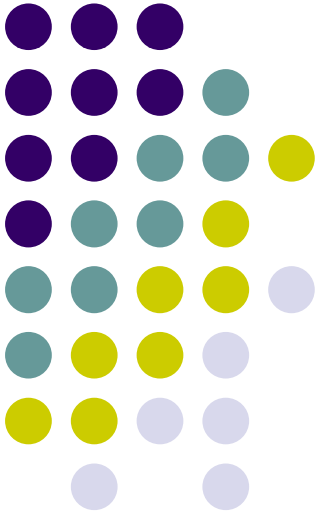
ME 472 – Engineering Metrology and Quality Control

Chp 10 - Measurement of Gears



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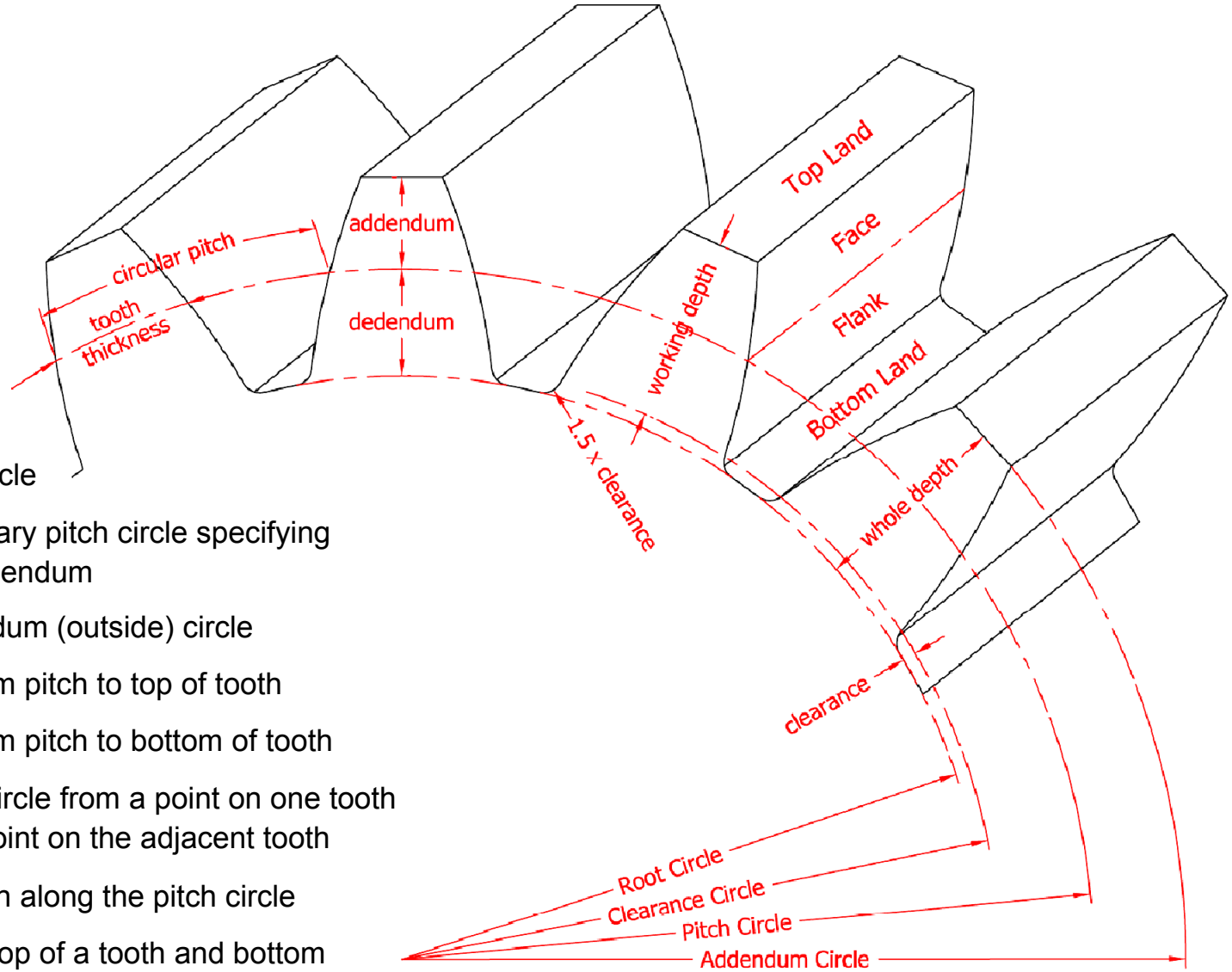
Gear Tooth Terminology



Root Diameter : Diameter of root circle

Pitch Diameter : Diameter of imaginary pitch circle specifying addendum and dedendum

Outside Diameter : Diameter of addendum (outside) circle

Addendum : Radial distance from pitch to top of tooth

Dedendum : Radial distance from pitch to bottom of tooth

Circular Pitch : Distance on pitch circle from a point on one tooth to corresponding point on the adjacent tooth

Tooth Thickness : Thickness of a tooth along the pitch circle

Clearance : Distance between top of a tooth and bottom of mating space

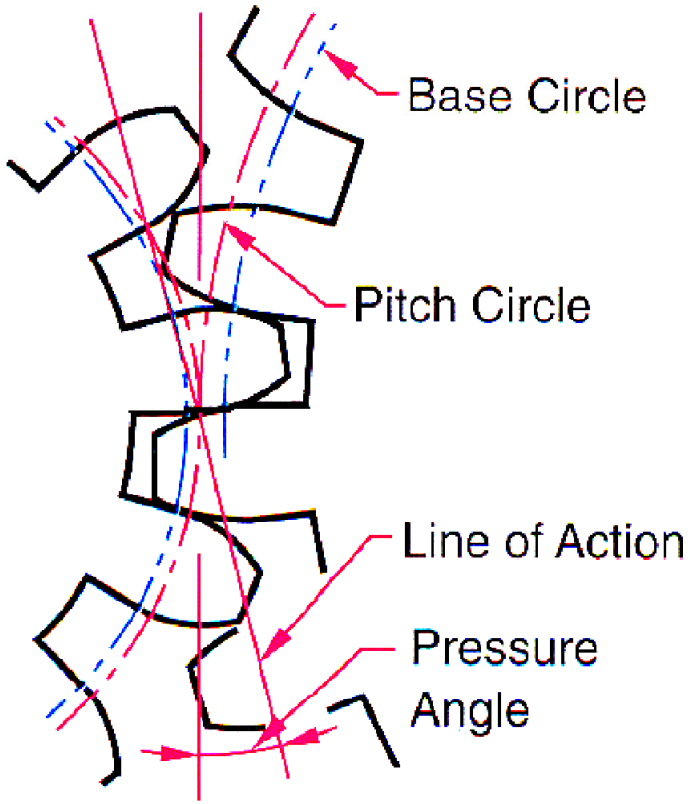
Working Depth : Distance a tooth projects into mating space

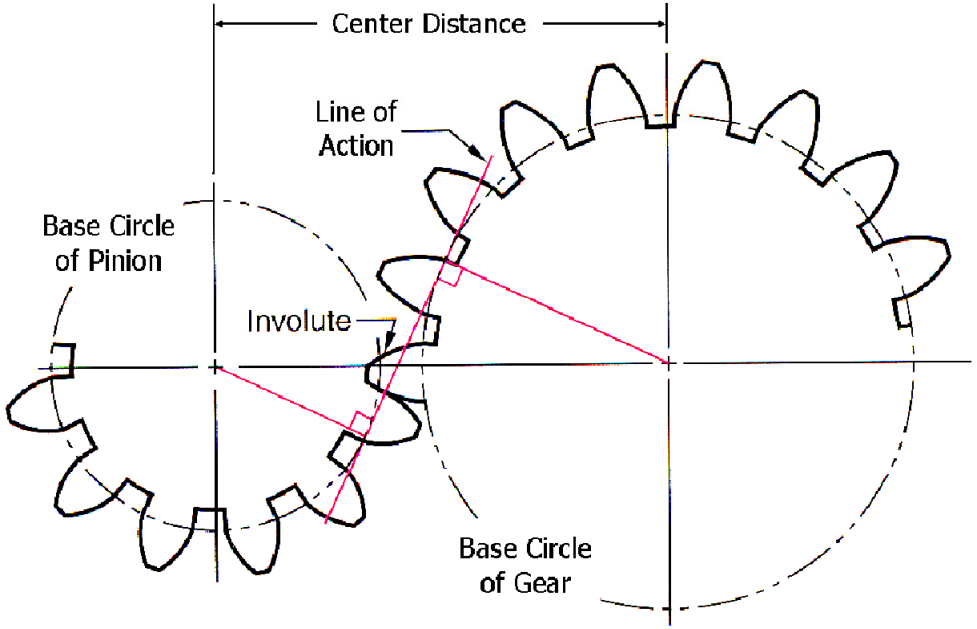
Whole Depth: Total height of the tooth

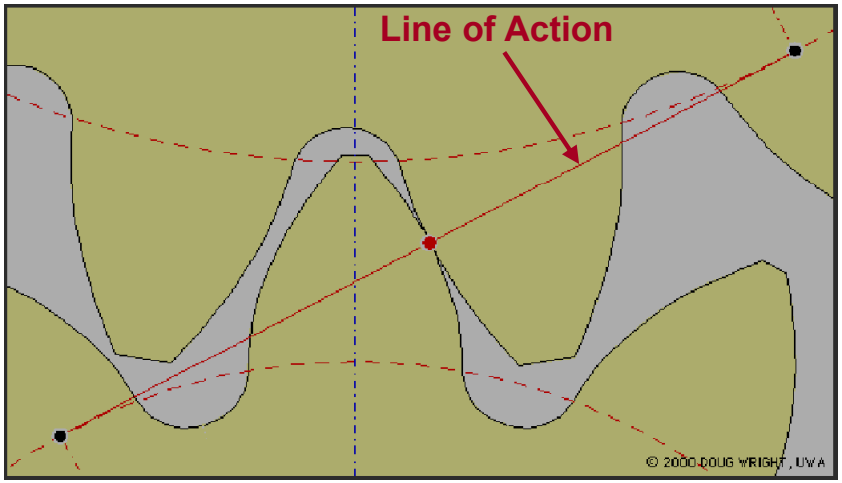
Face width: The width of the tooth

Gear Meshing

- Two gears having an identical module can be meshed. Meshing of two spur gears with a center distance is shown below.
- The **line of action** (also known as **"pressure line"**) is a line drawn tangent to the base circle of pinion and gear.
- When two gear teeth are in contact, the kinematic principle of gearing is demonstrated: the angular velocity ratio of the meshing gears is constant along the line of action.
- The **pressure angle** is the angle between the tangent to the pitch circles and the line of action.
- Gear catalogs are **classified according to the number of teeth and the pressure angle**.



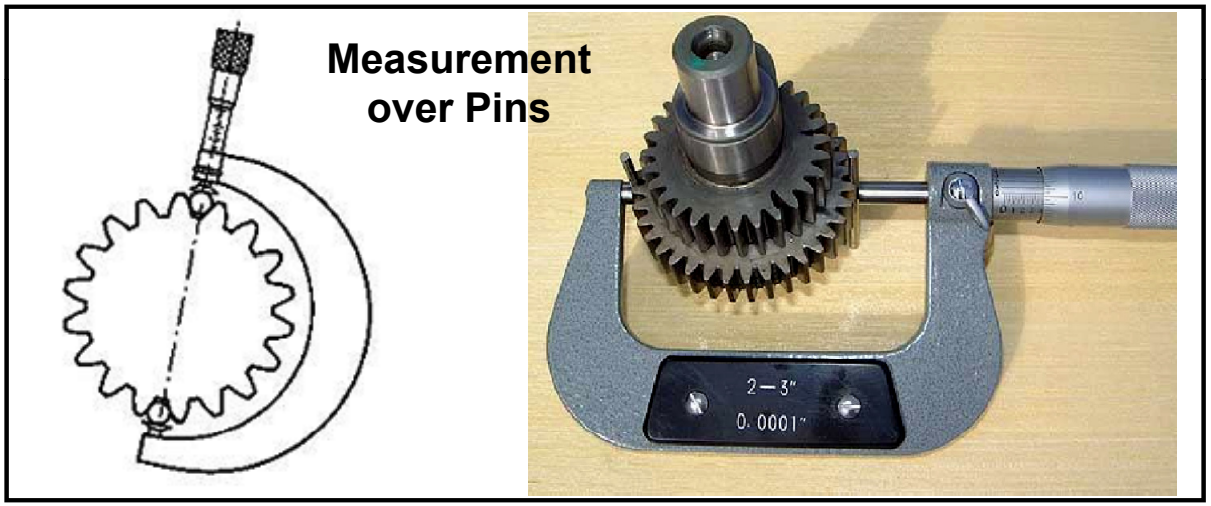


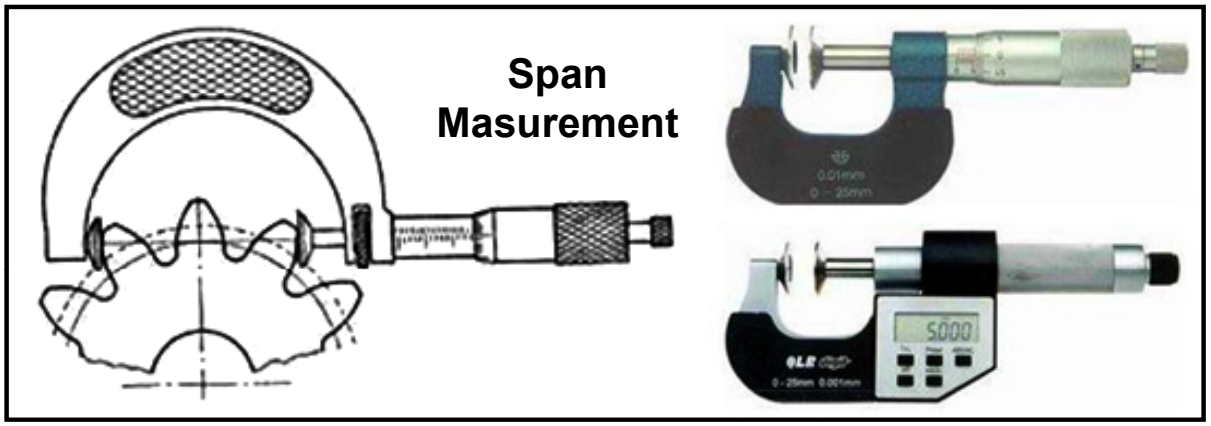


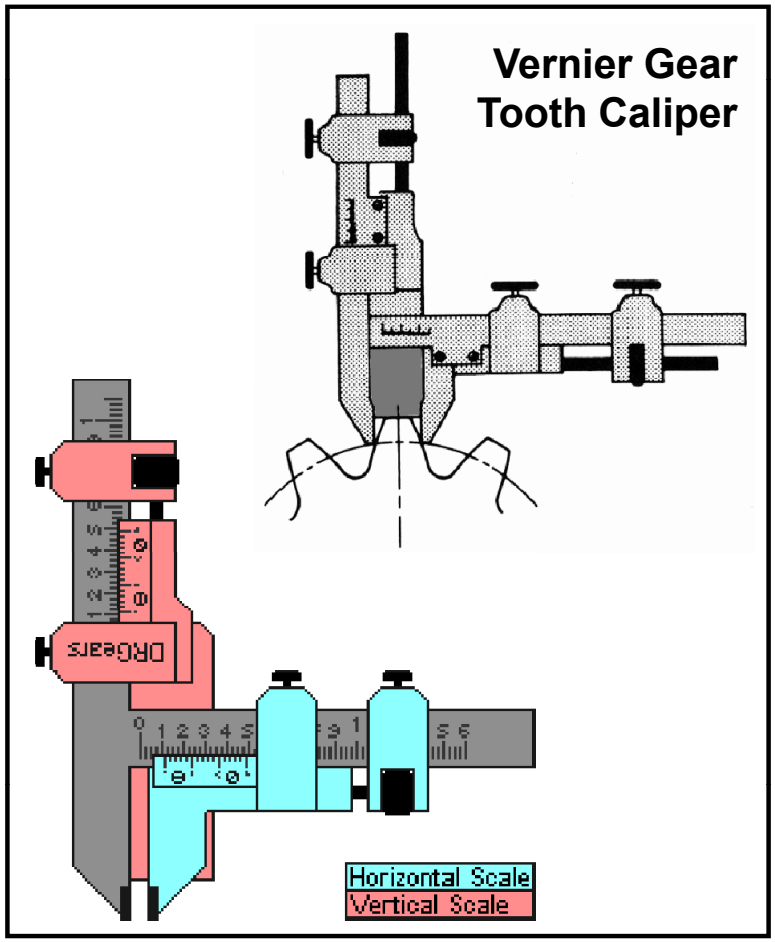
Tooth Thickness Measurement

The measurement of tooth thickness is a common feature for gears to be checked using following methods (see the standards by **American Gear Manufacturers Association – www.agma.org**):

- **Measurement over Pins:** Special size pins are placed between the teeth, and the distance between pins are measured (**AGMA 231.52** for spur gears and **AGMA 239.03** for helical gears).
- **Vernier Gear Tooth Caliper:** The chordal tooth thickness and height are measured.
- **Span Measurement:** The distance between a number of teeth is measured (**AGMA 239.01**)







Measurement using Vernier Gear Tooth Caliper

Chordal thickness (X) and height (Y) are:

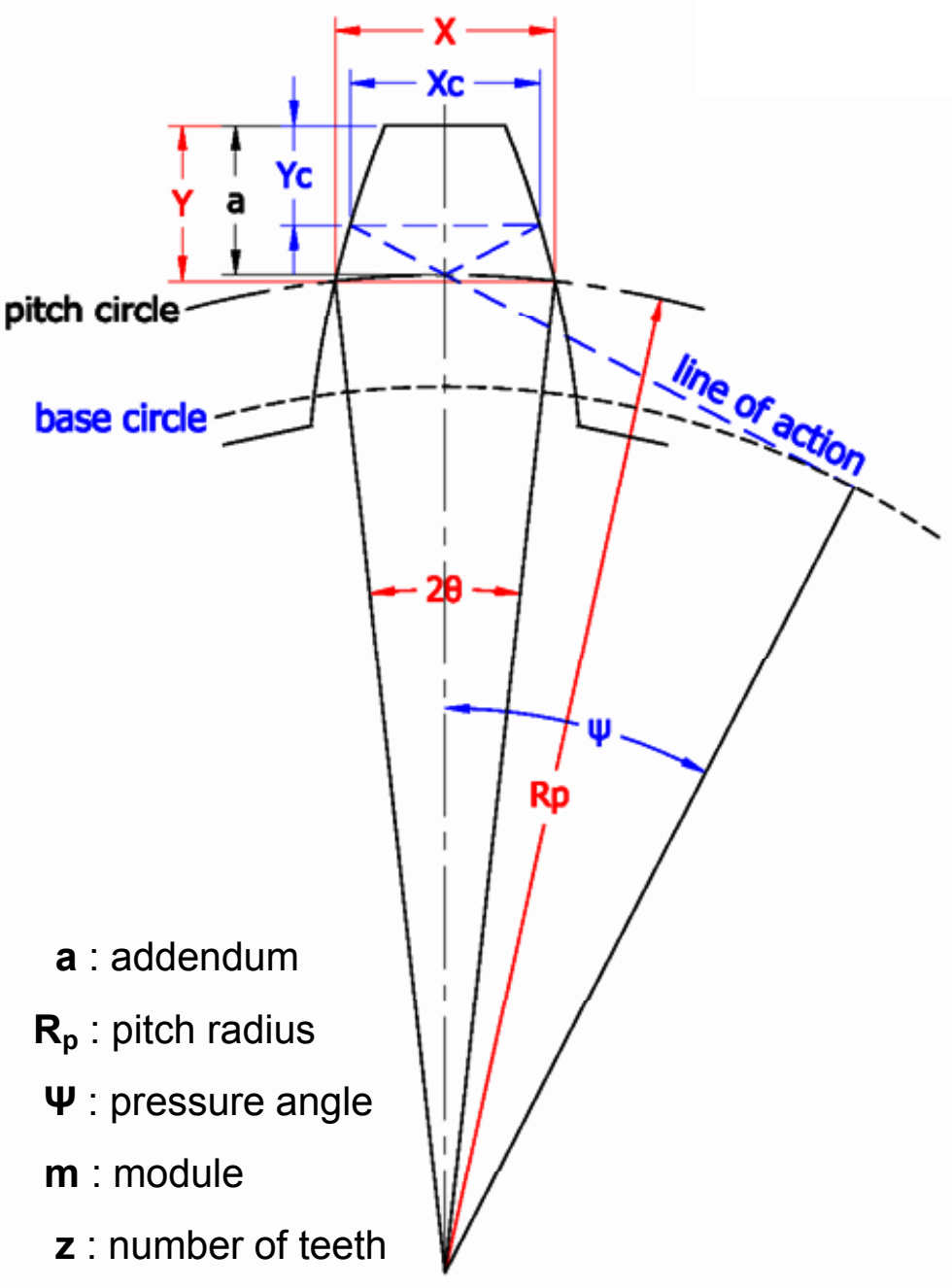
$$X = 2R_p \sin\theta \quad \text{and} \quad Y = a + R_p(1-\cos\theta)$$

where $a = \frac{2R_p}{z}$ and $\theta = \frac{\pi}{2z} = \frac{90°}{z}$

If a large number of gears (each having different no. of teeth) are to be measured, the calculations would become laborious. So, **constant chord thickness (X_c) and height (Y_c)** are calculated **as independent from no. of teeth**:

$$X_C = \frac{\pi m}{4}\cos^2\psi \quad \text{and} \quad Y_C = m - \frac{\pi m}{8}\sin 2\psi$$

Constant chord is defined as the chord joining points on opposite faces of tooth which make contact with the mating teeth at the line of action. It should be noted that the above formulae are for spur gears. For **helical gears**, the **normal module (m_n)** must be employed in calculations.



a : addendum

R_p : pitch radius

Ψ : pressure angle

m : module

z : number of teeth

Measurement over Pins

The **tooth thickness** is found as:

$$t = D_p\left(inv\,e - inv\,\psi - \frac{D_g}{D_p * \cos\psi} + \frac{\pi}{z}\right)$$

The **measurement over pins** equals to:

For z is even: $H_e = 2h + D_g$

For z is odd: $H_o = 2h * \cos(90/z) + D_g$

The **involute of angle e** is calculated by:

$$inv\,e = \tan e - (e * \pi/180)$$

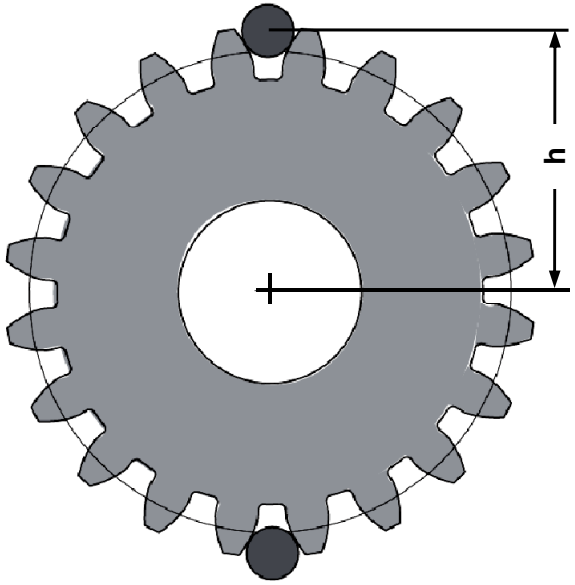
The **angle e** is calculated as:

For z is even: $e = \arccos\left(\frac{z * \cos\psi}{D_p(H_e - D_g)}\right)$

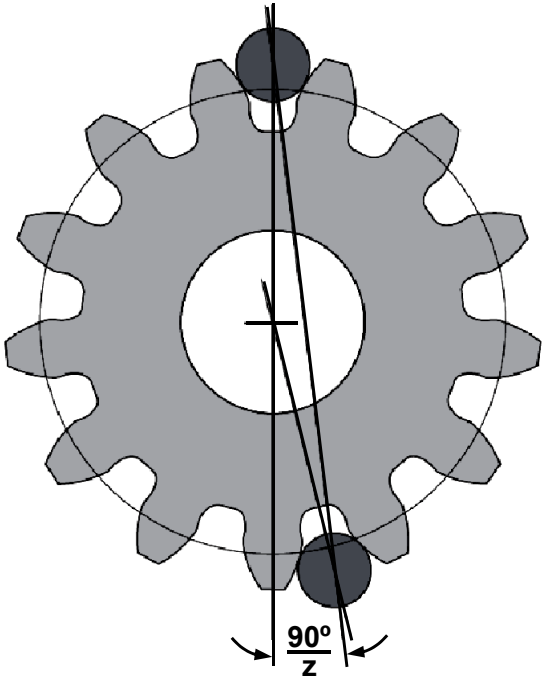
For z is odd: $e = \arccos\left(\frac{z * \cos\psi}{D_p(H_o - D_g)} * \cos\left(\frac{90}{z}\right)\right)$

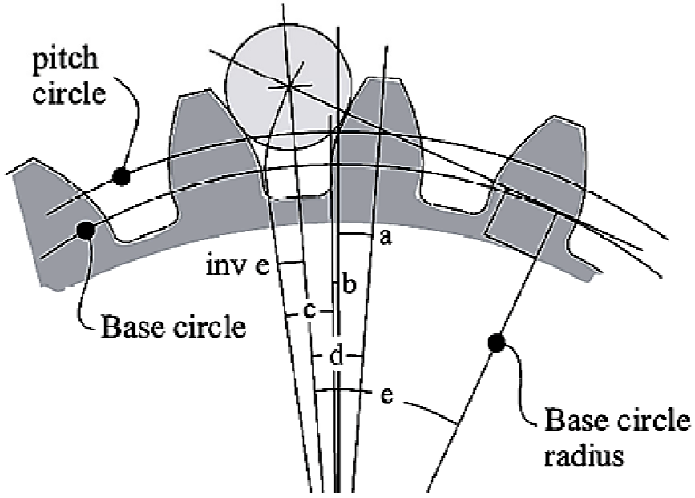
The **pin diameter** is specified as $D_g = 13.58\,m$ for internal gears and $D_g = 13.97\,m$ for external gears.

Even number of teeth



Odd number of teeth





t : tooth thickness

D_p : pitch diameter

D_g : pin diameter

z : number of teeth

H : Distance over pins

m : Module

ψ : pressure angle

inv : involute of an angle

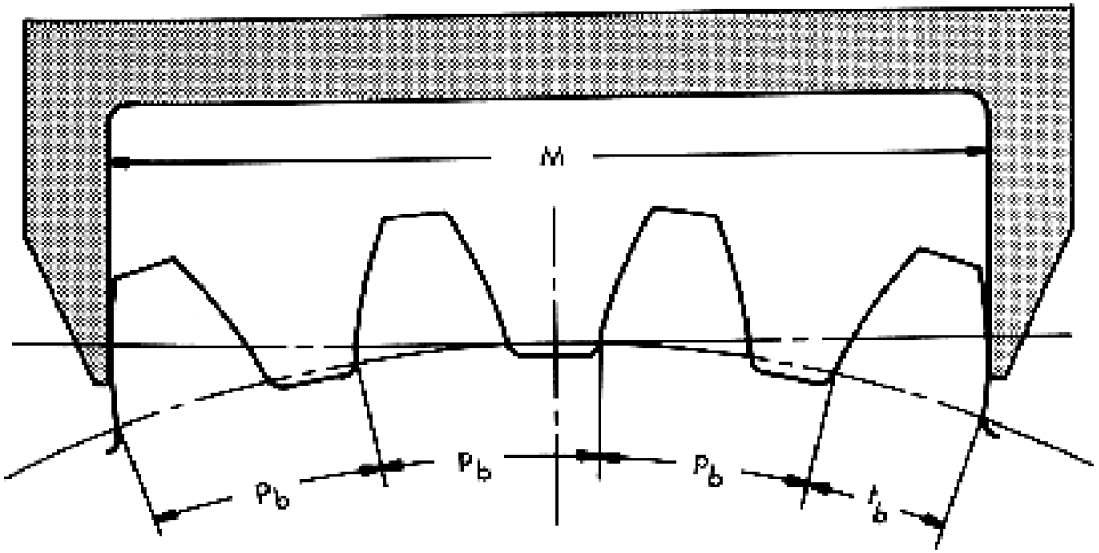
Span Measurement

The **distance M** is expressed as:

$$M = D_p * \cos\psi * \left(\frac{\pi}{2z} + inv\,\psi + \frac{\pi}{z} * s \right)$$

Hence, tooth thickness can be determined based on base circle pitch and measured distance of M.

It should be noted that the **module in normal plane (m_n)** and **pressure angle in normal plane (ψ_n)** must be employed in case of helical gears.



M : span distance
D_p : pitch diameter
ψ : pressure angle
z : number of teeth
s : number of tooth spaces within M
P_b : base circle pitch
t_b : tooth thickness at base circle

Comparison of Measurement Methods

METHOD	ADVANTAGES	DISADVANTAGES
Measurement over Pins	☺ Measurements are not affected by outside diameter variations and/or by runout of outside diameter.	☹ It is crucial that the most appropriate pins must be selected. For gears having non-standard features, the estimate of pin diameter may be a bottleneck.
Vernier Gear Tooth Caliper	☺ It is relatively cheaper and easier to use as compared to other methods.	☹ The precision of vernier caliper directly affects measurements. ☹ Measurements depend on two vernier readings, each of which is a function of each other. ☹ Measurements are made with an “edge” of the measuring jaw (not its “face”), which does not lend itself to accurate measurement.
Span Measurement	☺ Measurements are not affected by outside diameter variations and/or by runout of the outside diameter.	☹ It cannot be applied when a combination of high helix angle and narrow face width prevent the caliper from spanning a sufficient number of teeth. ☹ Readings are influenced by errors in base pitch and tooth profile. Readings would be erroneous if attempted on a portion of profile which had been modified from true involute shape.

Gear Tooth Profile Measurements using CMM