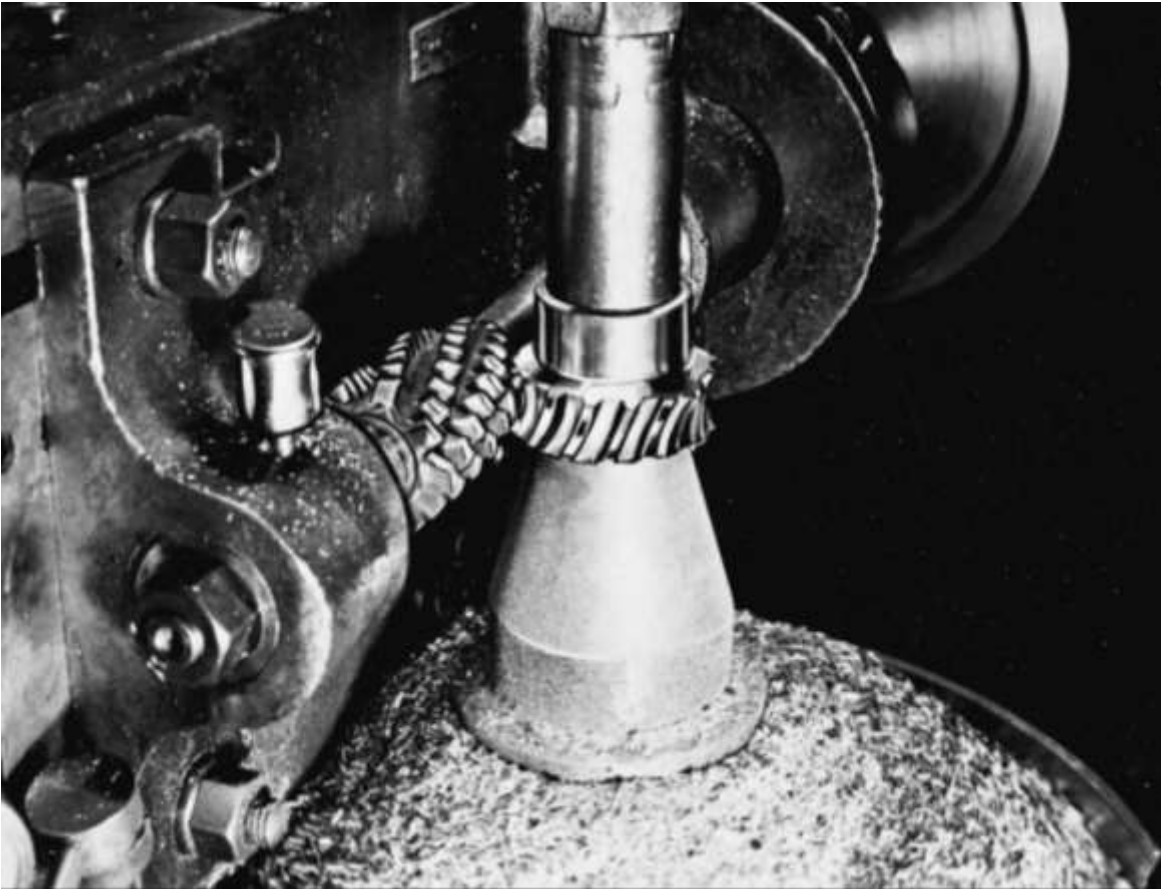
# Generating a spur gear with a pinion cutter



# Shaping Operating: Shaping teeth with a rack



# Hobbing



The hobbing process is illustrated in Fig. 13–20. The hob is simply a cutting tool which is shaped like a worm. The teeth have straight sides, as in a rack, but the hob axis must be turned through the lead angle in order to cut spur-gear teeth.