Semi-topping shaper cutters

Semi-topping shaper cutter are used during gear cutting to generate chamfers on the tooth tip. The fig.N°1 show clearly the part of the cutter that generate the chamfer.

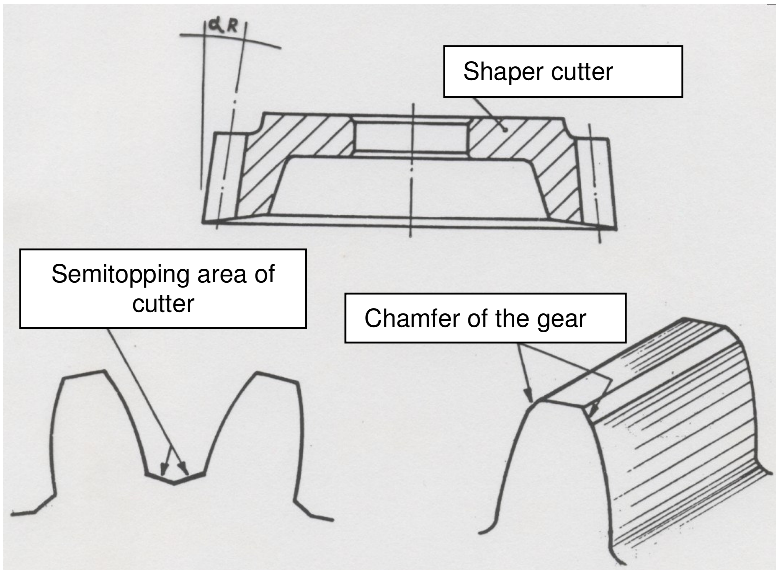

Fig. N°1

Not only is it difficult to design and produce these cutters, but it is even more difficult to ensure that the gear chamfer remains constant throughout the life of the shaper cutter.
It is impossible to guarantee the constancy of the chamfer on the finished gear not only because of the production tolerances of the teeth (chordal thickness and outside diameter) and the shaper cutter itself, but also because of the profile grinding system.
It is well known that the profile is ground according to the angle α_R .
There are two recognized grinding systems:
a)- by fixed grinding wheel (nowadays not often used)
b)- by translating grinding wheel.
We will now briefly examine the basic features of these two methods.
a)- By fixed grinding wheel
As can be presumed b the name itself, the wheel axis is maintained immobile in relation to the shaper cutter and therefore the wheel will generate a tooth root whose profile will reflect the curve of the wheel's outside diameter (see fig. N°2).

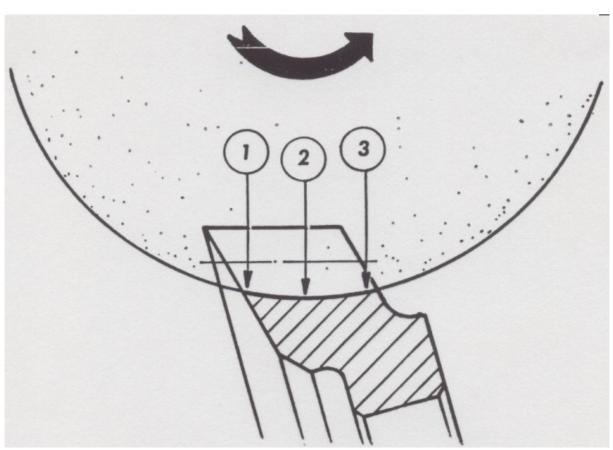

Fig. N°2

It is obvious that in these cases the gear chamfer will vary greatly, depending on whether the cutter is at the beginning (position 1), at the middle (position 2) or at the end of its life (position 3).
From figure N°2 we can see clearly that at beginning of cutter life the chamfer will be large, at the middle of cutter life the chamfer will be small and at the end of cutter life the chamfer will once more be large.
Then, apart from the variations deriving from the shaper cutter geometry, there also the gear's chordal thickness and outside diameter tolerances to be remembered.
All this means that in the majority of cases it is not possible to obtain a single acceptable chamfer from the shaper cutter in all its hypothetical life.
So, the alternatives are either to accept poor quality tolerances or to use the shaper cutters for a very small number of resharpening, which means that production costs are very high.

b)- By translating grinding wheel
This manufacturing technique gives a rectilinear tooth root to the shaper cutter since the wheel translates along the direction of grinding (see fig. N°3)

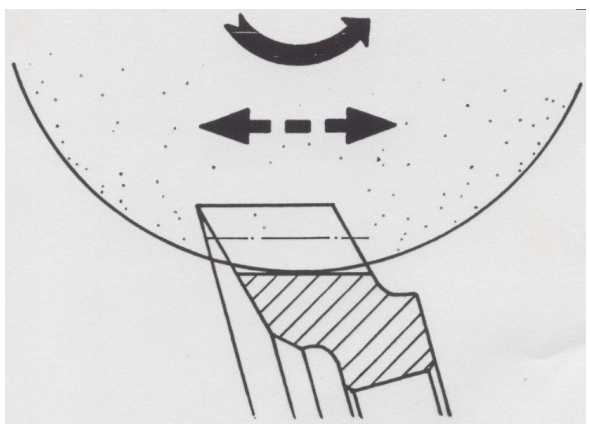

Fig. N°3

Initially this might lead us to believe that we have solved our problem, but this is not true.
Of course, compared to situation a) we have made enormous steps forward, but we still have not managed to achieve constancy for the chamfer within acceptable limits.
This is because the center distance variation between the shaper cutter and the gear ceases to be linear as the cutter gradually wears down.
We will now demonstrate mathematically that the center distance variation is not linear and in order to simplify the problem we will consider the shaper cutter's outside diameter, that is to say, that area which generates the gear's inside diameter. The problem is similar to that of semitopping variation even if, from a mathematical aspect, the outside -diameter is easier to analyze.
From a conceptual point of view, the results can be extrapolated to the part which create the chamfer.

Let us consider a spur gear with the following characteristics:

- *Module:* $m = 2{,}5$ *mm*
- *Pressure Angle:* $PA = \alpha_0 = 20°$
- *Number of teeth:* $Z_1 = 30$
- *Circular thickness on pitch diameter:* $S_{0n1} = 3{,}927$ *mm*
- *Inside diameter:* $D_{i1} = 68{,}75$ *mm*

The shaper's cutter principal characteristics can be taken to be:

- *Number of teeth:* $Z_2 = 40$
- *Side clearance angle:* $\varepsilon = 2°10'$
- *Useful height:* $H_{ut} = 20\ mm$
- *Circular thickness at start life:* $S_{0n2SL} = 5\ mm$

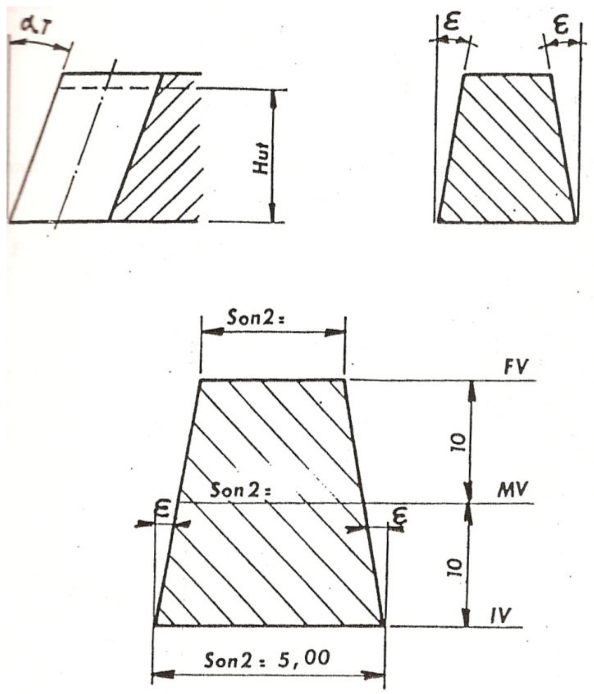

Fig. N° 4

Firstly we calculate the gear correction factor X_1 , bearing in mind that $X \cdot m = v$ is the profile shift.

$$X_1 = \frac{S_{on1} - \dfrac{\pi \cdot m}{2}}{2 \cdot tg\alpha_0 \cdot m}$$

And that of the shaper cutter:

$$X_2 = \frac{S_{on2} - \dfrac{\pi \cdot m}{2}}{2 \cdot tg\alpha_0 \cdot m}$$

Now we must calculate the working pressure angle α_b between the gear and the shaper cutter (pag. 195 Henriot vol.1).

$$inv\alpha_b = inv\alpha_0 \cdot 2 \cdot tg\alpha_0 \cdot \frac{X_1 + X_2}{Z_1 + Z_2}$$

And from this we may obtain the gear working pitch diameter D_{F1}

$$D_{F1} = \frac{m \cdot Z_1 \cdot cos\alpha_0}{cos\alpha_b}$$

And the shaper cutter working pitch diameter

$$D_{F2}=\frac{m\cdot Z_2\cdot cos\alpha_0}{cos\alpha_b}$$

With this information we may calculate the outside diameter of the shaper cutter:

$$D_{K2} = D_{F1} - D_i + D_{F2}$$

And substituting we obtain:

$$D_{K2}=\frac{m\cdot cos\alpha_0\cdot(Z_1+Z_2)}{cos\alpha_b} - D_i$$

If we observe this formula we can see that all the values are constant, with the exception of α_b , derived from the profile shift which, in turn, depends of the shaper cutter's chordal thickness and therefore on the clearance angle **ε.**

Basically, this is a complex function which contain a trigonometric function $(cos\alpha_b)$ and therefore cannot be a linear variation.

So if we grind the shaper cutter's outside diameter according to the inclination α_T given by:

$$tg\alpha_T = \frac{D_{k2(SL)} - D_{k2(EL)}}{2\cdot H_{ut}}$$

Where:

SL = start of life of cutter

EL = end of life of cutter.

The inside diameter of the gear D_i will not remain constant.