Preface

This monograph together with its complimentary volume, D. A. Siginer, *Dynamics of Tube Flow of Viscoelastic Fluids*, Springer, New York, 2014 in this series is an attempt to give an overall comprehensive view of a complex field, which has developed rapidly in the second half of the twentieth century, still far from being settled on firm grounds, that of non-linear constitutive equation formulations for viscoelastic fluid media and their impact on the dynamics of viscoelastic fluid flow in tubes. This monograph covers the development of constitutive equation formulations in their historical context together with the latest progress made, and *Dynamics of Tube Flow of Viscoelastic Fluids* covers the state-of-the-art knowledge in predicting the flow of viscoelastic fluids in tubes highlighting the historical as well as the most recent findings. Most if not all viscoelastic fluids in industrial manufacturing processes flow through tubes, which are not necessarily circular, at one time or another during the processing of the material. It is critically important that the flow of non-linear viscoelastic fluids in tubes can be predicted on a sound basis, thus the *raison d′ être* of the volume on *Dynamics of Tube Flow of Viscoelastic Fluids*. As flow behavior predictions are directly related to the constitutive formulations used, *Dynamics of Tube Flow of Viscoelastic Fluids* relies heavily on this volume when viscoelastic fluids are the working fluids.

The science of rheology defined as the study of *the deformation and flow of matter* was virtually single handedly founded and the name invented by Professor Bingham of Lafayette College in the late 1920s. Rheology is a wide encompassing science which covers the study of the deformation and flow of diverse materials such as polymers, suspensions, asphalt, lubricants, paints, plastics, rubber, and biofluids, all of which display non-Newtonian behavior when subjected to external stimuli and as a result deform and flow in a manner not predictable by Newtonian mechanics.

The development of rheology, which had gotten to a slow start, took a boost during WWII as materials used in various applications, in flame throwers for instance, were found to be viscoelastic. As Truesdell and Noll famously wrote (Truesdell C, Noll W (1992) The non-linear field theories of mechanics, 2nd edn. Springer, Berlin) "By 1949 all work on the foundations of rheology done before 1945 had been rendered obsolete." In the years following WWII the emergence and rapid growth of the synthetic fiber and polymer processing industries, the appearance of liquid detergents, multigrade oils, non-drip paints, and contact adhesives, and developments in pharmaceutical and food industries and biotechnology spurred the development of rheology. All these examples clearly illustrate the relevance of rheological studies to life and industry. The reliance of all these fields on rheological studies is at the very basis of many if not all of the amazing developments and success stories ending up with many of the products used by the public at large in everyday life.

Non-Newtonian Fluid Mechanics, which is an integral part of rheology, really made big strides only after WWII, and has been developing at a rapid rate ever since. The development of reliable constitutive formulations to predict the behavior of flowing substances with non-linear strain–stress relationships is quite a difficult proposition by comparison with Newtonian fluid mechanics with linear stress–strain relationship. The latter does enjoy a head-start of two centuries tracing back its inception to Newton and luminaries like Euler and Bernoulli. With the former the non-linear structure does not allow the merging of the constitutive equations for the stress components with the linear momentum equation as it is the case with Newtonian fluids ending up with the Navier–Stokes equations. Thus the practitioner ends up with six additional scalar equations to be solved in three dimensions for the six independent components of the symmetric stress tensor. The difficulties in solving in tandem this set of non-linear equations, which may involve both inertial and constitutive non-linearities, cannot be underestimated. Perhaps equally importantly at this point in time in the development of the science we are not fortunate enough to have developed a single constitutive formulation, which may lend itself to most applications and yield reasonably accurate predictions together with the field balance equations. The field is littered with a plethora of equations, some of which may yield reasonable predictions in some flows and utterly unacceptable predictions in others. Thus we end up with classes of equations that would apply to classes of flows and fluids, an ad hoc concept at best that hopefully will give way 1 day to a universal equation, which may apply to all fluids in all motions. In addition the stability of these equations is a very important issue. Any given constitutive equation should be stable in the Hadamard and dissipative sense and should not violate the basic principles of Thermodynamics.

Efforts have not been spared to be thorough in the presentation with commentaries about the successes and failures of each theory and the reasons behind them. The link between different theories and the naturally unfolding succession of theories over time borne out of the necessity of better predictions as well as the challenges in the field at this time are given much emphasis at the expanse of a detailed in-depth development of various theories. This monograph provides a snapshot of a fast developing topic and a bridge connecting new research results with a timely and comprehensive literature review. For a detailed in-depth exposition of any one subject included in this book the reader is referred to the extensive reference list given at the end of each chapter. The responsibility for any mistakes and misquotes that may have crept up into the text in spite of extensive checking remains solely with the author.

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