COLD STRANGLING HOLLOW PARTS FORCES CALCULATION OF CONICAL AND CONICAL WITH CYLINDRICAL COLLAR

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Abstract. *This paper presents an application of the energy method to solve the problem of determining the force to strangle cave or hollow parts by cold plastic deformation. Analytical relationships have been established for the calculation of the total force of conical tapered and conical with cylindrical collar of cave parts. These relationships show that the total force of strangling affects by physical and mechanical characteristics of the material blank, deformation semi-angle strangling cone, radius strangling mould and friction coefficient between the die and the blank material.*

Keywords: *strangling force, strangling conical tapered, conical with cylindrical collar strangling, strangling mould.*

1. Introduction

Machining strangling belongs in the category of processes by moulding and can be defined as reducing the cross-sectional size of the hollow pieces, hollow or solid cylindrical profiles by pressing the material in the radial direction from the outside. Machining process strangling is applied to obtain by cold plastic deformation of parts of different type metal packaging, tubes war cartridges, muff, parts for installations, etc. Strangled parts can be tubular or hollow with cone shape (fig. 1, *a*), conical with cylindrical collar (fig. 1, *b)*, toroidal (fig. 1, *c*) and toroidal with cylindrical collar (fig.1, *d*).

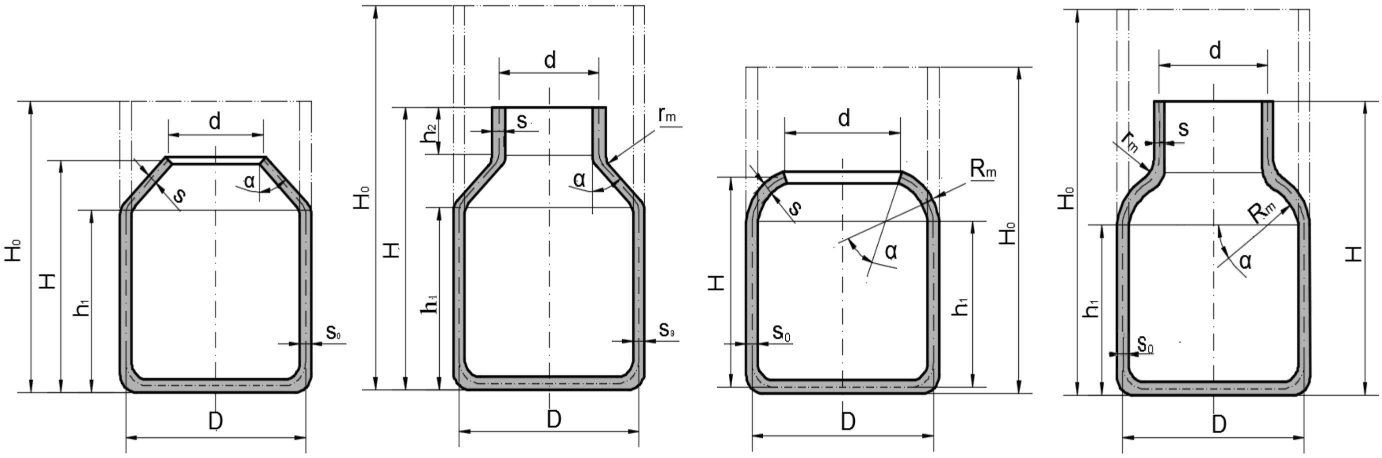
Characteristic processing by moulding parts cave is changing the low wall thickness, so it can be considered from the perspective of engineering, part thickness remains the same and after

To obtain a diameter *d* through the of hollow or tubular parts processing of diameter *D*, by the coefficient m_{gi} it is estimated, which is the inverse of the degree of deformation, and is defined by the relationship:

$$m_g = \frac{d}{D} \tag{1}$$

where *d* is the average diameter of the piece section by strangling and *D* is the average diameter of the first section piece blank. This strangling factor m_g must be greater than the allowable value m_{ga}. The factor m_{ga} is function to the physical and mechanical proprieties material blank, the relative thicknesses of the walls, s_0/D, the geometric shape of the strangled zone, the design of the mould supporting wall piece, friction between the blank and the mould surface [1, 2. 3].

The knowing of the tapered force by cold plastic deformation is an important parameter of the strangling process, and both in terms of choice of pressing machine, but especially in terms of stability piece wall during processing



a *b* *c* *d*

Figure 1. *Strangled cave parts forms*

2. Calculation of strangling conical force

In conical cold deformation by strangling of parts, the active tool of mould acts with $\overline{N}$ force on the blank to deform blank walls (figure 2). Mould-blank at the interface, due to friction with the friction coefficient μ, frictional force $\overline{F_f}$ occurs which acts on the surface the wall and acts against the walls. By composing the two forces $\overline{N}$ and $\overline{F_f}$ resulting force $\overline{R}$. The vertical projection of the resultant force $\overline{R}$ will be the force required to be applied to the die necking $\overline{F_{tgc}}$, formed by two components, corresponding forces projections $\overline{N}$ and $\overline{F_f}$.

As shown in figure 2, can be written:

$$\overline{F_{tg}} = \overline{F_{gc}} + \overline{F_{fv}} \tag{2}$$

where the vertical force $\overline{F_{gc}}$ is only required for plastic deformation of walls and $\overline{F_{fv}}$ is the vertical component of friction force $\overline{F_f}$.

From geometric considerations we can write:

$$F_{fv} = F_f \cos\alpha \tag{3}$$

in which $F_f = \mu N$ and $N = \dfrac{F_{gc}}{\sin\alpha}$

(4) Taking into account the relations (3) and (4) the relationship (2) becomes:

$$F_{tgc} = F_{gc}(1 + \mu\, ctg\, \alpha) \tag{5}$$

Plastic material deformation the force required size

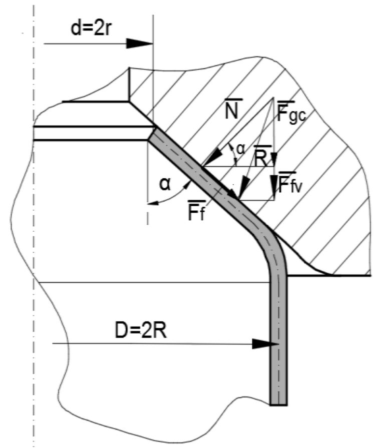


Figure 2. *Conical strangling forces system*

F_{gc}, can be calculated using the energy method, by equating the external strangling forces work with the internal tensions work during deformation, as follows:

$$L_e = L_i \tag{6}$$

The elementary work of internal tensions L_i, determined the relationship [1]:

$$dL_i = \sigma_c \varepsilon_i dV \tag{7}$$

where: σ_c is yield strength of the blank material; ε_i - intensity of deformations at the point *M*; *dV*-deformed volume element by elementary mechanical work, dL_i in the vicinity of *M* (figure 3).

The intensity of the deformations can be calculated by the relation [4]:

$$\varepsilon_i = \frac{\sqrt{2}}{3}\sqrt{\left(\varepsilon_\rho - \varepsilon_\theta\right)^2 + \left(\varepsilon_\theta - \varepsilon_z\right)^2 + \left(\varepsilon_z - \varepsilon_\rho\right)^2} \quad (8)$$

where ε_ρ, ε_θ and ε_z are the main deformations, to direction ρ, θ and z (fig.3).

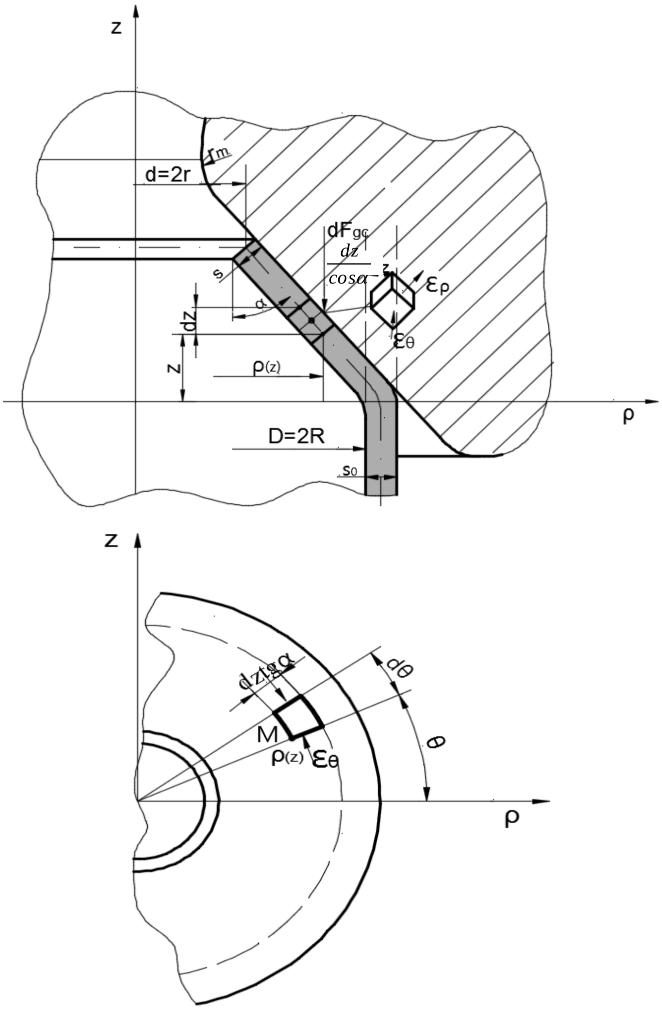


Figure 3. *Deformations scheme at conical strangling*

The main deformations in the circumferential direction, corresponding to figure 3, is defined by
the equation:

$$\varepsilon_\theta = \frac{\rho(z) - R}{R} \quad (9)$$

where:

$$\rho(z) = R - z\, tg\, \alpha \quad (10)$$

If substitute relation (10) in (9) results:

$$\varepsilon_\theta = -\frac{z}{R} tg\, \alpha \quad (11)$$

If the point *M* is written relationship of constant volume at cold plastic deformation defined by relation:

$$\varepsilon_\rho + \varepsilon_\theta + \varepsilon_z = 0 \quad (12)$$

and it is considered that $\varepsilon_z \approx 0$, because the stretch deformations of wall at strangling cave part are relatively small, results:

$$\varepsilon_\theta = -\varepsilon_\rho \quad (13)$$

The size of the specific deformation of the wall thickness ε_ρ, is defined by the equation:

$$\varepsilon_\rho = \frac{s - s_0}{s_0} \quad (14)$$

In equation (14) taking into account the relation (11) it follows:

$$s = s_0\left(1 + \frac{z\, tg\, \alpha}{R}\right) \quad (15)$$

Elementary volume *dV* corresponding to figure 3 is defined by the equation:

$$dV = dA\, s \quad (16)$$

where:

$$dA = \rho(z)\, d\theta\, \frac{dz}{\cos\alpha} \quad (17)$$

By substituting *dA* in (12) and taking into account the relations (10) and (15) gives:

$$dV = s_0 \frac{\left(R^2 - z^2 tg^2\alpha\right)}{R} \frac{d\theta\, dz}{\cos\alpha} \quad (18)$$

If you take into account the relations (11) and (13), the intensity of deformations defined by equation (8) will have the following calculation expression:

$$\varepsilon_i = \frac{2}{\sqrt{3}} \frac{z}{R} tg\, \alpha \quad (19)$$

By replacing relation (18) and (19) in equation (7) is obtained by calculating formula elementary mechanical work of internal tensions, dL_i, as follows:

$$dL_i = \sigma_c s_0 \frac{2}{\sqrt{3}} \frac{z}{R} tg\, \alpha \frac{R^2 - z^2 tg^2\alpha}{R} \frac{d\theta\, dz}{cos\, \alpha} \quad (20)$$

At conical strangling the mechanical work of internal tensions, L_i, is obtained by integrating the relation (20), as follows:

$$L_i = \frac{2}{\sqrt{3}}\sigma_c s_0 \int_0^{2\pi} d\theta \int_0^h \frac{\left(R^2 z - z^3 tg^2\alpha\right)}{R^2}\frac{dz\, tg\,\alpha}{cos\,\alpha} \quad (21)$$

After the calculation results:

$$L_i = \frac{2}{\sqrt{3}}\sigma_c s_0 2\pi\left(\frac{h^2}{2} - \frac{h^4}{4R^2} tg^2\alpha\right)\frac{sin\alpha}{cos^2\alpha} \quad (22)$$

The work of external force deformation L_e, to strangle cone has the expression [3]:

$$L_e = \lambda F_{gc} h \quad (23)$$

where: $\lambda \approx \frac{1}{2}$, because during processing F_{gc} increases from *0* to the maximum value [3]; *h*-size displaced for deformation. After equalizing the relationship (22) to (23) gives:

$$F_{gc} = \frac{4\pi}{\sqrt{3}}\sigma_c s_0\left(h - \frac{h^3}{2R^2} tg^2\alpha\right)\frac{sin\alpha}{cos^2\alpha} \quad (24)$$

The deformation stroke *h* is approximately equal to the generatrix of the cone, and has the value:

$$h = \frac{R - r}{\sin\,\alpha} \quad (25)$$

By substituting the relationship (15) in (24) we obtain:

$$F_{gc} = \frac{4\pi}{\sqrt{3}}\sigma_c s_0\left[R - r - \frac{(R-r)^3}{2R^2}\frac{1}{cos^2\alpha}\right]\frac{1}{cos^2\alpha} \quad (26)$$

or

$$F_{gc} = \frac{2\pi}{\sqrt{3}}\sigma_c s_0 (D-d)\left[1 - \frac{1}{2cos^2\,\alpha}\left(1 - \frac{r}{R}\right)^2\right]\frac{1}{cos^2\alpha} \quad (27)$$

Another form is obtained if in (27) to take account of the relationship (1):

$$F_{gc} = \frac{2\pi}{\sqrt{3}}\sigma_c s_0 (D-d)\left[1 - \frac{1}{2cos^2\,\alpha}\left(1 - m_g\right)^2\right]\frac{1}{cos^2\alpha} \quad (28)$$

In equation (28) using equation (5) gives the expression for calculating the total force of tapered strangling under the form:

$$F_{tgc} = \frac{2\pi}{\sqrt{3}}\sigma_c s_0 (D-d)\left[1 - \frac{1}{2cos^2\,\alpha}\left(1 - m_g\right)^2\right](1 + \mu ctg\,\alpha)\frac{1}{cos^2\alpha} \quad (29)$$

The total force of strangling process will be slightly higher if it neglects term defined by the relationship $\frac{1}{2cos^2\alpha}\left(1 - m_g\right)^2$ and safety resulting:

$$F_{tgc} = 1{,}15\,\sigma_c s_0 (D-d)(1 + \mu ctg\alpha)\frac{1}{cos^2\alpha} \quad (30)$$

3. Calculation of conical with cylindrical collar strangling force.

Getting the conical strangling parts with cylindrical collar utilizing hollow cylindrical or tubular workpiece is in fact a continued of mould strangling moving after conical strangling completion form so that the cylindrical collar diameter *d* is obtained (figure 4).

Analysis of wall deformation highlights in this case that after the strangling to diameter $d + 2r_m(1 - cos\,\alpha)$ the material continues to deform, moving on the radius r_m mold, reducing the diameter to the value *d.* On connection area with a radius r_m the material blank continues to strangle to the diameter *d*, but simultaneously bend until mid angle α then straightening, forming cylindrical surface diameter *d*.

The total force of strangling F_{tg} in this case, using overlapping effects, it will consist of the total force of strangling of the conical surface F_{tgc} and pulling force for bending and straightening plastic material piece $F_î$ on the walls of the mold radius r_m, as follows:

$$F_{tg} = F_{tgc} + F_î \quad (31)$$

The amount of force F_{tgc} is determined by the relation (30) and bending and straightening force for using the energetically method of the work of the external force $F_î$ to moving blank across r_m with that of internal tensions. Thus we can write:

$$L_e = F_î\, r_m\, \alpha;\, L_i = 2M_î\,\alpha \quad F_î = \frac{2M_î}{r_m} \quad (32)$$

The inner strain bending moment is determined by integrating the elemental momentum necessary bending a strip with b_m

average width, along circumference of collar, as follows:

$$M_{\hat{i}} = \int_0^{2\pi} dM_{\hat{i}} \qquad (33)$$

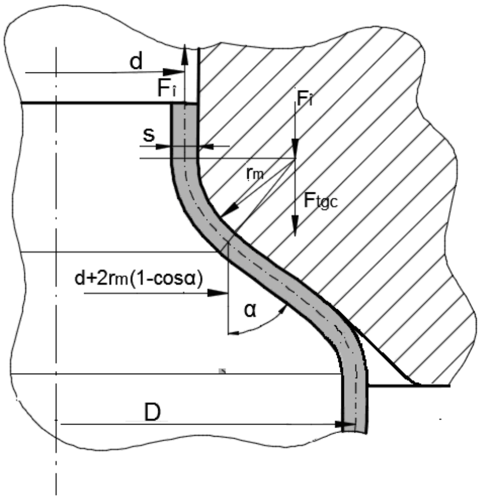


Figure 4. *Cconical with cylindrical collar strangling scheme*

The amount of elemental moment is given by [4]:

$$dM_{\hat{i}} = \frac{db_m s^2}{6}(1{,}5+\varepsilon_r)\sigma_r \qquad (34)$$

where the value of b_m is given by expression

$$db_m = \frac{d + r_m(1-\cos\alpha)}{2} d\theta \qquad (35)$$

By substituting db_m in (34) and performing the integration, it follows:

$$M_{\hat{i}} = \frac{2\pi[d + r_m(1-\cos\alpha)]}{2}\frac{s^2}{6}(1{,}5+\varepsilon_r)\sigma_r$$

(36) The thickness s is determined by the rate of strangling, m_g [2,5]

$$s = \frac{s_0}{\sqrt{m_g}} \qquad (37)$$

Relation (37) is substituted in (36) and this one gets (32) to form:

$$F_{\hat{i}} = \frac{2\pi[d + r_m(1-\cos\alpha)]}{m_g\ r_m}\frac{s_0^2}{6}(1{,}5+\varepsilon_r)\sigma_r$$

(38) In generally, the strangling processed parts have a good plasticity material, and if adopted $\varepsilon_r \approx 24\%$, equation (38) will take the following form:

$$F_{\hat{i}} = \frac{1{,}82 s_0^2 \sigma_r\left(1 + \frac{d}{r_m} - \cos\alpha\right)}{m_g} \qquad (39)$$

If are replaced $F_{\hat{i}}$ as defined by (39) and F_{tgc} obtained by equation (30) in (31) results the total force F_t of the conical with cylindrical collar strangling, following form:

$$F_t = 1{,}15\,\sigma_c s_0(D-d)(1+\mu ctg\,\alpha)\frac{1}{cos^2\alpha} + \frac{1{,}82 s_0^2\sigma_r\left(1+\frac{d}{r_m} - cos\,\alpha\right)}{m_g} \qquad (40)$$

4. Conclusions

Shown that processing of the strangling tubular or hollow parts are a complex process, over which it exerts influence of several factors. The conical strangling total force increases with physical and mechanical characteristics of the material workpiece, hollow blank diameter, the degree of deformation, cone semi-angle, initial thickness of the blank walls and friction coefficient between the die and strangled cave or tubular blank.

Expression of calculating the conical with cylindrical collar strangling force shows that it is higher than the conical strangling total force. This increase is due to bending and straightening walls for forming cylindrical zone of part.

As against conical strangling, the conical with cylindrical collar strangling besides others also viewing are added mentioned influence factors the initial thickness of the walls of the square, and the radius of the cylindrical collar connection with conical mould surface. With the growth of these, increase total strangling force of conical with cylindrical collar of hollow parts

5. References.

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