ANALYTICAL MODEL OF FORGE CUTTING PROCESS WITH ASYMMETRICAL TOOLS

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ABSTRACT

In this paper is developed the theory of forge cutting process feasible with asymmetrical tools. The asymmetrical cutting process is different of the symmetrical cutting process. This type of process is necessary to realize the slash of billet when it has one or many steps of diameters, and when is necessary a good precision of slicing.
Based on the mathematical model established above we developed a calculation program that calculates using the MATLAB package.
Force is calculated in three stages, until the penetration is less or equal with high of the oblique zone, and that is uniform.

KEYWORDS: algorithms, simulation, forge cutting process.

1.Introduction

The forging process consists of the deformation operations and cutting operations. The cutting process may be with total or partial separation of the parties of forged body.

For some forge cutting operations the use of symmetrical tool is recommended. In case of other operations the asymmetrical tool is recommended.

The theory of the first case, of the forge cutting with the symmetrical tool, is developed in the [1] reference.

The asymmetrical cutting process is different of the symmetrical cutting process. In this paper is developed the theory of asymmetrical cutting process.

We adopt the following initial conditions:

- The tool body is very hard and consequently, practically the deformation of tool is equal of zero,
- The material of deformation body is homogeneous and isotropous,
- The geometry of active zone of cutting tool is proper of the Figure 1.

The asymmetrical cutting tool has an edge of radius r, an inclined zone of angle γ and the straight zone.

In the developing of the cutting process the first stage is the process of the symmetrical cutting. This process corresponds to the penetration of tool from z = 0 until z = t.

The second stage corresponds to the penetration partial asymmetrical from z = t, until z = r and the third stage corresponds of the penetration of tool until z = h.

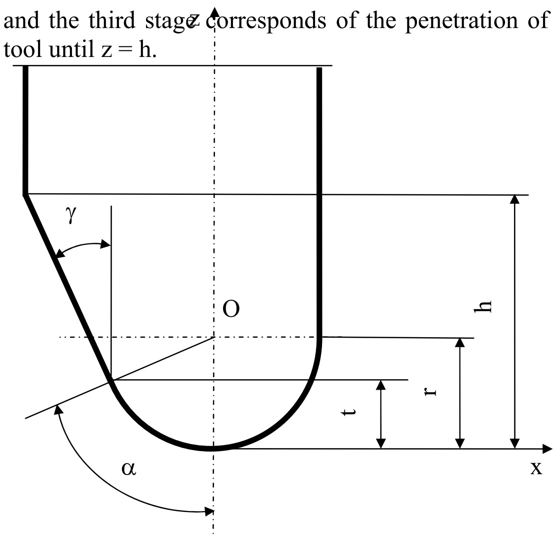

Figure 1. *The geometry of asymmetrical cutting*

2.Theoretical modeling of cutting process

2.1. In the first stage

The problem of the theoretical modeling of the symmetrical cutting process is solved in the paper [6]. The geometrical scheme of the cutting process in this stage is sowed in Figure 2.

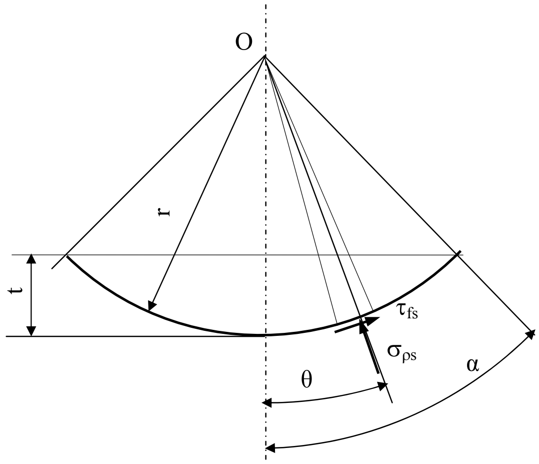

Figure 2. *The scheme for calculus of cutting force in the first stage*

Using the equilibrium equation for radial coordinate we obtain for stress $\sigma_{\rho s}$ the relation:

$$\sigma_{\rho s} = -\sigma_0\left[1 + \mu \cdot \left(2 - \frac{r}{r_\alpha - 1}\right) \cdot (\alpha - \theta)\right] \quad (1)$$

Relation of elementary force:

$$dF = \left|\sigma_{\rho s}\right| \cdot l_t \cdot r \cdot \cos\theta \cdot d\theta + \tau_{fs} \cdot l_t \cdot r \cdot \sin\theta \cdot d\theta \quad (2)$$

For $\theta \in [0, \alpha]$ we obtain:

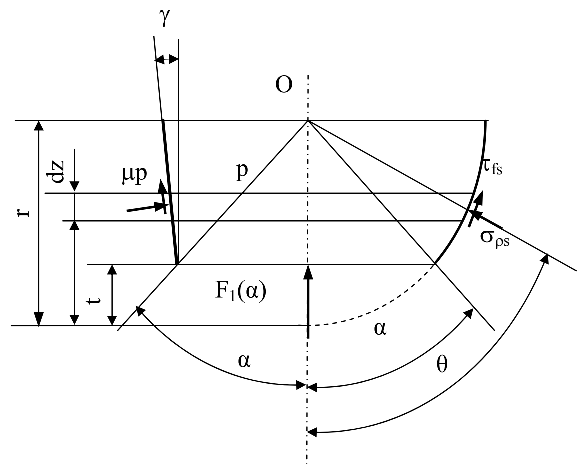

Figure 3*. The scheme for calculus of cutting force in the second stage.*

$$F_1(\theta) = 4k \cdot l_t \cdot r \cdot \left\{\sin\theta + \mu \cdot \left(2 - \frac{r}{r_\alpha - r}\right) \cdot \left[(\alpha - \theta)\sin\theta + 1 - \cos\theta\right] + \mu(1 - \cos\theta)\right\} \quad (3)$$

The signification of the factors from the relation (3):

k – critical stress of the deformed material,

l_t – cutting dimension of the body,

r – radius of edge of the cutting tool,

μ – Friction coefficient,

r_α – radius of plastic deformation zone inside of the body,

α – angle pursuant to figure 3, and depending of penetration on symmetrical zone.

For θ=α we obtain:

$$F_1(\alpha) = 4k \cdot l_t \cdot r \cdot \left[\sin\alpha + \mu \cdot \left(2 - \frac{r}{r_\alpha - r}\right) \cdot (1 - \cos\alpha) + \mu(1 - \cos\alpha)\right] \quad (4)$$

2.3. *In the second stage*

The geometrical scheme of the second stage of the asymmetrical forge cutting is rendered in Figure 3.

We denominate F1 (α) the value of the force what corresponds of the limit of first stage of the cutting process.

Relation defines the force in the second stage:

After integration we obtain:

$$F_2(z) = F_1(\alpha) + 2k \cdot l_t \cdot (tg\gamma + \mu)(z - t) + \\ + 2k \cdot l_t \cdot r \cdot \left\{ \sin\theta - \sin\alpha + \mu\left(2 - \frac{r}{r_\alpha - r}\right) \cdot \left[(\theta - \alpha)\sin\theta + \cos\theta - \cos\alpha\right] \right\} \quad (5)$$

Between the factors of expression (4) exist the following relation:

$$\alpha = \frac{\pi}{2} - \gamma, \quad \alpha = \arccos\left(\frac{r - t}{r}\right) \\ \theta = \arccos\left(\frac{r - z}{r}\right), \quad \theta \in \left(\alpha, \frac{\pi}{2}\right], z \in (t, r] \quad (6)$$

2.4. In the third stage

The geometrical scheme of the third stage of cutting process is presented in Figure 4.

We denominate F2(r) the value of the force what corresponds of the limit of second stage of cutting process. $F_2(r)$ corresponds to z=r, respectively too $\theta = \frac{\pi}{2}$.

Thus we have:

$$F_2(r) = F_1(\alpha) + 2k \cdot l_t \cdot (tg\gamma + \mu)(r - t) + \\ + 2k \cdot l_t \cdot r \cdot \left\{ 1 - \sin\alpha + \mu\left(2 - \frac{r}{r_\alpha - r}\right) \cdot \left[\left(\frac{\pi}{2} - \alpha\right)\sin\theta + \cos\alpha\right] \right\} \quad (7)$$

Relation defines the force in the third stage of cutting process:

$$F_3(z) = F_2(r) + 2k \cdot l_t \cdot (tg\gamma + 2\mu) \cdot (z - r) \quad (8)$$

The mathematical relation (7) is applied for $z \in (r, h]$, h is the active zone of the cutting tool. For z > h to the surface of cutting tool the interaction between materials of body- tool is not developed.

Using asymmetrical tools the transversal surface is perpendicular on longitudinal axes, and material addition is smaller.

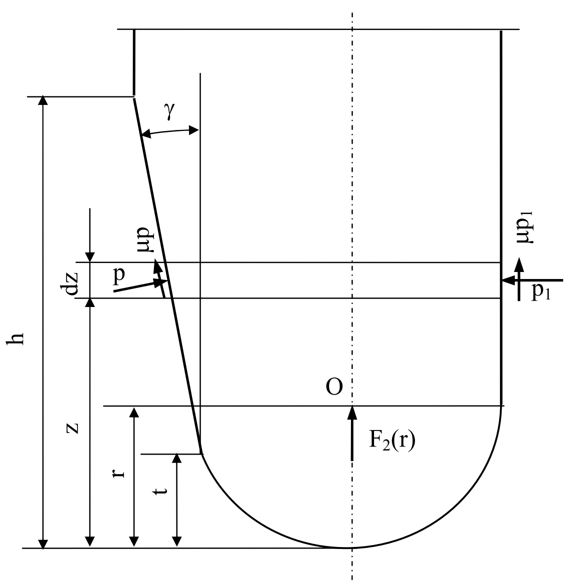

***Figure 4**. The scheme for calculus o cutting force in the third stage.*

3. The computer calculation of asymmetrical cutting force

Using the mathematical model established above we developed a calculation program that calculates using the algorithm present in this paper.

May be calculate Force versus penetration, in that three phase, using the MATLAB programmer package.

The results of simulation are shown in figure 5.

4. Conclusion

Is possible to see that in first stage force is quickly on the increase and then increase velocity is less, in second stage, and in the third stage it is linear increase. This algorithm is helpful for students from metallurgical and mechanical domains, the engineers from forging wards, or projectors engineers.

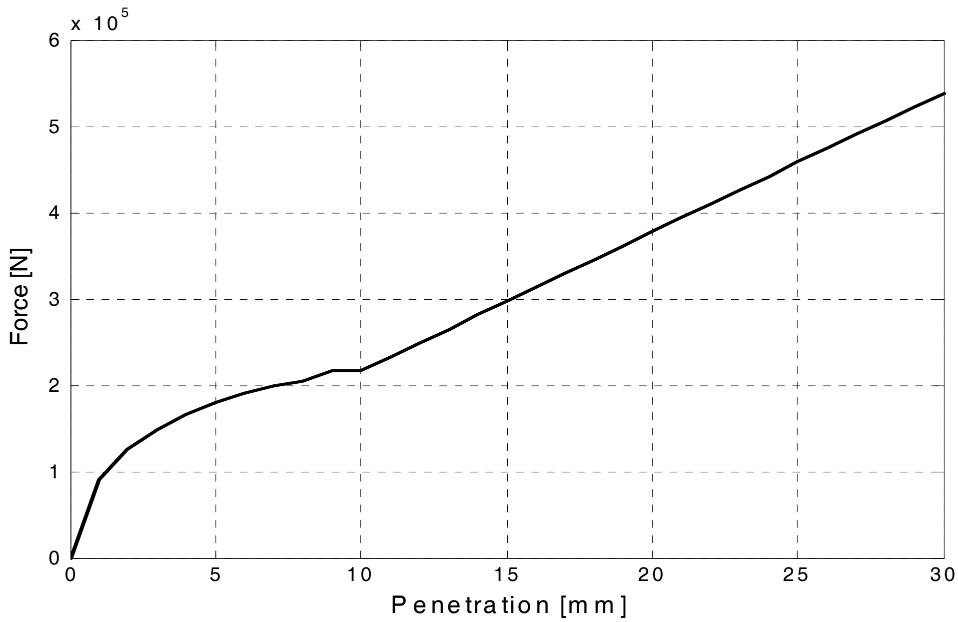

Figure 5. *Force versus penetration of the symmetrical tool*

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