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CONTRIBUTIONS TO THE DEMOLDING MOMENT CALCULATION FOR INJECTED PARTS WITH THREAD

Simion HARAGÂŞ, Iuliu NEGREAN, Ovidiu BUIGA

Abstract: *This paper presents a computation methodology of the demolding moment in the case of plastic injected parts with external trapezoidal thread. The value of this moment directly influences the design solution of the ejector system.*
Key words: *injected part, demolding moment, trapezoidal thread.*

1. INTRODUCTION

The thread with round profile is mainly used in the case of plastic injected parts with thread. However, there are situations in which the thread profile is trapezoidal or saw. For the manufacture of these parts, the molds with mechanical unscrewing of the threaded cavity (for parts with external thread) are used. The rotation motion of the threaded cavity is performed using a spur gearing driven by a multiple-threaded power screw.

Such a mold (for a part with external thread) is presented in Figure 1 [1] resulting its design and operation. For this design version the external thread of the product is performed through the toothed rotating cavity 2, meshed using a screw through the gear 3. The product has internal longitudinal ribs, through which it is ensured against the rotation with the help of the core 1.

When designing the ejector system for such a mold several factors have to be considered, such as the number of cavities and the demolding moment (the moment necessary to detach the injected part from the mold). The demolding moment is calculated as a function of the demolding force and of the dimensions of the injected part.

The demolding force is calculated using the relation [2]:

$$F_D = \mu \cdot p \cdot A \qquad (1)$$

where: μ - coefficient of friction between the injected part and the cavity. It depends on the plastic injected material and on the processing quality of the active surfaces of the mold; p - contact pressure between the part and the cavity; A - contact area between the part and the cavity.

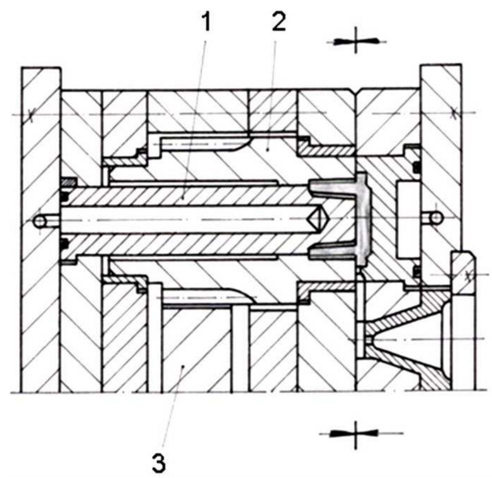

Fig. 1 Mold for external thread with rotating cavity
1 - core; 2 - cavity; 3 - gear.

Theoretical aspects regarding the calculation of the demolding force are presented in the papers [2] and [3] and the results of the experimental approaches of this problem in the papers [4] and [5].

The pressure p is determined from the relation [2]:

$$p = E_{(T)} \cdot \varepsilon_{(T)} \cdot \frac{h}{\rho} \; F_D = \mu \cdot p \cdot A \qquad (2)$$

where:

$E_{(T)}$ - modulus of elasticity of the injected part (at the demolding temperature).

$\varepsilon_{(T)}$ - specific contraction of the material (at the demolding temperature).

h - wall thickness of the injected part.

ρ - curvature radius of the profile.

2. DEMOLDING MOMENT CALCULATION

An injected part with external trapezoidal thread is considered (fig.2).

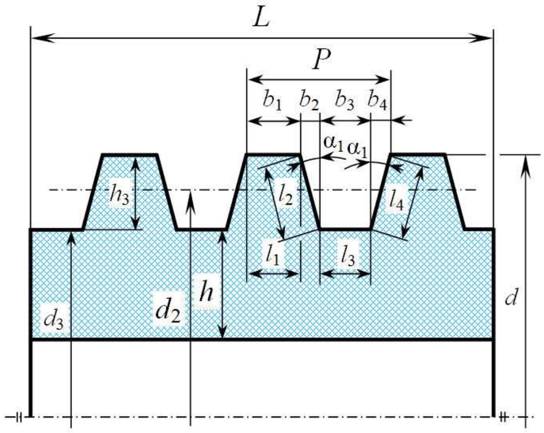

Fig.2 Injected part with external trapezoidal thread

According to the thread pitch, four sections with the widths b_1, b_2, b_3, and b_4 are considered. All the quantities are expressed as a function of the main dimensions: the mean diameter d_2, the thread pitch *P*, the length of the part *L*, and the thickness *h* of the part wall [1].

The height of the thread is:

$$h_3 = H_1 + a_c = 0.5 \cdot P + a_c \qquad (3)$$

and the diameters:

$$d_3 = d_2 - 0.5 \cdot P - 2 \cdot a_c \qquad (4)$$

$$d = d_2 + 0.5 \cdot P \; F_D = \mu \cdot p \cdot A \qquad (5)$$

For the trapezoidal thread α_1=15° and a_c (the clearance at the bottom) is a function of *P*:

$$\begin{aligned} a_c &= 0.25\,mm \quad for \quad 2 \le P \le 5\,mm \\ a_c &= 0.5\,mm \quad for \quad 6 \le P \le 12\,mm \\ a_c &= 1\,mm \quad for \quad 14 \le P \le 44\,mm \end{aligned} \qquad (6)$$

The dimensions b_1, b_2, b_3, b_4, respectively l_1, l_2, l_3, l_4 corresponding to the four sections (fig.2) are calculated using the equations:

$$b_1 = 0.366 \cdot P \;\; ; \;\; b_2 = 0.134 \cdot P \qquad (7)$$

$$b_3 = 0.366 \cdot P \;\; ; \;\; b_4 = 0.134 \cdot P \qquad (8)$$

$$l_1 = b_1 = 0.366 \cdot P \;\; ; \;\; l_2 = \frac{b_2}{\sin \alpha_1} = 0.518 \cdot P \qquad (9)$$

$$l_3 = b_3 = 0.366 \cdot P \;\; ; \;\; l_4 = \frac{b_4}{\sin \alpha_1} = 0.518 \cdot P \qquad (10)$$

The total lengths of the thread helixes considering the *z* spires in contact:

$$y_1 = z \cdot \sqrt{(\pi \cdot d)^2 + P^2} = \frac{L}{P} \cdot \sqrt{\pi^2 \cdot (d_2 + 0.5 \cdot P)^2 + P^2} \qquad (11)$$

$$y_2 = y_4 = z \cdot \sqrt{(\pi \cdot d_2)^2 + P^2} = \frac{L}{P} \cdot \sqrt{(\pi \cdot d_2)^2 + P^2} \qquad (12)$$

$$y_3 = z \cdot \sqrt{(\pi \cdot d_3)^2 + P^2} = \frac{L}{P} \cdot \sqrt{\pi^2 \cdot (d_2 - 0.5 \cdot P - 2 \cdot a_c)^2 + P^2} \qquad (13)$$

where: *z* – the number of spires (*z* = *L*/*P*).

The areas of the helix unfoldings corresponding to the four sections are:

$$A_1 = l_1 \cdot y_1 = 0.366 \cdot L \cdot \sqrt{\pi^2 \cdot (d_2 + 0.5 \cdot P)^2 + P^2} \qquad (14)$$

$$A_2 = A_4 = l_2 \cdot y_2 = 0.518 \cdot L \cdot \sqrt{(\pi \cdot d_2)^2 + P^2} \qquad (15)$$

$$A_3 = l_3 \cdot y_3 = 0.366 \cdot L \cdot \sqrt{\pi^2 \cdot (d_2 - 0.5 \cdot P - 2 \cdot a_c)^2 + P^2} \qquad (16)$$

The thicknesses of the walls of the injected parts are presented in Figure 3:

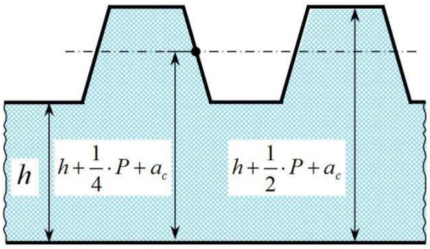

Fig.3 The thicknesses of the part walls

The pressures:

$$p_1 = E_{(T)} \cdot \varepsilon_{(T)} \cdot \frac{h}{\frac{d}{2}} = E_{(T)} \cdot \varepsilon_{(T)} \cdot \frac{2 \cdot h}{d_2 + 0.5 \cdot P} \quad (17)$$

$$p_2 = p_4 = E_{(T)} \cdot \varepsilon_{(T)} \cdot \frac{h + 0.25 \cdot P + a_c}{\frac{d_2}{2}} \cdot \sin\alpha_1 = = 0.258 \cdot E_{(T)} \cdot \varepsilon_{(T)} \cdot \frac{2 \cdot (h + 0.25 \cdot P + a_c)}{d_2} \quad (18)$$

$$p_3 = E_{(T)} \cdot \varepsilon_{(T)} \cdot \frac{h}{\frac{d_3}{2}} = = E_{(T)} \cdot \varepsilon_{(T)} \cdot \frac{2 \cdot h}{d_2 - 0.5 \cdot P - 2 \cdot a_c} \quad (19)$$

From (1), (14), (15), (16), (17), (18), and (19) the equations for the demolding forces result:

$$F_{D1} = \mu \cdot p_1 \cdot A_1 = \mu \cdot E_{(T)} \cdot \varepsilon_{(T)} \cdot 0.366 \cdot L \cdot F_{D1}^{*}$$
$$F_{D1}^{*} = \frac{2 \cdot (h + 0.5 \cdot P + a_c)}{d_2 + 0.5 \cdot P} \cdot F_{D1}^{**} \quad (20)$$
$$F_{D1}^{**} = \sqrt{\pi^2 \cdot (d_2 + 0.5 \cdot P)^2 + P^2}$$

$$F_{D2} = F_{D4} = \mu \cdot p_2 \cdot A_2 = = \mu \cdot E_{(T)} \cdot \varepsilon_{(T)} \cdot 0.134 \cdot L \cdot F_{D2}^{*} \quad (21)$$
$$F_{D2}^{*} = \frac{2 \cdot (h + 0.25 \cdot P + a_c)}{d_2} \cdot \sqrt{(\pi \cdot d_2)^2 + P^2}$$

$$F_{D3} = \mu \cdot p_3 \cdot A_3 = \mu \cdot E_{(T)} \cdot \varepsilon_{(T)} \cdot 0.366 \cdot L \cdot F_{D3}^{*}$$
$$F_{D3}^{*} = \frac{2 \cdot h}{d_2 - 0.5 \cdot P - 2 \cdot a_c} \cdot F_{D3}^{**} \quad (22)$$
$$F_{D3}^{**} = \sqrt{\pi^2 \cdot (d_2 - 0.5 \cdot P - 2 \cdot a_c)^2 + P^2}$$

The demolding moment is:

$$M_D = M_{D1} + M_{D2} + M_{D3} + M_{D4} \quad (23)$$

$$M_{D1} = F_{D1} \cdot \frac{d}{2} = 0.366 \cdot \mu \cdot E_{(T)} \cdot \varepsilon_{(T)} \cdot L \cdot M_{D1}^{*} \quad (24)$$
$$M_{D1}^{*} = (h + 0.5 \cdot P + a_c) \cdot \sqrt{\pi^2 \cdot (d_2 + 0.5 \cdot P)^2 + P^2}$$

$$M_{D2} = M_{D4} = F_{D2} \cdot \frac{d_2}{2} = 0.134 \cdot \mu \cdot E_{(T)} \cdot \varepsilon_{(T)} \cdot L \cdot M_{D2}^{*} \quad (25)$$
$$M_{D2}^{*} = (h + 0.25 \cdot P + a_c) \cdot \sqrt{(\pi \cdot d_2)^2 + P^2}$$

$$M_{D3} = F_{D3} \cdot \frac{d_3}{2} = 0.366 \cdot \mu \cdot E_{(T)} \cdot \varepsilon_{(T)} \cdot L \cdot M_{D3}^{*} \quad (26)$$
$$M_{D3}^{*} = h \cdot \sqrt{\pi^2 \cdot (d_2 - 0.5 \cdot P - 2 \cdot a_c)^2 + P^2}$$

From the equations (23), (24), (25), and (26) it results:

$$M_D = \mu \cdot E_{(T)} \cdot \varepsilon_{(T)} \cdot L \cdot \cdot \left[0.366 \cdot \left(M_{D1}^{*} + M_{D3}^{\div}\right) + 0.268 \cdot M_{D2}^{*}\right] \quad (27)$$

$$M_D \cong 0.33 \cdot \mu \cdot E_{(T)} \cdot \varepsilon_{(T)} \cdot \pi \cdot L \cdot \left(M_D^{*} + M_D^{**} + M_D^{***}\right)$$
$$M_D^{*} = (h + 0.5 \cdot P + a_c) \cdot \sqrt{(d_2 + 0.5 \cdot P)^2 + (P/\pi)^2} \quad (28)$$
$$M_D^{**} = h \cdot \sqrt{(d_2 - 0.5 \cdot P - 2 \cdot a_c)^2 + (P/\pi)^2}$$
$$M_D^{***} = (h + 0.25 \cdot P + a_c) \cdot \sqrt{d_2^2 + (P/\pi)^2}$$

With the relation (28) the demolding moment for a plastic injected part with external trapezoidal thread can be calculated in the design phase of the mold.

3. NUMERICAL RESULTS

The demolding moments were calculated for several parts with external trapezoidal thread made of polyethylene, for which the following are known: modulus of elasticity of the injected part at the demolding temperature (60°C), $E_{(T)}$=1150 MPa [2], coefficient of friction μ=0.31 [2], specific contraction of the material at the demolding temperature $\varepsilon_{(T)}$=0.01. The results are presented in Table 1.

4. CONCLUSIONS

The design of the pneumatic ejector systems should take into account many factors, including the demolding moment. The magnitude of this moment directly influences the design solution of the ejector system.

The demolding moment M_D can be calculated according to the above proposed methodology if the material, technological parameters, and the geometric dimensions of the injected part are known.

Table 1

Demolding moments

Thread	**Mean diameter** d_2 [mm]	**Thread pitch** P [mm]	**Clearance at the bottom** a_c [mm]	**Part thickness** h [mm]	**Part length** L [mm]	**Demolding moment** M_D [N·m]
Tr 10x2	9	2	0.25	3	20	7.37
Tr 12x3	10.5	3	0.25	3	20	9.26
Tr 16x4	14	4	0.25	4	20	16.37
Tr 20x4	18	4	0.25	4	20	20.1
Tr 24x5	21.5	5	0.25	5	30	46.64
Tr 28x5	25.5	5	0.25	5	30	55.16
Tr 32x6	29	6	0.5	6	30	76.56
Tr 36x6	33	6	0.5	6	30	86.96
Tr 40x7	36.5	7	0.5	7	40	148.9
Tr 44x7	40.5	7	0.5	7	40	165
Tr 48x8	44	8	0.5	8	40	204.1
Tr 52x8	48	8	0.5	8	40	222.4

5. REFERENCES

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CONTRIBUŢII PRIVIND CALCULUL MOMENTULUI DE DEMULARE LA PIESELE INJECTATE CU FILET

Rezumat: Lucrarea prezintă o metodologie de calcul a momentului de demulare în cazul pieselor injectate din mase plastice cu filet trapezoidal exterior. Valoarea acestui moment influenţează în mod direct soluţia constructivă a sistemului de aruncare.

Simion HARAGÂŞ Professor Ph.D., Department of Mechanical System Engineering, Technical University of Cluj-Napoca, Simion.Haragas@omt.utcluj.ro, Office Phone 0264/401665.

Iuliu NEGREAN Professor Ph.D., Head of Department of Mechanical System Engineering, Department of Mechanical System Engineering, Technical University of Cluj-Napoca, Iuliu.Negrean@mep.utcluj.ro, Office Phone 0264/401616.

Ovidiu BUIGA Lecturer Ph.D., Technical University of Cluj-Napoca, Department of Mechanical System Engineering, Ovidiu.Buiga@omt.utcluj.ro, Office Phone 0264/401753.