Plastics Pocket Power

Rao

Diagnostics of Extrusion Processes

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Preface

The plastics engineer working on the shop floor of an industry that manufactures blown film, blow-molded articles, or injection-molded parts, to name a few processes, often needs quick answers to questions, such as why extruder output is lower than expected, whether changing the resin will produce a better quality product, or how to estimate the pressure drop in the die. Numerical analysis to address these kinds of issues is time-consuming and costly, and requires trained personnel. As experience shows, most of these issues can be addressed quickly by applying proven, practical calculation procedures that can be performed by pocket calculators, and therefore can be handled on the site where the machines are running.

This book is an abridged version of the same topic treated in *Understanding Plastics Engineering Calculations* by Natti S. Rao and Nick R. Schott. Yet in this compact format it has all the features of the original work and can be used, not only for estimating the effect of design and process parameters on the product quality, but also for troubleshooting practical problems encountered in the field of polymer processing by extrusion. This book is intended for beginners as well as for practicing engineers, students, and teachers in the field of plastics engineering, and also for scientists from other areas who deal with polymer engineering in their professions.

The underlying principles of design formulas for plastics engineers, with examples, have been treated in detail in the earlier works of Natti Rao.

Bridging the gap between theory and practice, this book presents analytical methods based on these formulas that enable the plastics engineer to solve everyday problems related to machine design and process optimization quickly. The diagnostic approach used here is in examining whether the machine design and the resin properties are suited to each other to achieve the desired process targets.

In order to facilitate easy use, the formulas have been repeated in some calculations so that the reader does not need to refer back to the same formulas given elsewhere in the book.

Chapter 1 deals with the rheological properties of polymer melts and their use in designing polymer machinery, illustrating the topic with a number of easily understandable practical examples.

In Chapter 2, starting from melting in the screw, the relationship between screw design and the melt homogeneity is first explained by means of problems in processing taken from blown film, thermoforming, and extrusion coating. It is then shown how product quality can be improved by redesigning the screw using analytical software based on extrusion modeling techniques. Design and performance of spider dies, spiral dies, and flat film dies are the topics of Chapter 3. Here again, software based on analytical procedures evaluates the performance of the die and optimizes the design in order to meet the target values such as desired die pressure. Examples given relate to blown film and blow molding. Parametrical studies in practice on the shop floor are an important tool for optimizing the process.

Taking blown film as an example, the effect of various parameters such as film cooling and blow up are illustrated in Chapter 4. The features of two software programs that can be applied to design and optimize extrusion machinery are explained in Chapter 5. The resin data bank that is used for storing polymer property data is described in detail. Chapter 6 covers the thermodynamic properties of polymers, necessary for doing heat transfer calculations when designing polymer machinery.

Chapter 7 is a case study on the application of heat transfer and dimensionless analysis for predicting the relative importance of the parameters, such as melt temperature and dwell time of melt in the air gap in an extrusion coating process.

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Natti S. Rao, Ph.D.

1 Rheological Properties of Molten Polymers

The basic principle of making parts from polymeric materials is in creating a melt from the solid material and forcing the melt into a die, the shape of which corresponds to the shape of the part. Thus, as Fig. 1.1 indicates, melt flow and heat transfer play an important role in the operations of polymer processing.

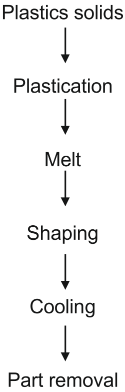

Figure 1.1 Principle of manufacturing of plastics parts

1.1 Polymer Melt Flow

Macromolecular fluids, such as thermoplastic melts, exhibit significant non-Newtonian behavior. This is noticed in the marked decrease of melt viscosity when the melt is subjected to shear or tension as shown in Figs. 1.2 and 1.4. Melt flow in the channels of dies and polymer processing machinery is mainly shear flow. Therefore, knowledge of the laws of shear flow is necessary for designing machines and dies for polymer processing. For practical applications, the following summary of the relationships was found to be useful.

1.1.1 Apparent Shear Rate

The apparent shear rate for a melt flowing through a capillary is defined as

$$\dot{\gamma}_a = \frac{4\dot{Q}}{\pi R^3} \qquad (1.1)$$

where $\dot{Q}$ is the volumetric flow rate per second and R is the radius of the capillary. This relationship is for *steady state*, incompressible flow without entrance or exit effects, no wall slip, and with symmetry about the center line.

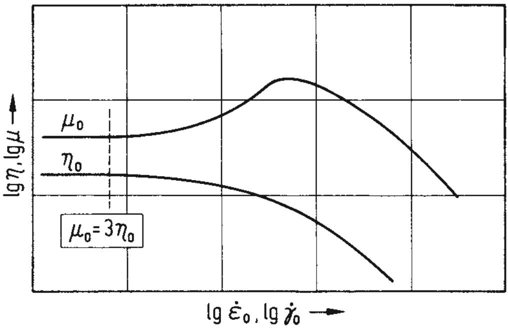

Figure 1.2 Tensile viscosity and shear viscosity of a polymer melt as a function of strain rate [1]