Dynamic Response of a Drag Plate for Atmospheric Turbulent Measurements

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Mathematical models of physical behavior, as well as experimental studies in the laboratory, are powerful mechanical engineering tools used for design optimization, prior to building costly, full-scale prototypes. The design of modern structures, such as automobiles, airplanes, and buildings, requires an understanding of fluid and solid interactions. Anytime a fluid, such as air or water, flows over a solid surface, a boundary layer is formed near the surface. The boundary layer exerts a shear stress on the surface, which is responsible for a large portion of the drag experienced, for example, by moving vehicles. As the flow speed increases, the boundary layer becomes turbulent. Engineers and scientists quantify how turbulent the flow is with a parameter called the Reynolds number. For example, commercial aircraft operate at a Reynolds number of about 500,000. In contrast, most laboratory wind tunnel studies on scaled-down models can only achieve Reynolds numbers around 5000. In this manner, laboratory studies are often insufficient in reproducing the true operating environment. The extrapolation of laboratory results toward aiding the design of a full-scale prototype aircraft, hence, is questionable, because the Reynolds numbers cannot be matched.

The RAFD (Research in Advanced Fluid Dynamics) group at the University of Utah has come up with a unique way of tackling this problem by probing a naturally high Reynolds number flow, namely the atmospheric boundary layer. Every summer, RAFD conducts experiments over the salt flats in Utah’s western desert in order to better understand how the Reynolds number affects the structure of the turbulent boundary layer.

Results are expected to aid in the design of more aerodynamically efficient aircraft and submarines. As part of this effort, the present study focuses on the development and calibration of a drag plate, which is an instrument capable of directly measuring the surface shear stress associated with the atmospheric flow in the desert. Accurate measurement of the surface shear stress is important in order to compare two flows at two different Reynolds numbers, i.e., the laboratory and the atmosphere. Preliminary results of the dynamic response of the drag plate indicate good agreement with a mathematical model under development. Future design modifications are presented that are expected to improve the dynamic response, and therefore the operational use of the drag plate in the atmosphere.

This work is supported by the Office of Naval Research.