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THEORETICAL AND EXPERIMENTAL STUDIES OF SELECTED TOPICS IN THE RHEOLOGY OF FLUIDS

FINAL REPORT

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U.S. ARMY RESEARCH OFFICE
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UNIVERSITY OF MINNESOTA

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Theoretical and experimental studies of the consequences of short-term elastic response in liquids. Theoretical studies include analysis of the origins of viscosity in relaxing elasticity, the analysis of equations of motion according to type; e.g., hyperbolic or elliptic, with particular attention to problems of identification of physical phenomena and numerical analysis of flow associated with (1) change of type from subcritical to supercritical conditions in steady flow ("transonic" problems), (2) loss of well-posedness or short wave length instabilities in unsteady flow, (3) regularization of short wave instabilities with viscosity. We invented a wave speed meter, which enables us to measure the effective shear modulus in liquids. The wave speeds also enter into hyperbolic analysis like sound speeds in gas dynamics. Now we are developing an instrument to measure the speed of shear waves into a sheared media. We discovered delayed die swell and demonstrated experimentally that it is a critical phenomenon which appears to be like a hydraulic jump with speeds greater than the shear

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wave speed measured on our meter before the swell and less than the shear wave speed after the swell.

We discovered that the fluidization of particles at finite, but even small Reynolds numbers was dominated by local mechanisms associated with wakes and turning couples on long bodies. One sphere falls in the wake of another, they kiss, then tumble by the action of the turning couple which turns long bodies broadside onto the stream. We are working on showing that these mechanisms lead to stable arrays of spheres aligned perpendicular to the stream giving a physical foundation to the mathematical assumption that there are regimes of flow governed by one dimensional equations. We are studying the two phase flow of two liquids including rollers, fingering flows, the formation of emulsions and controlled breaking of liquid filaments.

We have carried out a complete linearized analysis of the stability of water lubricated pipelining of viscous oils which includes all of the main physical mechanisms underway, except gravity. The theory appears to be in good agreement with experiments.

We studied coating and rimming flows the context of a theory of rigid rotations of two fluids. We explained the dynamics of rollers in terms of minimizing an interfacial potential. We showed how to compose coating flows from this potential for axial variations and lubrication theory for radial variations.

Statement of the Problems Studied

1. Theoretical studies of hyperbolicity and change of type in the flow of viscoelastic fluids.

2. Experimental studies of shear wave speeds in viscoelastic fluids.

3. Mathematical studies of short wave instabilities and ill-posed problems.

4. Experimental studies of nonlinear mechanisms in the fluidization of beds of particles.

5. Theoretical studies of rigid motions of two fluids, coating and rimming flows. Experiments for this theory.

6. Linearized stability studies of water lubricated pipelining.

Sumary of Results

A brief summary is found in the "abstract" on the report documentation page.

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