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INVESTIGATION OF ROTOR BLADE TIP-VORTEX AERODYNAMICS

Final Report

Covering Period

1 June 1968 to 30 September 1971

Reported by W. S. Lewellen

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on

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Investigation of Rotor Blade Tip-Vortex Aerodynamics

This grant covering the period from June 1, 1968 to September 30, 1971 has dealt with several aspects of the aerodynamics of rotor-blade tip vortices. The work can be divided into two categories; that dealing with the dynamic loads on a blade passing close to or intersecting a trailing vortex, and that associated with the response of the trailing vortex core to changes in the flow.

In the first category, experimental pressure-differential measurements were made on a stationary airfoil as a trailing vortex was made to interact perpendicularly with it. Results for various vortex sizes and free-stream velocities are given by Walsh.[1] Maximum dynamic pressure coefficients obtained were as high as 1 when the vortex core impinged directly on the airfoil. Measurements were also taken on a rotating blade as it interacted with a trailing vortex. Results of this study are given by Baczek.[2] The vortex was unexpectedly pushed out of the rotor plane, either above or below it, resulting in lower pressure gradients than anticipitated. Results suggested the formation of a separation bubble over a portion of the blade under certain conditions.

Procedures for the use of lifting surface theory to calculate the airloading induced on a helicopter rotor blade by a nearby tip vortex were developed by Johnson.[3,4,5] Theoretical calculations using his method showed good correlation between experiment and theory when the vortex was not too close to the rotor hub[6] and have been used for the calculation of helicopter airloads.[7]

In the second category, relating to the response of the vortex, Strickland[8] theoretically demonstrated that as long as the flow is subsonic, the vortex core amplifies any changes in the bounding streamlines. The most striking example of this amplified response is vortex breakdown. A simplified model of breakdown was presented in a thesis by Hawkes.[9] A review of the phenomenon was given by Lewellen.[10] There are still several questions unanswered surrounding the phenomenon, particularly those associated with the change in flow parameters across the breakdown. Mr. Kantha whose work on these questions has been supported by this grant will continue his investigation with support from another project.

Responses of a trailing vortex to changes in its convective velocity produced by either injection of air into the vortex core or by the flow field of a lifting surface in the path of the core were investigated. Flow pictures and vorticity measurements are given by Kantha, Lewellen and Durgin.[11] When axial momentum greater than approximately 30% of the airfoil drag is injected directly into the tip vortex, the core vorticity is relatively rapidly dispersed. A note[12] based on these results is being submitted to the AIAA J. of Aircraft. Flow patterns of the region of interaction between the flow field of a lifting surface and the vortex core show that the vortex either bends following the streamline shape until it intercepts the wake where it is dispersed or the core may be sliced into two smaller vortices when the vortex hits the leading edge of the airfoil.

An investigation of the effect of tip shape on the vortices shed from helicopter rotors was made by Hamilton-Smith.[13] Although inconclusive, there did appear to be a correlation between trailing edge sweep angle at the tip and vortex core size.

References

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