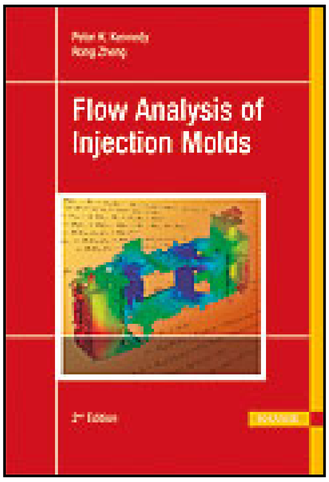

Preface

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Flow Analysis of Injection Molds

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Preface

Injection molding is an ideal process for fabricating large numbers of geometrically complex parts. Many everyday items are injection molded: mobile phone housings, automobile bumpers, television cabinets, compact discs, and lunch boxes are all examples of injection molded parts. Parts produced by the process are also becoming commonplace in less obvious applications. For example, the relatively new area of micro-injection molding is providing new methods of drug delivery and optical couplers [195].

Variations of injection molding that have been developed over the years include co-injection or two-component molding, water injection, and gas-assisted injection molding (GAIM). All these processes provide additional scope for designers of plastic parts. Excellent examples are provided by Neerincx [267] and Neerincx et al. [268, 269]. Indeed it is possible to combine these variations with each other or injection molding to achieve other processes. In particular, Neerincx and Meijer combined GAIM and two-component molding [270] to produce a part with unique qualities.

An important characteristic of injection molding, including variations, is that it may not be possible to fix a part defect in production by simply varying process conditions. Frequently the mold must be modified to overcome a problem. This is expensive and costs valuable time. It is far better to avoid problems in the design phase than to fix them in production. Consequentially, simulation of injection molding is industrially valuable.

Not surprisingly, there are several commercial companies offering software for simulation of injection molding and its variants. Due to the complexity of the physics of the process, various assumptions are made to simplify the mathematical model used for simulation. Over the years many descriptions of modeling and simulation of injection molding have appeared in academic journals and books. While readily available to specialist readers, an understanding of principles used in simulation software is difficult for nonspecialists to obtain. This is due to the multi-disciplinary nature of simulation software. In particular, aspects of rheology, materials science, and numerical methods are used. There are some excellent books on polymer processing that discuss injection molding. One of the original classics was by Tadmor and Gogos [351]. This was followed by Tucker's book [368] which focused on modeling for computer simulation. More recently, Osswald and Hernández-Ortiz [279] provided an overview of modeling and simulation for polymer processing, while Kamal et al. [190] have produced a book focused on injection molding that discusses variations and other aspects of the injection molding process.

Given the importance of injection molding as a process, and the simulation industry that has grown to support it, we believe there is a need for a book that deals solely with modeling and simulation of injection molding. One of the authors wrote a book in 1995 [196] along these lines. It discussed filling and packing phase simulation, but is no longer in print. Moreover, there have been many developments in modeling and simulation since that time.

The current book is intended to address this need. It provides a comprehensive description of modeling and simulation of injection molding. While some parts of the book may be relevant to other polymer forming processes, we assume injection molding is the process under discussion, and so do not deal with variants.

The book is divided into two parts and a considerable number of appendices. Each appendix is meant to provide detailed information on the topics discussed in the main parts of the book. Hopefully, moving specialist and routine information into appendices makes the book more readable.

Part I is written for the user of simulation software who seeks an explanation of the basic modeling and assumptions made. Modeling and simulation details of filling, packing, residual stress, shrinkage, and warpage of amorphous, semi-crystalline, and fiber filled materials are described. Additionally, it introduces numerical methods for solving mathematical models of the process. This part is intended to be self-contained but presumes knowledge of algebra and calculus at the level of a degree in physical sciences or engineering. Tensor concepts are given in Appendix B.

Part II deals with improved modeling. This part is aimed at interested users of software, graduate students, and researchers who are interested in enhancing simulation. A knowledge of the history of simulation is useful for anyone so disposed. Appendix A provides some background on both academic and commercial developments in simulation to around 2008. Much of the material presented in Part II covers developments from 2000 to the present. At the time of writing, this information is not implemented in commercial simulation software, and is meant to be a starting point for improvement in modeling and simulation. It presents some models that incorporate more of the physics of the molding process. Although we present some possible approaches, we do not cover all areas of improvement. We do, however, try to reference other approaches to the problems we consider. In particular, we focus on fiber-filled and semi-crystalline materials, but some ideas may be applied to amorphous materials. Hopefully it will be a source of ideas that lead to better simulations. Part II uses more advanced ideas of tensor calculus. Where these are not provided in the text, we prescribe external references.

We hope our readers enjoy the challenge of modeling and simulating the injection molding process. Injection molding is a technology that has been around for approximately 140 years [172]. However, it was only in the 1950s, with the development of the reciprocating screw method, that the process showed its true potential.

Despite the immaturity of computer technology, simulation of injection molding can be traced to 1960 [367]. Since then it has become a field of both academic and commercial interest. Moreover, the physics of injection molding are still being researched. It is this latter aspect that provides us with the hope that this book will inspire others to improve simulation by improved modeling and by taking advantage of the computational power available today and in the future.

Peter K. Kennedy and Rong Zheng, Melbourne, Australia, 2013