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DIRECT NUMERICAL SIMULATIONS OF TRANSITIONAL/TURBULENT WAKES

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ABSTRACT

The interest in transitional/turbulent wakes spans the spectrum from an intellectual pursuit to understand the complex underlying physics to a critical need in aeronautical engineering and other disciplines to predict component/system performance and reliability. Cylinder wakes have been studied extensively over several decades to gain a better understanding of the basic flow phenomena that are encountered in such flows. Experimental, computational and theoretical means have been employed in this effort. While much has been accomplished there are many important issues that need to be resolved. The physics of the very near wake of the cylinder (less than three diameters downstream) is perhaps the most challenging of them all. This region comprises the two detached shear layers, the recirculation region and wake flow. The interaction amongst these three components is to some extent still a matter of conjecture. Experimental techniques have generated a large percentage of the data that have provided us with the current state of understanding of the subject. More recently computational techniques have been used to simulate cylinder wakes, and the data from such simulations are being used to both refine our understanding of such flows as well as provide new insights.

A few large eddy and direct numerical simulations (LES and DNS) of cylinder wakes have appeared in the literature in the recent past. These investigations focus on the low Reynolds number range where the cylinder boundary layer is laminar (sub-critical range). However, from an engineering point of view, there is considerable interest in the situation where the upper and/or lower boundary layer of an airfoil is turbulent, and these turbulent boundary layers separate from the airfoil to contribute to the formation of the wake downstream. In the case of cylinders, this only occurs at relatively large unit Reynolds numbers. However, in the case of airfoils, the boundary layer has the opportunity to transition to turbulence on the airfoil surface at a relatively lower unit Reynolds number because the characteristic length of the airfoil is typically one to two orders of magnitude larger than the trailing edge diameter. This transition to turbulence would occur unless there is a strong favorable pressure gradient that results in the boundary layer remaining laminar or transitional over the surface of the airfoil.

This presentation will focus on two direct numerical simulations that have been performed at NASA ARC. The first is of a cylinder wake with laminar separating boundary layers. The second is the wake of a flat plate with a circular trailing edge. The upper and lower plate surface boundary layers are both turbulent and statistically identical. Thus the computed wake is symmetric in a statistical sense. This flow is more representative of airfoil wakes than cylinder wakes. Results from the two simulations including flow visualization and turbulence statistics in the near wake will be presented at the seminar.

The results to be presented at the seminar have appeared in the following AIAA papers:

1. Rai, M. M. "A Computational Investigation of the Instability of the Detached Shear Layers in the Wake of Circular Cylinder," 38th Fluid Dynamics Conference, Seattle, Washington, June 2008.

2. Rai, M. M., "Flow Physics and Self-Similarity in the Turbulent Near Wake of a Flat Plate," AIAA Paper No. 2011-3575, 41st Fluid Dynamics Conference, Honolulu, Hawaii, June 2011.

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