Study regarding the Establishment of Cross-sectional Parameters of Forming Taps

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Abstract: - In the paper is presented some consideration regarding the parameters that influence the cross sectional parameters of forming tap. It is taking into account the parameters that have a great influence on the ridges of the forming taps which determine the contour shape of the forming tap's ridges, the radius of the ridge profile, and determination of the radial chamfer relief of the forming tap.
Also are shown the influence of the correlation angle on ridge thread that determine the contact area between the top of the working ridge and of the part subjected to plastic deformation in order to avoid its cutting.

Key-Words: - formed taps, chamfer zone, plastic deformation, tap life.

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1 Introduction

The geometric parameters of the cross-sectional of the forming taps must satisfy the optimum condition of the plastic deformation, namely the minimum torque.
The minimum torque is obtained by correlating the geometric parameters resulting in the optimal shape of the cross-section. This section is characterized by the *z*-number of the working sides and the *k* value of the relief angle.
In the paper [1] we recommend the theoretical equations that can be used to determine the contour of the cross section.

$$\rho = \sqrt{\left(\frac{d-k+k\sin z\varphi}{2}\right)^2 + z^2 \cdot \frac{k^2}{4} \cdot \cos z\varphi} \quad (1)$$

$$\theta = \varphi + \mathrm{arctg}\frac{z \cdot k \cdot \cos z\varphi}{d-k+k \cdot \sin z\varphi} \quad (2)$$

where:

ρ - contour radius;

θ - coordinate of the polar angle;
d - outer diameter of the tap;
φ -angle of the rotation of the tap in the tapping process.

2 Setting the cross-sectional parameters of the forming tap

2.1 Determining the contour shape

Based on the motion analysis of the 5822 grinding machine, the kinematic scheme (Fig. 1) used to profile the forming tap was developed. According to Fig. 1, the tappet 4 together with the cam 5 forms a system (OO_2 – connecting rode, O_2O_1 - crank) which causes the movement of the point "O" with the vertical equation:

$$a(\varphi_k) = \overrightarrow{r_0} + \overrightarrow{r_r} + \vec{e} - \vec{x} \quad (3)$$

where (φ_k) is the displacement of the tappet in the extreme left position.

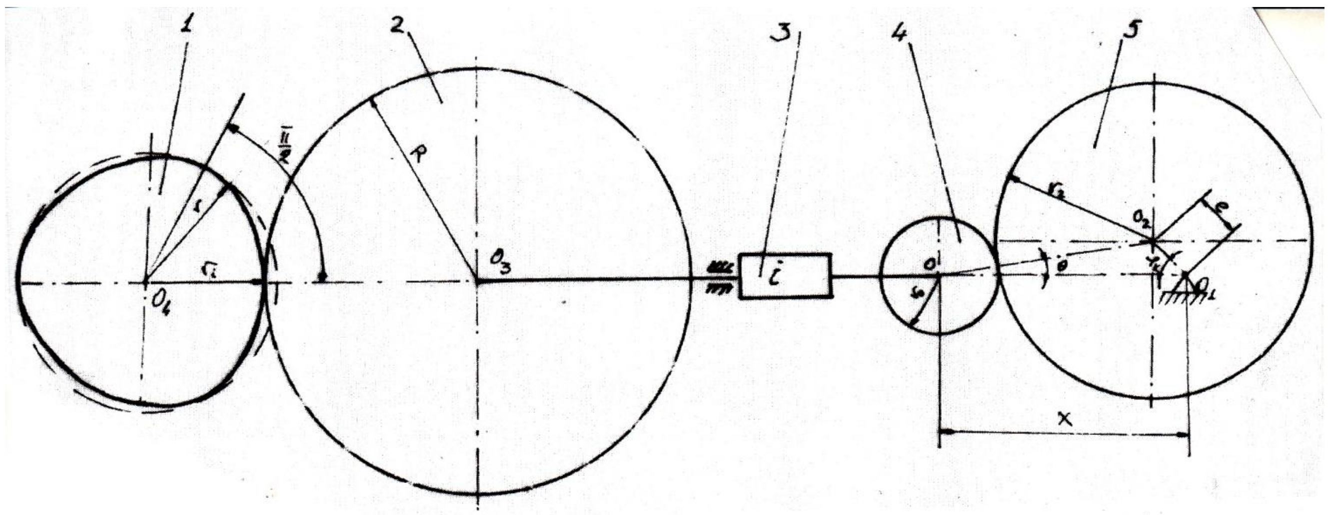

Fig. 1 Kinematic scheme of the model 5822 grinding machine used for profiling the forming tap.

But:

$$\vec{x} = \overrightarrow{(e \cdot cos\varphi_k)} + \left[\overrightarrow{(r_0 + r_2) \cdot cos\theta}\right] \quad (4)$$

$$\cos\theta = \frac{OB}{OO_2} = \frac{\sqrt{O_2O_2'-O_2B^2}}{r_0+r_2} = \frac{\sqrt{(r_0+r_2)^2-(e\cdot sin\varphi_k)^2}}{r_0+r_2} = \sqrt{\frac{(r_0+r_2)^2-(e\cdot sin\varphi_k)^2}{(r_0+r_2)^2}} = \sqrt{1-\frac{(e\cdot sin\varphi_k)^2}{(r_0+r_2)^2}} = \sqrt{1-\lambda^2\cdot sin^2\varphi_k} \quad (5)$$

where:

$\lambda = \frac{e}{r_0+r_2}$; $e = 2{,}5\ mm$; $r_0 = 16{,}5\ mm$; $r_2 = 36\ mm$;

So:

$$x = (e \cdot cos\varphi_k) + (r_0 + r_2)\sqrt{1-\lambda^2 \cdot sin^2\varphi_k} \quad (6)$$

We can approximate $\lambda^2 = 0$.
Substituting the relation (6) in relation (2) results:

$$a \cdot (\varphi_k) = e \cdot (1 - cos\varphi_k) \quad (7)$$

Taking into account the transmission ratio I between the tappet and the abrasive disc, we obtain:

$$A(\varphi_k) = i \cdot a(\varphi_k) \quad (8)$$

Since $\varphi_k = Z \cdot \varphi$, where Z is the number of working sides result:

$$A(\varphi) = e \cdot i(1 - coszφ) \quad (9)$$

But $k = 2 \cdot ei$

So: $A(\varphi) = \frac{k}{2}(1 - cosz\varphi)$ (10)

In the case considered by analogy, the contour of the cross-section in polar coordinates is:

$$r_i = r - \frac{k}{2}(1 - cosz\varphi) \quad (11)$$

Where r_i is the radius of the forming tap contour. By solving the equations (11) and (12), the contours of the forming taps were obtained in the two cases. Small differences in shape resulted, although in both situations the radial chamfer relief angle *K* had the same value.

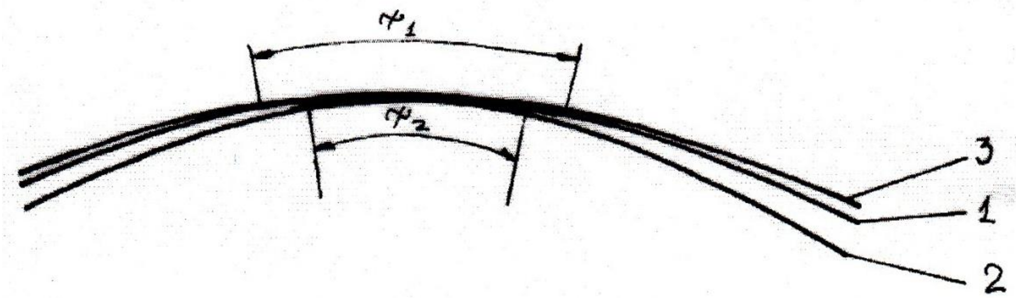

Fig.2 Graphical representations.

The shape differences increase the contact angle between the forming tap and the workpiece $\psi_1 > \psi_2$), resulting in an increased torque in the contour, obtained after the previous work. It is considered optimal shape (2) based on the above.

2.2 Determination of the radius of the working ridge

Analyzing the relationship (11) results that the increase of *K* and *Z* the possibility of cutting the top of the working ridge. The method of calculating the peak radius of the working ridge (Fig. 3) is further developed to avoid the phenomenon of cutting off.

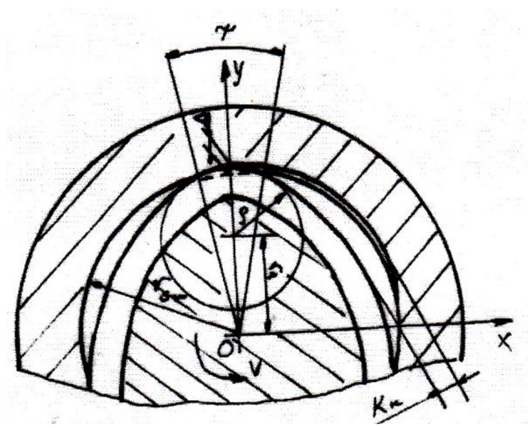

Fig.3 Calculating the peak radius of the working ridge.

Using the relation of the radius of the working spiral from the work [2] it follows:

$$\rho_i = \frac{\left[r_i^2 + (r_i')^2\right]^{\frac{3}{2}}}{r_i^2 + 2\cdot(r_i')^2 - r_i \cdot r_i''} \quad (12)$$

where r' and r'' are the first and the second derivative of the forming tap contour.

$$r_ı = r - \frac{k}{2}\cdot(1 - cosz\varphi) = r - \frac{k}{2}\cdot\left(1 - cosz\cdot\frac{\pi}{z}\right) = r - k \quad (13)$$

$$r_i' = \frac{k}{2}\cdot z\cdot sinz\varphi = \frac{k\cdot z}{2} sinz\frac{\pi}{z} = 0 \quad (14)$$

$$r_i'' = \frac{k\cdot z^2}{2} cosz\varphi = \frac{k\cdot z^2}{2} cosz\cdot\frac{\pi}{z} = -\frac{k\cdot z^2}{2} \quad (15)$$

Making the calculations we have:

$$\rho = \frac{(r-k)^2}{r-k+\frac{k\cdot z^2}{2}} \quad (16)$$

The relationship (16) represents the optimum peak thread radius for a certain recommended *K* value. At the limit, for a K_{max}, the phenomenon of cutting off of working ridge ($\rho = 0$). occurs.
From Fig.3 it follows:

$$r_1 = r - \rho \quad (17)$$

Entering the relation (11) in (17) we get:

$$r_1 = r_i + k - \frac{(r-k)^2}{r-k+\frac{k\cdot z^2}{2}} \quad (18)$$

At the point $r_1 = r_i$ result:

$$\left(2 - \frac{z^2}{2}\right)\cdot k^2 - 3\cdot r\cdot k + r^2 = 0 \quad (19)$$

$$k_{\frac{1}{2}} = \frac{3r \pm \sqrt{9r^2 - 2r^2(4 - z^2)}}{4 - z^2}$$

The solution $k_1 < 0$ is impossible.
Fig. 4 shows the diagram $d = f(K_{max})$, values at which the forming tap has no resistance to the plastic deformation process.

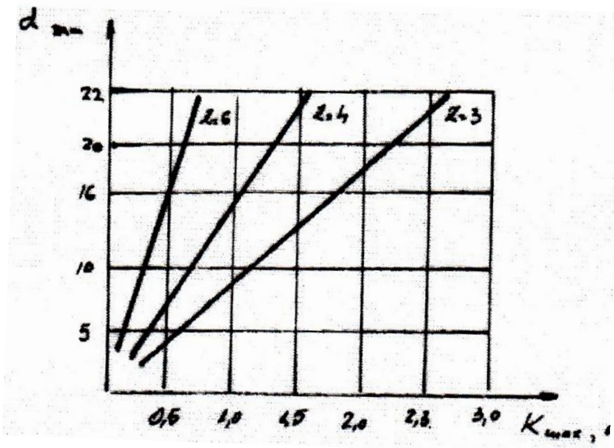

Fig.4 The diagram $d = f(K_{max})$.

2.3 Determination of the radial chamfer relief *K* value of the forming tap

The radial chamfer relief K value is:

$$K_{normal} = \frac{\pi D_1}{2z} tg\varphi_c; \quad K_{normal} < K_{max} \qquad (20)$$

where:
D_1 - is the minor diameter of the forming tap;
φ_c - angle of the chamfer relief.

In paper [3] it is recommend $\varphi_c = 8^0 - 12^2$.
It is necessary to be respected these values because all parameters of the cross section depend on *K*.

2.4 Determining the correlation angle

Angle ψ is defined as the contact area between the top of the working ridge and of the part subjected to deformation.
Define Δ as the workpiece material subject to plastic deformation processing on one side of the forming tap:

$$\Delta = \frac{p}{2} \cdot tg\varphi_c \qquad (21)$$

where:
p - the pitch of the thread;
$\varphi_c -$ the angle of the chamfer taper;
Z - the number of working sides.

From Fig. 3 it follows:

$$r_i = r - \Delta \qquad (22)$$

By replacing the relation (11) and (21) in (22) it follows:

$$r - \frac{p}{z} \cdot tg\varphi_c = r - \frac{k}{2}(1 - cosz\psi_r) \qquad (23)$$

ie:

$$\psi_r = \frac{2arccos\left(1 - \frac{2ptg\varphi_c}{zk}\right)}{z} \qquad (24)$$

The graphical representation of the relationship (24) is presented in Fig. 5.

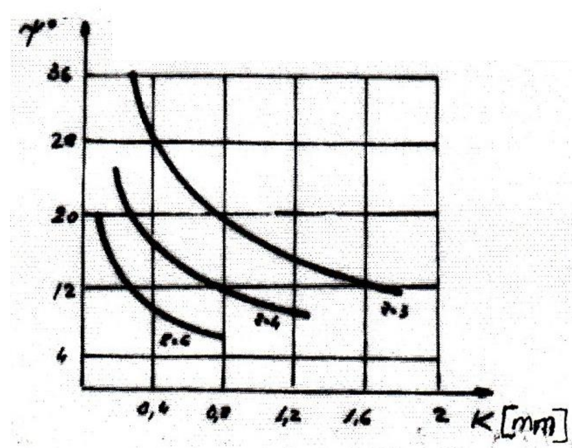

Fig.5 Graphical representation of the correlation angle.

As the *K* increases, the contact angle of the ridge threads decreases. It is once again necessary to use a certain *K* value depending on the diameter of the tap to avoid cutting the working ridge.

3 Conclusions

The calculation method of cross section parameters can apply to the entire metric thread range. The parameters thus correlated lead to ensuring the precision necessary for the correct formation of the inner thread profile.
Using the technology of forming tap the resulting thread is burnished and toughened by the cold forming action with many advantages and the threads produced are generally stronger and have a smooth surface finish.` Materials particularly well suited for thread forming include aluminum, brass, copper,

lead, stainless steel, carbon steel, cast steel, leaded steel and zinc. In general, any material which produces a stringy chip is a good candidate for forming. Generally, materials that produce a continuous chip when drilling are good for thread forming.

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