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Current Topics, Trends and Needs in Rheology

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I. INTRODUCTION

A number of current topics are chosen to illustrate the range of rheological research at the present time: they include work in numerical analysis, in rheological theory, in experimentation and in applied topics. From these activities, and from the thrust of papers being presented at rheology meetings, several suggestions for continuing research arise.

II. CURRENT TOPICS

A. Numerical work

Numerical studies have emerged as a major productive component of theoretical and applied rheology. They enable the complexities of real flows of commerical interest to be studied. Since such flows are frequently transient from a Lagrangian viewpoint, and may involve both shearing and stretching deformation, they provide an exceptional class of problems for evaluating the ability of rheogical consititutive equations to portray fluid behavior under rather general circumstances. The subject has recently been studied in great detail by Pilitsis and Beris[1], who applied sophisticated new numerical techniques to unravel some of the complexities and apparent inconsistencies found during studies of flows through porous media. We consider their results in some detail in the oral presentation.

B. Theoretical work

Almost all analyses in fluid mechanics have employed an adherence (no-slip) boundary condition, yet this common assumption rests to a significant degree upon data obtained in the previous century for air and water-i.e. linear fluids of low viscosity level. As we turn to studies involving high viscosity polymer melts and highly concentrated suspensions, will this boundary condition still apply? Surely the adhesion of a fluid to a solid surface cannot be so strong as to withstand relative motion as shearing stresses of arbitrarily large magnitudes are applied.

The question appears to have been clarified in a landmark contribution by A.V. Ramamuthy[2]. We will review this work and some recent extensions of it by Schowalter and his students[3, 4].

In a second area of theory we will consider an example of the coupling between rheology, thermodynamics and diffusional transport rates in flow of multilayer films of fluid. In these it is observed that the "viscosity" of a system composed of a series of concentric, or parallel, thin fluid layers may be even *lower* than that of the constituent having the lowest viscosity[5, 6]. We are as yet unable to propose a definitive analysis of this pragmatically-important phenomenon, but some tentative ideas[7] will be described.

C. Experimental studies

We will focus on studies by D.F. James of flows through converging channels[8,9]. The Problem is of pragmatic interest and it represents one possible mechanism for measurement of stresses in predominantly extensional flows at very high deformation rates.

Are there any circumstances under which pressure transducers, mounted along the wall of a converging channel, can indicate a pressure which *increases* with increasing downstream position? An analysis has been prepared which shows that this superficially-unlikely phenomenon is a natural consequence of the high tensile stress levels which may be developed in such flows. It provides an interesting cautionary note to the value of our intuitive notions when applied to rheologically-complex materials.

D. Applications, Applied studies

As one specific problem, we shall consider the flow of polymeric melts containing long suspended fibers. Such fluid-fiber mixtures might be employed as injection molding compounds yielding molded parts of improved strength and stiffness. The flows are found to be very erratic and appear to be highly unstable[10,11]. Yet while the instability(melt fracture) of *neat* polymers commonly increases with increasing flowrate or with decreasing channel length, these fiber-polymer mixtures show exactly the inverse kinds of behavior. We will present some analysis which predicts these differences[11], although the complexity of the process prohibits conclusions which are entirely definitive at this time.

III. FUTURE TRENDS AND NEEDS

It is virtually impossible-and would be simply arrogant-to attempt to provide any definitive list of future trends and needs. Several will be evident from the previous examples. Other possibilities might include.

- the development of better consititutive equations for the deformation and flow of conventional polymers (as noted earlier), but also for rigid-rod (liquid crystalline) polymers, for colloids, and for highly concentrated suspensions as employed, for example, in the molding of ceramic articles. This generic need for better constitutive equations in all phases of rheology underlies progress in almost everything rheologists wish to do. There is also an important addition required to the conventional activities of rheologists in the area of constitutive equations. Too frequently we have been content with providing equations which only portray the stress-deformation rate-time behavior of fluid. Important and difficult as this may be it is not the whole story: what one frequently needs, in practice, is the additional description of evolving microscipic or molecular structure of the deforming material. It is this rheological consideration which is so important in providing information on the relation between the manufacturing process, used to fabricate a product and the end-use properties of the finished article. Rheology is a very central issue in this aspect of manufacturing technology, and the development of rheological constitutive equations which address this need is an important consideration. Since the deformation of polymeric materials is necessarily accompanied by changes in their entropy, and hence in their thermodynamics phase behavior, the closer coordination of advances in rheology and in thermodynamics is also desirable.
- electrorheology and the rheology of fluids subjected to high pressures.
- studies of the deformation, flow and structure of solids.

- studies of the intensification of processing operations, frequently rate-limited by instabilities which arise in the deforming fluid. This is a traditional area of analysis yet it has yielded exploitable insights only fairly recently. Availability of more powerful computational tools, including parallel processing, and of better rheological constitutive equations, may enhance the productivity of furture studies in this area. Much remains to be done.
- the development of new techniques for measurement of rheological properties especially at high deformation rates, at high pressures, and in controllable extensional deformations.
- biorheology
- georheology and astrorheology.
- food rheology, and the development of scientific methods for measuring, monitoring and controlling the quality of foodstuffs.

IV. SUMMARY COMMENTS

There is a rich variety of both theoretical and applied work in rheology to challenge the theorist, the numerical analyst and the experimentalist. Applications abound, not only in the numerous polymeric materials industries but in petroleum (enhanced oil recovery, lubrication and torque transmisstion), in the manufacture of composites for the automotive, aircraft, electronics, and sporting goods industries, in the coating operations of the paper, photographic film, building materials, and packaging industries and in many others. Some considerable variety of opportunities appear to be available in which an incisive technological development could lead to world-wide dominance in the industry involved.

The emergence of the Korean Society of Rheology at this juncture would appear to be a very timely development in Korea's highly technological society. You are already, at the time of your very first meeting, the 5th or 6th largest rheological society in the world, and you are still growing! The challenge is to become one of the best and most productive, both pragmatically and theoretically. All of us from overseas who have been privileged to work with some of you know that the Korean qualities of creativity, competence, enthusiasm, and vigor, will enable you to compete most impressively in the world scene. We wish you well-both in an inspired choice of the problems you elect to study and in the celerity with which you develop them.

V. REFERENCES

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