BOOK REVIEW

Polymer Melt Processing: Foundations in Fluid Mechanics and Heat Transfer

By M. M. Denn, Cambridge University Press, New York, NY. 2008. 264 pp., $92.

This book is about the underlying foundations of polymer melt processing, which can be derived from concepts in fluid mechanics and heat transfer. Other aspects of polymer processing, such as handling of particulate solids, melting and polymer structure and property development, to mention a few, are not the subject of this book. Professor Denn does a masterful job in introducing advanced topics and adding them to the basics in a seamless and natural manner to create the fluid mechanics and heat transfer foundations of polymer processing. His didactic approach enables the reader to understand and appreciate the current important intellectual issues in the field. Some of the material in the book is not found in other texts on the same subject and level, such as the effect of the interplay between temperature, pressure and viscosity on the flow (Chapter 4), the detailed analysis of fiber spinning, the excellent chapter on process sensitivity and process stability, including the phenomena of draw resonance and wall slip, and a discussion on spinline failure. The book emphasizes the common fundamental principles that underlie all polymer melt processes and it guides the reader to understand how these principles are applied to practical processing situations. The author's approach allows the reader to develop his own independent "polymer processing thinking". In short, the book "teaches" polymer processing. It is a student-oriented textbook. It is very well written in an easy to read, lucid and succinct style, it is thorough and of the right length. All these features make it definitely to stand out. In addition, it comes in an elegant edition with clear illustrations which make it enjoyable to read. The level of the book is that of an advanced undergraduate or beginning graduate course and its target audience is students, engineers and physical scientists interested in obtaining a firm command of the basic fluid mechanics and heat transfer principles involved in polymer processing. A minor criticism might be that the book does not have homework problems.

The book has 14 chapters in which the material is presented in a logical and pedagogically effective way. The first chapter gives an overview of polymer processing by briefly describing some of the most important melt processes and introducing some basic concepts of polymer chemistry and physics. The next chapter presents the balance equations for mass, momentum and energy and it introduces the Newtonian and power-law fluids and the concept of creeping flow. The third chapter analyzes the melt flow and temperature development in an elementary extruder and it extends the analysis to a single-screw extruder. The fourth chapter addresses the effect of temperature and pressure on the melt viscosity and it describes how the increase of viscosity due to high-pressure drop can lead to the phenomenon of "choking". In this chapter the author also discusses the phenomenon of multiplicity and, thus, he makes the reader aware of the possibility that in highly coupled nonlinear systems instabilities can develop because the process can exist in more than one state for a given set of flow conditions. This is typical of discussions that one finds in this book, but not in other books on the subject. These discussions are good examples of how professor Denn introduces the reader methodically to the subtleties of polymer processing and how he constantly guides him to obtain a deeper understanding and appreciation of the issues. The next chapter deals with the important "thin gap approximation" which has many applications in polymer processing. In Chapter 6 the creeping flow approximation is applied to obtain quasi-steady state solutions for mold filling in injection and compression molding. Chapter 7 covers the process of melt fiber spinning. After a discussion of uniaxial extensional flow, the thin filament equations are derived in detail. These derivations are very instructive because of the physical insight that they provide and some of them can seldom be found conveniently elsewhere. Such examples are Eq. 7.9 for the total axial stress in a rod undergoing extensional flow and the thin-filament equations for a spinline in section 7.3.2 and Appendix 7.A. A discussion of radial temperature variation in the spinline follows and the chapter closes with a section on outstanding issues. Chapter 8, coauthored with Benoit Debbaut, discusses why numerical analysis is necessary in dealing with complex polymer processing geometries and why the polymer processor should be familiar with this powerful and useful tool. The chapter gives an overview of the method of finite elements and it presents results from its application to specific processes, e.g., sheet-coating, extrusion and squeeze flow. Polymer melt rheology is addressed in Chapter 9. This chapter discusses linear viscoelasticity, shear and extensional flows, normal stresses, constitutive equations and entry and exit losses. Chapter 10 covers viscoelasticity in polymer flows. Most polymer melt flows are dominated by the viscous rather than the elastic characteristics of a viscoelastic melt. However, there are cases where the elastic character of a viscoelastic melt must be taken into account as well because it becomes important. Examples discussed in this chapter are extrudate swell, fiber spinning, film blowing, converging flow, secondary flows and flow past an obstruction. Chapter 11 presents an excellent discussion of process sensitivity and linear and nonlinear process stability with illustrations from fiber spinning and film blowing. The phenomenon of draw resonance, a spinline instability, and spinline sensitivity are discussed in detail. Interfacial instabilities and the criteria for spinline failure are also addressed in the same chapter. The next chapter continues with instabilities due to "wall slip" (e.g., sharkskin) and with the phenomenon of "melt fracture". Chapter 13 discusses the flow of some structured fluids: fiber suspensions, such as those that might be used for thermoplastic composites, liquid-crystalline melts and fluids that exhibit a yield-stress, which might include nanoparticle-filled melts. Chapter 14 is a brief chapter that intends to note the state of the art in two areas critical to many aspects of polymer processing, namely, laminar mixing and droplet breakup and coalescence.

All chapters start with an introduction and, most of them, end with concluding remarks. These sections are thoughtfully written and help the reader, especially the uninitiated, to develop a mental framework within which to place and interconnect the material from the various chapters. In addition, they make the transition from chapter to chapter smooth and logical. The references in the book are up to date and the bibliographical comments that the author makes about the various references are very useful.

I highly recommend this book. It can be used as a textbook for a course in polymer processing for advanced undergraduate or beginning graduate students as well as a reference book for engineers and scientists who are interested in polymer processing. All readers will find it easy to read, interesting, authoritative, thoughtful and instructive.

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