Preface

Elastic solids and viscous fluids are two types of engineering materials whose response to loads, almost everyone, either seems to understand or takes for granted. Then there are materials whose response to loads combines the features of both elastic solids and viscous fluids. Not surprisingly, these materials are called viscoelastic and are a little trickier to understand than elastic solids or viscous fluids. The engineering discipline that developed to provide a rigorous mathematical framework to describe the behavior of such materials is called viscoelasticity. This book presents a comprehensive treatment of the theory and applications of viscoelasticity.

Polymers are viscoelastic materials. The term polymer has been around since Berzelius used the word "polymeric" in 1832; at a time when chemists were still unsure of the structure of even the simplest of molecules. Today, it is hard to imagine our world without polymers. Polymers and polymeric-based products are commonplace in virtually every industry. This is unquestionably true of the aerospace, rubber, oil, automotive, electronics, construction, piping, and appliances industries; and many more. Yet, despite the fact that viscoelasticity has been taught in universities for several decades, providing the necessary tools to design with polymers, today many polymeric-based products are still designed as if the materials involved were elastic. One reason for this practice is that viscoelasticity has been taught exclusively at the graduate level, yet most practicing professionals lack an advanced degree in engineering; and those with advanced degrees, never studied viscoelasticity, because the subject is usually an elective one.

If one thinks about it, the basic design courses, such as machine design, structural steel design, reinforce concrete design, and so on, are taught at the undergraduate level. The foundation of all these courses is mechanics of materials—the strength of materials of old—whose mastery requires a background in statics and some differential and integral calculus. If truth be told, the derivations of the design equations for viscoelastic materials are the same as for elastic solids; and the resulting expressions, virtually identical. The difference lies in that for viscoelastic materials the relationship between stress and strain is not an algebraic product of a constant modulus and the strain, as it is for elastic solids, but is given by a special type of product—called convolution—between a function which represents the modulus, and the time derivative of the strain. The point being made here is that it is just as demanding—perhaps only a tad more—to learn the art of designing with viscoelastic materials, as it is to learn the mechanics of elastic solids.

This book is intended to help Academia close the gap that exists between current practice and the proper way to designing with polymers, as well as to serve as a text on the theory of viscoelasticity. The book accomplishes these goals by presenting a self-contained, rigorous, and comprehensive treatment of all the topics that are relevant to the mechanical behavior of viscoelastic materials, and by providing all the background in mathematics and mechanics that are central to understanding the subject being presented.

As will be seen, Chaps. 1–7 could be used to teach a complete course on viscoelasticity at the undergraduate level. These chapters cover the theory in the one-dimensional form needed for design. The same chapters, complemented with Appendix A—which provides the mathematical background used in the derivations of the theory—contain all that a practicing professional would need to master the art of designing with polymers.

All equations in these chapters are developed from first principles, without presuming previous knowledge of the subject matter being presented. This approach is followed for two reasons: first, because it is necessary for readers who have no formal training in mechanics of materials; and second, because it provides a method to follow when the use of popular engineering shortcuts, like the use integral transform techniques, might not be clear.

The contents of Appendix B—which provides an introduction to tensors and an overview of solid mechanics together with Chaps. 8–11, are written with the graduate student in mind. A graduate-level course in viscoelasticity could be taught with this material, and perhaps selected sections of earlier chapters, as a continuation to an undergraduate course.

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