Book Review

An Accessible Guide to Polymer Material Processing? A Review of *Plastics Process Analysis, Instrumentation, and Control* by J.K. Fink

Albert E. Patterson [1,2]

[1] Faculty of Manufacturing and Mechanical Engineering Technology, Department of Engineering Technology and Industrial Distribution, Texas A&M University, College Station, TX 77843, USA
[2] J. Mike Walker '66 Department of Mechanical Engineering, Texas A&M University, College Station, TX 77843, USA
* Correspondence: aepatterson5@tamu.edu; Tel.: 979-845-4953

Abstract: This review examines the newly published book *Plastics Process Analysis, Instrumentation, and Control* authored by Johannes K. Fink and published by Scrivener Publishing LLC and John Wiley & Sons, Inc. This book examines the last ten years of polymer processing technology and provides a good look at the state-of-the-art in terms of processing techniques, control methods, analysis methods, and known and predicted problems in the processing of these materials. The book is highly accessible and easy to understand for those with basic prior knowledge of polymer processing and manufacturing processes, making it a good resource for both academic research and practical use in manufacturing and design.

Keywords: Polymer manufacturing; manufacturing technology; process control; materials characterization; manufacturing automation

Of the major engineering materials available in the modern world, polymer-based materials are some of the most common and widely used. As their used became widespread in the 1960s, these synthetic or semi-synthetic materials have become more and more ubiquitous in the production of consumer products. These materials (including polymer matrix composites) have special processing needs and characteristics that are sometimes difficult to predict and control since the final properties are heavily dependent on the processing method used. While easy to process for general consumer products, their widespread modern use in medical, aerospace, and other sensitive applications have made process and property control absolutely essential. Unlike metals and ceramics, polymer-based materials (from here, "plastics") have a heavy dependence on the heat transfer, rheological, and fluid behavior (since most plastic processing is done with a non-Newtonian liquid or molten starting form) of the starting material before polymerization (or solidification). They are also dependent on the processing time, temperature profiles, and shear history and tend to degrade quickly if not handled appropriately during processing. Many thermoplastics (the most common form of plastics for consumer goods) also have a clear transition temperature (i.e., the highest temperature at which the material is structurally stable and not able to creep) which may be significantly lower than the actual melting temperature. Therefore, the processing conditions must be carefully controlled to obtain reliable and repeatable material properties; however, this can be an additional challenge since many of the instruments used to monitor and control the processing must be non-contact (generally less accurate than contact instruments) in order to avoid disturbing the polymerization process.

While researching reference materials (particularly searching for a ready and accessible design handbook) for plastics processing technology, I was made aware of the newly published book *Plastics Process Analysis, Instrumentation, and Control* by J.K. Fink [1]. This book focuses on advances in plastics processing technology in the past 10 years or so (since approximately 2010), but also discusses some

previous knowledge and methods used up to that time. While I was expecting a book focusing on process modeling and control, the text was surprisingly comprehensive within its stated domain, covering several different aspects of process modeling and control, instrumentation, basic polymer engineering and design principles, design for manufacturing, process risks and safety procedures, analytical and numerical modeling techniques, experimental techniques, cost modeling, and other essential plastics processing topics. A large number of useful and practical examples are provided, helping to illuminate the theoretical discussion in the text. The various chapters of the book can be divided into two major areas, with some additional material related to implementation provided: (1) General plastics processing analysis and design, (2) process instrumentation and controls, and (4) post-processing and support knowledge. The mechanics of both thermoplastic and thermosetting polymer materials are covered extensively.

The first topic, presented in Chapters 1-3 and Chapter 6, covers general aspects and processing analysis. The most common processes are discussed, including plastic injection molding, extrusion blow molding, plastic foam processing, granule production, compression molding, and stamping. There is extensive discussion on the recycling and reuse of plastics for sustainable manufacturing. Analysis methods presented include the development of analytical models (based on differential equations due to the nature of plastics manufacturing) and numerical simulations, with extensive discussion on the experimental validation of the models developed. Several standard fluid flow models (both Newtonian and non-Newtonian) are compared and explored for their fitness to predict the behavior of the plastic material during processing. While not as comprehensive as a dedicated textbook on plastic flow behavior, the material presented in these chapters is more than enough for a typical academic or practical user to be able to understand and implement the knowledge provided. The focus is on traditional manufacturing technologies, but some interesting and useful conclusions relevant to additive manufacturing are presented in these chapters.

In the second area of interest, presented in Chapters 4-5 and Chapter 7, process instrumentation and control methods are covered. Both contact and non-contact methods are discussed, including actuators, thermocouples, resistance temperature detectors (RTDs), infrared sensors, position transducers and gages, and IR interferometers, X-ray diffractors, and other matter identification methods. Discussion about machine and material surface preparation, special considerations for certain materials and special medical applications is also provided. This is followed by an extensive analysis of system elements that influence or are influenced by the need to use instruments to control the plastic processing, including servos, values, heaters, and various kinds of motors. Advice for both modeling and practical implementation is provided, making this section especially useful for anyone trying to validate the models developed of plastics processing technology. While this section does not address the special problems encountered in additive manufacturing in detail, the principles discussed is also relevant to that domain and will be helpful in exploring it.

Overall, this is a very useful, accessible, and clearly written book for its intended audience. A very large amount of practical knowledge is offered by the author, but some previous knowledge of polymer science and processing is required to make the most of the opportunity. While the book is very strong within its stated domain and useful for its intended audience, some improvements could be made in future iterations or editions of the book. While the purpose of the book is to provide a practical guide to modeling, control, and instrumentation, an additional chapter on basic polymer processing and its history would be useful. In addition, some more discussion of the unique problems encountered in polymer additive manufacturing would strengthen the text. Finally, it would expand the usefulness of the book even more to add some short discussion of how to use the presented knowledge in making design decisions when working with plastics. While it might be difficult to use as a stand-alone textbook on plastics processing, due to the amount of prior technical knowledge required before starting it, it is an excellent complement to the previous plastics processing texts such as those written by Gogos & Tadmor [2], Baird & Collias [3], Guo [4], Bruder [5] and Osswald, Baur, and Rudolph [6]. It could be useful as a text for an advanced undergraduate or graduate course in plastic manufacturing, modeling, or design as long as the students have already taken a basic course on polymer science and have a basic

understanding of manufacturing processes. In summary, this book presents itself as one written as a handbook for students and practicing engineers/technologists who already have some basic knowledge of polymer processing. As such, it is an excellent text and I highly recommend it as a reference for researchers and plastics engineers who need advanced knowledge and advice on methods for solving problems related to plastics manufacturing. The book is available on demand from Scrivener Publishing LLC and John Wiley & Sons, Inc in both hardcover and electronic versions.

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References

1. Fink, J.K. *Plastics Process Analysis, Instrumentation, and Control*; Scrivener Publishing LLC: Salem Massachusetts and John Wiley & Sons: Hoboken New Jersey, 2021.
2. Gogos, C.G.; Tadmor, Z. *Principles of Polymer Processing*, 2nd ed.; John Wiley & Sons: Hoboken New Jersey, 2006.
3. Baird, D.G.; Collias, D.I. Polymer Processing: Principles and Design, 2nd ed.; John Wiley & Sons: Hoboken New Jersey, 2014.
4. Guo, Q. *Polymer Morphology: Principles, Characterization, and Processing*; John Wiley & Sons: Hoboken New Jersey, 2016.
5. Bruder, U. *User's Guide to Plastic*, 2nd ed.; Hanser Publications: Munich, Germany, 2019.
6. Osswald, T.A.; Baur, E.; Rudolph, N. *Plastics Handbook: The Resource for Plastics Engineers*, 5th ed.; Hanser Publications: Munich, Germany, 2019.