Aerodynamic Interference of Dissimilar Aircraft Flying in Close Proximity

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Introduction

ON Jan. 14, 1992, an F-14A aircraft experienced an unsafe landing gear indication prior to recovery at a Naval air station. The air crew requested a chase aircraft to conduct a visual inspection of their landing gear in accordance with standard operating procedures. A T-34C aircraft with instructor and student pilot joined on the F-14 to inspect the landing gear. Shortly after the F-14 crew was notified that their gear looked good, the T-34 collided with the substantially larger aircraft. The T-34 and air crew were lost and the F-14 received minor damage and returned to the airfield.

A study of Navy and Air Force midair collisions involving formation flying over the past 10 years has shown that pilot error is the predominant common denominator. Task saturation, preoccupation with cockpit duties, and failure to judge closure rates and to take sufficient, timely, and appropriate action to avoid a collision are major factors in mishap findings.[1,2] Mutual aerodynamic interference of aircraft in close proximity is rarely discussed in mishap findings or in flight training, yet may be a significant causal factor. Interference of airflow over lifting surfaces, because of the pressure field of another aircraft and to the changes in local flow direction, can alter the aerodynamic characteristics of the trailing aircraft. Unexpected changes in lift and pitching moments may occur that affect closure rate and task saturation of the unaware or uninformed pilot.

A numerical study of the aerodynamic interference between dissimilar aircraft in close proximity was conducted. The example aircraft involved a T-34 flying beneath an F-14 in an approach configuration. A short training video[3] and report[4] were produced for the Naval Air Systems Command to indicate the causal mechanisms of the aerodynamic interference and the trim changes to be expected by the pilot in such a situation with the aim of improving aviation safety education. This Note briefly describes the results of the study. For more complete information see Ref. 5.

Analysis

A view of the model of the T-34 and F-14 flying in close proximity is shown in Fig. 1. The aircraft were closing vertically, with the F-14 as the lead aircraft. The F-14 at 57,000 lb was trimmed with flaps down at 135 KTAS. The T-34 at 3750 lb and identical airspeed was approaching from beneath. The two aircraft were aligned in the vertical plane such that their c.g. were located one above the other. Distances between the two aircraft varied between 170.8 and 12.5 ft, or about 5.0 and 0.4 wingspans of the T-34.

A widely used potential-flow panel code, PMARC,[6] was used for the study. A Cray Y-MP computer was used for running the code, and a Silicon Graphics Inc. Iris workstation was used for the presentation of graphics. CPU time for one run of the flow over the two aircraft was about 25 min.

The T-34 was trimmed in steady level flight and then considered at the original trim pitch attitude at various positions beneath the F-14. Resultant pitching moments, changes in aircraft lift, and elevator deflections required to retrim (bring the pitching moment to zero) were determined. For the sake of simplicity in running the test cases, the aircraft pitch attitude was not adjusted for each new case, though in actuality the aircraft would require a change in attitude to maintain level flight at each vertical position. The results are to give the pilot an indication of expected changes in aircraft lift and elevator trim when approaching a larger aircraft from beneath, not to provide exact values characterizing the actual maneuver.

The T-34 pitching moment was greatly affected as the vertical separation between the two airplanes was decreased, as indicated in the graph in Fig. 2. As the T-34 approached from five wingspans away at a constant pitch attitude, the nose-up pitching moment increased by a factor of 7 until one wingspan distant. Downwash effects on the T-34 tail because of the presence of the F-14 provide the main causal mechanism; streamline changes and tail surface pressures are presented in Ref. 5.

Changes in pitching moment coefficients for each vertical distance were used to determine the changes in elevator deflection required to maintain trim (zero pitching moment) at the original pitch angle. A positive change represents an increased trailing-edge-down (TED) condition. A change of approximately 3.5 deg in elevator deflection TED was required for trim as the T-34 approached to within 25 ft of the F-14. The T-34 formation pilot should expect such nose-down trim

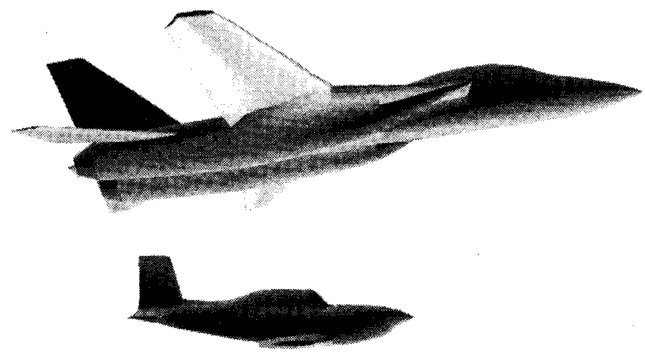

Fig. 1 Computer model of the T-34 and F-14 aircraft.

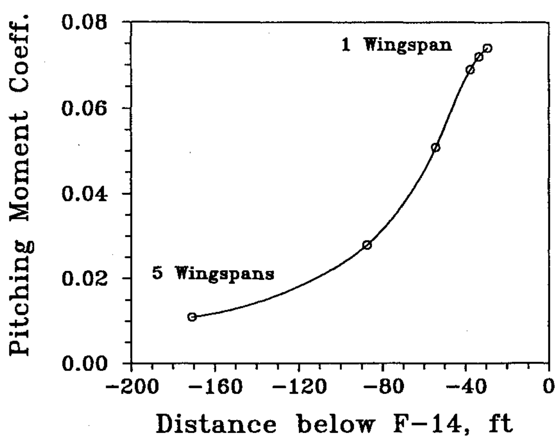

Fig. 2 Change in pitching moment of T-34 because of vertical closure on F-14.

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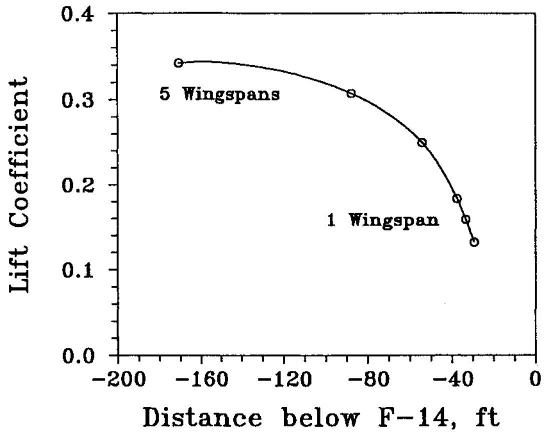

Fig. 3 Change in lift of T-34 because of vertical closure on F-14.

changes to be necessary for approaches to within a wingspan of the F-14.

A second effect of the aerodynamic interference of the F-14 on the T-34, besides the change in the local flowfield direction in the tail region, is the increased pressure in the vicinity of the underside of the F-14. The increased pressure flowfield results in higher pressures on the upper or suction side of the wing of the T-34, and accordingly a loss in lift, as shown in Fig. 3. The T-34 loses approximately 55% of its lift when it is one wingspan away from the larger aircraft and 90% of its lift when a semispan away. To the pilot, this loss of lift can correspond to a sensation of being pushed away by the F-14. Conflicting cues of loss of lift and a nose-up rotation may be disorienting to the pilot unfamiliar with closing on a dissimilar aircraft. As noted earlier, the pitch angle of the T-34 was held constant for all test cases. The pilot would actually expect nose-up trim to be necessary to regain the lift as the larger aircraft was approached. The nose-up rotation is ironically supported by the pitch-up tendency; an enhanced awareness of the two responses and their interaction is necessary on the part of the pilot when closing on a dissimilar aircraft.

Concluding Remarks

This Note has indicated the flowfield effects of mutual interference for only one scenario; it is not intended to be a primer on formation flying. The closure position considered of the T-34 beneath the F-14 may be one of the most unsafe positions possible for approaching another aircraft. The natural tendency as the pilot looks up to the belly of the F-14 will be to pull back on the stick, increasing the closure rate. Because of the proximity of the leading aircraft, visual cues used to judge closure are lacking, and even an alert pilot will have difficulty recognizing vertical closure rates. Formation flying requires skills learned in specific training, which includes an understanding of the responsibilities of both leader and wingman.

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Computational Analysis of a Wingtip-Mounted Pusher Turboprop

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Nomenclature

C_L	=	configuration lift coefficient, lift/$(q_\infty S_{ref})$
q	=	dynamic pressure, $(\rho V^2)/2$, lb/ft^2
S_{ref}	=	reference area (baseline wing exposed planform area), ft^2
V	=	flow velocity, ft/s
α	=	angle of attack, deg
$\beta_{3/4}$	=	three-quarter tip radius blade setting angle, deg
ξ, η, ζ	=	computational coordinates; axial, radial, and circumferential, respectively
ρ	=	flow density, slug/ft^3

Subscript

∞	=	freestream conditions

Introduction

THE aerospace community has had a long history investigating methods for the reduction of induced drag (drag due to lift of a finite wing).[1] Although induced drag is about 50% of the total drag for subsonic transport aircraft at cruise conditions, most of the recent innovative research in transport aircraft drag reduction has concentrated on skin-friction drag (i.e., laminar flow and turbulent-drag reduction schemes such as riblets). Increasing aspect ratio and tailoring the span-load distribution have been the designers' primary tools for minimizing induced drag. Though means have been found to minimize induced drag, it has long been accepted as a necessary by-product of generating lift on a finite span wing. However, induced drag is not essential for the production of lift, but only an adverse consequence of that process.

Results from wind-tunnel tests have indicated large reductions in induced drag for wings with tip-mounted engines.[2,3] The results of an exploratory investigation to determine the

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