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THE STRUCTURAL DESIGN AND STRENGTH CALCULATION WORM EXTRUSION MACHINES FOR PRODUCING PLASTIC PROFILES

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ABSTRACT: *The most practical and the most widely used technology of plastic profile extrusion technology is worm extruder. The contribution deals with the design and stress analysis of a single worm extruder. Extrusion technology is one of the leading production technology for processing thermoplastics, as well as elastomers (rubber). The introduction is given substance and principle of extrusion technology. In other parts of the paper is processed with design and stress analysis of a single worm.*
KEYWORDS: *extruders, extrusion, worm*

INTRODUCTION

Extrusion technology is one of the leading production technology for processing thermoplastics, as well as elastomers (rubber). The essence of this technology lies in the heated feed material (plastic) in the melting chamber at a temperature of about 200°C (at which the plastic in the plastic state), which is also stirred by the worm and then extruded through the exit portion of a worm into the mold or mold through the hole.

After printing, material should be cool for the stabilization of product shapes and sizes. Profile resulting from the extrusion head is continuously pulls and further adjusts depending on the technology. In the production of extruded profiles after the mold processing there are cooling process continued, which is in the most cases cooling medium is water. For extrusion through a hole shaped, this profile which is created have to be stabilized by water or air-cooling.

To avoid over cooling the melt extruded profile, change dimensions, there are placed it in the profiled bore gauges, where the profile is cooled to a temperature such as, that the resulting profile was dimensionally stable. In the case of extrusion rubber mixtures can be extruded profile led directly to vulcanization [4] [7].

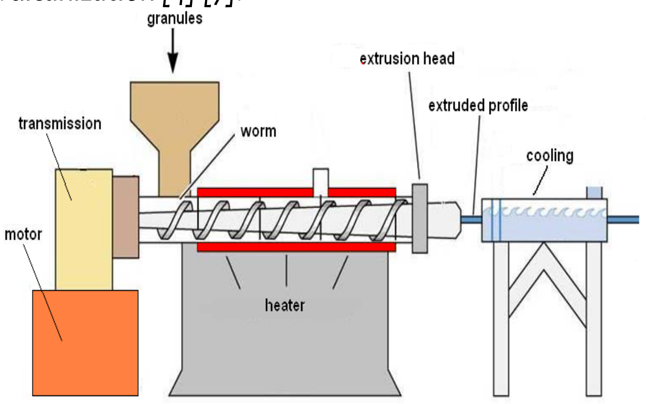

Figure 1. The principle of a worm extruder

THE STRUCTURAL DESIGN WORM EXTRUDERS

Worms are among the main functional parts of the worm extrusion machines, whose construction depends on the type of processed material. An important variable is the compression ratio, which expresses the ratio of the volume profile for a worm pitch of the worm in two places. A change of a compression ratio is usually achieved by varying the thickness profile of the worm. The size depends on the size of a worm extruder. Worm is determined by diameter D and length L, which usually refers to the average L / D. For extruding thermoplastic extruder worms are used most frequently with a length of 23 to 30 D and a compression ratio of 1:1.5 to 1:4,5 and polymers with narrow melting temperature range is typically processed to worm with a higher compression ratio. When geometry of a worm is selecting, should be taken care of the material characteristic to be processed. Compression ratio for the machine filled with a preheated mixture ranges from 4 to 6, for machines to meet a cold mixture of 10 to 18. [4]

Save the worm machine is bearings. Worm is connected to the drive shaft coupling or pen. In processing there are must respect certain technological parameters, mainly because power must be designed so that the performance was sufficient and the worm speed should normally be continuous or stepped and changeable in a wide range. [7]

Worms from the design point of view can be divided into:

a.) variable angle of climb,
b.) long transition zone,
c.) double-acting worm,
d.) short transition zone,
e.) completed a smooth torpedo,
f.) with the driving element degassing and stirring part.

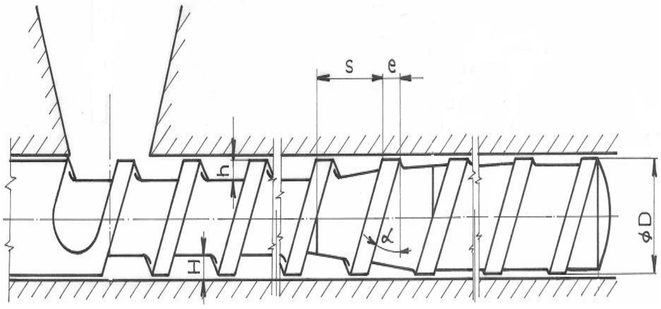

Figure 2. Diagram of a simple worm [7]

Figure 1 shows a diagram of a simple worm, where they are displayed basic geometric parameters too. Total volume of material transported by worm can be calculated from the basic relationship [4]:

$$Q = \alpha . n - \frac{\beta}{\eta} \cdot \frac{\Delta P}{L}$$

where:
Q – total volume of the worm material per unit time [$mm^3.s^{-1}$],
n – rotational speed [s^{-1}],
ΔP – pressure gradient in the direction of the worm axis [MPa],
η – viscosity of the polymer [$kg.m^{-1}.s^{-1}$],
D – worm diameter [mm]

STRENGTH CALCULATION OF SIMPLE WORM EXTRUDERS

Worms are much stressed functional parts of the worm extruders. They are stored in the bearings, which allow rotational movement of the worm and capture the axial and radial forces. [3] [7]

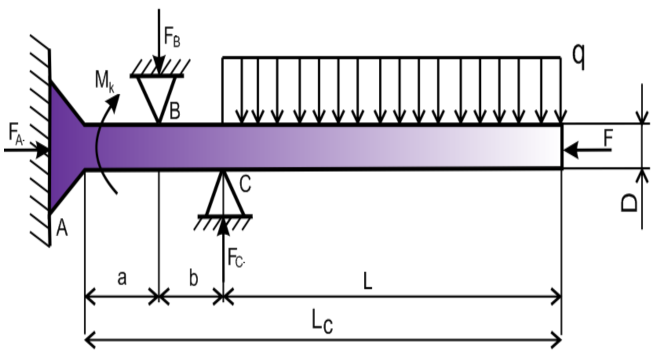

Figure 3. Load a single worm

The sizes of forces acting on the bearings are calculated from the following relations:

$$F_A = \frac{\pi D^2}{4} \cdot p\,;$$

$$F_B = \frac{qL^2}{2b}\,;$$

$$F_C = \frac{qL}{2b}(1+2b)$$

where:
D – worm diameter [mm],
p – pressure at the end of the worm [MPa],
q – continuous load [$N.mm^{-1}$]

Worms are loaded with axial force on the pressure or buckling. It depends on the ratio of worm length and its diameter. It is therefore necessary to calculate the slenderness ratio (λ).

$$\lambda = \frac{L_o}{i}$$

where:
λ – slenderness ratio [-],
L_o – reduced length [mm],
i – radius of inertia [mm]

Worms whose slenderness ratio exceeds 50 (λ> 50) are strained to the bar and worm whose slenderness ratio is less than 50 (λ> 50) are stressed by the pressure. When stress is calculated on the pressure reduced stress (σ_r), which must be less than the allowed voltage (σ_D). [6] [7]

$$\sigma_r = \sqrt{\sigma_{max}^2 + 4\tau_{max}^2} \le \sigma_D$$

$$\sigma_{max} = \sigma + \sigma_O = \frac{F}{S} + \frac{M_O}{W_O}\,;$$

$$\tau_{max} = \frac{M_{Kmax}}{W_K}$$

where:
σ_r – reduced stress [MPa],
σ_{max} – maximum normal stress [MPa],
τ_{max} – maximum tangential stress [MPa],
σ_D – maximum possible stress [MPa],
F – axial force applied to the worm [N],
S – Cross-section worm [mm^2],
M_O – bending moment [N.mm],
W_O – selectional module for bend [mm^3],
M_{Kmax} – maximum torque [N.mm],
W_K – sectional module for torsion [mm^3]

The maximum deflection at the end of the worm is calculated from the relationship:

$$y_{max} = \frac{qL^4}{8EJ}\,;$$

$$J = \frac{\pi D^4}{64}\left[1 - \left(\frac{d}{4}\right)^4\right]$$

where:
y_{max} – maximum deflection [mm],
q – continuous load [$N.mm^{-1}$],
L – worm length [mm],
E – Modulus of elasticity [MPa],
J – moment of inertia of the cross section of the worm [mm^4],
D – maximum diameter of the worm [mm],
d – minimum diameter of the worm [mm]

For reliable operation of these machines is also important to twist the worm. Twisting the worm should not exceed 1.5 to 3° degrees [7]. For the true size of the torsion:

$$\varphi^{\circ}_{max} = \frac{M_K L}{GJ} \cdot \frac{180}{\pi} \leq \varphi_D$$

where:
φ°_{max} – maximum tortion [°],
M_K – torque [N.mm^{-1}],
L – worm length [mm],
G – modulus of elasticity [MPa],
φ_D – the maximum possible tortion[°]

CONCLUSIONS

Design and calculation of components of the machinery is a creative activity using theoretical and practical experience. This activity must be geared mainly to meet the requirements. At present, virtually all areas of design activities supported by computer technology that can be effectively used in the design of machinery components particularly in the construction of technical documentation and field strength calculations.

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