Medical Catheters and Plastics – Part VII

In our previous article, we explored the stages of material drying and extrusion in the manufacturing process of medical catheters. Building on that discussion, this article will focus on a critical element within the extrusion process: the flow of the melt through the tubing die. We will delve into the factors related to die design that influence this process.

The flow characteristics of the material, along with its correlation to shear and temperature, can be precisely assessed through rheological studies. Consequently, it is essential to examine the rheology of the polymer before utilizing it as a catheter material and choosing a specific screw design. This approach will guarantee that the plastic is extruded under appropriate conditions, resulting in a final catheter with optimal physical properties.

An extruder die is positioned at the end of the extruder, shaping the initial form and dimensions of the extruded tube. The tubing die comprises two primary components: a mandrel or pin that creates the tube's inner diameter (ID), and a die that shapes the tube's outer diameter (OD). Together, the die and the mandrel make up the extrusion head. Various designs of dies, heads, and mandrels exist, and these designs are crucial in the extrusion process, significantly influencing the capability to produce tubes with precise dimensions.

A drawing of a multi-lumen tubing die is shown in Figure 1.

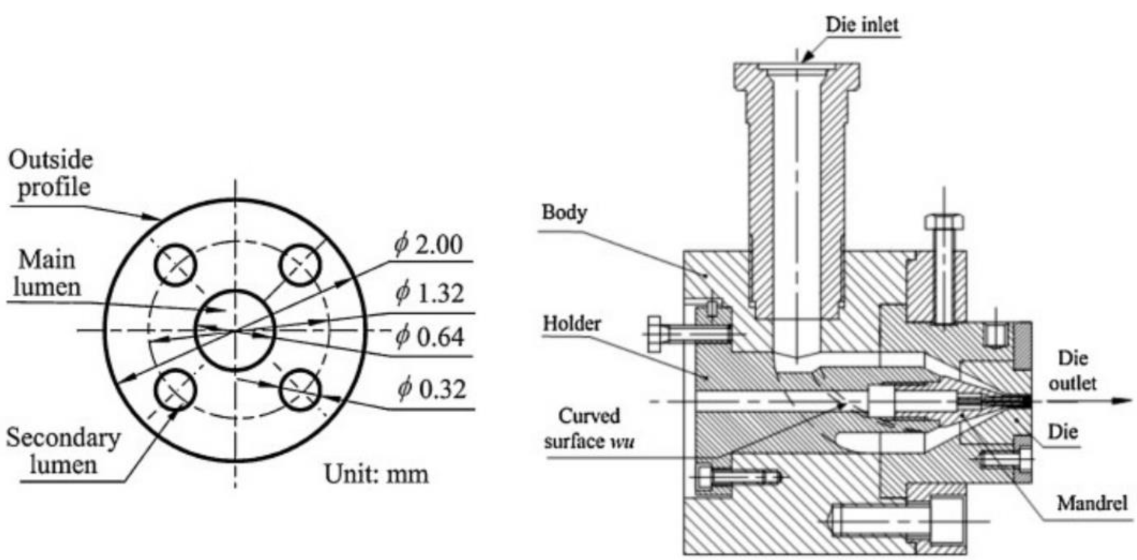

Figure 1: A drawing of the tube and die arrangement (courtesy Elsevier Publications – Jin, G., Wang, M., Zhao, D., Tian, H. and Jin, Y. (2014). Design and experiments of extrusion die for polypropylene five-lumen micro tube. *Journal of Materials Processing Technology*, 214(1), pp.50-59.*)*

The design of extrusion dies is based on the principles of rheology, thermodynamics and heat transfer. The quantities to be calculated are pressure, shear rate and residence times as functions of the flow path of the melt in the die. The pressure drop is required to predict the screw design and its performance, the shear rate calculation in the die shows melt flow is within the normal shear rate range and the residence time of the melt in the dies gives an indication of the uniformity of melt flow.

$$\dot{Q} = KG^n \Delta p^n \tag{1}$$

Where,

$\dot{Q}$ = volumetric flow rate

G = die constant

Δp = pressure drop in the die

n = power law exponent

$$G = \left(\frac{\pi}{6}\right) \frac{(R_o+R_i)^{\frac{1}{n}}(R_o-R_i)^{1+\frac{2}{n}}}{2L} \tag{2}$$

$$\dot{\gamma} = \frac{6.\dot{Q}}{\pi(R_o+R_i)(R_o-R_i)^2} \tag{3}$$

Where,

Ro = outer radius of the die

Ri = inner radius of the die

L = Length of die/pin

$\dot{\gamma}$= Shear rate

Using modifications to these basic set of equations (1 – 3) accurate simulations of polymer melt flow through the die geometry is made possible by software packages. These simulations depend on the correct input of the material's rheological and thermal properties hence the accurate measurement of these properties is critical to the success of these simulations. These simulations can help the equipment designer and the material scientist to design the entire process so as to match the process conditions and the material properties. These simulations can significantly contribute to preventing common problems associated with catheter extrusion, including flow balancing, high melt temperatures and pressures, polymer degradation, as well as the formation of voids and gels.

If you have any other questions or would like to suggest topics for us to write about, please feel free to contact us at info@polymerupdateacademy.com

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