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THE USEABLE SECTION OF PROFILE SHIFT COEFFICIENT

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Abstract: The basic aim of this paper is to determine the possible limits of profile shift coefficient. Another interesting problem is the behaviour of the limit. The paper interprets that the limits are absolute ones, because the geometrically correct tooth profile can be produced only between the limits.

Keywords: *undercut, zero topland, profile shit coefficient limits*

1. INTRODUCTION

During the design of a gear pair, especially in the geometrical predesign we define the number of teeth, the module of the gears and the working centre distance of axles. By defining the working centre distance, which is not equal to the standard centre distance, we define the sum values of the profile shift coefficients also.

In view of the sum of profile shift coefficients and by the usage of various methods, the profile shift values for each gear can be calculated. For example by equalizing the relative sliding in the end points of meshing or by the values of flash temperature in the same points etc. [1], [2].

In this paper we analyse if these profile shift coefficients have an upper and lower limits and if they have what is it?

We made our test on involute spur gears machined by straight edged tool. The results can be expanded to spur and helical gears made by shaper cutter.

The value of profile shift coefficients shows that the distance between the centre line of the cutting tool and the pitch line, the profile shift value is how many times of the module. The indication shows the direction of shift.

With this in mind if we shift the cutting tool towards the centre of the machined gear, from the machining position of the standard toothing to the centre point the value will be negative.

If we move it in the other direction, or pulling it out, than the value will be positive.

Examine that if this movement of the cutting tool has any limits.

2. THE UNDERCUT

It is known that the start points of the involute profiles of the gear are lying on the base circle and the involute profiles starting from this points are lying on a larger circle than the base circle. The involute profile points can not be made on a circle what has smaller radius than the base circle.

At first examine the tip of the cutting tool, because this part of the tool gets the closest to the centre point of machined gear.

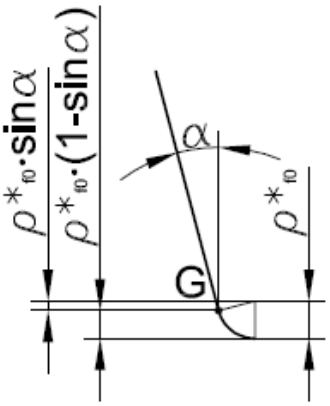


Figure 1. The rounding of the tool edge

As it can be seen on the first figure, the G point is the limit point belonging last to the straight line of the edge. Going on the tool edge to the tip, the rounding comes next, which cannot be used for making involute profile because it is not part of the straight profile. This rounding forms the bottom radius of the tooth, which is not involute.

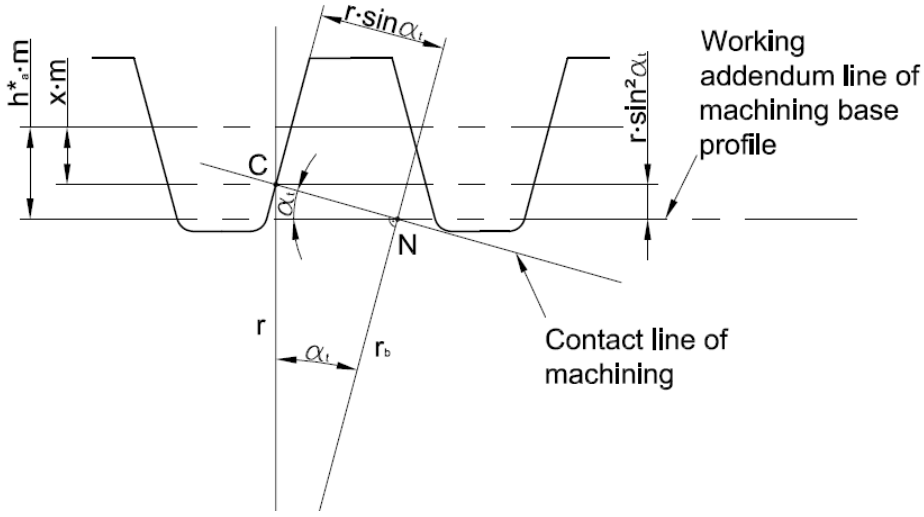


Figure 2. The limit of the base profile

The second figure shows the border-line case, when the working top line crossing the limit point *N* of the gear. The last point of the straight profile on the cutter useable to make involute profile, when it crosses the base point *N* on machined gears. In this position the distance between the working top line of the tool and the centre point of the machined gear is smaller than the radius of the base circle of the gear. Thus the points near the tip of the tool are cutting on the area where involute profiles cannot be made on the gear blank. In this case during the roll out of the tool, the cutting edges are cutting parts of the useable profiles made during roll in [3]. It is called machining interference or undercut.

Using the notation on the *Figure 2.* it can be written, when there are no undercut, like in the limit case shown on the figure:

$$(h_a^* - x)m = rsin^2\alpha_t = \frac{m\,z}{2}sin^2 \propto_t. \tag{1}$$

So

$$x_{min} = h_a^* - \frac{zsin^2\alpha_t}{2}. \tag{2}$$

From the *Equation (2)* the minimal value of the profile shift coefficient can be determined in every machined gear, when undercut just not happen.

Using smaller values than this causes undercut, that is the lower limit of the determined value which gives accurate tooth profile.

3. ZERO TOPLAND

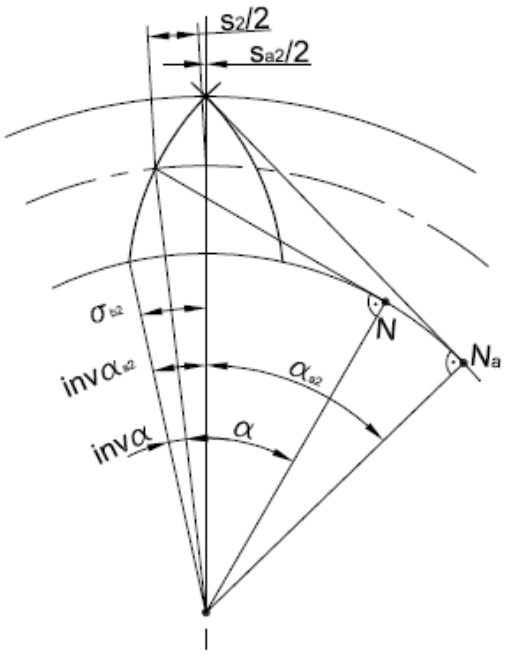


Figure 3. The phenomenon of the tooth thickness

Next examine the geometrical relations when the cutting tool is „pulled out", when the profile shift coefficient has a positive value, respectively is it have a limit value?

As it is shown on the *Figure 3.* the tool by pulling outside, receding from the centre point of the machined gear, we make the farther points of the elemental involute profile [4]. In a border-line case it can happen that we would make that area where the two involute arcs crosses each other. In this case during the rolling out of the tool, the cutting edges machines down the profiles on a larger circle than the circle lies on the intersection point of the two tooth sides. This phenomenon called another machining interferences, tip relief.

In practice the minimal topland thickness have to be granted, because if it grows thin it causes strength problems. In literature the minimal value related to the module is advised to pi ck up between s^*_{amin} = 0,2…0,3. By using the nomenclature on *Figure 3* we can define the minimal topland thickness by the following equation:

The tooth thickness on the pitch circle from the figure is:

$$s = \frac{p}{2} + 2xmtan\alpha \tag{3}$$

where p is the pitch on the pitch circle, m is t he module, x is the profile shift coefficient, while α is the pressure angle of the profile.

The angle $\sigma_a$belonging to the profile can be determined:

$$\sigma_a = \frac{s}{2r} + inv\alpha = \frac{s_a}{2r_a} + inv\alpha_a. \tag{4}$$

Based on these equations the thickness on the topland is:

$$s_a = 2r_a\left(\frac{s}{2r} + inv\alpha - inv\alpha_a\right) \tag{5}$$

By substituting the tooth thickness and the profile angle belonging to the addendum circle, the topland thickness is:

$$s_a = d_a\left\{\frac{\pi}{2z} + \frac{2x}{z}\tan\alpha + \text{inv}\alpha - \text{inv}\left[\arccos\left(\frac{zm}{d_a}\cos\alpha\right)\right]\right\} \tag{6}$$

which cannot be smaller than the s_{amin}value given earlier.

In regard to that *Equation (6)* is transcendent to x, so defining x_{max} can be done by using some numerical method, by the presumption, that the value of the left side of *Equation (6)* is equal with s_{amin} selected from the literature.

Since the tip relief happens on that diameter when the two involute profiles cross each other, namely when the rolling out tool cuts off the profile made during roll in, on bigger diameter than this involute profile cannot be made.

4. EXAMPLE

For the limit values shown in this paper, we present the next sample without the detailed calculations:

Basicdata		
Number of teeth of thegears	$z_1 = 19$	$z_2 = 35$
Module	$m = 3\ mm$	
Centre distance	$a_w = 83\ mm$	
Pressure angle	$\alpha = 20\ fok$	
Addendum factor	$h_a^* = 1$	
Clearance factor	$c^* = 0{,}25$	
Calculations		
Base pitch	$p_b = 8{,}856\ mm$	
Base circles radii	$r_{b1} = 26{,}781\ mm$	$r_{b2} = 49{,}334\ mm$
Working pressure angle	$\alpha_{wt} = 23{,}502\ fok$	
Sum of profile shift coefficients	$\Sigma x = 0{,}724$	
Standard centre distance	$a = 81\ mm$	
Centre distance coefficient	$y = 0{,}667$	
Minimum values of profile	$x_{1min} = -0{,}111$	
shift coefficients	$x_{2min} = -1{,}04$	
Limit of topland	$s_{amin} = 0{,}3{\times}3\ mm$	
Maximum values of profile	$x_{1max} = 0{,}894$	
shift coefficients	$x_{2max} = 1{,}401$	

The obtained results are represented by the $x_2 = f(x_1)$ function with the limits in the x_1, x_2 coordinate system shown in *Figure 4.*

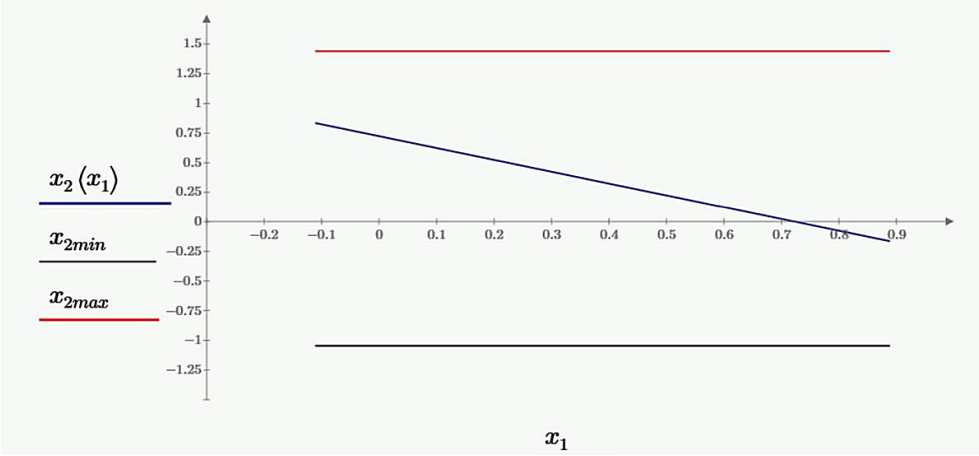


Figure 4. Relation of the profile shift coefficients with their limits

5. CONCLUSIONS

1. The domain of the profile shift coefficients can be defined on every machined gear with the minimum and maximum values, where geometrically correct involute profile can be made.
2. The upper and lower limit of this domain obtained, are critical values from the perspective of the geometrically correct tooth profile, because beside these limits geometrically correct involute profile on the given gear cannot be made.

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