THE DETERMINATION OF THE POSITIONING ANGLES IN SHARPENING ROMASCON CUTTERS WITH THE TOOTH AXIS PARALLEL TO THE SHANK OF THE CUTTER AXIS

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In order to obtain the geometric parameters φ_f, φ', α_{xf}, α_{yf}, γ_{xf}, γ_{yf} on the edges that are sharpened and re-sharpened, which correspond to work position it is necessary to rotate the tooth with the ϕ_1, ϕ_2, ϕ_3 , angles in sharpening the clearence surfaces, the rake surface and secondary clearence surfaces, and to move the grinding wheel along generating line of revolved surfaces inclined by $\mathbf{K_a}$, γ_a and $\mathbf{K_{sa}}$.

The revolution surface on which the sharpening operation is carried out may generally be considered a cone (figure 1).

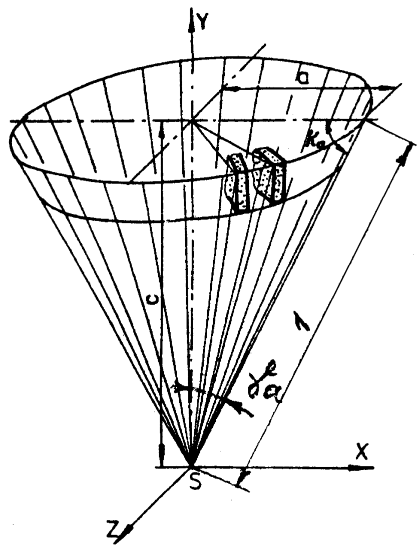

Figure 1

By selecting a system of coordinates **Sxyz**, where **Sx** coincides with the forward tool movement, and **Sz** is tangential to the trajectory described by one point on the tool, and **Sy** axis completes the right trihedron and coincides with the tool rotation axis, the resulting cone equation which defines the sharpening will be:

$$\frac{X^2 + Z^2}{a^2} = \frac{Y^2}{c^2} \qquad (1)$$

The a and c parameters are determined according to the angle already known or supposedly known, which is $\mathbf{K_a}$ or $\mathbf{K_{sa}}$ from the cone base in case of sharpening of clearence surfaces, secondary and auxiliary and finishing surface, and the φ_a semiangle from the cone vertex in case of rake surfaces sharpening, if the cone generating line is equal to the unit.

In order to determine the tooth positioning angles around its own axis in sharpening (ϕ_1, ϕ_2, ϕ_3) and the tool positioning in relation to grinding wheel ($\mathbf{K_a}$) the following algorithm is observed:

a) knowing that the sharpened surface shape remains unchanged following sharpening, the equation of the tangential plane to the surface is accordingly elaborated for **M** point, in sharpening position, according to the positioning parameters in sharpening equation which is maintained for work as well;
b) the equation of the tangential plane to the sharpened surface is expressed for the same **M** point (in the same reference system), but this time according to the geometric parameters which the tool must finally following sharpening ;
c) the condition is imposed that the 2 equations of the tangential planes in the **M** point represent the same plane, that is the coefficients of the 2 equations should be proportional.

In case of face milling cutters whose tooth axis is parallel to the shank of tool axis (figure 2), the flanks are sharpened following a cone which has the $\mathbf{K_a}$ base angle, and the tooth is rotated with ϕ_1 angle; these angles are to be determined so as to obtain the necessary tool geometric parameters following sharpening.

According to figure 1 in this case, it results:

$$a = \cos K_a ;\ c = \sin K_a \qquad (2)$$

which added to the cone equation gives:

$$X^2 + Z^2 = ctg^2 K_a \cdot Y^2 \qquad (3)$$

The $\mathbf{M_1}$ point located on the sharpening position of the flanks, in the reference system **Sxyz**, has the following coordinates:

$$X = \frac{D_1}{2} + r_m \cdot \cos(\varphi_1 + \varphi_m)$$
$$Z = r_m \cdot \sin(\varphi_1 + \varphi_m) \qquad (4)$$

The **Y** coordinate of the $\mathbf{M_1}$ point is determined as follows:

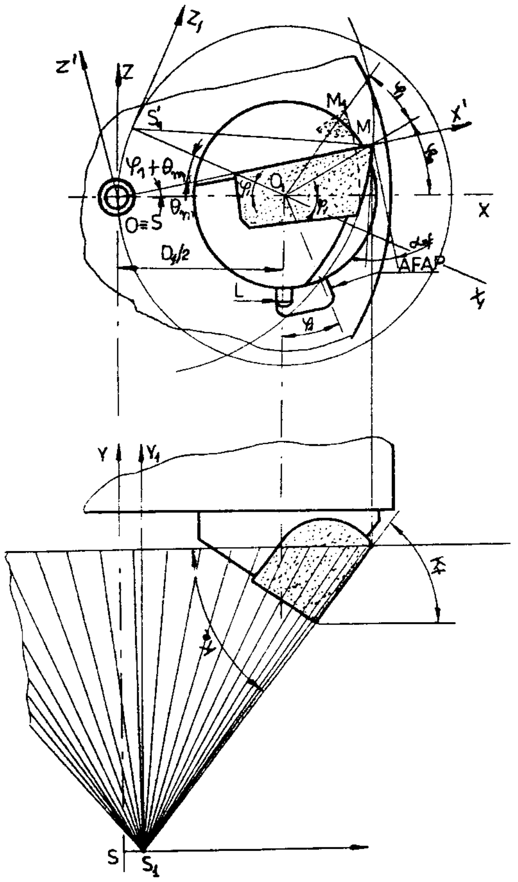

Figure 2

$$OM_1 = OA = O'A'$$

$$OM_1 = \sqrt{X_{M1}^2 + Z_{M1}^2}$$

$$SO' = O'A'\,tgK_a = tgK_a\sqrt{\frac{D_1}{4} + D_1 r_m \cos(\varphi_1 + \varphi_m) + r_m^2} \tag{5}$$

Accordingly the coordinates of the M_1 point are:

$$\begin{aligned} X &= \frac{D_1}{2} + r_m \cdot \cos(\varphi_1 + \varphi_m) \\ Y &= tgK_a\sqrt{\frac{D_1}{4}^2 + D_1 r_m \cos(\varphi_1 + \varphi_m) + r_m^2} \\ Z &= r_m \sin\left(\varphi_1 + \varphi_m\right) \end{aligned} \tag{6}$$

In as much as the rotation from sharpening position into work is centred around the tooth axis (figure 2) and as the shape and the flank equation in the new reference system $\mathbf{Sx_1y_1z_1}$ are the same as in the previous **Sxyz** system, then:

$$X_1^2 + Z_1^2 = ctg^2 K_a \cdot Y_1 \tag{7}$$

The equation of the tangential plane to the **M** point, written by multiplying relation (3) is:

$$X \cdot X_1 + Z \cdot Z_1 = ctg^2 K_a \cdot Y_1 \tag{8}$$

By replacing relation (6) in relation (8) results:

$$\left[\frac{D_1}{2} + r_m \cos(\varphi_1 + \varphi_m)\right] X_1 - ctgK_a Y_1 \cdot \sqrt{\frac{D_1^2}{4} + r_m \cos(\varphi_1 + \varphi_m) + r_m^2} + r_m \sin(\varphi_1 + \varphi_m) Z_1 = 0 \tag{9}$$

Relation (9) represents the equation of the tangential plane to the flank in **M** point, elaborated in conformity with the positioning parameters in the $\mathbf{Sx_1y_1z_1}$ system in sharpening.

The expression of the tangential plane to the flank in the **M** point, rendered in accordance with the geometric parameters of cutter is:

$$X' \cdot ctg\alpha_{xf} - Y' \cdot ctg\alpha_{yf} - Z' + A = 0 \tag{10}$$

where: A is the value pertaining to the translation of the system of coordinates.

The $\mathbf{Sx_1y_1z_1}$ system is rotated with the $\varphi_1 + \theta_m$ angle in relation to the **Ox'y'z'** system, thereforethe connection between these two systems is given by transformation:

$$\begin{aligned} X_1 &= X'\cos(\varphi_1 + \theta_m) - Z'\sin(\varphi_1 + \theta_m) \\ Y_1 &= Y' \\ Z_1 &= X'\sin(\varphi_1 + \theta_m) + Z'\cos(\varphi_1 + \theta_m) \end{aligned} \tag{11}$$

By replacing relation (11) in relation (9) the equation of the tangential plane to the flank in the **Ox'y'z**' system is:

$$X'\left[\frac{D_1}{2}\cos(\varphi_1 + \theta_m) + r_m \cos(\varphi_m - \theta_m)\right] - Y' ctgK_a \cdot \sqrt{\frac{D_1^2}{4} + D_1 r_m \cos(\varphi_1 + \varphi_m) + r_m^2} + Z' \cdot \left[r_m \sin(\varphi_m - \theta_m) - \frac{D_1}{2}\sin(\varphi_1 + \varphi_m)\right] = 0 \tag{12}$$

Imposing the condition that equations (10) and (12) represent the same plane, the result will be:

$$\frac{\left[\frac{D_1}{2}\cos(\varphi_1 + \theta_m) + r_m \cos(\varphi_m - \theta_m)\right]}{ctg\alpha_{xf}} = \frac{ctgK_a\sqrt{\frac{D_1^2}{4} + D_1 r_m \cos(\varphi_1 + \varphi_m) + r_m^2}}{ctg\alpha_{yf}} = \frac{\left[r_m \sin(\varphi_m - \theta_m) - \frac{D_1}{2}\sin(\varphi_1 + \varphi_m)\right]}{-1} \tag{13}$$

From the above equation if we consider the first and third member and after we are grouping the terms after $\mathbf{D_1}$ and $\mathbf{r_m}$ we obtain:

$$\sin(\varphi_1 + \theta_m - \alpha_{xf}) = \frac{2r_m}{D_1}\sin(\varphi_m - \theta_m + \alpha_{xf}) \quad (14)$$

From the relation (14) emerges the needed dependence, which is:

$$\varphi_1 = \alpha_{xf} - \theta_m + \arcsin\left(\frac{2r_m}{D_1}\sin(\varphi_m - \theta_m + \alpha_{xf})\right) \quad (15)$$

From the above equation it is determined the φ_1 positioning angle around tooth axis in rotation , according to the angle of clearence of the cutter and the elements taht determine the position of point on edge. Also, one can determine the inverse relation of dependence of α_{xf} angle of clearence according to the φ_1 rotation angle.

$$\alpha_{xf} = \varphi_1 + \theta_m - \arcsin\left[\frac{r_m \sin(\varphi_1 + \varphi_m)}{\sqrt{\frac{D_1^2}{4} + D_1 r_m \cos(\varphi_1 + \varphi_m) + r_m^2}}\right] \quad (16)$$

Considering the first and the second ratios from equation (12) it is obain succesively:

$$tgK_a = \frac{tg\alpha_{xf}\sqrt{\frac{D_1^2}{4} + D_1 r_m \cos(\varphi_1 + \varphi_m) + r_m^2}}{tg\alpha_{xf}\left[\frac{D_1}{2}\cos(\varphi_1 + \varphi_m) + r_m \cos(\varphi_1 + \varphi_m)\right]} \quad (17)$$

respectively:

$$tg\alpha_{yf} = \frac{tgK_a tg\alpha_{xf}\left[\frac{D_1}{2}\cos(\varphi_1 + \theta_m) + r_m \cos(\varphi_m - \theta_m)\right]}{\sqrt{\frac{D_1^2}{4} + D_1 r_m \cos(\varphi_1 + \theta_m) + r_m^2}} \quad (18)$$

Relation (17) represents the needed dependence of $\mathbf{K_a}$ angle in reciprocal positioning between tool and grinding wheel.

Relation (18) describes the variation of the α_{yf} longitudinal angle of clearence of cutter according to $\mathbf{K_a}$, α_{xf}, φ_1 and the other elements.

For the operating edge which is perpendicular to both the tooth and cutter axes, the $\mathbf{K_a = 0°}$, meaning that on this edge the α_{yf} angle is zero in accordance with the relation (18), for any φ_1 angle of the tooth rotation around its own axis. In order to obtain a positive value for α_{yf} on this edge the flanks on finishing edge are sharpened starting from sharpening position of the rake surfaces, according to the scheme from figure 1.

When the M point is situated on the tooth axis it results that $\mathbf{r_m=0}$ and $\mathbf{\theta_m = 0°}$ that is the α_{xf} angle of clearence is equal to the φ_1 angle which signifies the tooth rotation angle in sharpening such as it results from equation (16).

The rake surfaces (figure 3) are sharpened following a cone which has the γ_a as semiangle of cone edge, and the tooth is rotated with φ_2 angle, these angles are to be determined in such a way so as to have the γ_{xf} and γ_{yf} cutter parameters following sharpening.

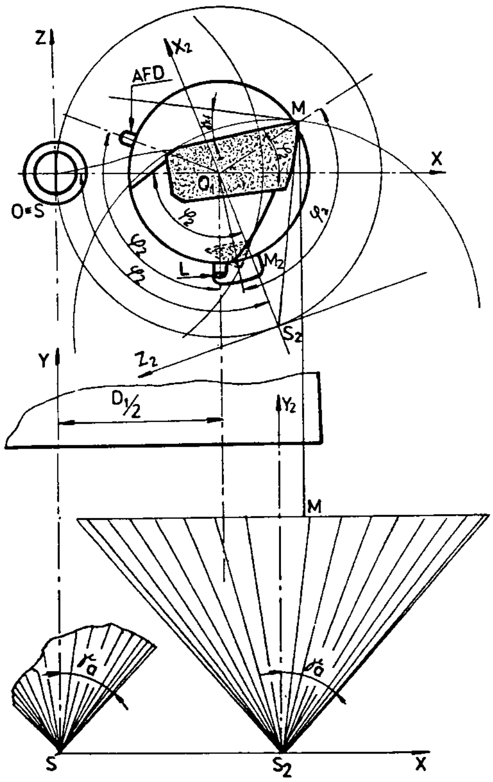

Figure 3

According to the figure 1 it can be deduced that :

$$a = \sin\gamma_a;\ c = \cos\gamma_a \quad (19)$$

which once introduced in the cone equations gives:

$$X^2 + Z^2 = tg^2\gamma_a \cdot Y^2 \quad (20)$$

The $\mathbf{M_2}$ point situated on sharpening position of the rake surfaces has in the **Sxyz** system of reference the following coordinates:

$$X = \frac{D_1}{2} + r_m \cos(\varphi_2 - \varphi_m)$$
$$Y = ctg\gamma_a\sqrt{\frac{D_1^2}{4} + D_1 r_m \cos(\varphi_2 - \varphi_m) + r_m^2} \quad (21)$$
$$Z = -r_m \sin(\varphi_2 - \varphi_m)$$

In as much as the rotation from sharpening position to wotk position is centered around tooth axis and as the form and the rake surface equation in new $\mathbf{Sx_2y_2z_2}$ system is the same as in the **Sxyz** system, namely:

$$X_2^{\ 2} + Z_2^{\ 2} = tg^2\gamma_a \cdot Y_2^{\ 2} \qquad (22)$$

The equation of the tangential plane to the rake surface is obtained by doubling the relation (22):

$$X_2 \cdot X_2 + Z_2 \cdot Z_2 = tg^2\gamma_a \cdot Y_2 \cdot Y_2 \qquad (23)$$

By turning relation (21) into (23) it results that:

$$X_2\left[\frac{D_1}{2} + r_m \cos(\varphi_2 - \varphi_m)\right] - Y_2 tg\gamma_a \cdot \sqrt{\frac{D_1^2}{4} + D_1 r_m \cos(\varphi_2 - \varphi_m) + r_m^2} - Z_2 r_m \cdot \sin(\varphi_2 - \varphi_m) = 0 \qquad (24)$$

The above relation represents the equation of the tangential plane to the rake surface in $\mathbf{M_2}$ point expressed in relation to the positioning parameters of $\mathbf{Sx_2y_2z_2}$ system in sharpening.

The equation of the tangential plane to the rake surface into the **M** point, expressed in relation to the cutter's geometric parameters of **Mx'y'z'** system is obtained from the relation (10) where β=0° which means:

$$x' \cdot tg\gamma_{xf} - y' \cdot tg\gamma_{yf} - z' + A = 0 \qquad (25)$$

The $\mathbf{Sx_2y_2z_2}$ system is rotated around $\mathbf{Sy_2}$ axis with the $\mathbf{[-(\varphi_2-\theta_m)]}$ and the connection between the 2 systems is given by the transformation:

$$\begin{aligned} X_2 &= x'\cos(\varphi_2 - \theta_m) + z'\sin(\varphi_2 - \theta_m) \\ Y_2 &= y' \\ Z_2 &= -x'\sin(\varphi_2 - \theta_m) + z'\cos(\varphi_2 - \theta_m) \end{aligned} \qquad (26)$$

By turning transformation (26) into relation (24) the result is:

$$x'\left[\frac{D_1}{2}\cos(\varphi_2 - \theta_m) + r_m \cos(\varphi_m - \theta_m)\right] - y' tg\gamma_a \sqrt{\frac{D_1^2}{4} + D_1 r_m \cos(\varphi_2 - \theta_m) + r_m^2} + z'\left[\frac{D_1^2}{2}\sin(\varphi_2 - \theta_m) + r_m \sin(\varphi_m - \theta_m)\right] \qquad (27)$$

Having for equations (25) and (27) the same plane as imposed condition, then:

$$\frac{\frac{D_1}{2}\cos(\varphi_2 - \theta_m) + r_m \cos(\varphi_m - \theta_m)}{tg\gamma_{xf}} = \frac{tg\gamma_a \sqrt{\frac{D_1^2}{4} + D_1 r_m \cos(\varphi_2 - \theta_m) + r_m^2}}{tg\gamma_{yf}} = \frac{\frac{D_1}{2}\sin(\varphi_2 - \theta_m) + r_m \sin(\varphi_m - \theta_m)}{-1} \qquad (28)$$

After grouping and re-grouping the terms of the above equation on needed dependence:

$$\varphi_2 = 180^\circ + \gamma_{xf} + \theta_m - ar\cos\left[\frac{2r_m}{D_1}\cos[\varphi_m - \theta_m - \gamma_{xf}]\right] \qquad (29)$$

By proceeding to verify graphically the relation above, it has been concluded that it is necessary for the solution to introduce the cosine function period, that is the angle of 180°.

By analysing the above relation it can be concluded that the $\boldsymbol{\varphi_2}$ angle which is necessary to position in sharpening the rake surface, depends both on the $\boldsymbol{\gamma_{xf}}$ cutter rake angle and on the parameters which determine the point position on the edge, respectively on cutter.

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