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Control of Flow Separation in Airfoil/Wing Design Applications

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Abstract

Existing aerodynamic design methods have generally concentrated on the optimization of airfoil or wing shapes to produce a minimum drag while satisfying some basic constraints such as lift, pitching moment or thickness. Since the minimization of drag almost always precludes the existence of separated flow, the evaluation and validation of these design methods for their robustness and accuracy when separated flow is present has not been aggressively pursued. However, two new applications for these design tools may be expected to include separated flow and the issues of aerodynamic design with this feature must be addressed.

The first application of the aerodynamic design tools is the design of airfoils or wings to provide an optimal performance over a wide range of flight conditions (multi-point design). While the definition of "optimal performance" in the multi-point setting is currently being hashed out, it is recognized that given a wide enough range of flight conditions, it will not be possible to ensure a minimum drag constraint at all conditions, and in fact some amount of separated flow (presumably small) may have to be allowed at the more demanding flight conditions. Thus a multi-point design method must be tolerant of the existance of separated flow and may include some controls upon its extent.

The second application is in the design of wings with extended high speed buffet boundaries of their flight envelopes. Buffet occurs on a wing when regions of flow separation have grown to the extent that their time varying pressures induce possible destructive effects upon the wing structure or adversely effect either the aircraft controlability or the passenger comfort. A conservative approach to the expansion of the buffet flight boundary is to simply expand the flight envelope of non-separated flow under the assumption that buffet will also thus be alleviated. However, having the ability to design a wing with separated flow and thus to control the location, extent and severity of the separated flow regions may allow aircraft manufacturers to gain an advantage in the early design stages of an aircraft, when configuration changes are relatively inexpensive to make.

Continuing the work begun last year, an airfoil design package has been modified to provide some control over the existence and extent of flow separation. This package consists of a 2-D Navies-Stolkes flow solver which is coupled to the CDISC (constrained direct/iterative surface curvature) design method. The first modification is a prediction method for determining whether separation is likely based solely upon a given pressure distribution. If separation is predicted but is undesirable, the new routines will modify the pressure distribution to alleviate the problem. This new pressure distribution is then used in the design method to generate a new aerodynamic shape. Since separation may be acceptable in some cases, particular if the separation does not extend to the trailing edge, another added logic estimates the extent of separation based upon a correlation with calculated separated flow cases. If a the flow behind a shock induced separation is not predicted to reattach before the trailing edge, the logic weakens the shock strength and otherwise alters the pressure distribution in order to promote reattachment. This later addition is as yet unreliable due to secondary separation effects, but additional work is being pursued to improve the method.