Engineering Notes

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Preliminary Wind Tunnel Tests of a Finite Aspect Ratio HighPerformance General Aviation Wing

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GENERAL aviation aircraft form a varied and important part of this country's transportation needs. In this period of shortages of engines fuels, congested roadways, and continually increasing levels of air pollution, the light airplane offers an economical and fast alternative to intercity transportation needs. In recent years the NASA and government in general have realized the important potential of light aircraft and have encouraged general aviation development through funding of research aimed at applying advanced technology to their airplanes. Concepts being considered include improved trailing-edge devices, spoilers, and leading-edge flaps as methods of improving light airplane maneuverability and handling. A Cessna Cardinal,[1] modified to study such devices, has been flying successfully since 1972.

Recently more ambitious projects have been aimed at evaluation of entirely new airfoil sections that would mean greatly increased operating economy for light airplanes. These new airfoils equipped with simple Fowler type flaps promise as much as a 50% improvement in maximum lift coefficient over current general aviation airfoils with similar flap arrangements. This would mean that wing area could be reduced to significantly increase cruise speeds while leaving approach and landing speeds essentially the same. The higher cruise speed accomplished with the same power setting would mean greatly increased operating economy for light airplanes.

The preliminary results reported here were derived from wind tunnel tests[2] directed at evaluating such an airfoil, the GA(W)-1, developed for low-speed flight, in direct comparison with a current general aviation airfoil of the NACA 2412 section. The GA(W)-1 airfoil was designed by R. T. Whitcomb and associates at the NASA-Langley Research Center,[3] based upon technology acquired during the development of supercritical airfoils. This airfoil has a 17% maximum thickness-to-chord ratio with a cruising lift coefficient of 0.40 at low Mach numbers. The rectangular planform GA(W)-1 and NACA 2412 airfoil shapes are shown in Fig. 1 with the 30% chord full span flap in the 30° deflected position. The dashed lines designate the flap retracted position. Optimum flap location to produce maximum lift for the 30° flap setting for the GA(W)-1 airfoil was determined through wind tunnel tests. The flap gap and overlap are shown in Fig. 1. The results of wind tunnel tests performed by Wenzinger and Harris[4] were used to established the optimum flap location of the NACA 2412 airfoil. It should be further noted that the optimized flap location for each airfoil was finally chosen based on a limited number of positions available in the flap attachment mechanism. Wing models were attached to an internal string-type balance system.

The wings tested were of rectangular planform with no tip treatment and the same geometric aspect ratio of 5.1. All tests were conducted in the University of Missouri-Rolla Low Speed Wind Tunnel at a Reynolds Number of approximately 4.5×10^5 based on the 6-in. (constant) wing chord.

Results and Conclusions

Force data test results of the NACA 2412 and GA(W)-1 airfoils are shown in Fig. 2, 3, and 4. Lift performance for both airfoils is shown in Fig. 2 as lift coefficient variations with angle of attack. The two-dimensional data for the GA(W)-1 wing with zero flap deflection as reported by Wentz and Seetharam[5] is included in Fig. 2 for purposes of comparison. Both maximum lift coefficient and lift curve slope can be seen to be reduced for the three-dimensional case as compared to the two-dimensional case. Maximum lift coefficient for the 30° flap position is increased by 28% for the GA(W)-1 wing when compared to the NACA 2412 wing.

Drag performance comparison is shown in Fig. 3 as drag coefficient as a function of lift coefficient. The relatively high values of drag coefficient in the low lift coefficient (low angle

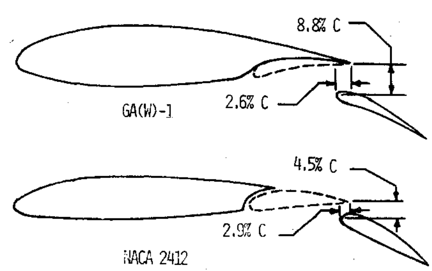

Fig. 1 Airfoil comparison, 30° flap deflection.

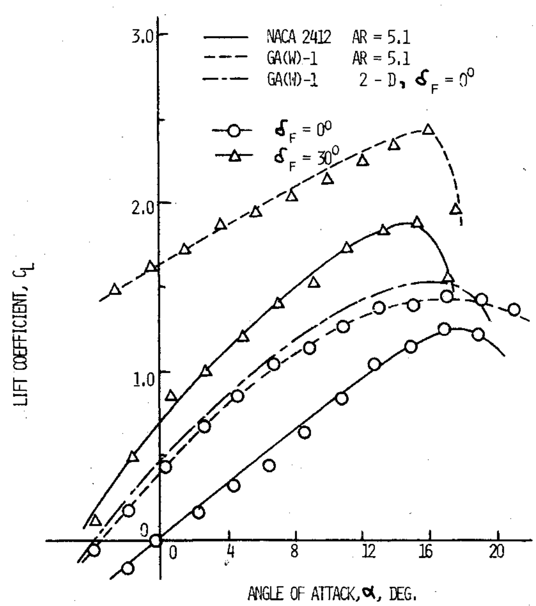

Fig. 2 Lift coefficient performance comparison, flap deflection at 0 and 30°.

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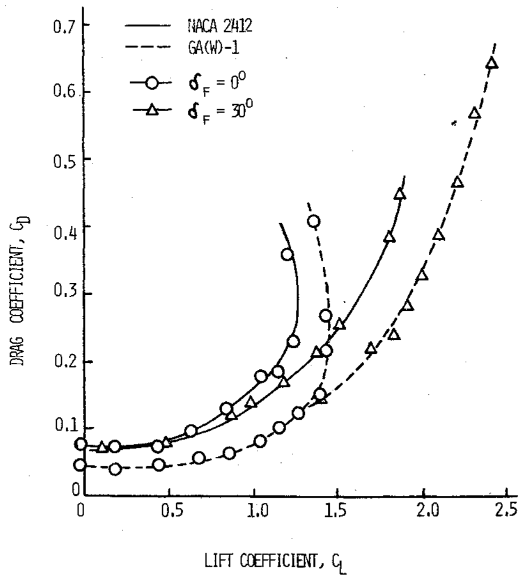

Fig. 3 Drag coefficient performance comparison, flap deflection of 0 and 30°.

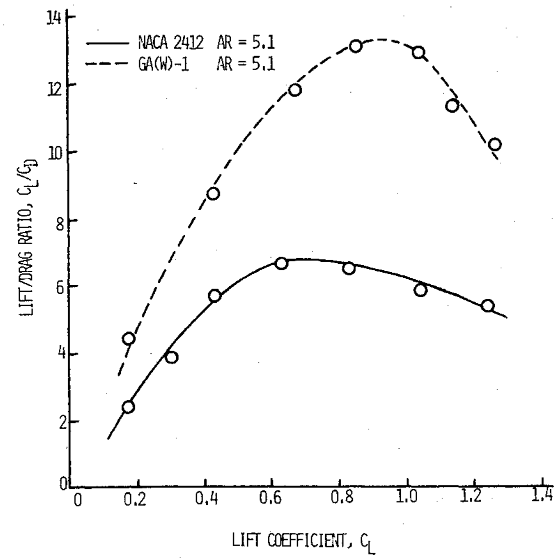

Fig. 4 Lift-to-drag ratio performance comparison, 0° flap deflection.

of attack) range for the NACA 2412 wing with no flap deflec-proved cruise performance for the light airplane. Climb per-tion can be attributed to the surface irregularity on the bottom of the wing at the flap/wing juncture. This surface irregularity can be seen in the dashed line flap retracted position for the NACA 2412 wing in Fig. 1.

Lift to drag ratio performance for cruise condition(zero flap deflection) of both airfoils is shown in Fig. 4. Maximum lift-to-drag ratio for the GA(W)-1 wing was 13.2 while the maximum value for the NACA 2412 was 6.7. At the design cruise lift coefficient of 0.40 for the GA(W)-1, the lift-to-drag ratio is 8.6. For a cruise lift coefficient of 0.25 for the NASA 2412 the lift-to-drag ratio is 3.5.

Results of the wind tunnel test program show that the GA(W)-1 airfoil offers improved lift performance when compared to a current general aviation airfoil of the NACA 2412 section. At 30° flap deflection the GA(W)-1 wing produced a 28% increase in maximum lift coefficient over that of the NACA 2412 wing. This increase in maximum lift coefficient, based on a 22% reduction in wing area and no change in powerplant size, could mean as much as a 20 mph increase in cruise speed while leaving takeoff and landing distances and the associated airspeeds essentially the same. Cruise speed increase with no change in powerplant size would result in improved cruise performance for the light airplane. Climb performance is improved as indicated by a doubling of lift-to-drag ratio of the GA(W)-1 wing over the NACA 2412 wing when compared at a typical climb lift coefficient of 1.0. Thus, installation of the GA(W)-1 airfoil on a light airplane would result in an improvement in both cruise and climb performance.

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