Engineering Notes

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Low-Speed Test Limit of V/STOL Model Located Vertically Off-Center

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Nomenclature

h/r = ratio of distance between floor and model to rotor radius
L = lift, lb
r = rotor radius, ft
v_∞ = freestream velocity, fps
θ_n = momentum downwash angle, deg
μ = tip speed ratio, $v/\Omega r$
Ω = rotor, rps

I. Introduction

THE successful development of a V/STOL vehicle largely depends on the understanding of its aerodynamics in the transition speed range. Due to the unique lifting method of the vehicle, V/STOL aerodynamics are characterized by highly deflected high-energy wakes. Testing of such vehicles in a wind tunnel presents difficult wake interference problems which require the application of new testing techniques. Some of the techniques to alleviate these problems are moving belts, newly developed wall correction theories, large V/STOL wind tunnels, and the low-speed test limit. All of these new methods and concepts have helped to better understand V/STOL aerodynamics in the transition speed regime.

The concept of the low-speed test limit for a powered V/STOL model tested in a wind tunnel has been reported,[1] and it has been studied and verified by other investigators elsewhere in other papers.[2-5] These previous studies were conducted with the model located on or near the vertical and lateral centerlines of the test section. The present paper reports the effect of a vertically off-centered model on the low-speed test limit.

II. Test Equipment and Procedures

For the present study, the University of Washington Aeronautical Laboratory 8- × 12-ft wind tunnel with and without ground plane, and an associated 3- × 4.5-ft test section insert were used. The model used for this study was a 2-ft-diam three bladed aluminum propeller operating in a rotor mode. Rotor rpm was held constant throughout the test, and the tunnel dynamic pressure was varied from 11.3 psf to 0.7 psf to yield corresponding tip speed ratios of 0.20 to 0.05. The basic aerodynamic lift variation with the tip speed ratio of this model was obtained in the 8- × 12-ft test section without the ground plane. The small ratio of tunnel area to model momentum area of this configuration permitted these data to represent approximate free air conditions.

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The ground plane extended from wall to wall and was 16 ft in length, and was placed in the 8- × 12-ft test section below the model at various heights to provide a h/r (the ratio of the distance between the floor and the model to the rotor radius) from 0.5 to 2.0.

The 3- × 4.5-ft test section insert was placed in the 8- × 12-ft test section to simulate a smaller wind tunnel. The technique of using the insert was described in Ref. 6. The vertical relocation of the insert with the model position fixed on the balance provided a h/r ratio range from 0.65 to 2.5.

The model aerodynamic data at a constant angle of attack (−3 deg) were recorded at selected tunnel dynamic pressures to provide adequate data points to define the model lift variation with respect to the tip speed ratio. This procedure was repeated at different floor heights relative to the model. The adverse effect of the rotor low-speed test limit can be observed in the form of lift change with respect to the tip speed ratio.

III. Results

A representative rotor lift variation with respect to tip speed ratio is presented in Fig. 1 which shows the lift variation in the large test section and near the ground. From this type of lift variation data, the point can be identified where the lift curve from runs with the ground plane begins to deviate from the trend shown by the 8- × 12-ft test section data. This trend shown by the data of runs with ground plane is not due to the classical ground effect because if it is, the lift is expected to increase. The point at which the lift begins to decrease is when the rotor senses the presence of a parabolic-shaped vortex on the floor and considered to be the minimum speed test limit.[1] In the case shown, the limit point was estimated at $\mu = 0.10$. Using the rotor lift with the ground plane, tip speed ratio, and the method to calculate the momentum downwash angle described in Ref. 7, the allowable maximum momentum downwash angle was calculated for this h/r configuration. The procedure was repeated for the other values of h/r, and Fig. 2 was constructed.

Figure 2 summarizes the 8×12 ground plane and 3×4.5 insert data, and illustrates the low-speed test limit caused by the influence of floor and ceiling of the test section. For h/r less than 1.25, the low-speed test limit is dominantly governed

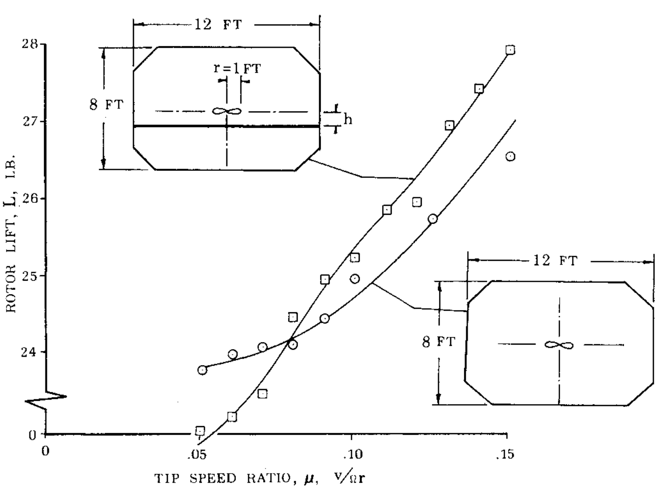

Fig. 1 Rotor lift variation with tip speed ratio.

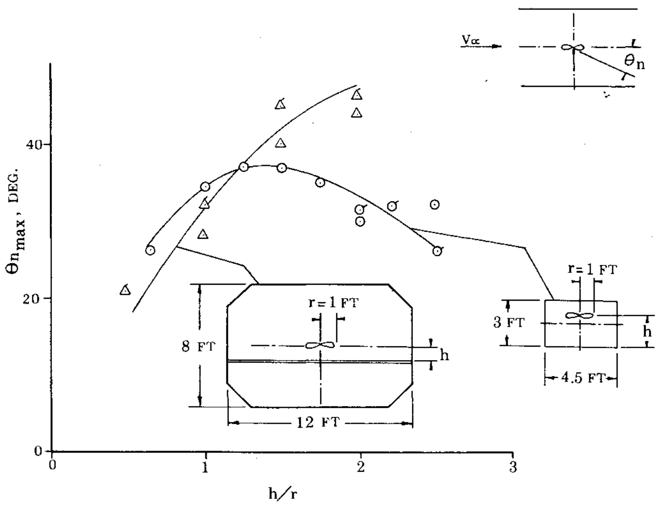

Fig. 2 Allowable wake deflection angle for vertically off-centered rotor.

by the h/r ratio. This is evidenced by the agreement of the two curves in the figure for $h/r<1.25$ to $h/r>1.25$; the small test section (3×4.5 ft) shows a decrease in the allowable $\theta_{n_{max}}$ which is believed to be caused by the impaired inflow to the rotor due to the close presence of the ceiling. On the other hand, $\theta_{n_{max}}$ for $h/r>1.25$ in the large test section (8×12 ft) with ground plane does not exhibit such a decrease, which is understandable because its ceiling height is large (four times the rotor radius), thus causing no significant effect on the lift of the rotor.

IV. Conclusions

There are two conclusions that can be drawn from the present data:

1) For rotors tested with a ground plane or in the vicinity of the floor, the h/r ratio defines the low-speed test limits.

2) For rotors tested vertically off-centered in a test section, the ultimate location is the centerline to obtain the lowest allowable minimum speed test limit. Rotors located either below or above the vertical centerline will suffer a loss of the allowable low-speed test limit at the approximate rate of the net momentum angle of 20 deg per h/r ratio.

Acknowledgment

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Handling Qualities of Aircraft in the Presence of Simulated Turbulence

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Introduction

IN an earlier paper,[1] the authors have shown that Instrument Flight Rule (IFR) handling-quality studies, in the presence of simulated turbulence, are critically affected by the suitable choice of a realistic turbulence model. The purpose of this Note is to present additional results obtained from flight simulator experiments on Visual Flight Rule (VFR) approach landings of a STOL type aircraft.

Reference 1 describes the four basic turbulence models tested on the NASA Langley Research Center Visual Motion Simulator (VMS): model 1 – Gaussian, models 2 and 3 – Modified Gaussian, model 4 – Rayleigh, and models 5 and 6 – Variable Length and Intensity (VLI). The details of the turbulence field generated by each of these models is presented in Ref. 2, where they are compared with measured real atmospheric turbulence.

Each of the turbulence models was simulated on the VMS with a pilot in the control loop. The flight simulator experiment was conducted for two sets of landing conditions. The first required the pilot to follow an IFR tracking task with no visual cues provided. The results of this study were discussed in Ref. 1. For the second condition, the simulator was equipped with a visual display that provides a realistic landing approach scene. Pilot opinion ratings (of the landing approach with visual display) were analyzed to establish the most realistic turbulence model and to identify the variables that critically affect the handling quality of aircraft in turbulence.

Aircraft Simulator

The Visual Motion Simulator (VMS) at the NASA-Langley Research Center, a synergistic motion base simulator with the basic interior and instrumentation of a jet transport cockpit, was employed to simulate the Canadian deHavilland DHC-6 Twin Otter. The simulator is equipped to provide two sets of conditions. In the first set of conditions the pilot flies straight and level and is not given any visual or "out the window" cue. In the second set, the pilot flies a landing approach and is given a visual display that generates a realistic landing scene. The aircraft motion signals, through a feedback loop, run a video camera on a scale model of the airfield and its

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