1982

Analogy Among Heat and Momentum-Transfer for Non-Newtonian Fluids in Laminar-Flow Through Pipes

Bahman Ghorashi
Cleveland State University, b.ghorashi97@csuohio.edu

Bela Hirsch
Cleveland State University

Original Citation

Ghorashi, B., & Hirsch, B. (1982). Analogy Among Heat and Momentum-Transfer for Non-Newtonian Fluids in Laminar-Flow Through Pipes. Journal of Rheology **26**, 75-76.

Repository Citation

Ghorashi, Bahman and Hirsch, Bela, "Analogy Among Heat and Momentum-Transfer for Non-Newtonian Fluids in Laminar-Flow Through Pipes" (1982). *Chemical & Biomedical Engineering Faculty Publications*. 5.
https://engagedscholarship.csuohio.edu/encbe_facpub/5

dients of the many small deformations computed along particle trajectories. Particular attention is given to the verification kinematical consistency.

B5. Numerical Simulation of the Curing Process for an Epoxy Resin.* C. E. Hickox, D. K. Gartling, J. W. Nunziato, and K. R. Hirschbuehler, *Sandia National Laboratories*,† *Albuquerque, New Mexico 87185.*

The transition of an epoxy resin from an initial liquid state to a relatively solid gel is, in general, a complex transient process that involves chemical reaction kinetics as well as heat and mass transfer. A finite element-based fluid mechanics code that utilizes the Boussinesq approximation has been modified and used for the numerical simulation of the gelation process associated with a particular epoxy resin. The modifications were concerned primarily with the implementation of the Arrhenius reaction kinetics which are assumed to describe the gelation process.

The specific gelation process chosen for simulation is one for which a limited amount of experimental data is available. An epoxy resin and a curing agent are combined, at constant temperature, in a small cubicle container (5 cm on a side) and placed in a constant temperature oven. As the curing process proceeds, heat is generated as a result of the exothermic nature of the reaction, convection cells are observed in the container, and a gelation process is subsequently initiated near the top of the container. Once initiated, a planer gel front propagates rather rapidly through the container (in approximately 5 min). The entire curing process requires approximately 75 min at an oven temperature of 344 K. The epoxy resin used in the experiments was DEGBA (diglycidylether of Bisthenol A), and the primary amine curing agent was TETA (triethylene tetramine).

Computed streamlines, isotherms, and contours depicting the extent of reaction and hence gelation were obtained and compared with experimental observations. Reasonably good qualitative agreement was obtained between experimental and numerical results. Specific difficulties encountered in the simulation process are enumerated.

* This work was supported by the U.S. Department of Energy under Contract DE-AC04-76-DP000789.

† A U.S. Department of Energy Facility.

B6. On the Flow of a BKZ Fluid in an Orthogonal Rheometer. K. R. Rajagopal, *Department of Mechanical Engineering, The Catholic University of America, Washington, D.C. 20064*, and A. S. Wineman, *Department of Mechanical Engineering and Applied Mechanics, University of Michigan, Ann Arbor, Michigan 48109.*

The motion occurring in the orthogonal rheometer has been studied by several authors. Recently, it has been established by Rajagopal that the equations of motion of a general simple fluid give rise to a differential equation of the same order as the Navier–Stokes equation because of the assumed form of the velocity field. Here we study the problem due to the flow of a BKZ fluid and obtain a numerical solution for the velocity field.

B7. Analogy among Heat and Momentum Transfer For Non-Newtonian Fluids in Laminar Flow Through Pipes. Bahman Ghorashi and Bela Hirsch,* *Department of Chemical Engineering, Cleveland State University, Cleveland, Ohio 44115.*

* Present address: Republic Steel Corporation, Cleveland, Ohio.

The heat transfer to a non-Newtonian fluid, flowing in a heated pipe in the range of $300 \leq G_z \leq 800$ was studied. A polyacrylic–water system which falls in the category of pseudoplastic fluids was used. Until recently, attempts to describe nonisothermal momentum and energy transfer to these fluids have been limited by certain assumptions or restrictions. The laminar flow equations have been solved with restrictive conditions for various non-Newtonian models, characterized by the empirically observed relationships between shear stress and velocity gradient.

In this work an attempt is made to obtain an analogy among heat and momentum transfer using the generalized power law function, valid for all time-independent non-Newtonian fluids. The difference between the Nusselt numbers found experimentally and those determined by the Metzner–Vaugh–Houghton relationship was considered to be due to the free convection, since effects of viscous dissipation of energy and heat generation owing to the internal sources were insignificant for the range of flow rates considered. The free convection, which determined approximately 17% of the total heat transfer, was accounted for by modified forms of Grashof and Prandtl numbers. A new term which includes the modified Grashof and Prandtl numbers is added to Metzner–Vaughn–Houghton relationship in order to include the effect of free convection. It is believed that the resulting equation would describe more adequately the heat transfer to this type of system.

Session C: Nontraditional Experimental Techniques for Determining Viscometric Functions
Chairman: J. J. Ulbrecht

C1. The Use of Nearly Viscometric Techniques to Measure The Normal Stress Function. R. I. Tanner, *University of Sydney, 2006 Sydney, Australia.*

The measurement of the viscometric functions at high shear rates presents several problems. The present paper discusses the measurement of N_1 by using a lubrication geometry. It is shown that the measurement of a single force, a single speed, and a single displacement is sufficient to deduce N_1 at a known shear rate provided the viscosity function is known. Preliminary results with a prototype apparatus show the feasibility of the technique. The use of a fan flow geometry for measuring N_2 at higher shear rates is also suggested, and progress is reported.

C2. The Measurement of Viscoelastic Functions Associated with Shearing at High Strain Rates. J. M. Dealy and S. S. Soong, *McGill University, Montreal, Canada.*

At present, the use of transient shear flows to characterize viscoelastic fluids is limited to rotational rheometers in which the strain rate is limited to low values by edge effects. This is a serious limitation, as many commercial processes involve shearing at large strain rates. Capillary rheometers can be operated at high shear rates, but can only measure viscosity. A new melt rheometer is described that can be used to carry out such tests as stress growth, stress relaxation, and large-amplitude oscillatory shear. The problems arising from rotational flows are avoided by using rectilinear flow, and edge effects are minimized by the use of a shear stress transducer of novel design to measure local wall shear stress.