# DETERMINATION OF THE EFFORTS THAT OCCUR IN THE CASE OF PERFORMING INNER THREADS WITH FORMING ROLLERS

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**Abstract: -** The aim of this paper is to present a simplified model for the theoretical calculation of the deformation efforts that occur in the case of performing inner threads by forming rollers. Firstly, determination of the normal stress distribution along the roll-blank separation line is presented and then the calculus of the resulting force of deformation.

**Key-Words**: -*Inner threads, forming rollers*

## 1. Introduction

Although known since the last century, internal threading by plastic deformation is not widely used because of a poor number of theoretical and practical researches made on this area; consequently, it would be necessary to continue and deepen the researches in order to setup the theoretical and practical basis concerning the tool geometry and its influence on the material behavior.

The execution of inner threads by rolling is made with thread rolling heads and it is specific to the threads with internal diameter bigger than 30 mm. Their breeding range is restricted because of their very high complexity.

Achieving inner threads by rolling differs from tapping; in the first case, rollers have a rolling motion over the interior surface of the workpiece, combined with a permanent plastic deformation made in the part material. The operation is similar to the exterior rolling but in the last case the rollers have a larger diameter. In the case of rolling with heads, the material flow will appear in a perpendicular plan to the diametric plan of the roller [1].

The methodology of examination the technological deformability of metals and alloys is highly complex, mainly because it is very difficult to objectively classify the metals plasticity under different strain conditions and in function of different technological parameters (temperature, degree of deformation, deformation speed, etc).

If in the case of tap threading the threading moments increase up to 100%, in the case of pipe threading with vortex roll-process (fig. 1), the loadings are 10 - 15 times smaller compared to the classical processing by cutting.

The forming roller *1* rotates around the axis of the device inserted inside the workpiece, eccentric to its axis. Every rotation will bring the forming roller in contact with the workpiece, forming the thread profile. Meanwhile, the workpiece rotates around its axis and moves on axial direction with a rotation step. From theoretical point of view this is the theory of final plastic deformation with a complex kinetics of the deformation. To avoid the great difficulties in solving these problems [2], a simplified model for the theoretical calculation of the deformation efforts, based on the use of slip lines properties, is proposed [3].

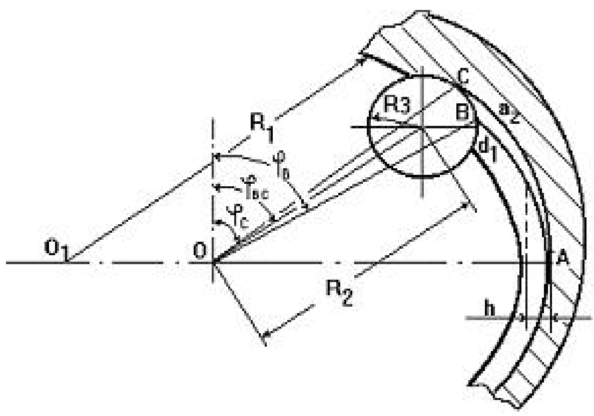


**Figure 1** *Roller threading scheme*

## 2 Problem Formulation

Assuming that the material has rigido-plastic properties and taking into account the marginal efforts for stress and speeds, it is necessary to calculate the efforts acting on the spindle of rolling head.

Considering the state of plane deformation, we determine the normal stress distribution along the roller-blank separation line and then the resulting force of deformation. In this case the contact arc may be replaced by a broken line [1], each segment representing the edge of penetrating wedge. Thus, the simplified scheme reduces to solving the problem of plasticity of plane deformation state.

The differential equilibrium equations will be reduced to a system of two equations. [2]

$$\frac{\delta\sigma_x}{\delta x} + \frac{\delta\tau_{xy}}{\delta_y} = 0 \qquad (1)$$
$$\frac{\delta\tau_{xy}}{\delta_x} + \frac{\delta\sigma_y}{\delta_y} = 0$$

The plasticity criteria of Mises and Treska-Saint Venant are analogous and differ only by the size of the constant *k*:

$$0{,}25\,(\sigma_x - \sigma_y)^2 + \tau^2_{xy} = k^2 \qquad (2)$$

Further it will be analyzed the penetration of the symmetrical sectioned wedge into the rigid-plastic semiplane, by assuming that the plastic mass are extruded on both sides. The boundary conditions of the problem for the right side of the semiplan are set up, by expressing the friction on the straight lateral contour lines through the angle $\delta$:

$$t = k \sin 2\delta,\ 0 \le \delta \le \pi/4 \qquad (3)$$

It is made the assumption that the roller acts with the speed *v*. The sliding field in the xy flow plane is shown in fig. 2. In our case the contour of roller consists of two sectors. The first sector, BP, is parallel to the x axis while the second one, PA, is tilted with the angle $\pi/3$ towards the first sector. Along the contact sector BP, the following relationships exist:

$$\sigma_y = -P,\ \tau_{xy} = 0,\ v_n = v_0 \qquad (4)$$

Along the sector PA:

$$\sigma_n = -n,\ \tau_{nt} = -t,\ v_n = -v_0\cos(\pi/3) \qquad (5)$$

Along the free surface AG:

$$\sigma_n = \tau_{nt} = 0 \qquad (6)$$

According to fig. 2, the angles $\gamma$, $\beta$, $\theta_0$ and $\theta$ are linked by relationships:

$$\theta_0 = \theta - \delta = \gamma - \beta \qquad (7)$$

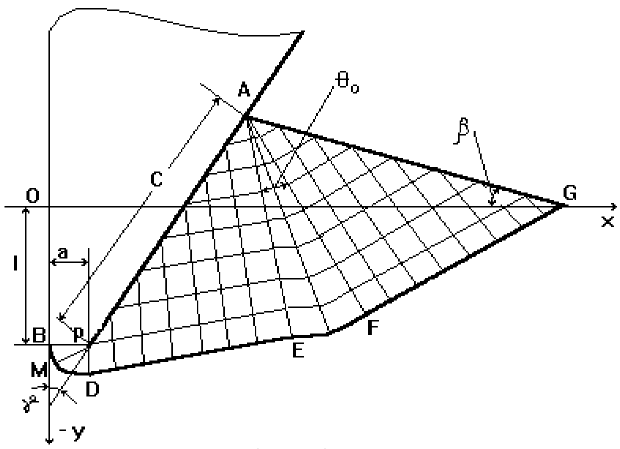


**Figure 2** *The field of plane stresses*

By pressing depth it can be expressed the length of the contact sector *c*, with the following relationship:

$$c[\cos\gamma - \sin(\gamma - \theta_0)] - a.\sin(\gamma - \theta_0) = h \qquad (8)$$

The uncompressed condition of the material leads to the equality between the surface under the x-axis, pressed by the roller, and the area of triangle situated above the x axis, represented by the extruded material. Hence, the equation (9) is obtained:

$$2ah + h^2 \operatorname{tg}\gamma = (c + a)(c\cos\gamma - h)\cos(\gamma - \theta_0) +$$
$$+ (c\cos\gamma - h)\operatorname{tg}\gamma \qquad (9)$$

The equations (8) and (9) allow us to establish a link between the angle $\gamma$ and the depth *h*, as well as between $\theta$ and *c*.Further, the equations (1) and (2) need to be solved such that to satisfy the boundary conditions and then the inverse problem must be solved. Assuming that the material is in plastic condition, the stresses distribution along the border of roller must be determined. From the equilibrium condition we can determine the pressing force of the roller in semiplane.

By analogy with the problem of stabilized flow when introducing a sharp wedge, the case of the sectioned wedge was examined. In this case the geometric similarity was violated, thus difficulties were encountered in the determination of the particle trajectory in the speed field. But there were no difficulties to establish the stresses field at a certain deformation step.

In this case, for each step the deformation is considered small. The stresses field is determined based on the integrals of the plasticity equations for the OXY coordinates. The necessary constructions in the OXY work plan are presented in Fig 2. In the areas BMP, PDEA and AFG, joined by central fields of slip lines, uniform stresses states occur.

In the AFG area the stresses field is determined from the condition at the boundary AG: $\gamma = \tau_{nt} = 0$. Hence:

$$\sigma = -k,\ f = \pi/2 - \beta \qquad (10)$$

where: σ - medium stress; f - angle between the x axis and the highest component of the main stress, σ1.

As simple stresses states are analyzed, along the characteristics are valid the integrals of the plasticity equations:

$$\sigma = 2kf + c_1 \qquad (11)$$

where $c_1$ is a constant determined in the AGF field:

$$2k\left(\frac{\pi}{2} - \beta\right) + c_1 = -k \Rightarrow c_1 = -k(\pi - 2\beta + 1) \qquad (12)$$

In the area PAED, the stresses field has the following expresion:

$$\sigma = k\cos 2\delta - n;\quad f = \pi/2 - \gamma - \delta \qquad (13)$$

while in the area BMP:

$$\sigma = k - p;\quad f = 0 \qquad (14)$$

Knowing the $c_1$ constant for the normal stress components, it results:

$$n = 2k(\gamma - \beta + \delta + \cos^2\delta) \qquad (15)$$

$$p = k(\pi - 2\beta + 2)$$

The punch pressure force, *P*, must be balanced by the normal and tangential stresses on the right:

$$P = 2aP + 2c(n\sin\gamma - t\cos\gamma) \qquad (16)$$

Finally we will obtain:

$$P = 2ka[\pi + 2 - 2(\gamma - \theta)] + 4kc[\theta_0 + \delta + \cos\delta \cdot \sin^{-1}\gamma \cdot \sin(\gamma + \delta)] \cdot \sin\gamma \qquad (17)$$

Establishing the pressing depth, *h*, the *γ* angle and the size of the coil facet, *a*, from the equations (8) and (9) it can be obtained the length of the contact sector, *c*, as a function of $\theta_0$:

$$c = \frac{a\sin(\gamma - \theta_0) + h}{\cos\gamma - \sin(\gamma - \theta_0)} \qquad (18)$$

By replacing eq. (18) into eq. (17), the following relation results:

$$2ah + h^2 tg\gamma = \left(\frac{a\sin(\gamma-\theta_0)+h}{\cos\gamma - \sin(\gamma-\theta_0)} + a\right) \cdot \left(\frac{a\sin(\gamma-\theta_0)+h}{\cos\gamma - \sin(\gamma-\theta_0)} \cdot \cos\gamma - h\right) \cdot \cos(\gamma-\theta_0) + \left(\frac{a\sin(\gamma-\theta_0)+h}{\cos\gamma - \sin(\gamma-\theta_0)} \cdot \cos\gamma - h\right) tg\gamma \qquad (19)$$

which is a transcendent equation in $\theta_0$. It can be solved by halving the interval [0; π/3].

## 4 Conclusion

An easier way to solve the transcendent equation consists in expressing the three variables a, h and c, as a function of the thread pitch. This can be done for metrics, trapezoidal and Whitworth threads by using the following relationships:

$$h = b_1 p;\quad a = b_2 p;\quad c = b_3 p \qquad (20)$$

The standardized values of the three coefficients are given in table 1 [4]

Table. 1

| Coefficients | Metric | Whitworth | Trapezoidal |
|---|---|---|---|
| $b_1$ | 5/16 tg $\alpha/2$ | 0,64 | 0,5 |
| $b_2$ | 0,25 | 0,137 | 0,36 |
| $b_3$ | 5/16 sin $\alpha/2$ | 0,72 | 0,517 |

By replacing eq. (20) into eq. (3) results:

$$b_3p\cdot[\cos\gamma - \sin(\gamma - \theta_0)] - b_2p\sin(\gamma - \theta_0) = b_1p \quad (21)$$

By dividing with *p* we obtain:

$$b_3 \cos \gamma - ( b_3 + b_2 ) \sin ( \gamma - \theta_0 ) = b_1 \quad (22)$$

and hence:

$$\sin(\gamma - \theta_0) = \frac{b_3 \cos\gamma - b_1}{b_3 + b_2} \quad (21)$$

From the eq. (21) we can determine the angle $\theta_0$ as:

$$\theta_0 = \gamma_0 - \arcsin\frac{b_3 \cos\gamma - b_1}{b_3 + b_2} \quad (22)$$

From the eq. (4) we can determine the thread pitch, *p*:

$$2b_1b_2p^2 + b_1^2p^2 tg\gamma = (b_2+b_3)p^2(b_3\cos\gamma - b_1)\cos(\gamma-\theta_0) + b_3p(b_3\cos\gamma - b_1p)tg\gamma \quad (23)$$

and hence:

$$p = \frac{b_3\cos\gamma}{2b_1b_2 + b_1^2 tg\gamma - (b_2+b_3)(b_3\cos\gamma - b_1)} \cdot \frac{1}{\cos(\gamma - \theta_0) + b_3b_1 tg\gamma} \quad (24)$$

where the value of $\theta_0$ is obtained from eq. (8).

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