

Design of Machines and Mechanical Systems (PC-BTM711)

Session 04

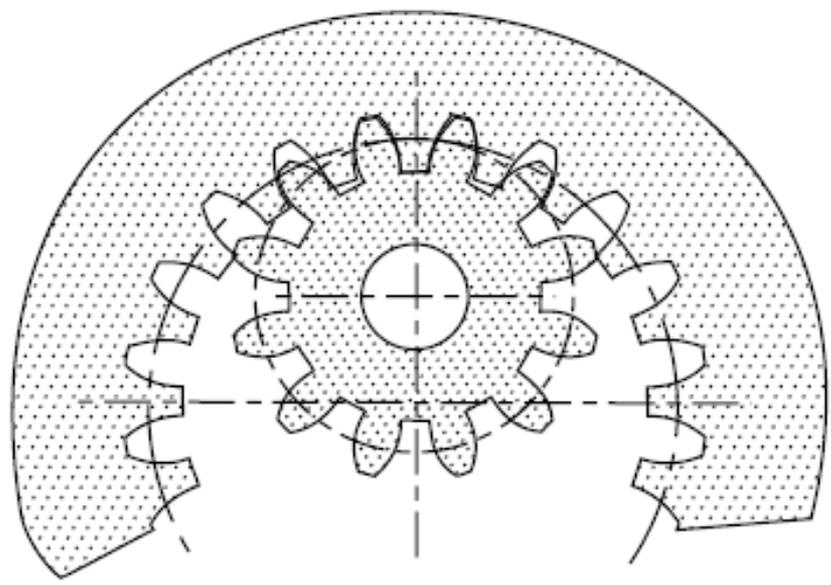
Module 1: Spur gear misc. topics
and
Helical gear design

Session Outcomes

- Discuss internal gears
- Explain gear lubrication
- Discuss AGMA gear design procedure
- Introduction to helical gears
- Analysis of forces on helical gear tooth
- Design calculations for helical gears

Design of Internal Gears

- Advantages and Disadvantages of Internal gears
- Difference in design approach from external gears
 - To avoid interference $z_g \gg z_f$
 - Need to check against beam and wear strength only for pinion



Ref: Bhandari V.B., Design of Machine Elements (2017)

SELF-STUDY

Gear Lubrication

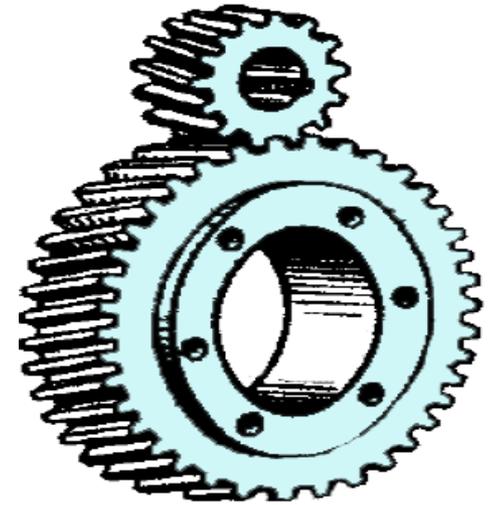
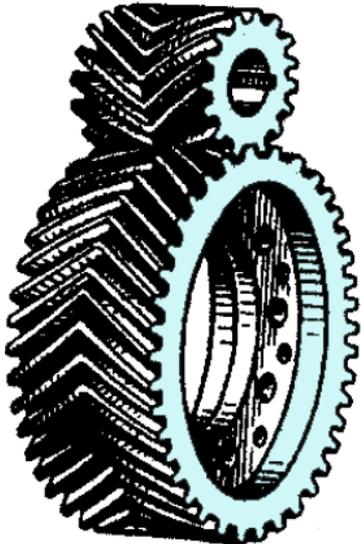
- Grease
- Straight mineral oil
- EP lubricant

AGMA Gear Design

Refer to extract from textbook “Shigley, Joseph E., Charles R. Mischke, and Richard G. Budynas. Mechanical engineering Design. McGraw-Hill, 2014”

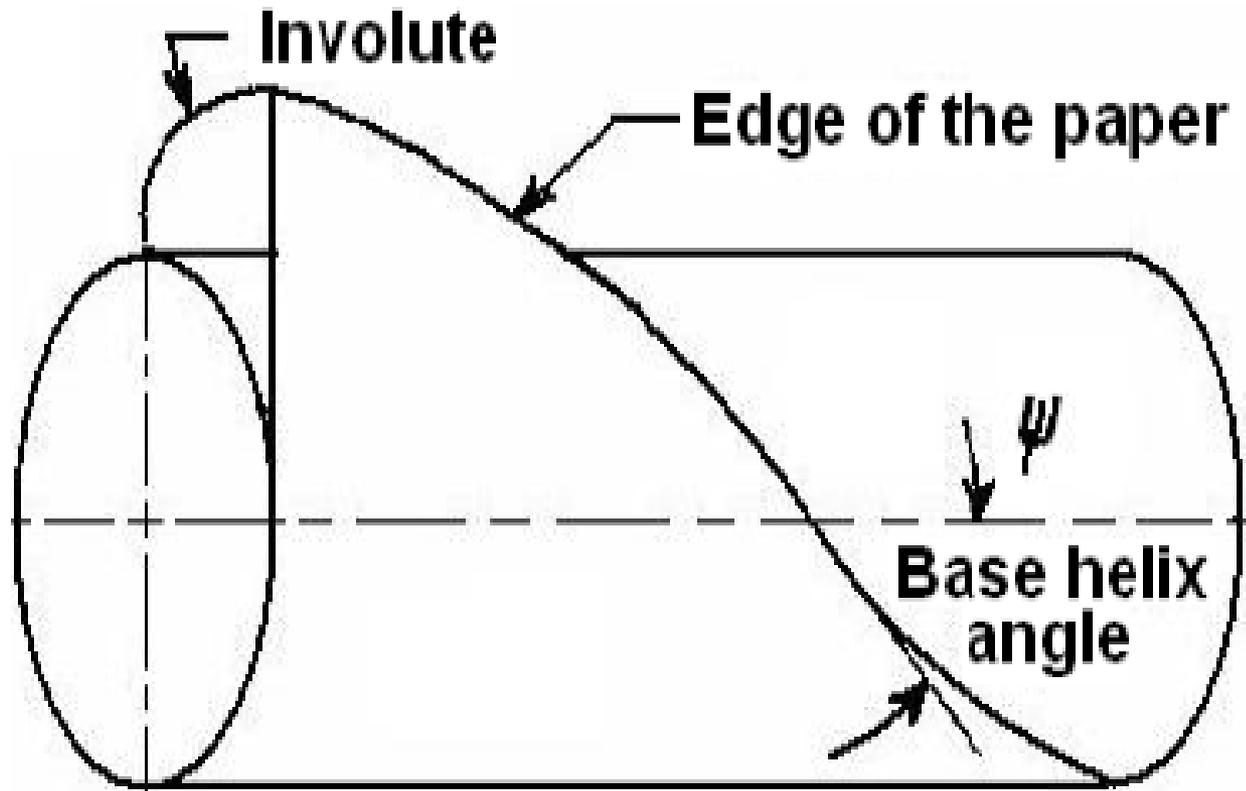
Helical Gears

- Types of Helical Gears
 - Parallel Helical Gears
 - Crossed Helical Gears
 - Herringbone gears



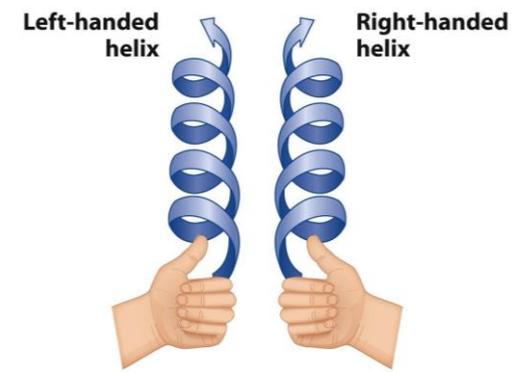
Credits: NPTEL course by Prof. K.Gopinath & Prof. M.M.Mayuram

Involute Helicoid Tooth Surface



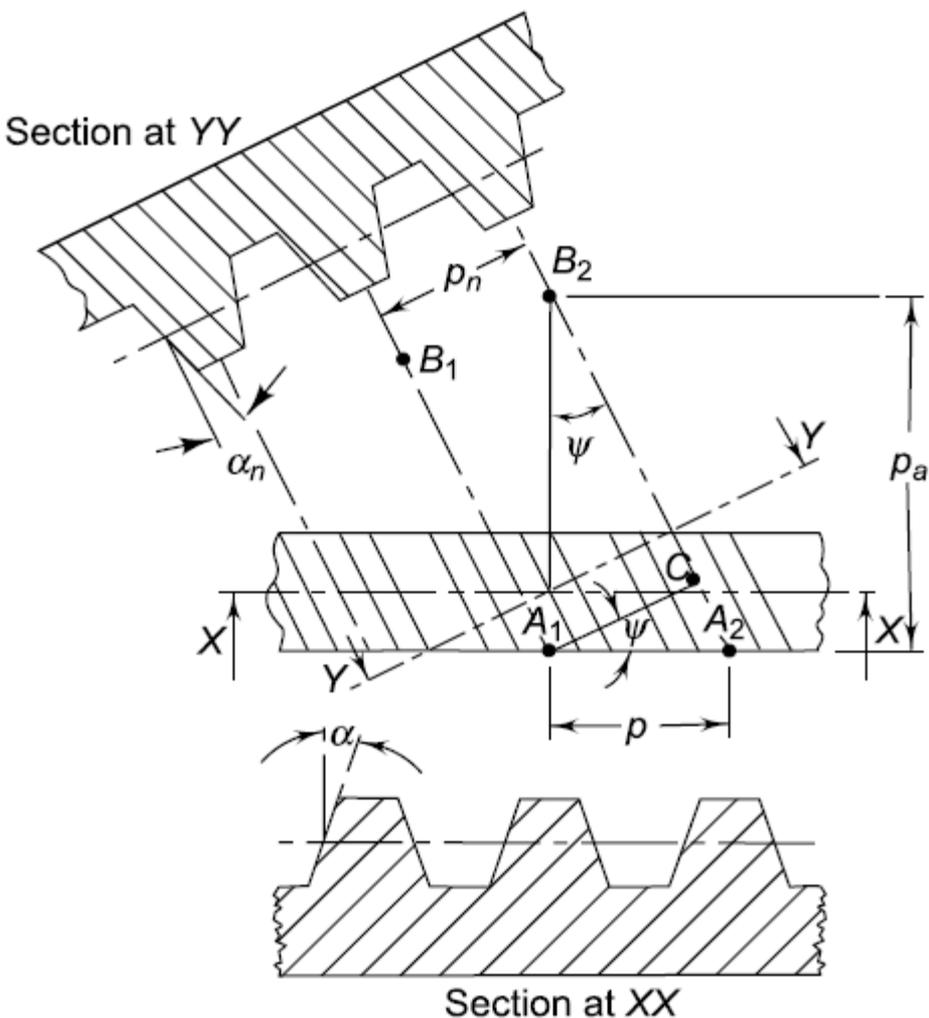
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Contact develops from point to line -> smooth operation



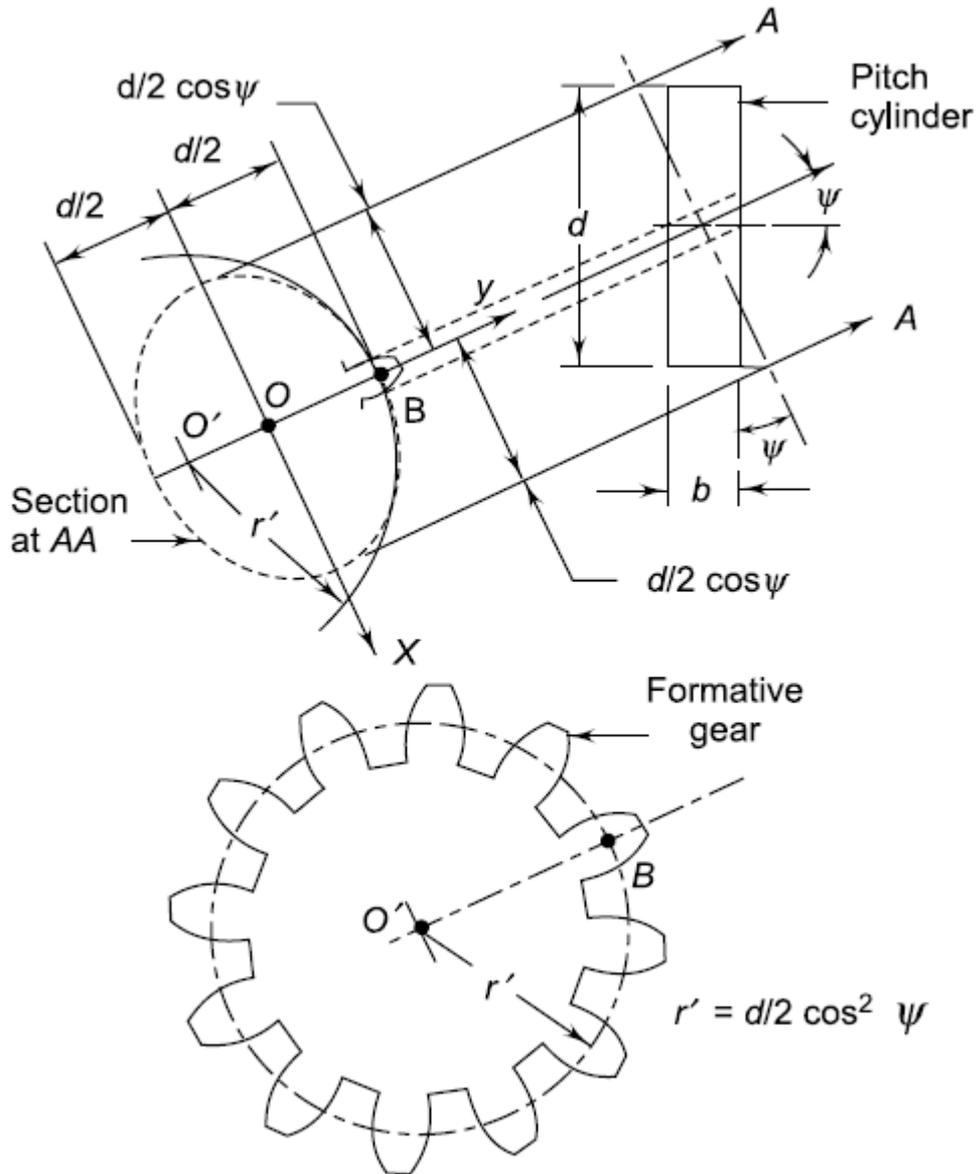
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Tooth Relationships

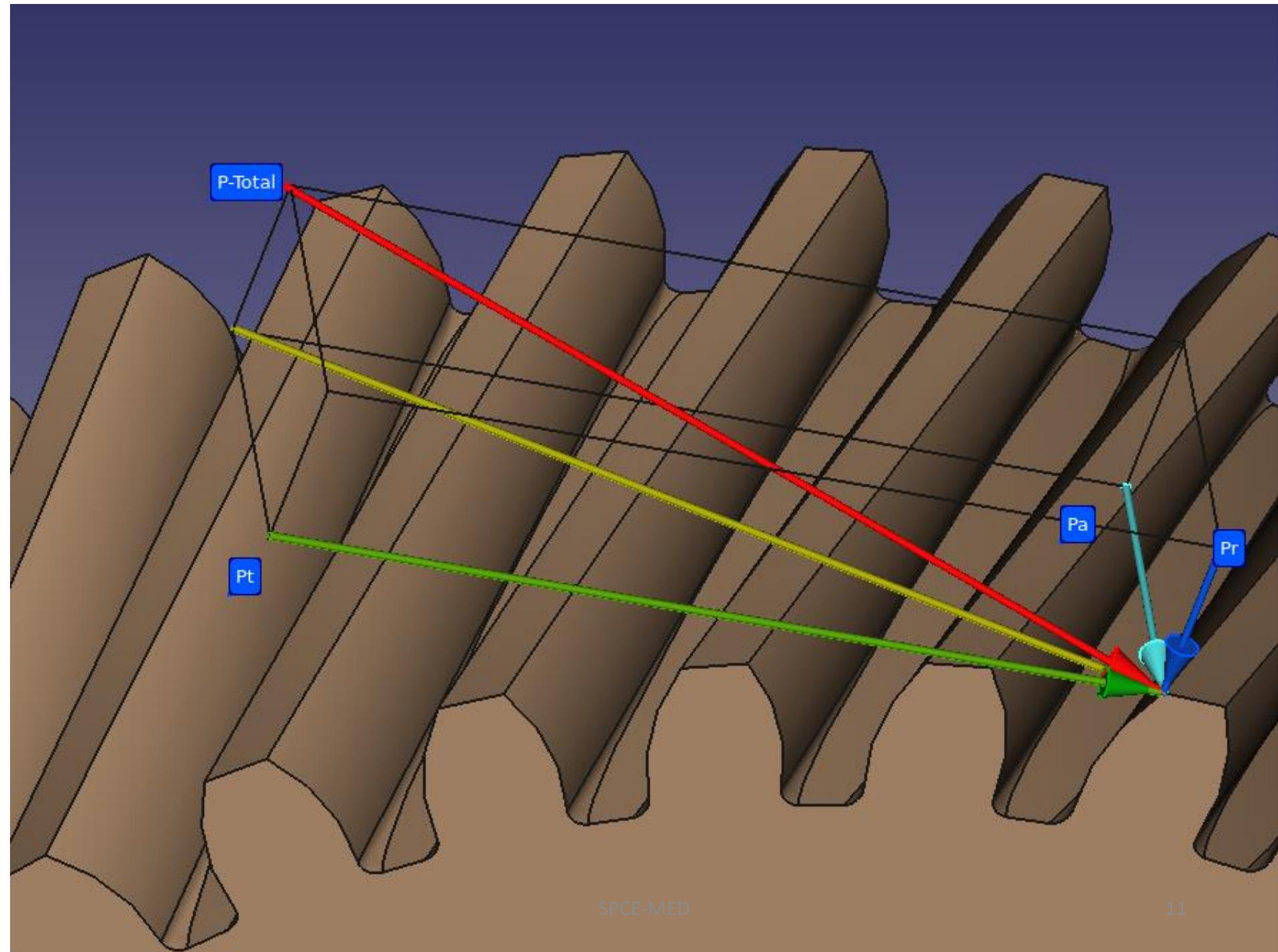


$p_n = p \cos \psi$	p_n = normal circular pitch (mm) p = transverse circular pitch (mm) ψ = helix angle (deg) (15° to 25°)
$P_n = \frac{P}{\cos \psi}$	P_n = normal diametral pitch (mm) P = transverse diametral pitch (mm)
$m_n = m \cos \psi$	m_n = normal module (mm) m = transverse module (mm)
$p_a = \frac{P}{\tan \psi}$	p_a = axial pitch (mm)
$\cos \psi = \frac{\tan \alpha_n}{\tan \alpha}$	α_n = normal pressure angle ($^\circ$) (usually 20°) α = transverse pressure angle ($^\circ$)
$d = \frac{z m_n}{\cos \psi}$	d = pitch circle diameter (mm) z = number of teeth
$a = \frac{m_n (z_p + z_g)}{2 \cos \psi}$	a = centre-to-centre distance (mm) z_p = number of teeth on pinion z_g = number of teeth on wheel
$i = \frac{\omega_p}{\omega_g} = \frac{z_g}{z_p}$	i = speed ratio

Virtual or Formative Teeth



$$z' = \frac{z}{\cos^3 \psi}$$



Helical Gear – Design Equations

Table 18.6 *Beam strength of gear tooth (Lewis' equation)*

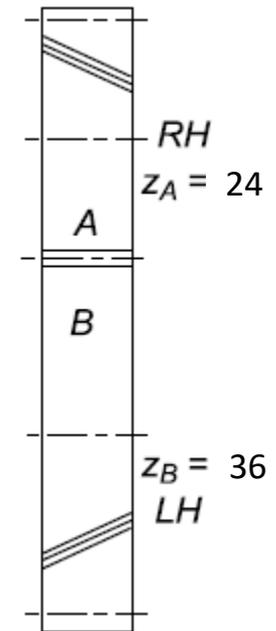
Beam strength (S_b) indicates the maximum value of tangential force that the tooth can transmit without bending failure.	
$S_b = m_n b \sigma_b Y \quad (18.17)$	S_b = beam strength of gear tooth (N) σ_b = permissible bending stress (MPa or N/mm ²) Y = Lewis form factor based on virtual number of teeth (z') (Table 17.15)
$\sigma_b = S_e = \left(\frac{1}{3}\right) S_{ut} \quad (18.18)$	S_e = endurance limit (MPa or N/mm ²) S_{ut} = ultimate tensile strength (MPa or N/mm ²)

Table 18.7 *Wear strength of gear tooth (Buckingham's equation)*

Wear strength (S_w) indicates the maximum value of tangential force that the tooth can transmit without pitting failure.	
$S_w = \frac{b Q d_p K}{\cos^2 \psi} \quad (18.19)$	S_w = wear strength of the gear tooth (N) Q = ratio factor d_p = pitch circle diameter of pinion (mm) K = load – stress factor (MPa or N/mm ²) ψ = helix angle (°)

Ex.1: Force Analysis for helical gears

A pair of parallel helical gears are shown in figure. A 6 kW power at 800 rpm is supplied to pinion 'A' through its shaft. Normal module is 5 mm and normal pressure angle is 20 deg. The pinion has right handed teeth while gear is left handed. The helix angle is 30 deg. The pinion rotates in clockwise direction when seen from left side of figure. Determine the tooth force components.



Ex.2: Strength Design for helical gears

A pair of parallel helical gears consists of a 24 teeth pinion meshing with 120 teeth gear. The pinion rotates at 600 rpm. The normal pressure angle is 20 deg., helix angle is 30 deg. The face width is 50 mm and the normal module is 5 mm.

The pinion as well as gear is made of forged steel with UTS = 600 MPa and heat treated to surface hardness of 350 BHN. The service factor and factor of safety are 1.25 and 2.5 respectively.

Assume that velocity factor accounts for the dynamic load and calculate the power transmitting capacity of the gears.