Tooth thickness measurement and pitch inspection

Tooth thickness measurement

When you resharpen a shaving cutter you reduce the chordal thickness of the teeth of a value included between 0.06 and 0.10 mm.

In function of this value you have to reduce the cutter outside diameter accordingly, in order to maintain the even contacts conditions. For this purpose, each cutter is always accompanied by a resharpening diagram that defines the correspondence between tooth thickness and outside diameter.

The thickness measurement of each tooth is not very comfortable, and for this reason it is more common to measure, with a plate micrometer the **W$_n$** size on **n** teeth as indicated in figure N°1.
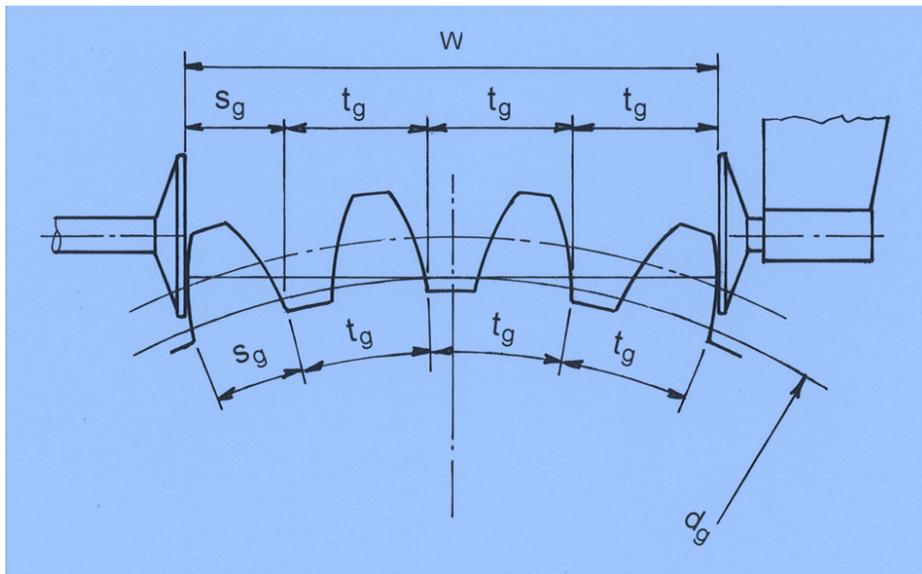
Fig.N°1- *Span measurement W on more teeth with plates micrometer*

There is a quite precise relationship between value $\overline{S_o}$ and value **W$_n$**.

Considering the following symbols and making reference to figure N°1, you have the below stated relationships:

$\overline{S_o}$ = tooth chordal thickness
S_{on} = normal chordal thickness
l_o = space width on pitch diameter
d_o = pitch diameter
r_o = pitch radius
h_o = addendum
m = module
m_n = normal module
d_g = base circle diameter
t_g = base pitch
α_o = pressure angle
α_{on} = normal pressure angle
α_{os} = apparent pressure angle
β_b = base helix angle
x = profile shift factor

$$\frac{S_o}{\pi \cdot d_o} = \frac{\delta_{rad}}{2 \cdot \pi} \qquad \overline{S_o} = d_o \cdot sen\frac{\delta}{2}$$

for spur gears:

$$W_n = m \cdot \cos\alpha_o \left[(Z_n - 1) \cdot \pi + \frac{S_o}{m} + Z \cdot inv\alpha_o \right] + 2 \cdot x \cdot m \cdot sen\,\alpha_o$$

The number of teeth to considered for the measurement Z_n can be calculated with:

$$Z_n = Z\frac{\alpha_o}{180°} + 0,5 \qquad \text{(with } \alpha_o \text{ in degrees)}$$

For helical gears you have :

$$W_n = m_n \cdot \cos\alpha_{on} \left[(Z_n - 1) \cdot \pi + \frac{S_{on}}{m_n} + Z \cdot inv\alpha_{os} \right] + 2 \cdot x \cdot m_n \cdot sen\,\alpha_{0n} \qquad \text{being}$$

$$Z_n = Z \cdot \left(\frac{\alpha_{os}}{180°} + \frac{tg\alpha_{os} \cdot tg^2\beta_b}{\pi} \right) + 0,5$$

Sometimes it is not possible to carry out this measure because there is no chance for the two micrometer plates to touch the flanks of the gears in the same time; see figure N°2.
The condition that is required to be able to carry out the measurement is

$$b \geq W_n \cdot sen\,\beta_b + b_M \cdot \cos\beta_b$$
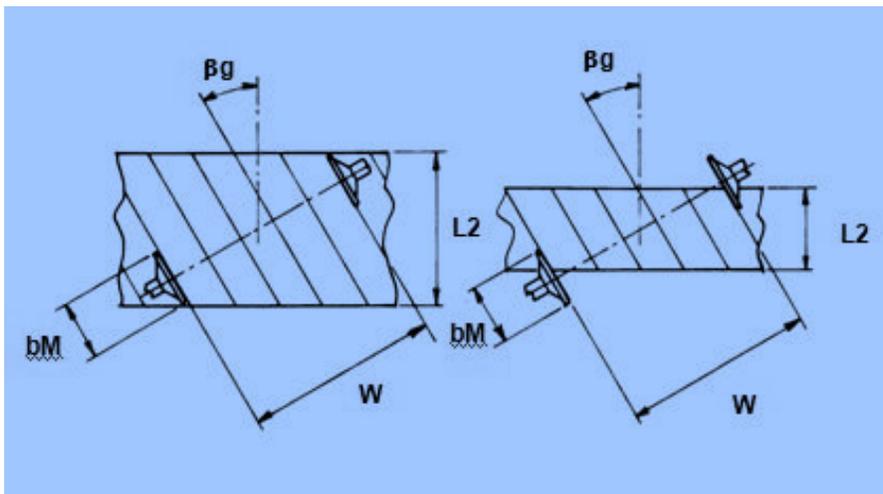
Fig.N° 2- *Sometime you cannot measure span measurement W on more teeth with plates micrometer*

If this is not possible it will be necessary to perform the size over rollers measurement.
With reference to figure N°3 you can have 4 cases:
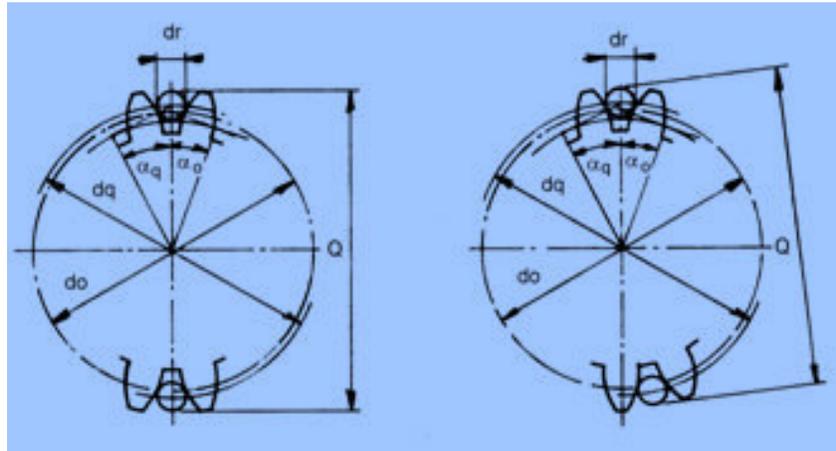
Fig.N°3- *Measure of size Q on rollers on even number of teeth or odd one*

1)- Spur Teeth with Z = even number:

$$inv\alpha_q = inv\alpha_o + \frac{d_r}{2 \cdot r_o \cdot \cos\alpha_o} - \frac{l_o}{2 \cdot r_o} \qquad \text{from which you obtain } \alpha_q$$

$$r_q = r_o \cdot \frac{\cos\alpha_o}{\cos\alpha_q} \qquad \text{and then} \qquad Q = 2 \cdot r_q + d_r$$

2)- Spur Teeth with Z = odd number
with α_q and r_q values obtained from the previous formulae you calculate:

$$Q = 2 \cdot r_q \cdot \cos\frac{\pi}{2 \cdot Z} + d_r$$

3)- Helical Teeth with Z = even number:

$$inv\alpha_{qs} = inv\alpha_{os} + \frac{d_r}{2 \cdot r_s \cdot \cos\beta_o \cdot \cos\alpha_{on}} - \frac{l_{os}}{2 \cdot r_{os}}$$

$$r_{qs} = r_{os} \cdot \frac{\cos\alpha_{os}}{\cos\alpha_{qs}} \quad \text{from which} \quad Q = 2 \cdot r_{qs} + d_r$$

4)- Helical Teeth with Z = odd number:
with α_{qs} and r_{qs} values obtained from the previous formulae you calculate:

$$Q = 2 \cdot r_{qs} \cdot \cos\frac{\pi}{2 \cdot Z} + d_r$$

But this measurement too is not easy to make, considering the quite big value of Q that would make necessary the use of large and awkward micrometers.
Quite often, then it is preferable to carry out the measurement between one roller and the closest bore wall as indicated in figure N°4.
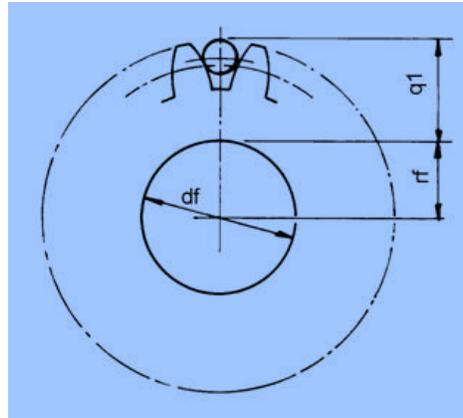
Fig.N°4- *Measure of size Q_1 between bore and rollers*

For Spur Teeth : $Q_1 = r_q + r_r - r_f$

For Helical Teeth: $Q_1 = r_{qs} + r_r - r_f$

The Q_1 and W_n values are normally indicated in the resharpening diagram.

Pitch and eccentricity error inspection

The inspection of the main characteristics of the shaving cutter, such as profile, helix and pitch, is normally performed on CNC inspection units (Klingelnberg, Hoefler, M&M, etc.) which guarantee an extremely high measurement accuracy. The repeatability of the various measurements is in the area of a few microns.

Profile and helix inspections do not pose any particular problem, except for the fact that when you check the profile you have to position the probe ball surely in the middle of a serration tooth.

As far as the helix is concerned, you will obtain a graph that put into evidence the interruption due to the serrations spaces, but the reading of the shape does not present any difficulty.

It is necessary to go more in detail for the pitch and eccentricity errors.

The problems come when you have to inspect shaving cutters with helical serrations (offset), i.e. the cutters working underpass and plunge.

Once you position the probe, when you rotate the cutter to be able to check the next teeth, it is also necessary to move the prove longitudinally of the same amount of the offset of each tooth, otherwise, after one or two teeth the probe would fall into the empty space.
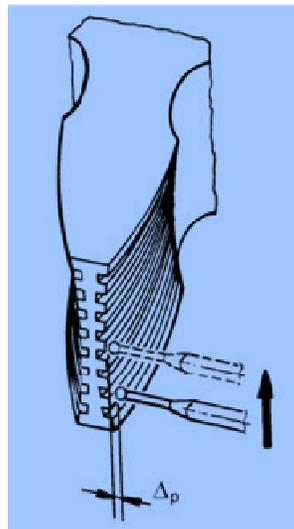
Fig.N°5- *For the pitch inspection of underpass an plunge cutters a special software is necessary*

If it is a cutter with theoretical involute, the procedure would be over, but if, as it frequently happens, the helix is hollow, the longitudinal movement of the probe would cause the probe to touch the flank in different areas, i.e. in points where the tooth has a different thickness.

The inspection equipment would detect this as a pitch error.

The checking equipments for shaving cutter inspection are normally endowed with an appropriate software that not only moves the probe according to the serrations offset, but also takes into account the measurement variations due to the helix hollow.

A normal checking equipment that is not endowed with such special software cannot check the pitch on underpass and plunge shaving cutters.

The pitch inspection is performed by touching every tooth on both flanks. In practice the equipment determines the position in the space of all the teeth flanks.

These data are elaborated and an appropriate software determines which is the eccentricity of the toothing F_r, as if this last parameter is measured by touching each space with a sphere or a roller.