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PRE-TOOTHING WITH WORM CUTTER OF GEAR WHEELS ON NON EVOLVENTIC PROFILE

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Abstract: Toothing by copying method presents special disadvantages caused by dividing systems of processing machines, introducing unacceptable dividing errors for the gear cinematic conditions. That is why, it is preferred finishing and also pre-toothing, by rolling processing, which also affects processing tools: the *shaver* and the *rotary shave cutter*.

Finishing toothing by copying method presents special disadvantages as it causes dividing errors unacceptable for the gear cinematic conditions. Constructing some machines specialized for processing the respective toothing, that should stimulate the main generating moves of toothing, unacceptable due to great variety and complexity of non evolventic profiles used, in particular for gears specific to pumps.

Since the rolling process as a procedure, acts as a connection of two wheels having axes crossed, establishing the worm cutter tooth profile is reduced to analyzing the gear considering the general conditions of toothing (processing the whole active profile of the wheel, continuation in gearing, uniform distribution of cutting forces on the length of gearing line, ensuring the shaver cutting addition, etc.).

In the case of a given gear, the conjugated flanks of teeth are embodied on two surfaces, one wound and the other envelope, tangent at the point of contact, point that shifts after the characteristic curve in the case of monoparametric winding.

To determine the joint surfaces the following algorithm for the problem will be implemented:

- motion law of engagement point is chosen in the immobile space (connected to the axes of the gear wheels);
- characteristics lines are found in cylindrical coordinates systems, connected to the two wheels (contact lines) and immobile system (gearing line);
- it is envisaged that, when contact occurs, the surfaces should not intersect in the limits of the portions used as active flanks of the teeth;
- through teeth contact lines are drawn surfaces which, must satisfy the conditions in order to be conjugated surfaces:
  - common normal at contact surfaces, in all points of contact lines;
  - is perpendicular to the relative speed vector of conjugated points and on the tangent to contact lines;
  - form of conjugated surface sand position of contact lines must ensure the requirement that surface curvature in normal plan to the contact line should be at least equal to the geodesic curvature of contact line.

$$\frac{1}{\tau_g} \geq \frac{1}{2} \cdot \left(\frac{1}{\rho_1} \cdot \sin 2\varphi - \frac{1}{\rho_2} \cdot \sin 2\varphi \right)$$

$$\frac{1}{r} \cdot \cos\theta = \left(\frac{1}{\rho_1} \cdot \cos^2\varphi - \frac{1}{\rho_2} \cdot \sin^2\varphi \right)$$

According to figure 1, notations have the following meanings:

$\frac{1}{\rho_1}; \frac{1}{\rho_2}$ – main curvatures of conjugated surfaces;

$\frac{1}{\tau_g}$ – geodesic curvature of contact line;

$\frac{1}{r}$ – contact line curvature;

θ – angle between normal to surface and main normal; to the contact line;

φ – angle between direction and tangent to curve having main curvature.

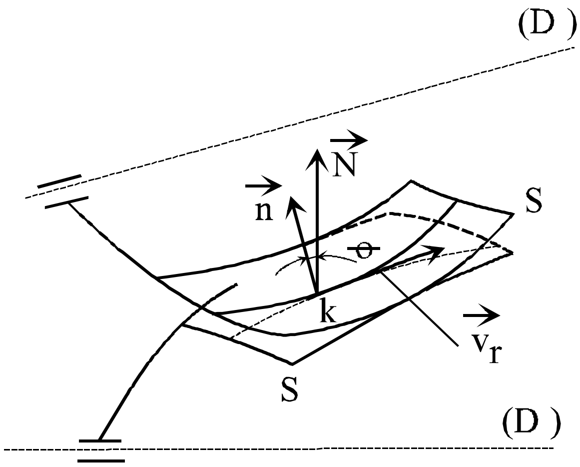

Figure 1. Elements of conjugated surfaces in crossed axes gearing

If we consider a contact point on the characteristic, the condition that the two surfaces do not leave or intertwine, is that the relative speed is must perpendicular to the common normal.

$$\vec{v}_{r21} \cdot \vec{n} = 0$$

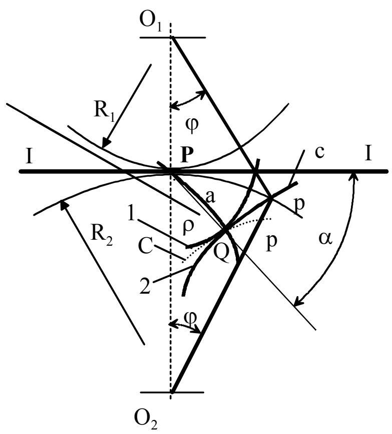

Figure 2. Elements of a tooth profile

To effectively establish the worm cutter tooth profile, in accordance with the general theory of conjugated profiles in flat frontal gearing, when switching to equivalent gear, the problem comes to determine the conjugated profile of a given profile (gear wheel profile equivalent to processing wheel). In this sense a system of current polar coordinates is taken into consideration (figure 2). A current point M on the tooth profile is defined by the normal PM = □ to the profile and through angle □□ that it makes with the tangent in point P. Arch P_0P on radius circle R_r with the center O is defined by the angle □ which position radius OP makes with the fixed radius OP_0. To define point M in polar coordinates system, the defining elements should be expressed by a single variable (angle □). In this case point M equations of profile are:

$$\rho = \rho(\varphi, R_r); \quad \alpha = \alpha(\varphi, R_r); \quad arcP_0P = \varphi \cdot R_r.$$

If radius R_r becomes infinite, the wheel turns to gear rack, and the current defining pole of the profile moves down a straight line, called *rolling line* (figure 3). In this case, segment $\overline{P_{oc}P} = x$ become variable function by which are defined the equations of the current point of gear rack profile:

$$\rho_c = \rho_c(x); \quad \alpha_c = \alpha_c(x); \quad \overline{P_{oc}P} = x$$

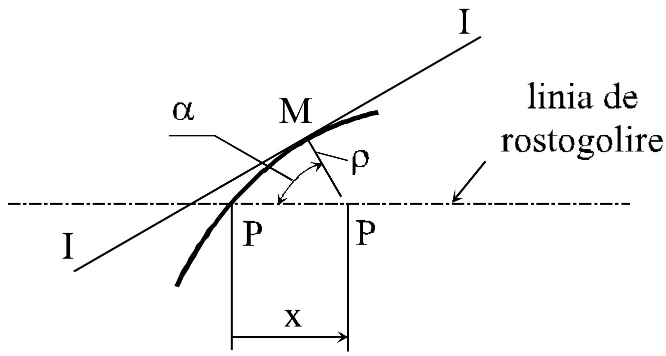

Figure 3. Gear rack rolling line

Because current point M belongs both to the wheel tooth profile (radius R_{r1} and angle □$_1$), and also to worm cutter tooth profile (radius $R_r 2 = \infty$ and angle □$_2$) the defining equations in the two polar coordinate systems connected to the two wheels are:

$$\rho_1 = \rho(\varphi_1, R_{r1}); \quad \alpha_1 = \alpha(\varphi_1, R_{r1}); \quad arcP_{01}P = \varphi_1 \cdot R_{r1}$$

$$\rho_2 = \rho(\varphi_2, R_{r2}); \quad \alpha_2 = \alpha(\varphi_2, R_{r2}); \quad arcP_{02}P = \varphi_2 \cdot R_{r2}$$

We note that the equation of worm cutter tooth profile, combined to wheel 1, is easily obtained from the profile 1 equation. Curve “a” which represents the gearing line, (figure 4) being fixed (independent of rotating gears is defined in fixed polar coordinates with the fixed pole in P, and the reference line is represented by the common tangent II. The gearing line equations, function of rotation wheel 1, are:

$$\rho_a = \rho(\varphi_1, R_{r1}); \quad \alpha_a = \alpha(\varphi_1, R_{r1})$$

Curve "c", which engages both sides of wheel 1 and respectively worm cutter, are embodied in the profile of two gear racks c_1 and c_2, which is a negative of the other, and their profile equations are:

$$\rho_{c1} = \rho(\varphi_1, R_{r1}); \quad \alpha_{c1} = \alpha(\varphi_1, R_{r1}); \quad \overline{P_{0c1}P} = x$$

$$\rho_{c2} = \rho(\varphi_2, R_{r2}); \quad \alpha_{c2} = \alpha(\varphi_2, R_{r2}); \quad \overline{P_{0c2}P} = -x$$

Because rolling on radius circles R_{r1} and $R_{r2=}\infty$ is achieved without sliding, the arches on these circles are equal: $\varphi_1 \cdot R_{r1} = -\varphi_2 \cdot R_{r2} = \infty$

The two profiles being conjugated between them and conjugated to the gear rack profile, their equations can be expressed by parameter x function. Parametric equations, in polar coordinates, of the two gear racks profiles, of the gear wheels 1 profile and worm cutter and the gearing line, parameter x function are:

$$\rho_{c1} = \rho(x); \ \alpha_{c1} = \alpha(x); \ \overline{P_{0c1}P} = x$$

$$\rho_{c2} = \rho(x); \ \alpha_{c2} = \alpha(x); \ \overline{P_{0c2}P} = -x$$

$$\rho_1 = \rho(x); \ \alpha_1 = \alpha(x); \ arcP_1P = x$$

$$\rho_2 = \rho(x); \ \alpha_2 = \alpha(x); \ arcP_2P = -x$$

$$\rho_a = \rho(x); \ \alpha_a = \alpha(x)$$

Wheel 1 was considered equivalent to the processing wheel and wheel 2 equivalent to *worm cutter*. We notice that, being defined the profile a wheel, is immediately defined the profile of the conjugated wheel, the gearing line and the associated gear racks.

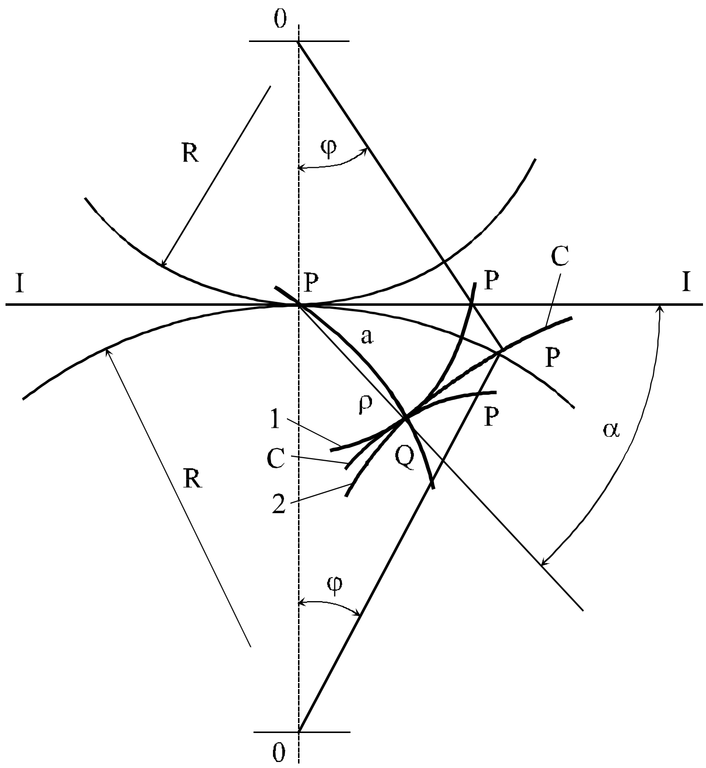

Figure 4. Elements of frontal engagement

After calculations, it results the elements of a worm cutter tooth profile for processing the non-evolventic profiles (see figure 5).

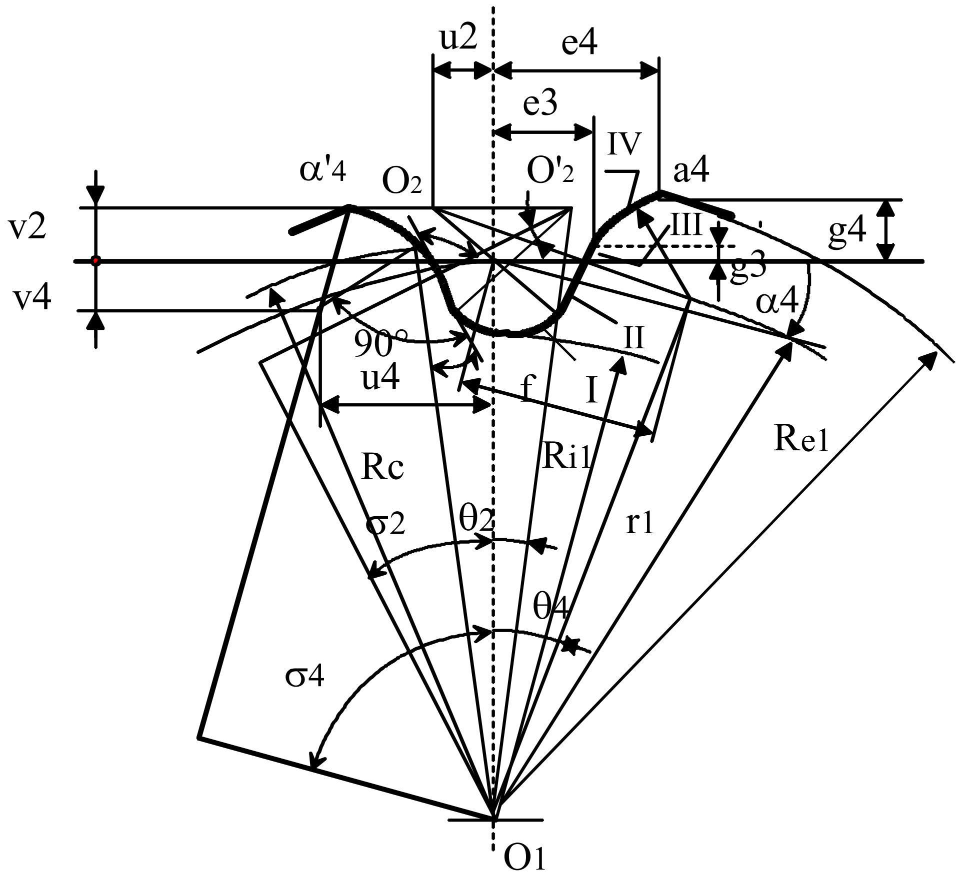

Figure 5 Elements of a worm cutter tooth profile for processing the non-evolventic profiles

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