Inside Dimensions of Dies Determined from Elastomeric Casting

Polymers are commonly extruded or spun to produce an indefinite length of product with a carefully specified, uniform cross section. A forming channel or die of close tolerance and smoothness is required for such operations. The spinneret plate used to manufacture textile fibers is an example. Furthermore, very precise measurement of dimensions is necessary to determine flow properties of molten polymers by one of the best methods for obtaining data at high shear rates.[1] The material is extruded through a small orifice or capillary tube, and the force required and the flow rate enable properties such as viscosity to be determined. The hard-to-reach inside dimensions of these capillaries can be critical for proper interpretation of the data. For example, the viscosity of a Newtonian fluid in laminar flow is proportional to the fourth power of the tube diameter. A mere 1% error in diameter measurement results in about a 4% error in viscosity; a measured diameter which is 10% higher than the actual gives a calculated viscosity which is nearly 50% above the correct value. Imperfections of small size can likewise cause flow disturbances that change the pressure drop greatly and, of even more importance, affect the appearance and size of the extruded filament.

Dimensions such as the hole diameter are commonly measured by a microscope, with eyepiece markings calibrated against a stage micrometer. Focus is limited to a single plane at any time, thus providing accurate measurement of the ends of a hole. It is difficult, however, to determine the inside diameter of a drilled or machined hole, particularly when it has many markings. More complex shapes such as conical holes are even more difficult to measure with the microscope.

We have found that an elastomeric casting technique permits accurate measurement and contour determination of the inside of capillary dies that are used with a piston rheometer. A low-viscosity silicone liquid that can be vulcanized at room temperature is used to make the casting.[2] Silicones are used industrially to prepare molds which reproduce faithfully extremely fine detail including the finest wood grains.[3] Small crevices and deep undercuts are also successfully handled by making molds from such a rubber.

The silicone liquid is mixed with a catalyst and drawn through the inside of the extrusion die with vacuum until the cavity is completely filled. Curing overnight at room temperature is required but may be accelerated by heating. Excess material is sliced from the die face so that dimensions can be determined. Because of high elongation and tear strength of the cure elastomer, it can be distorted during removal from the cavity, but it will then return to its original dimensions. Should removal be difficult, chilling the die and casting will shrink the casting more than the die and aid this process.

The casting is then measured and examined under the microscope. Variations in diameter and imperfections are easily observed on the casting. Angles can be determined with an eyepiece grid. However, photographing the casting with a scale is probably the most convenient method of determining the dimensions accurately.

For certain shapes of castings, it is desirable to section the rubber to obtain flat surfaces perpendicular to the direction in which dimensions are to be determined. Cooling the rubber will produce the required stiffness, and sectioning can be conveniently performed with a microtome.

Figure 1 shows several examples of photomicrographs of orifice castings. The long orifice (left) is well constructed and shows only a slight irregularity at the intersection of the conical inlet and cylindrical section (right side of picture). A large-diameter orifice (center) shows differing degrees of rounding at this intersection. The short orifice casting (right) was photographed slightly off the perpendicular to the flow axis. Machining marks on the flat inlet surface are visible, and the degree of rounding of the inlet edge of the small orifice at the bottom is evident. Angles and dimensions can be accurately measured; a 20-mm-stage micrometer photographed at the same magnification is included in the figure.

An orifice which was specified to be constructed identically with the one shown at the left (Fig. 1) was in use when this technique was being developed. The flow from this

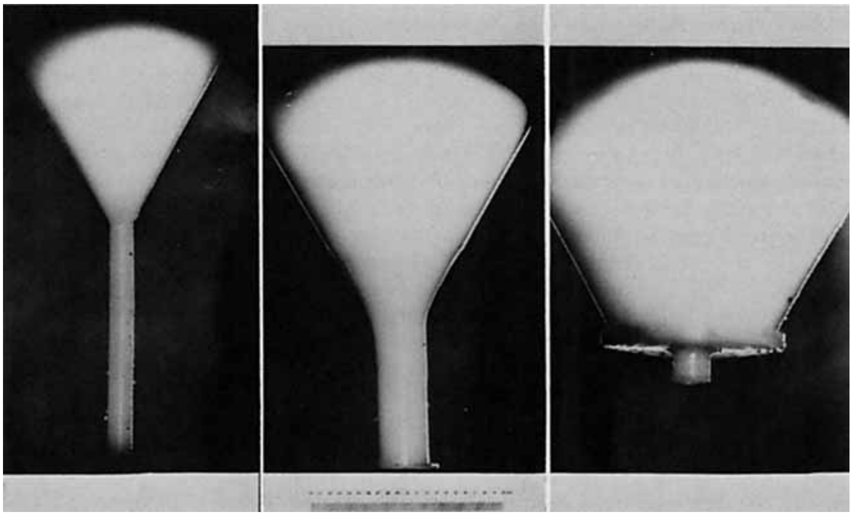

Fig. 1. Photomicrographs of silicone rubber castings of the inside flow channels of three orifices with a stage micrometer at the same magnification.

orifice was unstable while flow through this photomicrographed orifice was stable at the same throughput. A casting of the orifice producing the unstable flow showed a major imperfection. The conical inlet was not formed on the same center as the small-diameter cylindrical portion. Flow around the resulting sharp edge led to the unstable flow. Thus this method is recommended as a quality control method in the construction of orifices and other small parts, and also has application in identifying the source of off-quality product resulting from spinneret flaws.

References

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