book reviews

Progress in Modelling of Polymer Processing: Recent Developments

A. I. Isayev (Ed.)
Carl Hanser Verlag, Munich, 1991,
312 pp., £51.00,
ISBN 3-446-16031-0

This multi-author book is aimed at those involved in research and development of polymer processing. Its purpose is to present and review recent advances in some of the major polymer processing operations. Altogether, 16 leading researchers have contributed to nine chapters covering extrusion, die flow, thermoforming, blow moulding and injection moulding of plastics and rubbers. A total of 680 references are provided to bring the reader up-to-date with the latest literature in the various subjects.

In Chapter 1, the editor provides a brief overview of modelling of polymer processing. This is entirely descriptive and outlines the stages in the development of the theory in the various polymer processing sectors. It is a useful introduction to the subject for the non-specialist reader and an extensive reading list is provided to complement the contents of the subsequent chapters.

Chapters 2–4 look at the computer simulation of flow in extruders. In Chapter 2, the advantages and difficulties of applying the concept of inverse formulation to flow through extruder dies are discussed. The principle of inverse formulation is first described and its application in other fields is reviewed. Its utilization in the area of heat conduction and pressure loss in extrusion dies is then illustrated. Unfortunately the treatment of each subject is rather cursory and there is no attempt to show how the analysis may be applied to a real situation or to indicate what accuracy may be expected from the predictions. Chapter 3 considers flow simulation in twin-screw extruders and Chapter 4 analyses the transport processes in this type of equipment. These are useful contributions which should be of interest to the practising engineer. In Chapter 4, extensive numerical results are presented to illustrate the effects of the process variables.

Chapter 5 deals with free surface moulding in the form of thermoforming and blow moulding. The primary interest is simulation using finite element analysis but the chapter is a very valuable overview of the complex subject of thermal forming of sheet materials. Many of the techniques illustrated will have broader applicability to the newer forming technologies such as injection blow moulding.

The remainder of the book deals with injection moulding in relation to thermoplastics (Chapter 6), rubbers (Chapter 7) and flow within mould cavities (Chapter 8). The final chapter describes an interactive data acquisition system for injection moulding. Many industrialists will nowadays be familiar with software such as MOLDFLOW and these chapters provide an insight to the basis of such programs.

Overall the book can be regarded as a useful addition to the literature. It is not comprehensive nor has there been an attempt to rationalize the modelling approaches for the processes considered. Also, the authors have not made any real attempt to simplify the analytical procedures to the point where they could be used by practising engineers or designers. Nevertheless the book provides a valuable state-of-the-art starting point for those embarking on modelling of polymer processing. Extensive references are provided for further reading and in relation to modern prices, the book represents quite good value for money.

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Design Formulas for Plastics Engineers

Natti S. Rao
Hanser, Munich, 1991,
144 pp., £17.00,
ISBN 3-446-15687-9

This book aims to summarize useful formulae for the plastics engineer involved in designing machines and dies for polymer processing. Since much of this design is usually done with computer programs, a knowledge is needed of the fundamental equations on which computer models are based if programs are to be written or developed. The book covers rheology (viscous shear flow and viscoelasticity), thermodynamic properties, heat transfer, designing plastics parts, extrusion dies and screws and injection moulding. The formulae are introduced and defined with concise text and numerical examples given with worked solutions. There are also numerous schematic graphs of typical behaviour.

It is difficult to know what readership would best be served by this book. Because of the natural brevity of the text, it is unlikely to be used by people who are not already familiar with the principles and concepts involved. As a teaching text it is far too concise, and because the aim is to present formulae suitable for use in computer models there is little attempt to simplify them to bring out their physical significance. Of course the stated aim is to help design engineers to write computer programs. However, care must be exercised to ensure that the equations used are in an appropriate form. For instance, the power law for non-Newtonian viscosity uses shear rate as a function of shear stress raised to a power n, i.e. shear rate is plotted as the ordinate and shear stress as the abscissa. Thus the power law exponent n used here is the inverse of that often used. For low density polyethylene, for instance, the power law index is quoted here as 2.57, whereas it is commonly taken to be about 0.39 when shear rate is the abscissa. This also has an effect on the Rabinowitsch correction and although the alternative form is quoted in the text, mistakes could easily be made.

The chapter on viscoelastic behaviour relies heavily on schematic graphs which might be difficult to apply without the appropriate data. A more serious omission is any mention of loss tangent in the section on dynamic loading. Although storage and loss moduli are often sufficient, sometimes the only data available from polymer manufacturers are plots of loss factor against frequency or temperature. In the section on heat transfer there is a good summary of dimensionless groups which are defined both in symbols and in words. The chapter on designing plastics parts is of necessity brief since the potential applications are too diverse for a thorough treatment. Extrusion equations are given for flow in several channel geometries and for the solids conveying and melting regions of the screw. Perhaps because of the book's emphasis on machine design, the overall performance equations for extruder output (drag flow minus pressure flow) are not given. In the section on injection moulding the clamping force equation appears in an unduly complicated form and again there is little attempt to simplify difficult formulae, so that the reader must follow the argument in the given form in order to apply the equations easily.

Overall the book presents equations of plastics engineering that form the basis of computer models but it deliberately avoids details of the numerical routines themselves. In the section on cooling of injection mouldings there is a brief reference to finite difference methods but they are not mentioned at all in the chapter on heat transfer. Although there are other books which deal with computer modelling for polymer processing, it might have been useful if the equations presented here were linked in slightly more detail with possible computer implementation.

The book is well produced and clearly laid out with important equations highlighted, though perhaps more care could have been taken with proof-reading of the text. For the English-speaking reader the fact that many of the references are to the German literature could be a minor irritation. Generally, however, the book is clear and helpful, and subject to the provisos mentioned above should prove useful to polymer engineers involved in design.

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Liquid Transport Processes in Polymeric Materials: Modelling and Industrial Application

J. M. Vergnaud
Polymer Science and Engineering Science Series, Prentice Hall, 1991, £70.60

This book contains a mixture of two different styles. The first half deals with the mathematics of classical Fickian diffusion applied to a number of different geometries while the second half is more specific to polymers and has chapters on diffusion into and out of PVC, rubbers, wood and drugs. The first half has no references and reads rather like an undergraduate mathematical text while the second half has many references and is more reminiscent of published conference proceedings on diffusion. Sadly this reviewer finds the overall balance wrong and the book difficult to read or enjoy. This is a great pity as the book does contain useful information in a subject area that is of great importance.

There are many engineering texts on the analytic and numerical solution of the Fickian diffusion equation both for steady state and unsteady diffusion and for all of the geometries covered in the book, i.e. planar cylindrical and spherical geometry. Some readers may find the presentation of the results useful but in my opinion the results are somewhat fragmented and there seems to be little flow and too many subdivisions to the first seven chapters.

The final chapters probably hold a greater interest to the polymer scientist and the sections on PVC and rubber in particular contain plenty of experimental data. However, in these chapters the central issue of the concentration dependence of diffusion coefficients with polymeric materials and the additional rheological constitutive response are touched on but not rigorously developed, as in the earlier chapters.

Overall the book is disappointing and seems expensive. It may, however, contain some experimental gems that have not been picked up by this reviewer, which might justify enthusiasts of polymer diffusion delving deeper into the text.

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Modern Methods of Polymer Characterisation

H. G. Barth and J. W. Mays (Eds)
Wiley Interscience, 1991, £86, ISBN 0-471-82814-9

The book is volume 113 of the series of monographs on *Analytical Chemistry and its Applications*. It is written with two audiences in mind: those with little background in the field who want to know more about the techniques and applicability and those with some expertise who require an updated review of recent advances. The 12 chapters are written by a variety of contributors who meet these aims to varying degrees.

Chapters which meet the objectives well include those on size exclusion chromatography (s.e.c.) and h.p.l.c., field flow fractionation (f.f.f.), inverse gas chromatography (i.g.c.), photon correlation spectroscopy (p.c.s.), osmometry and viscometry. The last two provide an excellent reminder that in these days of 'high tech' methods, some of the classical techniques can still provide fairly rapid and low cost means of determining molecular weight and dimensions. Both chapters give a good overview of the practical techniques. Modern instruments for membrane and vapour pressure osmometry are well covered. In contrast to these traditional methods, f.f.f. and p.c.s. are relatively new and there is still the potential for significant development of experimental techniques and instrumentation. The chapters on these topics provide the newcomer with a good introduction to the fields and contain a good balance of the theoretical background, instrumentation and applications. The chapter on p.c.s. provides some useful practical tips and that on f.f.f. gives a neat comparison of the relative merits of this technique and s.e.c.

Chapters which are less well balanced are those covering data reduction in s.e.c. and polymer characterization using the ultracentrifuge. The former contains much theory and repetition of points covered in the immediately preceding chapter on s.e.c. and h.p.l.c. There is an overemphasis on deriving equations, several of which are only of practical value to simple systems. The final conclusions of this chapter do, however, give a good summary of some of the pitfalls in interpreting s.e.c. data. The chapter on the ultracentrifuge does not cater very well for a newcomer to the field. Little space is given to instrumentation and what comments there are assume a prior knowledge of the technique. The limitations of the method are well covered, but one is left with the impression that the technique is primarily applicable to biopolymers, particularly DNA.

The final two chapters cover the application of n.m.r. and mass spectrometry for polymer characterization. The advances in high field liquid and solid state n.m.r. have turned n.m.r. into a very powerful technique for polymer characterization, particularly for probing polymer microstructure and determining polymer dynamics. The difficulty faced by the author is to convey this richness in the short space available. In some areas this is done successfully, as in the summaries of special pulse sequences and 2-dimensional experiments. However, in other instances the author is tempted to venture too deep in too little space. An example of this is the detailed coverage given to reaction probability models for interpreting copolymer sequence distributions. In other parts of the chapter a good overview is given, such as the use of relaxation parameters to provide information on polymer dynamics, the brief introduction to high resolution solid state n.m.r. and the use of cross polarization/magic angle spinning techniques. Perhaps a little more space devoted to solid state and a little less to the details of reaction probability models would have improved the overall balance of the chapter. The advances in mass spectrometry are covered well, but the lasting impression is that, despite the progress, further advances will be required before the technique becomes generally applicable to high molecular weight polymers.

Overall, the volume gives a good introduction to the techniques it covers and will therefore be useful to the newcomer. It is probably of less value to those who are familiar with the field because the literature is covered only up to about 1988 and in some instances only as far as 1987. For the newcomer who wants a complete overview of techniques for polymer characterization, there are some surprising omissions. For instance, no coverage is given to techniques for thermal analysis, vibrational spectroscopy