[ME 472]

Engineering Metrology & Quality Control

[CHAPTER 8]

Measurement of Gears

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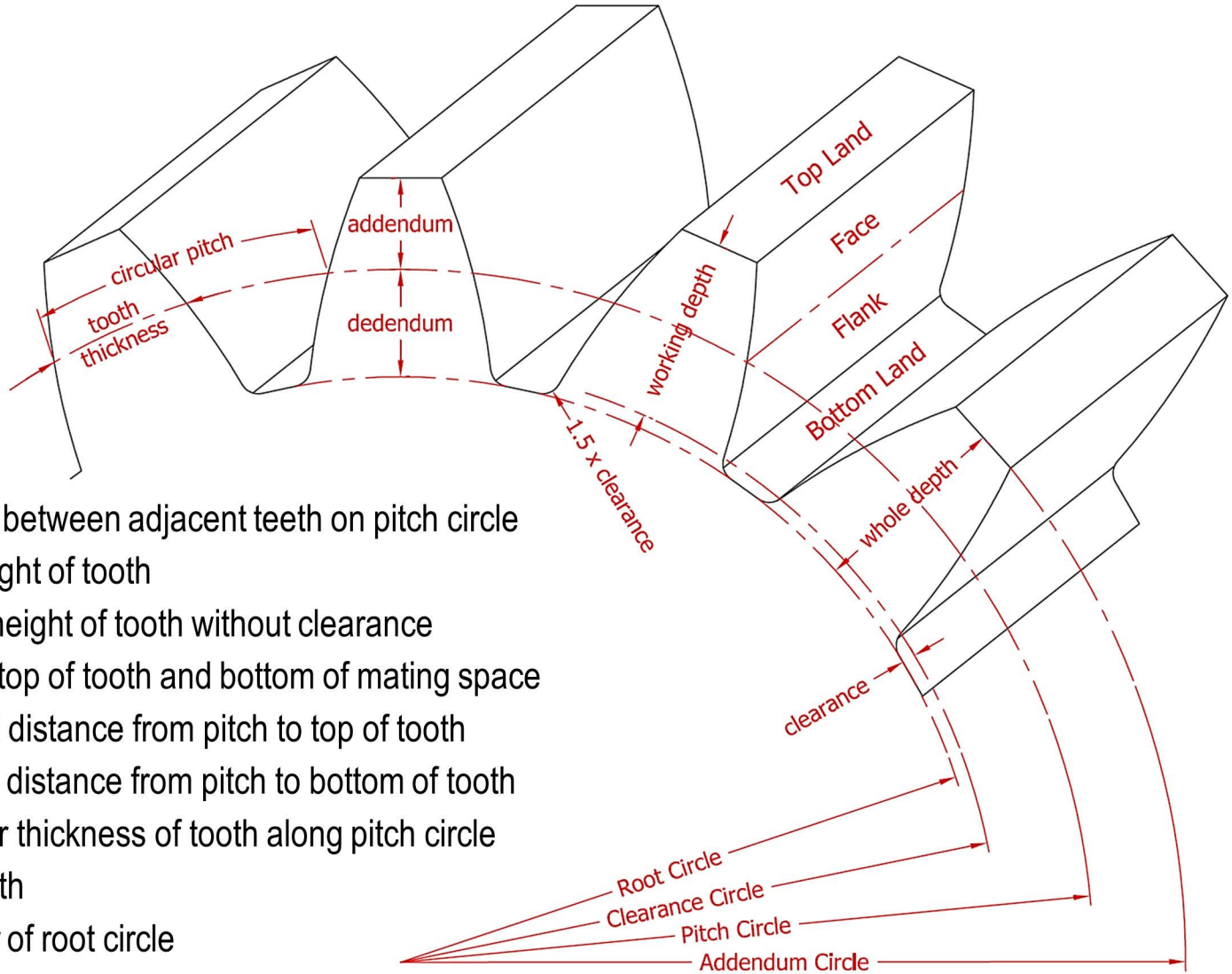
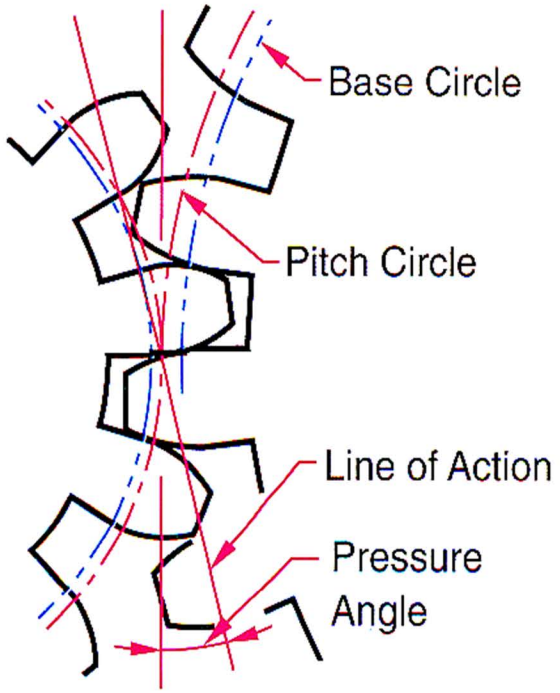


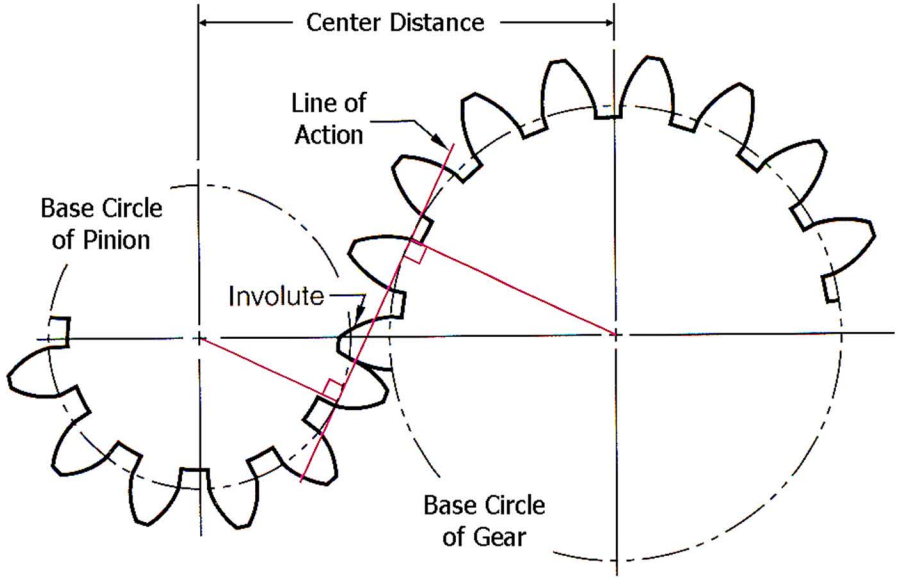
Terminology (Spur Gear)

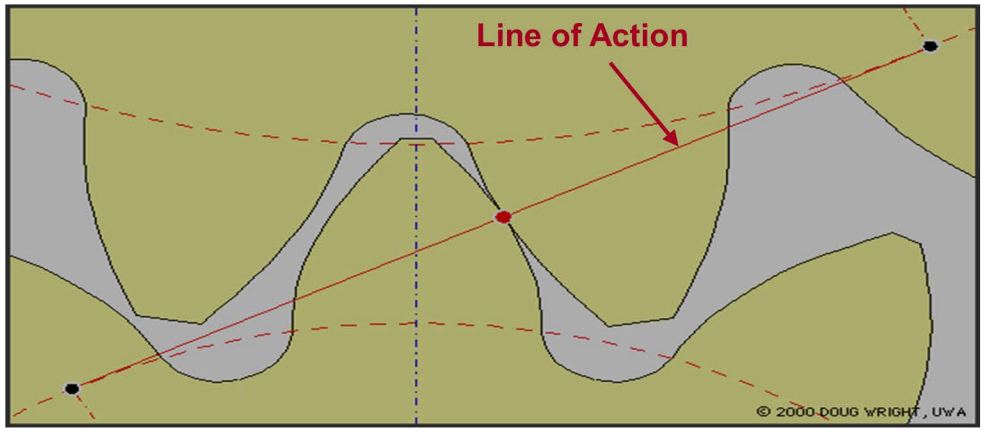
- **Circular Pitch (adım):** circular distance between adjacent teeth on pitch circle
- **Whole Depth (diş yüksekliği):** total height of tooth
- **Working Depth (çalışma yüksekliği):** height of tooth without clearance
- **Clearance (diş açıklığı):** distance from top of tooth and bottom of mating space
- **Addendum (diş üstü yükseklik):** radial distance from pitch to top of tooth
- **Dedendum (diş üstü yükseklik):** radial distance from pitch to bottom of tooth
- **Tooth Thickness (diş kalınlığı):** circular thickness of tooth along pitch circle
- **Face Width (diş genişliği):** width of tooth
- **Root Diameter (diş dibi çap):** diameter of root circle
- **Outside Diameter (diş üstü çap):** diameter of addendum circle
- **Pitch Diameter (bölüm çapı):** diameter of imaginary pitch circle

Meshing of Gears

- The standard gear size is defined by **module** & **number of teeth**.
- **Only the gears having identical module** can be meshed.
- Meshing of two spur gears with center distance is shown below (smaller one is called **"pinion"** whereas **"gear"** refers to the larger)
- **Line of action (pressure line)** is drawn tangent to the base circle of pinion and gear.
- The kinematic principle of gearing applies when gear teeth are in contact: **angular velocity ratio of the meshing gears is constant along the line of action**
- **Pressure angle** is the angle between tangent to the pitch circles and the line of action.

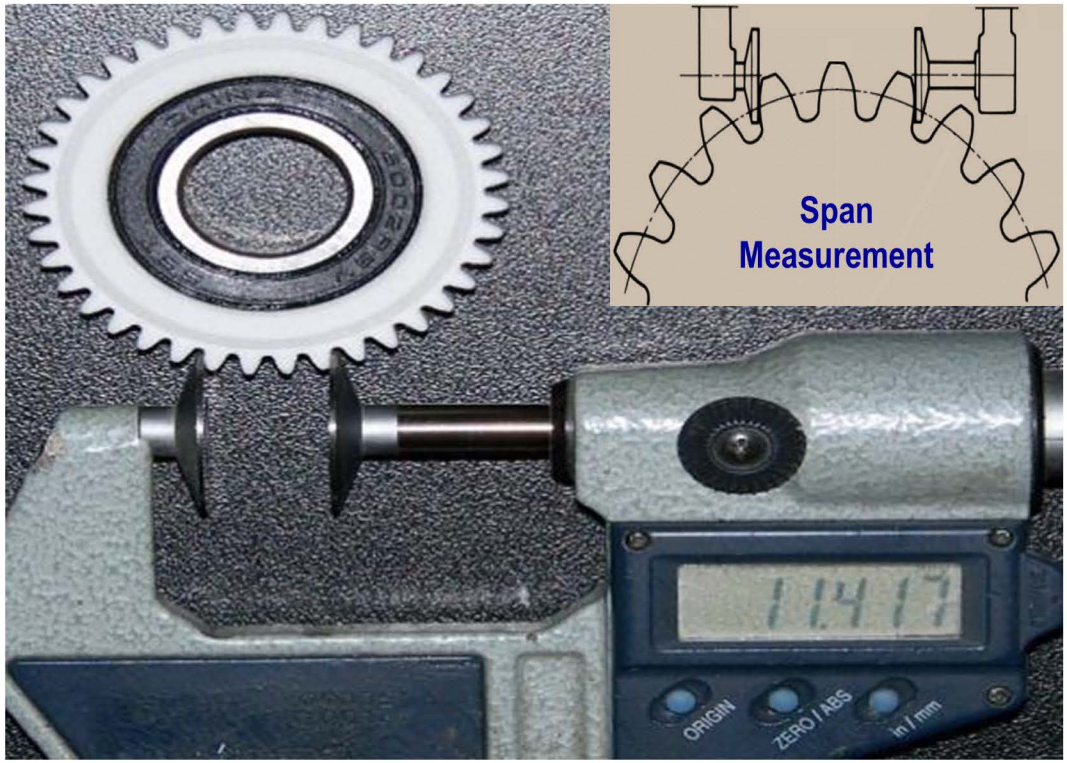


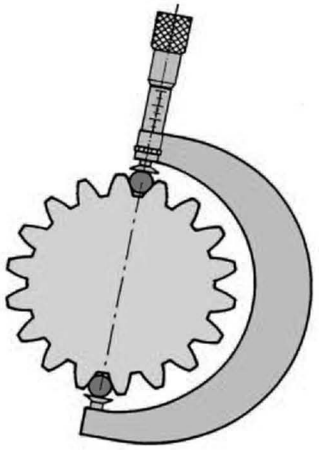




Measurement of Gears

- **Gear measurement** according to **ANSI/AGMA 2002-C16**:
  (standard by **American Gear Manufacturers Association**)
  - **Measurement over Pins:** distance over pins placed within teeth
  - **Gear Tooth Vernier Caliper:** chordal tooth thickness & height
  - **Span Measurement:** distance between a number of teeth





Measurement over Pins (Spur Gears)

- **Tooth Thickness (t)** is calculated by:

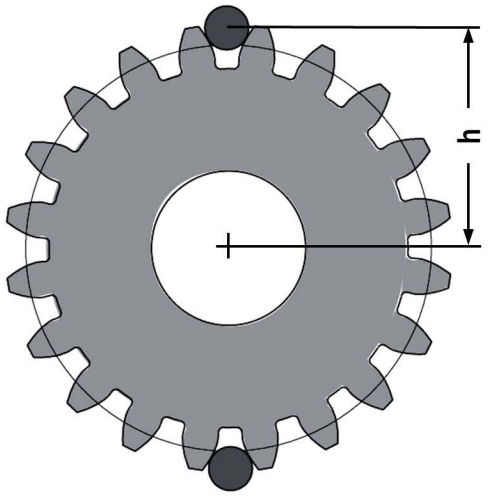
$$t = D_p\left[\text{inv}(e) - \text{inv}(\Psi) - \frac{D_g}{D_p * \cos(\Psi)} + \frac{\pi}{z}\right]$$

- **Pin Diameter (D_g)** is defined as:
  - External gears: $D_g = 13.97\ m$
  - Internal gears: $D_g = 13.58\ m$
- **Distance over Pins (H)** equals to:
  - Even no. of teeth: $H_e = 2h + D_g$
  - Odd no. of teeth: $H_o = 2h * \cos(90°/z) + D_g$
- **Involute of an angle** is found as:

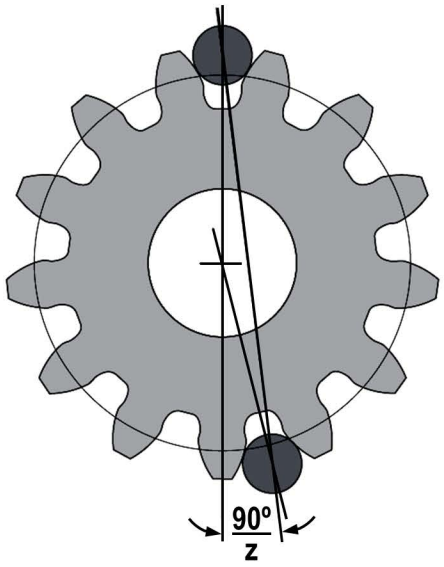
$$\text{inv}(x) = \tan(x) - [x * (\pi/180°)]$$

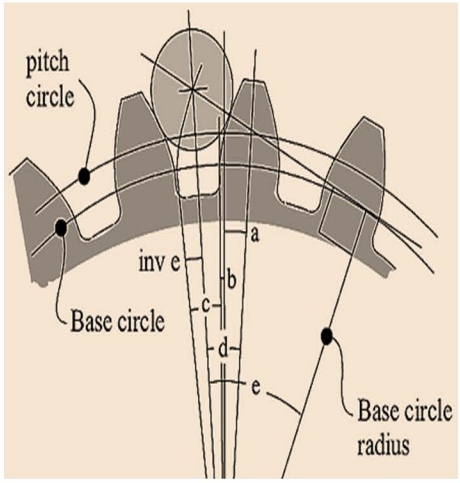
- **Angle "e"** is specified by:
  - Even no. of teeth: $e = \arccos\left[\frac{z * \cos(\Psi)}{D_p * (H_e - D_g)}\right]$
  - Odd no. of teeth: $e = \arccos\left[\frac{z * \cos(\Psi)}{D_p * (H_o - D_g)} * \cos\left(\frac{90°}{z}\right)\right]$

Even number of teeth



Odd number of teeth





t : tooth thickness
D_p : pitch diameter
D_g : pin diamater
H : distance over pins
z : number of teeth
m : module
Ψ : pressure angle
e : angle of pin location

Gear Tooth Vernier Caliper (Spur Gears)

- Usual practice is to measure **Chord Thickness & Height**:

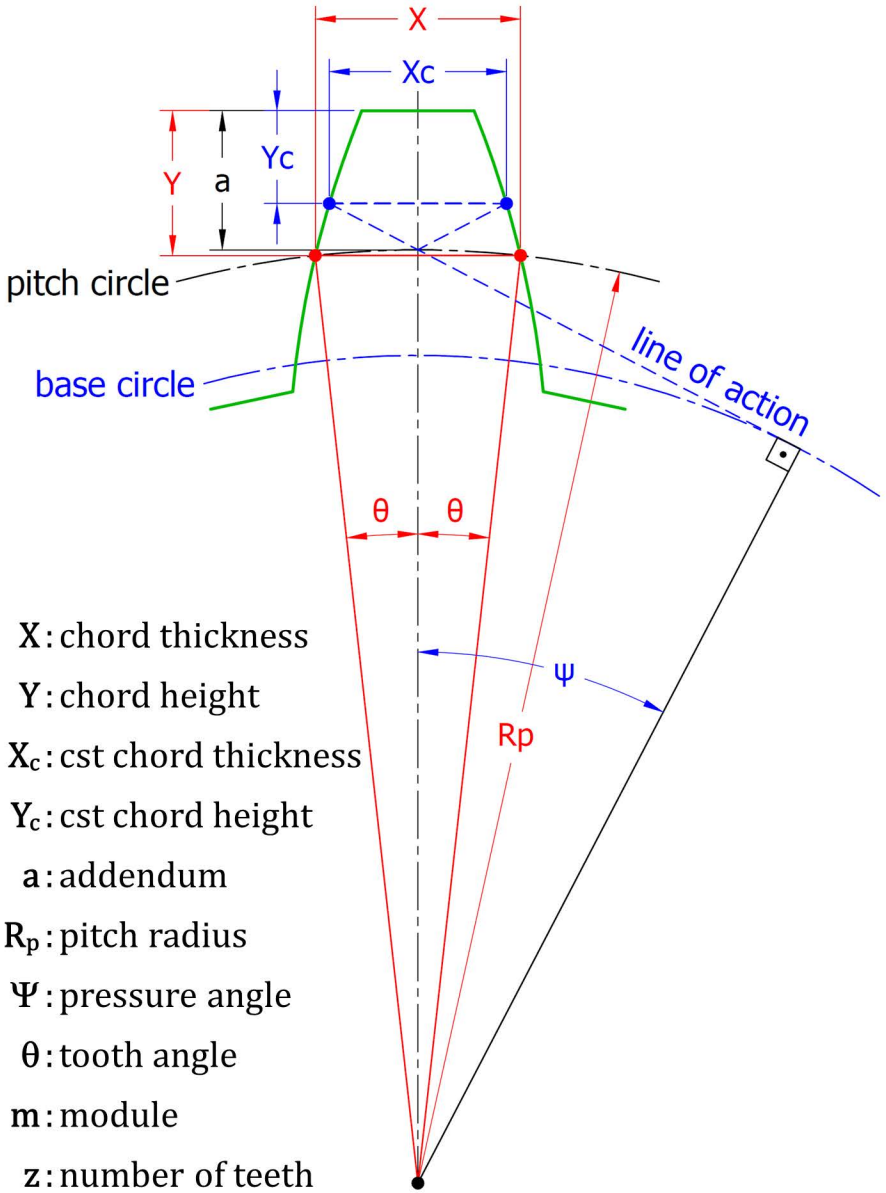
$$X = 2R_p * \sin(\theta) \;\&\; Y = a + R_p\,[1 - \cos(\theta)]$$

where $a = m = \frac{2Rp}{z}$ & $\theta = \frac{\pi/2}{z} = \frac{90°}{z}$

- When many gears (with different number of teeth) to be measured, the calculations would become laborious. Thus, **Constant (Fixed) Chord Thickness & Height** are found **as independent from number of teeth**:

$$X_c = \frac{\pi}{4} * m * \cos^2(\Psi) \;\&\; Y_c = m - \frac{\pi}{8} * m * \sin(2\Psi)$$

- **Constant (Fixed) Chord** is the length joining the points on opposite faces of tooth, making contact with the mating teeth at the line of action.



Span Measurement (Spur Gears)

- **Span Length (M)** refers to **the base tangent length**, expressed in terms of base tooth thickness (t_b) and base pitch (p_b) depending on teeth in span length (k):

$$M = t_b + p_b * (k-1)$$

- **Base Tooth Thickness (t_b)** is expressed as:

$$t_b = m * z * \cos(\Psi) * \left[\frac{\pi/2}{z} + \text{inv}(\Psi)\right]$$

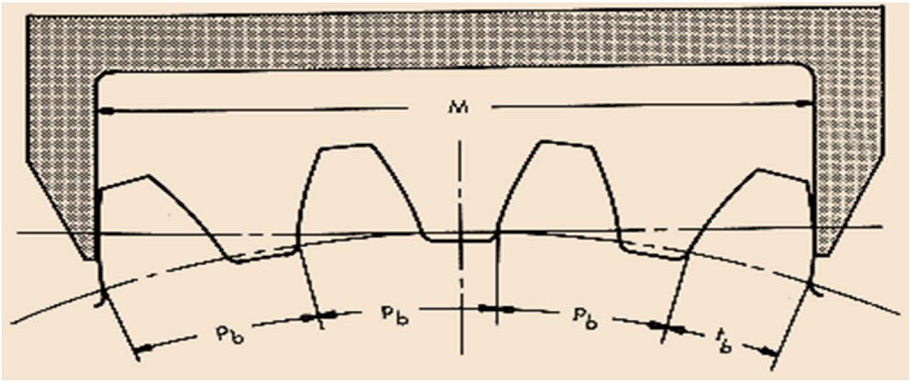
- **Base Pitch (p_b)** is expressed as:

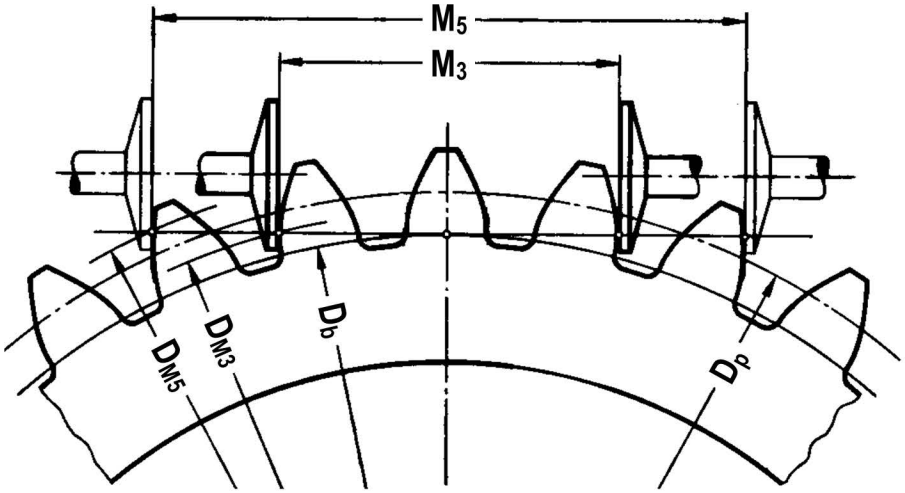
$$p_b = m * \pi * \cos(\Psi)$$

- Rearranging the terms gives the span length:

$$M = D_p * \cos(\Psi) * \left[\frac{\pi/2}{z} + \text{inv}(\Psi) + \frac{\pi}{z} * (k-1)\right]$$

- As seen from figure, **span length defines the points at which measuring device grabs the teeth** during measurement.





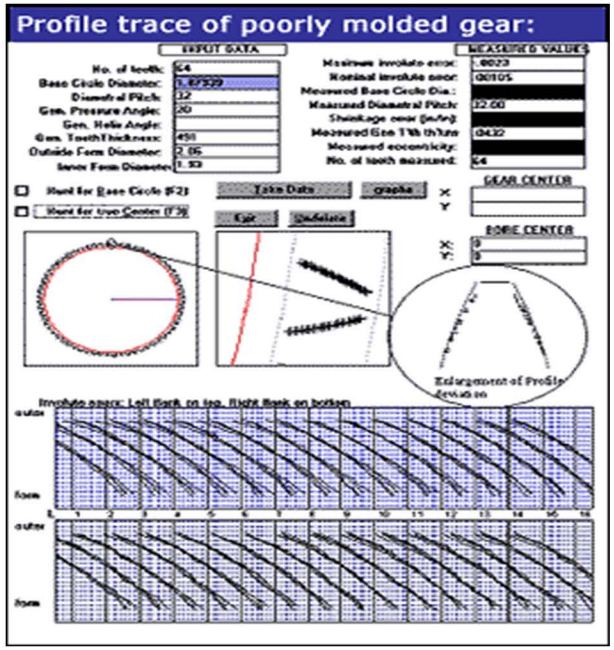
M_3 : span length ($k = 3$)

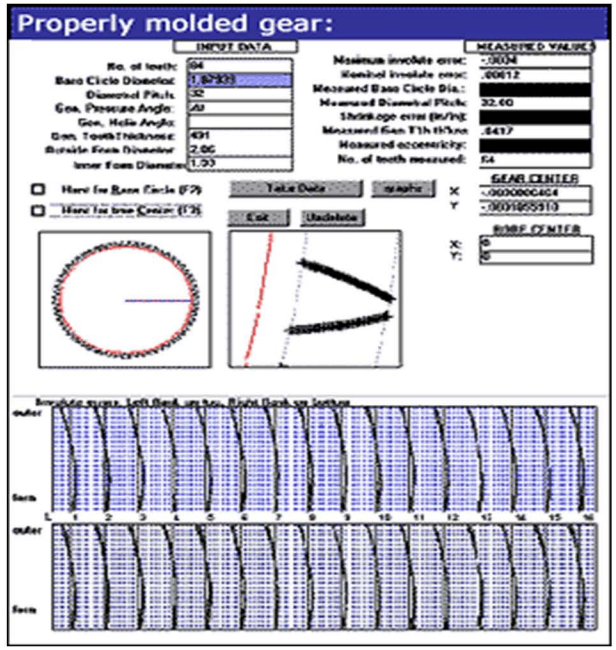
M_5 : span length ($k = 5$)

D_b : base diameter

D_p : pitch diameter

Gear Measurement by CMM





METHOD	ADVANTAGES	DISADVANTAGES
Measurement over Pins	☺ **Measurement not affected** by form errors and/or runout along the outside diameter	☹ **The most appropriate pins must be selected** (a bottleneck for gears having non-standard features)
Gear Tooth Vernier Caliper	☺ Relatively **cheaper & easier** to use	☹ **Precision of caliper** directly affects results ☹ Measurement depend on **two vernier readings**, each of which is a function of the other. ☹ Measuring with **"edge"** of caliper jaw (**not "face"**), which does not lend itself to accurate measurement
Span Measurement	☺ **Measurement not affected** by form errors and/or runout along the outside diameter	☹ Not usable for **high helix angle & narrow face width** (spanning a sufficient number of teeth is the problem) ☹ Affected by **errors in base pitch & tooth profile** (due to modified profile from true involute shape)
Measurement by CMM	☺ **Very accurate** in case of undamaged teeth ☺ Measurement of **dimensions & form of gear** ☺ Can be used for **almost all gear profiles**	☹ **Time consuming** for set-up & process control ☹ **Appropriate probe sizes** must be employed (i.e. small size of gears cannot be measured)