HEAT AND MASS TRANSFER IN RHEOLOGICALLY COMPLEX FLUIDS

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In the nearly two decades since the 1970 International Seminar in Herceg Novi on "Heat and Mass Transfer in Rheologically Complex Fluids", activity in the field has intensified and substantial progress has been made. Several of the Herceg Novi papers addressed issues which were foreseen as critical to our fundamental understanding of transport processes in rheologically complex fluids. Events of subsequent years have shown that the participants of the seminar exhibited remarkably clean insights of future needs. The rheology of suspensions is a case in point. This subject might be considered to have been the source from which modern activities in constitutive modeling have evolved. I am thinking of course of the work of Einstein in which he predicted the viscosity of a dilute suspension of rigid spheres. Fundamental studies of the rheology of suspensions after the pioneering work of Einstein, Jeffery, Frohlich and Sack, and others, were relatively infrequent until approximately 1970. The paper at the Herceg Novi seminar by Brenner (1) sets out some of the important questions which, since 1970, have been the stimulus of the role of rotational Brownian motion on bulk stress than was available at the time of Brenner's paper. We also know much more about geometric and physicochemical effects, both of which are addressed by Brenner.

Several of the seminar papers dealt with flow instabilities and/or secondary flows. The paper by Hayes and Hutton [2] continues to be one of the best sources for documentation of the analogue of Taylor instability in non-Newtonian fluids. That work is nicely balanced by Giesekus' [3] description of instabilities in other flow geometries, such as free jets issuing from axisymmetric or plane channels containing grooved walls. Vinogradov [4] documented the flowcurve discontinuity that can take place during conversion to a "high elastic state". This conversion is known to be related to the possibility of loss of adherence between a polymer and the wall of a conduit through which the polymer is flowing. The paper by Shulman, et al, [5] illustrates the special instabilities that complex rheology confers on mass transfer in rotating fluid systems.

During the past two decades there has been and increased reliance by scientists on scaling laws as a means for organization and explanation of physical phenomena. Such an activity is a branch of the general subject of dimensional analysis. An example of the interplay between dimensional analysis, mathematics, and physics is demonstrated in the paper by Pearson [6], who has shown how, through proper scaling, one has a hope of performing useful analyses of complicated problems in which close coupling exists between momentum and heat transfer.

There are areas of intense current rheological activity that were not clearly in evidence at Herceg Novi. One of these is computational fluid dynamics. To be sure, a paper by Spalding [7] contains algorithms for computation of transport coefficients in turbulent pipe flow of non-Newtonian fluids. However, the last decade has seen and enormous growth in interest, parallel to the development of computer capacity, in overcoming limits imposed by elastic behavior on the flow rate at which numerical schemes fail to converge. This "high Weissenberg-number problem" is alluded to in the context of heat transfer in boundary layers by Astarita and Nicodemo [8].

Because heat transfer was an important part of the seminar, several papers dealt with one or more aspects of thermodynamics, an example being the brief communication by Gorodtsov and Leonov [9]. Thermodynamics as it applies to dynamic processes of non–Newtonian fluids is a subject which has not progressed in the years since the Herceg Novi seminar as much as one might have hoped. The subject, requiring a foundation in general nonequilibrium thermodynamics, is difficult. Continuum thermodynamics has attracted the attention of several superbly qualified researchers. However, the connection with coupled transport problems of engineering interest has yet to be made in a way comparable to the connection of engineering problems with continuum mechanics. I hope that twenty years hence ans of server will be able to recount the blossoming of the thermodynamics as it applied to transport problems in rheologically complex fluids.

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