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PROPELLER STUDY PART I

INTRODUCTION AND OVERVIEW

by

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PROPELLER STUDY PART I
INTRODUCTION AND OVERVIEW

This study, begun in November, 1972, had as its objective the determination of criteria for the acoustical design of general aviation propellers. The study included a theoretical and an experimental part. The theoretical part is discussed in detail in Part II of this report, and the experimental program is discussed in Part III.

Theoretical Study

The theoretical study was confined to consideration of a free-running propeller at zero angle of attack specified over speed. The aerodynamic model consisted of a lifting surface vortex sheet for the blade, attached to a helical vortex sheet extending downstream to infinity. Superposed on the blade vortex sheet was a source-sink distribution to model thickness effects. The general aerodynamic-acoustic theory for this system was then developed, including first-order thickness and camber effects.

In order to make the optimum design problem numerically tractable, a simplified form of the general problem was formulated which replaced the lifting surface with a line vortex, ignoring thickness and camber effects. The acoustical model was simplified to contain only a radial line dipole representing blade-loading effects only. A non-linear program formulation for this simplified problem was developed and numerical solutions were obtained. The details of the method and the results are contained in Part II of this report.

Experimental Program

The initial expectation in the program was to utilize the results of the theoretical investigation to design and manufacture a propeller which would then be mounted on a YO-3A aircraft, and the noise and performance characteristics measured. Difficulties with the theoretical study precluded this event however, and the focus of the experimental portion of the program was the measurement of thrust and torque of the propeller in flight.

The accessibility of approximately 20 cm. of propeller shaft forward of the main propeller shaft bearing on the aircraft indicated that direct instrumentation to measure strains in this portion of the shaft was the appropriate approach to measurement of thrust and torque. Two methods of measurement were considered. Mechanical amplification of the thrust-induced strains in the shaft was pursued to the point of laboratory bench testing. The presence of severe torque-induced signals in the mechanically amplified thrust signals could not be resolved, and this approach was discarded. The direct measurement of shaft strains using foil gauges for the torque-induced strain measurement and using semiconductor gauges for the measurement of thrust-induced strain was adopted. The presence of torque-induced signals in the thrust-induced measurement could not be avoided. However, laboratory bench tests and in situ static tests on the aircraft demonstrated that these effects were repeatable and calibratable.

A series of flight tests were conducted during the Spring of 1977 utilizing this method. The results were not definitive due primarily to the presence of unanticipated temperature gradients in the shaft. The experimental set-up was designed on the expectation that the temperature of the engine oil in the shaft used to energize the constant-speed propeller would determine the steady state temperature of the shaft itself. It was discovered during the course of the flight tests that ambient air in the shaft compartment had at least as large an effect on shaft temperature, and the longitudinal temperature gradients generated by this effect prevented the acquisition of reliable data. The primary problem due to the temperature gradients is the extreme temperature sensivity of the foil gauges used for the thrust measurement. Time did not permit refinement of the installation to account for these thermal effects; however, it was concluded that they could be accounted for and reasonable results could be expected utilizing this technique. The details of this study are presented in Part III of this report.

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