Journal of Fluids Engineering

Guest Editorial

The papers included in this special section of the Journal of Fluids Engineering are drawn from those presented at the IMECE 2002 in New Orleans in the Symposia on the ‘‘Rheology and Fluid Mechanics of Nonlinear Materials,’’ ‘‘Advances in Processing Science,’’ and ‘‘Electric and Magnetic Phenomena in Micro and Nano-Scale Systems’’ sponsored by the Fluids Engineering and the Materials Divisions. They represent excellent examples of cross-disciplinary research as well as investigations relevant to important issues in manufacturing processes.

Symposia focused on the theme of complex and smart fluids that have been organized in every Winter Annual Meeting of the ASME starting in the very early 1990s. The focus of early Symposia emphasized electro-rheological fluids and the broader topic of non-Newtonian fluids and industrial applications. The series widened its scope and adopted a more encompassing recurring theme on the ‘‘Rheology and Fluid Mechanics of Nonlinear Materials’’ in the mid-1990s. Lately, parallel and complementary Symposia series addressing issues on the related themes of ‘‘Electric and Magnetic Phenomena in Micro and Nano-Scale Systems,’’ ‘‘Advances in Materials Processing Science,’’ and ‘‘Flows in Manufacturing Processes’’ have been organized regularly, the former two were held during IMECEs and the latter during summer meetings of the Fluids Engineering Division all initiated and led by Dennis Siginer.

These series developed as an interdivisional effort and has been sustained thanks to the support of the Fluids Engineering, Materials, and Applied Mechanics Divisions with organizing committees led by Dennis Siginer. The ongoing concurrent series of Symposia truly reflect the overlapping interests of the participants and present excellent examples of interdisciplinary research. The interests of the fluid mechanician, applied mathematician, continuum mechanician and the material scientist, as well as the industrial practitioner find a home in these series and feed on each other culminating in syntheses leading to new developments. Over the years, excellent and occasionally groundbreaking papers have been presented and published in the Proceedings of these Symposia. A prominent example which leaps to mind is the papers on suspensions by the late Yuri A. Buyevich presented at the IMECEs in the mid-1990s, and in particular the paper on fine suspensions in IMECE in Anaheim, Calif., in 1998.

Knowledge of non-Newtonian behavior is of vital importance to numerous manufacturing processes. The ‘‘Rheology and Fluid Mechanics of Nonlinear Materials’’ encompasses intriguing phenomena with enormous potential for manufacturing processes not observed in the case of materials with linear constitutive behavior. New materials are discovered constantly. Engineers are tasked with the design and manufacture of products by taking advantage of the special properties of these materials, which may undergo phase changes during the manufacturing process. Materials at the forefront of innovative technological applications rarely exhibit linear Newtonian stress—strain rate relationships, rather behaving in a very nonlinear fashion that needs to be characterized. This characterization is then used to describe their flow behavior under applied stress. Fluid flow and heat transfer phenomena may significantly affect the feasibility and the efficiency as well as the economic aspects of materials processing. Most manufacturing processes are strongly affected by the related transport phenomena. Product quality in particular and the efficiency of the process depend to a large extent on optimizing the characteristics of a given flow and/or heat transfer phenomenon pivotal to the process.

The 12 papers in this collection are loosely divided into three groups. The first five papers are more centered on fundamental issues with underlying important practical applications. The three papers in the next group present novel measurement techniques. The final four papers in this special section are directly related to manufacturing processes.

To begin the first group, Yamamoto et al. discuss new experimental results for the penetration problem of a long gas bubble through a viscoelastic fluid in a tube. This problem is relevant to the displacement of oil by a low viscous fluid in enhanced oil recovery as well as film coating on the inner wall of a tube and gas-assisted injection molding where viscous fingering may occur. They show that for values of the Weissenberg number larger than one ($We>1$) elastic normal force is the dominant factor in shaping the film thickness between the bubble and the wall, and when $We<1$ shear thinning viscosity defines the thickness. They discuss the consequences of their findings.

The petroleum industry relies on a number of polymer-based viscoelastic fluids in various operations such as well drilling and stimulation. These fluids are pumped partly through coiled tubing. The prediction of energy losses is central to the design of coiled tubing pumping operations. The drag reducing property of these fluids as well as viscoelasticity generated secondary flows in the curved geometry impact the energy losses in addition to frictional effects. The paper ‘‘Rheological Properties and Frictional Pressure Loss of Drilling, Completion, and Stimulation Fluids in Coiled Tubing’’ by Zhou and Shah explores these issues and presents interesting new experimental results, which point at the energy losses in coiled tubing to be significantly higher than straight tubing.

The addition of polymers to lubricants to produce viscoelastic ‘‘multigrade’’ oils is reported to lead to reduced bearing wear and engine friction. The mechanism associated with these effects remains unclear despite recent efforts to elucidate the physics of the phenomenon. The authors of ‘‘Rheology of Dilute Polymer Solutions and Engine Lubricants in High Deformation Rate Extensional Flows Produced by Bubble Collapse’’ experimentally investigate liquid jets formed by the collapse of bubbles under cavitation generated pressure waves. High rates of extension found in such jets are relevant to oil flows in dynamically loaded bearings, which subject the fluid to extension rates of the order of several thousand per second within a millisecond transit time. They report a mitigating effect of viscoelasticity on the cavitation damage mechanism.

Applied large electric fields generate a dramatic response in the rheological properties of electro-rheological suspensions. Development of industrial applications, including electro-rheological clutches, brakes, engine mounts in the automotive industry and robotic actuators, is at this time limited by a lack of understanding of the underlying mechanisms with the added difficulty of producing stable suspensions. Kadaksham et al. develop a novel numerical approach based on distributed Lagrange multiplier method for the direct simulation of the dynamics of electro-rheological suspensions subjected to spatially nonuniform electric fields. They show that particle collection time in a flowing electro-rheological fluid subjected to a nonuniform electric field depends on the ratio of dielectrophoretic and viscous forces as well as the relative importance of the electrostatic particle-particle interaction force, the dielectrophoretic force, and the hydrodynamic forces.

Liquid crystal technology is crucial to electronic display component manufacturing among other things. Nematic phase is the simplest phase in a liquid crystal (LC) with an orientation order but no translational order. Of particular interest are rod-like and disk-like polymer-molecule-based LCs. Most hydrodynamic theories formulated for flows of LC materials are predicated on rod-like polymer molecules. Wang, the lead author of the paper on the kinetic theory for nonhomogenous nematic liquid crystalline polymers, recently developed a kinetic theory for spheroidal liquid crystal polymers with the aim of establishing a unified theory for rod-like and disk-like LCPs. In the present paper together with his co-authors, he discusses the extension of the previously proposed unified field theory to account for the translational diffusion and the related density variations. The constitutive theory presented is applicable to flows of rod-like liquid crystal polymers at large aspect ratios and to flows of disk-like LCPs at small aspect ratios.

The three papers in the next group present novel measurement techniques. Greenwood and Bamberger describe a noninvasive technique to measure the density of a liquid or slurry through the stainless steel pipeline wall. The self-calibrating ultrasonic sensor they introduce measures the density by coupling measurements of acoustic impedance and velocity of sound. The technique and the associated self-calibrating sensor represent an exciting development, and may have a variety of applications.

Bakhtiyarov et al. present a new technique for measuring fraction solid in molten metals and alloys, as well as the results of the application of the method to a commercial aluminum alloy. The technique is based on measuring the opposing torque generated by the circulating eddy currents induced by a rotating magnetic field in a stationary solidifying metal sample or vice versa. The torque is related to the amount of solid phase in a solidifying melt. The method is an important contribution to the understanding of the solidification phenomenon in the mushy zone. Fraction solid is a pivotal parameter in optimizing metallurgical processes and in developing mathematical models of the casting process.

Ferrofluids are rapidly becoming a commercially viable example of polarizable suspensions with potentially promising applications in microfluidic pumps and actuators driven by alternating or rotating magnetic fields, in drug delivery vectors and other biomedical applications such as magnetocytolysis of localized tumors. These fluids are suspensions of magnetized colloidal particles coated with a stabilizing dispersant in a carrier fluid. For theoretical modeling, they present a challenge, in that they are characterized by body-couples and nonsymmetric viscous stresses as well as couple stresses representing the transport of microstructure angular momentum. The paper by Rosenthal et al. discusses theoretical developments and experimental observations concerning the spin-up flow and the measurement of the torque required to restrain a hollow cylinder containing the ferrofluid with the underpinning aim of clarifying an ongoing controversy in the spin-up flow of ferrofluids.

The remaining four papers in this special section are directly related to manufacturing processes. High-speed water jets proved to be feasible replacements for cutting tools, be it surgical scalpels or rock cutting. Among the myriad of applications, the capability of water jets and water/ice slurries to perfectly clean contaminated surfaces in an inexpensive and environmentally sound way is particularly noteworthy. The paper by Petrenko et al. describes a numerical study to investigate the dynamics of the water slug propelled by powder explosion in a water cannon. The slug is very much like a bullet, but moves at speeds significantly exceeding that of a bullet driven by a similar explosion, typically speeds in excess of 1.5 km/s. The computational method is based on a finite difference scheme coupled with the method of characteristics and predicts the pressure, velocity and density fields in the course of slug acceleration.

The collaborative effort of Correia et al. examines extensively the vacuum assisted resin transfer molding process (VARTM) widely used in a variety of manufacturing processes involving composite materials. A governing equation for VARTM is developed, followed by a numerical 1D/2D solution predicting the flow and time-dependent thickness of the preform by introducing models for compaction and permeability. The paper also provides a comparative study of VARTM with the conventional resin transfer molding (RTM).

Boutaous and Bourgin explore the flow of an air layer squeezed between a solid smooth substrate and a plastic film. The problem is of pivotal importance in obtaining good quality plastic film rolls, as stresses generated by trapped air pockets lead to defects. Experimental evidence points to the plastic film roughness as the governing parameter in determining the flow characteristics. The authors present experimental measurements of the plastic film roughness, a very involved concept in itself as the word roughness contains so much information, and an elegant theoretical analysis of the squeeze flow via Hele-Shaw approximation introduced by T. C. Fung in 1969 together with periodic homogenization techniques.

The last paper in this collection explores the effect of buoyancy convection on the growth of a particular type of crystal grown by the traveling solvent method (TSM) under different heating conditions. Saghir et al. use a finite-element approach to solve simultaneously the full Navier-Stokes equations together with the energy and solutal equations. The TSM is a commonly used method in industry to produce pure and homogenous simple crystals for the production of high-quality semiconductors. The modeling in this paper accounts for the heat losses by radiation. The authors present interesting results pointing to strong convection currents in the solvent detrimental to the growth uniformity of the crystal rod.

I would like to thank the authors of the papers in this special section of the Journal of Fluids Engineering for their devoted efforts in preparing and improving their manuscripts in response to the reviews. Special thanks are due to the referees who contributed their time and expertise.

Dennis A. Siginer
Associate Editor