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A NEW ROUGH CUTTING METHOD FOR INVOLUTE GEAR TEETH

Viorel PETRARIU
Stelian ALACI
Dumitru AMARANDEI

"Ştefan cel Mare" University of Suceava
str. Universităţii nr.1, RO-5800 Suceava
petrariu@fim.usv.ro, alaci@fim.usv.ro, mitica@fim.usv.ro

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Abstract: *The paper presents a rough cutting method for involute gear teeth with a hyperbolic one. The advantage of the new method consists in using of a straight fit cutting tool. The price of the new cutting tool is lower than classical ones.*

1. INTRODUCTION

The paper presents a coarse grind for the cylindrical pinions with involute teeth. The advantage of this new treatment method consists in using a cheaper tool with straight cuts, which would reduce significantly the wearing of the effective gear cutting tool.

2. THEORETICAL CONSIDERATIONS

The cylindrical teeth gears with involute profile are treated by the means of two procedures: by copying and by rolling. By copying the material between the teeth of the gear is cut out with a profile tool whose cost is very high. The transformation principle through rolling consists in the imitation of the gearing between the half-finished product and the gear teeth tool by the means of a cinematic rolling chain [1]. In this case, the tool comes from a gear teeth tool which has been given some cutting properties. The used tools are: the wheel knife, the comb knife (cremaillere) and the gear hob. For the external toothing of gears the last two tools are preferred as they are cheaper than the wheel knife. In a previous paper, the author shows that when treating toothing by rolling with cremaillere type tools, the phenomena which should be avoided are: the undercut and the teeth dressing. The displacement coefficient of the toothing has contrary influences upon these phenomena. Thus, once the displacement coefficient increases, the thickness of the tooth on the head circle decreases and once this decrease, the undercut is accentuated. For wheels with straight teeth, when the number of teeth is low *(z<0),* the two phenomena cannot be avoided simultaneously and it is imposed the transformation of the wheel knife wheel, thing that brings to a considerable increase of the transformation cost. In order to reduce the wearing of the wheel knife, we propose the execution of a coarse grind with a cheaper tool, with linear cuttings and after that the final transformation with a gear cutting tool. It is preferred that the coarse grind should lead to the closer profile of the theoretical one and the transformation addition further to the coarse grind should be distributed as uniform as possible on the entire length of the flank.

Consider a *T* line, inclined towards a line (axis) Δ with a β angle and situated at an r_0 distance against this one, Figure 1. By rotating the *T* line around the *D* axis, a rotation hyperboloid of one sheet. From Figure 1 we can deduce:

$$r^2 = r_0^2 + h^2 \tan(\beta)^2, \tag{1}$$

Where

$$h = Y, r^2 = X^2 + Z^2.$$

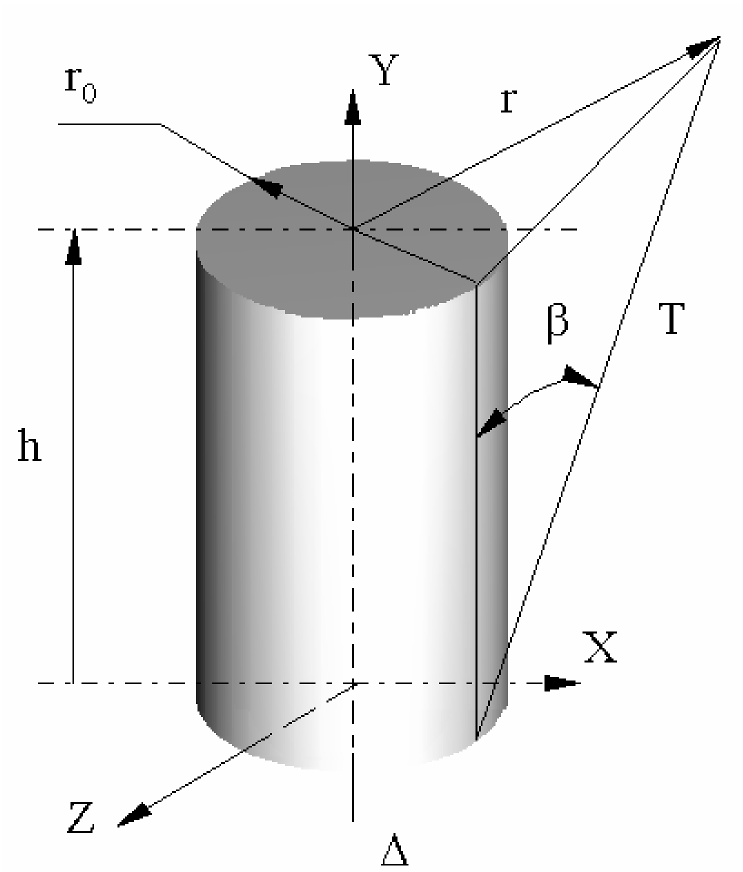

Figure 1.

From here, the equation of the hyperboloid in the *XYZ* system is the following, [2, 3]:

$$\frac{X^2 + Z^2}{r_0^2} - \frac{Y^2}{[r_0 \cdot \tan(\beta)]^2} = 1 \tag{2}$$

The transformation chart of the wheel is presented in Figure 2. The cutting movement is constituted by the *ω* rotation around its axis and de vertical movement of the *s* advance ensures a transformation of the tooth all along the entire generator. The index movement (*2π/z)* ensures the rotation of the half-finished product in an angular step. The axis of the tool is inclined towards the wheel plan with an angle *α* in order to realize the connection profile at the bottom of the space between the teeth. The origin of the reference centre of the tool is moved with the y_o quantity towards the centre of the half-finished product. The connection profile obtained further to the transformation is the semi ellipse:

$$\frac{x^2}{r_0^2} + \frac{(y - y_0)^2}{r_0^2 \cos(\alpha)^2} = 1, \tag{3}$$

$$y < y_0.$$

The relationship between the coordinates *X, Y*, on one hand, and *x* and *y* on the other hand are the following:

$$x = X \qquad (4)$$
$$y = y_0 + Y\cos(\alpha).$$

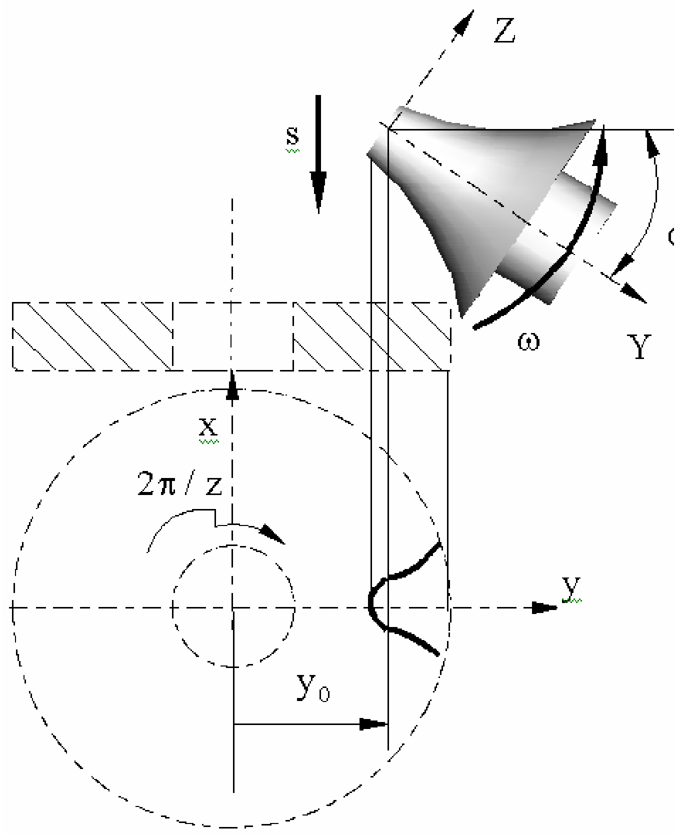

Figure 2.

The cutting points of the tool describe the branches of the hyperbola:

$$\frac{x^2}{r_0^2} - \frac{(y - y_0)^2}{[r_0 \tan(\beta)\cos(\alpha)]^2} = 1 \qquad (5)$$

As the non-involute connection part from the bottom of the space does not represent a special importance as it does not take part to the engagement, the parameters r_0, b and y_0 are determined considering that:

$$\alpha = 0. \qquad (6)$$

For this reason we consider a range of numbers $M(x_k,\ y_k)$ from the involute part of the flank. By applying the method of the smaller squares we are looking for the determination of the parameters a, b and y_0 for the hyperbole:

$$\frac{x^2}{a^2} - \frac{(y - y_0)^2}{b^2} = 1 \qquad (7)$$

or by explicating y:

$$y(x) = y_0 + b\sqrt{\frac{x^2}{a^2} - 1}\ . \qquad (7')$$

The optimum condition for interpolation is:

$$F(a,b,y_0) = \sum_{k=1}^{n} [y(x_k) - y_k]^2 = \text{minim} \qquad (8)$$

For the satisfaction of the condition 8 it is necessary to solve the system 9. The system 9 is a system of irrational equations for the solving of which we try the use of a numeric calculus method which proves not to be convergent. At a thorough analyze of the equations from the system 9, we can observe that the system is linear in the unknown *b* and y_0.

$$\begin{cases} \frac{\partial F(a,b,y_0)}{\partial a} = 0 \\ \frac{\partial F(a,b,y_0)}{\partial b} = 0 \\ \frac{\partial F(a,b,y_0)}{\partial y_0} = 0. \end{cases} \qquad (9)$$

In conclusion, these unknown can be eliminated, obtaining finally an equation with a as the only unknown.

$$f(a) = 0$$

In order to solve this one we apply the method of the bisection of the interval as it is the least restrictive (it is necessary only the continuity of the function *f(a)).* The equation 9 cannot be solved as a graphical representation of the function *f(a),* Figure 3, shows that the function is discontinuous.

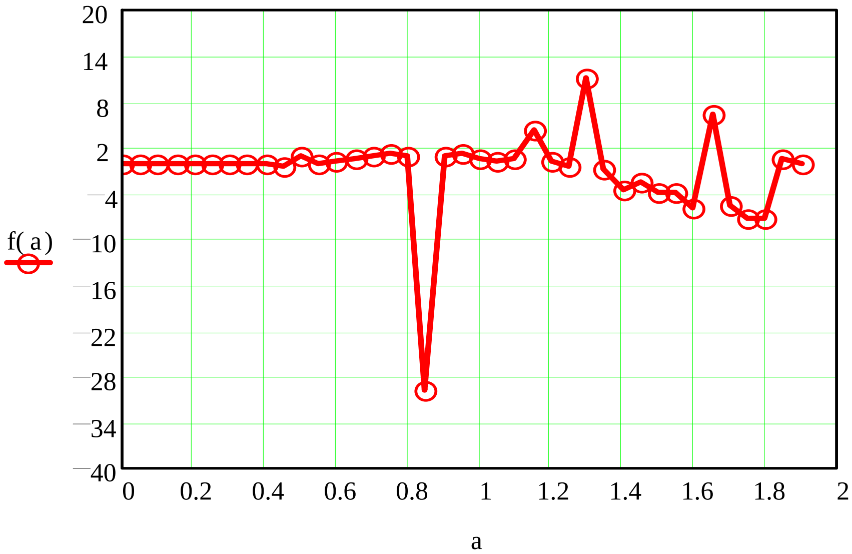

Figure 3.

The discontinuities of the f(a) function are due to the radical from the expression f' that, after the derivation operation, appears at the denominator. It results the conclusion that the equation of the hyperbole 7 cannot be determined by the method of the smallest squares. Another minus of the method of the smallest squares, supposing that the hyperbole 7 could be found, consists in the fact that the interpolation function passes through the points $M(x_k, y_k)$ so that it would exist some areas in which the hyperbole would cross the involute profile, substituting to this one.

In order to solve the problem we considered another range of points $M'(x_{k'}, y_{k'})$ situated on a curve (*E'*), equally spaced at the *δ* distance from the involute profile (*E*).

The parameters of the hyperbole 7 were determined by imposing to this one to cross the extreme points and an intermediary point. The intermediary point is chosen so that the hyperbole found itself between the involute profile (*E*) and the equidistant (*E'*). For small values of the *δ* distance, for a certain number of teeth there is a minimum value for which this condition is satisfactory. For small number of teeth it is necessary to adopt some greater values of *δ* and the additional material is less uniform distributed. We considered only wheels where the displacement coefficient is greater than the minimum necessary coefficient in order to avoid the undercut. In Figures 4 and 5 there are the curves of the hyperboles 7, the *E* profile and the *E'* equidistant, with the specification of the features of the wheel and of the additional material *δ*.

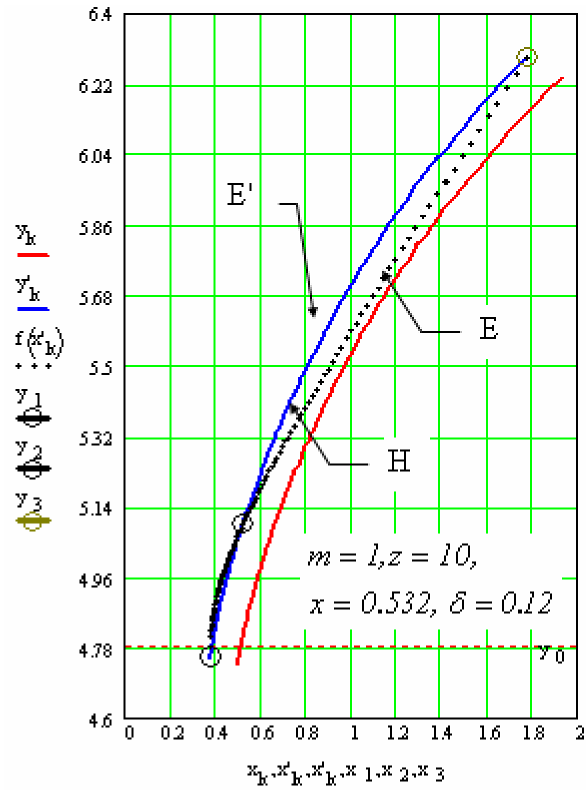

Figure 4.

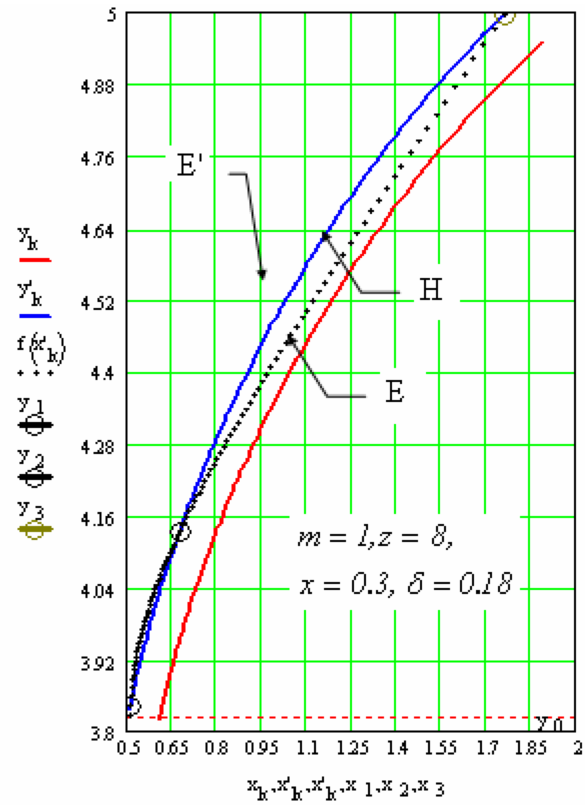

Figure 5.

After the identification of the coefficients from the equations 5 and 7, after the previous assessment of the angle *α,* we can determine the r_0 and *β* necessary for the construction of the tool and also the parameter y_0 for the positioning of the tool compared to the half-finished product.

3. CONCLUSIONS

By the present method, the involute portion of the space between the teeth of a cylindrical gear is approximated with a hyperbole and the non-involute portion with a semi ellipse. There are determined the parameters necessary for the design of the tool for the coarse grind gear cutting imposing the final addition for transformation. The final transformation, with a wheel knife, permits the getting of a gear with a wanted profile displacement, without the danger of undercutting. The addition remained after the transformation by the present method is uniformed on the teeth profile once the increase of the number of teeth of the gear.

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