Harvey Mudd College
Mathematics

Senior Thesis
Fall, 2002

Research Proposal:
Instability development in thin films sheared by wind

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1 Project Description

Laminar flow wings are sometimes used on light aircraft because of their increased efficiency, as compared to traditional wings where the boundary layer becomes turbulent relatively early along the wing. Their use is limited by the problem that small surface disturbances, particularly raindrops and the associated film that forms as they coalesce, induce turbulence in the boundary layer. This drastically reduces the lifting capability of the wing, sometimes by as much as 50 percent, making it extremely dangerous for aircraft with such wings to fly in conditions with any possibility of precipitation developing, and thus limiting their more widespread use. I plan on examining one or more of the flow issues involved, which are discussed specifically below.

2 Previous Work

I have been interested in fluid dynamics for much of my life, though it is only recently that I have acquired (some) of the mathematics necessary to understand it. Aside from the various less technical aerodynamics and aeronautical books I exposed myself to in younger years, I have taken the introductory fluid mechanics class from the engineering dept, in which we used White's 'Fluid Mechanics.' This semester I have been engaged in a three unit independent study with Professor Hosoi, in which we are stepping through most of Faber's book 'Fluid Dynamics for Physicists,' which has thus far imparted much more genuine understanding of fluids than the more application-oriented White. Essentially, my junior year has been spent developing a base understanding of the world of fluids and how the various regimes fit together. This is fortunate, because the problem I would like to work on involves many regimes: potential flow, boundary layer flow, wing theory, turbulence, thin films, wave propagation, and possibly droplet formation and surface tension effects.

3 Intended Reading and Body of Knowledge

There is a significant body of literature pertaining to the flow of gas over a thin film. A recently published paper, "Linear stability of a gas boundary layer flowing past a thin liquid film over a flat plate," (Pelekasis et al, J. Fluid Mech. 2001) gives a good introduction to work in the field, as well as new analysis. I plan on familiarizing myself with this paper and

its many relevant references as well as general theory of boundary layers, wave propagation, wings, and surface tension. General references I plan to use for the above topics include Faber, the book 'Laminar Boundary Layer Theory' by Evans, as well as Landau and Lifshitz's classic text, 'Fluid Mechanics.'

4 Plans for Original Research

The ideal outcome of research in this area would be to develop some means by which laminar flow wings could fly through rain and have their flow characteristics remain unaffected. This could be achieved by physical alteration of the surface (grooves, hatchings, riblets, etc.) or possibly by a different type of surface coating that prevented the formation of films. However, this outcome is a lofty goal, and there remains much to be understood before reaching that point. This summer I plan to do research with Professor Hosoi in this area, and my thesis will hopefully be a continuation of this research, some of which may include an experimental component. Possible areas to examine include: Interactions of droplet and film formation with varying surface alterations, methods for channeling accumulating water to minimize flow disturbance, the dependence of droplet, film and boundary layer behavior on the hydrophobicity of the surface, and also generalization of previous flat plate analysis to a wing, which has form-induced pressure variation. Which of these specific problems we settle on will be determined after further investigation into their feasibility and potential fruitfulness.