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8.5 Determination of the Level Flight Performance of Propeller-Driven Aircraft

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A flight test method to determine the level flight performance of propeller-driven aircraft is currently being investigated at Mississippi State University. By measuring the amount of power it takes to overcome a known increment of added drag to maintain steady state flight conditions, it may be possible to determine the overall drag and the propeller efficiency of a general aviation-type aircraft.

Propeller efficiency, η_p, is defined as the ratio of thrust horsepower to brake horsepower, or

$$\eta_p = \frac{TV}{550BHP} \tag{1}$$

Equating thrust to drag by the thrust inclination angle γ gives

$$\eta_p^* = \frac{DV}{550BHP} \tag{2}$$

where $\eta_p^* = \eta_p \cos\gamma$.

If an increment of drag ΔD is added and power is increased such that the airspeed remains constant, then

$$\eta_p^* + \Delta\eta_p^* = \frac{(D + \Delta D)V}{550(BHP + \Delta BHP)} \tag{3}$$

Using a propulsive efficiency factor

$$E_p = \frac{\eta_p^* + \Delta\eta_p^*}{\eta_p^*} = 1 + \frac{\Delta\eta_p^*}{\eta_p^*} \tag{4}$$

and eliminating drag gives

$$\eta_p^* = \frac{\Delta DV}{550[(BHP + \Delta BHP)E_p - BHP]} \tag{5}$$

Expressing BHP as the product of torque, Q, and propeller rpm, n, and substituting for η_p^* in (2) gives the basic incremental drag equation

$$D = \frac{\Delta D}{(1 + \frac{\Delta Q}{Q})E_p - 1} \tag{6}$$

If there is little or no change in propeller efficiency, $E_p \approx 1$ and

$$D = Q \frac{\Delta D}{\Delta Q} \tag{7}$$

Thus we have expressed the total drag of the aircraft as a function of three easily measured parameters. A standard propeller torquemeter will be used to measured Q and ΔQ, while a load cell attached to a drag chute will measure ΔD. By also measuring γ, the propeller efficiency η_p can be computed directly from (2).

Equations (6) and (7), however, neglect changes in induced drag and profile drag. It is expected that the profile drag will remain constant, but it may be necessary to consider ΔD_i, the change in lift-dependent drag. By using a parabolic polar for the aircraft and including an amount of lift ΔL, it is possible to express the drag as

$$D = \frac{2a_0 \Delta\alpha W + \pi\ AR\ e\ \Delta D_D}{\pi\ AR\ e\ [(1+ \frac{\Delta Q}{Q})E_p - 1]} \tag{8}$$

where a_0 is the slope of the lift curve, $\Delta\alpha$ is the change in angle of attack, W is the aircraft weight and ΔD_D is the incremental drag of the parachute. Further, e is the Oswald efficiency factor and AR is the aspect ratio.

Note that this equation requires measurement of flight test variables and aircraft parameters that are not included in the simpler forms. If the added drag is small, it is expected that equations (6) and (7) will be sufficient. However, the final form of the drag equation which will be most suitable remains to be determined.

The incremental drag method of determining aircraft performance appears to offer an excellent alternative to current flight test practice. The aircraft lift, drag and thrust values and propulsive efficiency are readily determined from a simple flight test procedure. It seems reasonable to expect that sophisticated data acquisition and processing systems will be unnecessary since the flight test is conducted under steady state conditions. The current practice of determining aircraft drag by the gliding flight method is tedious and provides no information concerning propulsive system performance. The incremental drag method appears to provide the potential for significantly greater flexibility and utility at reduced cost and complexity with increased safety.

9. ADDITIONAL PAPERS RECEIVED AFTER THE CONFERENCE

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