Indian Institute of Technology Kanpur

C. N. R. Rao Lecture

6 PM, Thursday, 17th April 2014, Venue: L 16

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Title: To yield or not to yield: Convection in Visco-plastic Fluids

Abstract

Based on our day to day experience with air and water, all of us have a general impression that all fluids flow as readily as air and water. There are, however, situations when this simplistic view is grossly inadequate, as there exists a class of structured-materials which yield only when the external applied stress exceeds a threshold value. A visco-plastic material is thus characterized by the existence of a threshold stress below which it behaves like an elastic solid (shows creep-like characteristics) and above the yield stress, it flows like a viscous fluid. These substances are also known as soft solids. The current interest in studying the behaviour of such fluids stems from both theoretical and pragmatic considerations. From a fundamental standpoint, much has been written about whether a true yield stress exists or not. One can argue that given sufficient time everything flows hence "*mountains flowed before the lords*!". While others view it as a bi-viscous material wherein the effective viscosity of the fluid medium drops dramatically by several orders of magnitude over a very narrow range of shear rate or shear stress. Irrespective of the fact that whether a true yield stress exists or not, the notion of a yield stress has proved to be of considerable value in approximating the rheological behaviour of many substances encountered in a range of applications. By virtue of its yield stress, such a material has the ability to support the weight of a particle. This concept is routinely used in designing and manufacturing sectors where the homogeneity of a product is germane to its satisfactory end use. Typical examples include personal care products, dishwashing and cleaning agents, paints, processed foods, fire fighting and shaving foams, processed food stuffs, mine tailings, pharmaceutical suspensions, for instance. Also, it is evident that in a given flow situation, depending upon the prevailing stress levels, there will be the so-called yielded (fluid-like) and unyielded (solid-like) regions.

In this talk, consideration is given to the definition, measurement and interpretation of yield stress in fluid-like systems. The level of difficulty in the fluid mechanics of such substances is demonstrated by considering the Stokes problem, i.e., the case of a sphere undergoing steady translation in such a fluid. We also try to address the question of whether, for a given sphere-fluid combination, the sphere will settle or not under its own weight, i.e., criterion for the initiation of particle motion and the size and shape of deformed cavities (yielded regions) during the flow of such substances. Also, it stands to reason that in the presence of a temperature gradient in a system, conduction will be the sole mechanism for heat transfer in the unyielded (solid-like) domains and convection will be restricted to the so-called fluid-like regions only. In summary, even such seemingly simple flows of visco-plastic fluids present immense difficulties from both numerical and experimental standpoints.

About the Donor

Prof. Chintamani Nagesa Ramachandra Rao was born on June 30, 1934 in Bangalore. In 1958, he completed his Ph.D. from Purdue University and became a research chemist at the University of California at Berkeley. Returning to India in 1959, he worked as a lecturer at the Indian Institute of Science in Bangalore. From 1963-76, he was a Professor of Chemistry at IITK. During 1984 -89, he was the Director of IISC Bangalore.

Prof. Rao has published more than 46 books and 1604 research papers with more than 42,000 total citations. Concurrent with his academic excellence, he currently serves as the Head of the Scientific Advisory Council to the Prime Minister of India. Recently, he received Bharat Ratna, the highest civilian award in India. He is the recipient of most of the major scientific awards, and is member of all major scientific organizations. He is a foreign member of the US National Academy of Sciences, American Academy of Arts and Sciences and of the Royal Society (London).

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About the Speaker

Prof. R P Chhabra received his BE, ME & PhD (all in Chemical Engineering) from the erstwhile University of Roorkee (1974), the Indian Institute of Science, Bangalore (1976) and the Monash University, Melbourne (1980) respectively. After a post-doctoral experience at the University of Swansea (UK), he joined the Indian Institute of Technology Kanpur in 1984. He has been a Professor of Chemical Engineering at IIT Kanpur since 1991.

His main research interests are in studying the influence of non-Newtonian characteristics (shear-dependent viscosity, visco-plasticity and visco-elasticity, for instance) as exhibited by most structured substances (of multiphase and/or high molecular weight nature) including foams, emulsions, slurries and polymeric systems on convective transport in such fluids in model configurations like the flow over a sphere (Stokes problem) or two-dimensional cylinders of different shapes. He has published widely in this field and has three books to his credit.

He is a Fellow of the Indian National Science Academy, of the Indian National Academy of Engineering, of the National Academy of Sciences, India and of the Academy of Sciences.

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