Abstract
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Evaluation of Airfoil Dynamic Stall Characteristics for Maneuverability

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In severe maneuvers, out of necessity for a military aircraft or inadvertently for a civil aircraft, a helicopter airfoil will stall in a dynamic manner and provide lift beyond what would be calculated based on static airfoil tests. The augmented lift that occurs in dynamic stall is related to a vortex that is shed near the leading edge of the airfoil. However, directly related to the augmented lift that results from the dynamic stall vortex are significant penalties in pitching moment and drag. An understanding of the relationship between the augmented lift in dynamic stall and the associated moment and drag penalties is the purpose of this paper. This relationship is characterized using data obtained in two-dimensional wind tunnel tests and related to the problem of helicopter maneuverability.

A systematic test of the dynamic stall characteristics of eight airfoils was undertaken at Ames Research Center in the late 1970s (Refs. 1-3). The tests included the NACA 0012, a first-generation airfoil, and six second second-generation airfoils. The second-generation airfoils included the FX 69–H–098, used on Bell Helicopter's AH–1T and AH–1W aircraft; the SC1095, used on Sikorsky's UH–60A; the HH–02 airfoil, used on the Boeing AH–64; the VR–7, used on the Boeing CH–47D; and two new airfoils, the AMES–01 and NLR–1, that have not been used for production aircraft. An eighth airfoil, the NLR–7301, a fixed-wing section, was added to contrast rotary-wing and fixed-wing airfoils. Data obtained from these tests has been characterized by examining the extrema that occur within each dynamic stall loop. That is, within each loop, the maximum lift coefficient, the maximum drag coefficient, and the minimum moment coefficient are used to represent a test condition. These extrema do not occur simultaneously, but are closely related to each other by the effects of the shed dynamic stall vortex. The maximum lift coefficient as a function of minimum moment coefficient for the Ames test data is shown in Fig. 1 and the maximum lift coefficient as a function of the maximum drag coefficient is shown in Fig. 2. Also in these figures are the static data that were obtained during the same test program. What should be noted in these figures is that there is, in general, a direct relation that characterizes the maximum lift and drag, and minimum moment for all of the airfoils. Each airfoil provides augmented lift compared to the static characteristics, but also shows large moment and drag penalties.

In the proposed paper, the relationship in Figs. 1 and 2, that is, the dynamic stall function, is examined to better understand what factors do or do not influence the relationship. It will be shown that in general the dynamic stall function is independent of the mean and oscillating angles of attack, reduced frequency, and Reynolds number. Aircraft profiles do have some influence, but basically an airfoil with a good static maximum lift coefficient will also have a good dynamic maximum lift coefficient (the ordinate intercept in Figs. 1 and 2). The dynamic stall function shows a weak dependency on Mach number and, for some airfoils, is sensitive to boundary layer conditions.

The dynamic stall function will also be used as a means of evaluating calculation of dynamic stall characteristics, both for semi-empirical models as well as direct calculation using Navier-Stokes flow solvers. The method will also be used as a means of evaluating some novel approaches for multi-element or deformable airfoils and it will be shown that it is possible, but difficult, to obtain increased lift without the associated moment and drag penalties.

References

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2. K. W. McAlister, S. L. Pucci, W. J. McCroskey, and L. W. Carr, "An Experimental Study of Dynamic Stall on Advanced Airfoil Sections Volume 2. Pressure and Force Data," NASA TM 84245, September 1982.

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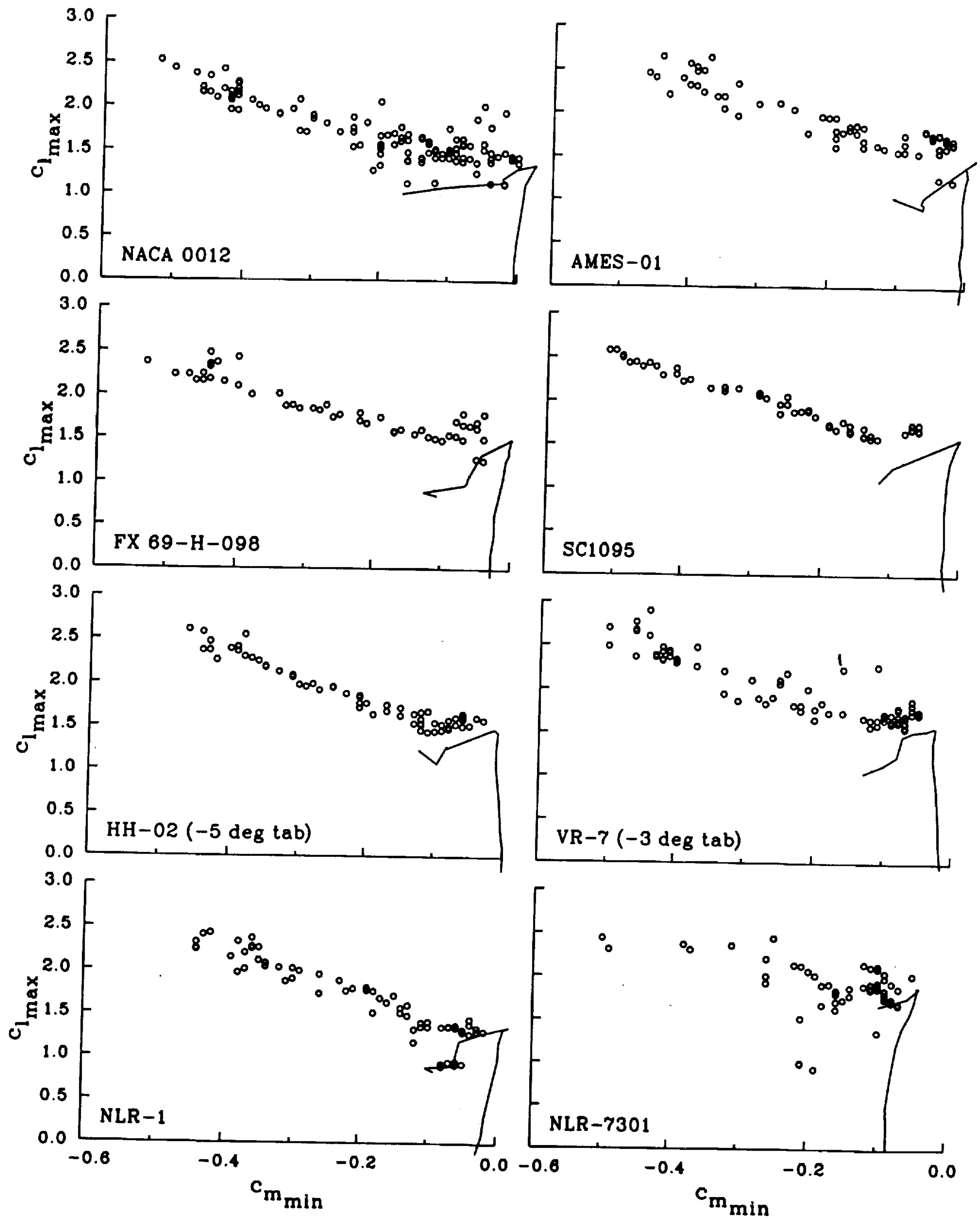

Figure 1. Maximum lift coefficient as a function of minimum moment coefficient for dynamic stall loops in Ames tests. Solid line shows static characteristics.

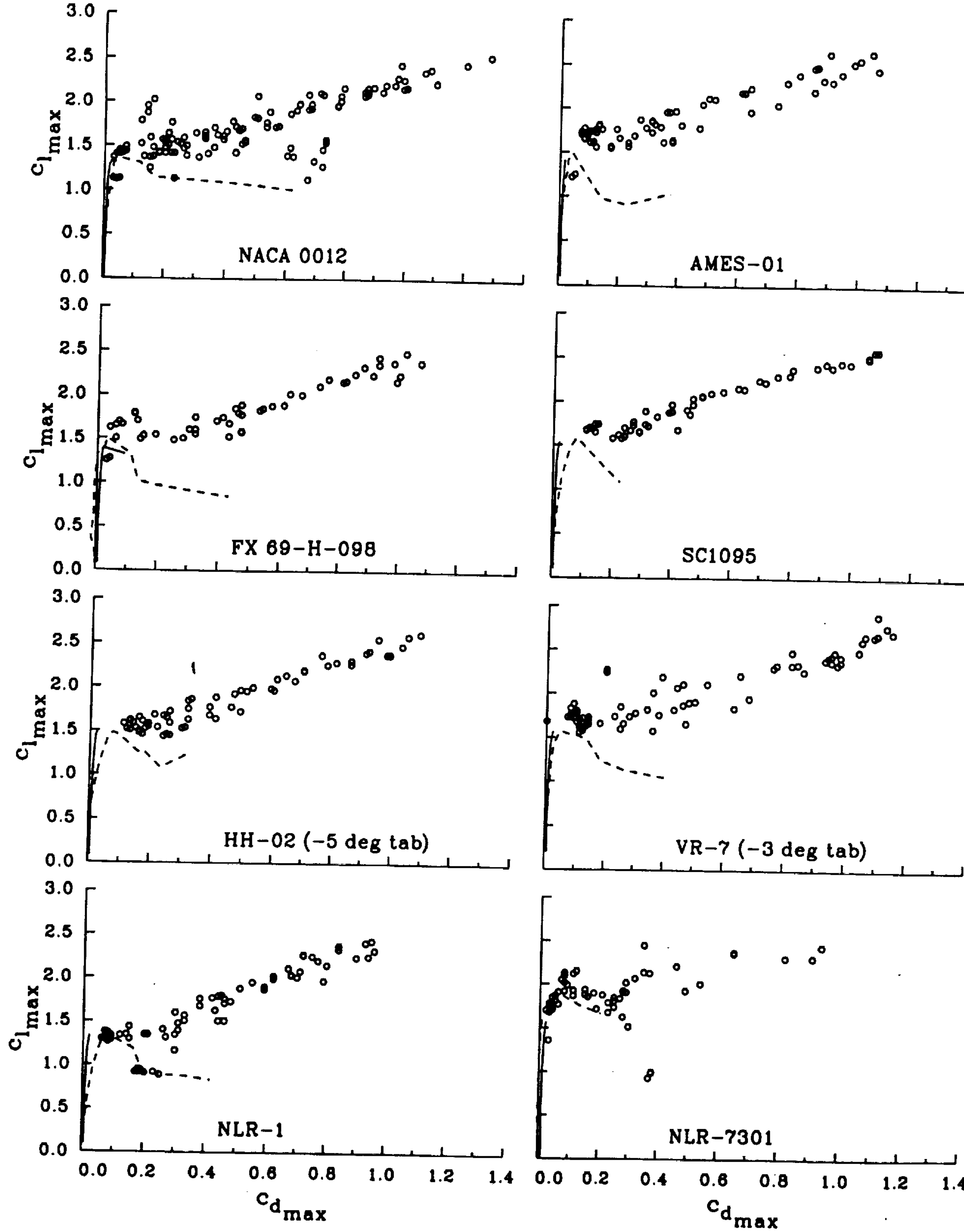

Figure 2. Maximum lift coefficient as a function of maximum drag coefficient for dynamic stall loops from Ames tests. Solid line shows the static wake drag and dashed line shows the pressure drag.