

Progress Report for DOE EPSCOR grant DE-FG02-04ER46119

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During the first year of the DOE Research grant funding (March 2004-current), we have successfully performed the following tasks.

1. We have completed *all* experimental measurements of the Jeffery-Hamel flow outlined in our proposal. All these measurements are now in process of being analyzed using PIV (particle image velocimetry) software to resolve the velocity fields. The results will be reported by the PI during the annual meeting of Division of Fluid Dynamics (DFD) of the American Physical Society in Seattle, Washington (November 2004). The trip to this conference is supported by DOE. A paper describing the experimental results is in preparation; we intend to submit it to the *Journal of Fluid Mechanics*. We also plan to make the results available for download on our web site, as well as the fluid mechanics experiments repositories, as was outlined in our proposal. This progress is according to the timeframe outlined in the proposal.
2. We have constructed a two-dimensional shear layer generator based on the soap-film tunnel design. We performed a series of experimental

measurements of the Kelvin-Helmholtz instability in two spatial dimensions using this experimental arrangement. The results have been interpreted quantitatively in terms of the mixing zone width, characteristic wavelength, and interfacial fractal dimension. These results are presented in the M.S. thesis of Ms. Aparna Korlimarla (co-PI's graduate student), scheduled for defense in November. This progress is according to the timeframe outlined in the proposal.

3. We have performed the first ever experimental realization of a source flow in two dimensions (which is Jeffery-Hamel flow without the walls). The results will be outlined in a paper by the PI, co-PI and the PI's graduate student Keith Mertens. This paper, currently in preparation, will be submitted to *Physics of Fluids*. The measurements of source flow are a part of the experimental program outlined in the proposal. The progress on this task is also consistent with the schedule.
4. We have started a theoretical study of the hysteresis in Jeffery-Hamel flows. The idea is to couple the almost inviscid flow outside the wedge and the viscous flow inside the wedge. A model using non-local Ordinary Differential Equations (ODEs) has been constructed and will be analyzed during the second year of funding. To date, we have analyzed a simpler problem of the flow in an expanding channel with the wall shape being close to that of our experiment. This theoretical work was done in collaboration with Prof. Shinya Watanabe, Ibaraki University, Japan (as was outlined in the proposal) during PI's two-month visit to Japan (supported by NSF) and Prof. Watanabe's visit to UNM (supported partially by Petroleum Research Fund). Together with Prof. Watanabe, we have done very extensive study of integral methods applied to our problem. We have completed the theoretical description of a flow in a channel with sudden expansion using integral methods. The use of integral methods in our problem has been envisaged in the proposal during the second and third year. Our theoretical results give us full confidence that we will complete the theoretical work on schedule.
5. The introduction of a model of the disordered flow components (*e.g.*, via turbulence modeling) is essential for better understanding of the phenomena and accurate quantitative predictions. Therefore, the PI, together with Profs. D.D.Holm (LANL) and S. Stechman (Courant

Institute), has undertaken the study of a problem where, in a turbulence model, all the *activity* was concentrated in very narrow strips. The paper *Rotating Co-centric Circular Peakons* has been published in *Nonlinearity*, **17**, 1-24 (2004). This work has been completed before the beginning of the funding; nevertheless, it plays an important role in the theoretical understanding of the phenomenon and has been done ahead of schedule.

6. PI has written a book chapter summarizing the properties of single- and two-fluid flows in two and three dimensions. The book is to be published by *Elsevier*. Complete citation is:
V. Putkaradze, *The role of inertial effects and conical flows in break-up of liquid threads*, in *Hydrodynamics of Droplet Collision and Fusion*, Series *Interfacial Science and Technology*, edited by Arthur Hubbard, *Elsevier* (2004) (in press). This work, summarizing the theory behind the Jeffery-Hamel flows and their extensions, is a part of modeling effort and has been completed ahead of schedule.

In summary, the first year of the funded research has resulted in the completion of the work scheduled to be done during this year, with our results giving us confidence that the entire work will be completed in time and within the budget. The results so far have been presented in one published paper, one book chapter, one M.S. thesis and two conference presentations. The papers discussed in this report are available upon request.