modified by the addition of strakes running the length of the span. Figure 3 compares the measured C_D with the "equivalent" circular section methods for different values of the ratio of strake heights to cylinder radius r. In the figure, C_{D0} corresponds to the drag of a cylinder without strakes and both C_D and C_{D_0} are based on the same (equivalent) area. The Newtonian impact theory appears to agree more closely with the test data in the transonic speed range.

Conclusions

Based on a wind-tunnel experiment conducted to measure the drag coefficients of circular cylinders at transonic Mach numbers, several conclusions can be made. The C_D is influenced by Reynolds number at most by only a few percent over a range including the low-speed "critical" region. The influence of a change in relative surface roughness of an order of magnitude also amounts to only a few percent difference. A reduction in the drag coefficient as Mach number increases through 0.7 to 0.8 is caused by the formation and location of shock waves and not by Reynolds number effects, as speculated in previous investigations. Finally, for the s/r ratios tested, the increase in drag due to the wingspan of a wing-body combination appears to be estimated adequately by current theoretical treatments.

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Technical Comments

Comment on “LTA Aerodynamic Data Revisited”

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AN excellent review has been given by Curtiss, Hazen, and Putman[1] on the subject of LTA aerodynamics. The classical aerodynamic goal for LTA is the minimization of propulsion power for a given hull volume and a given flight speed. The boundary layer must be assumed completely turbulent because of high Reynolds numbers ($>10^8$) and hull surface conditions. Recently, a methodology has been presented by Parsons, Goodson, and Goldschmied[2] for the automatic synthesis of minimum-drag hull shapes for incompressible axisymmetric bodies of specified volume at given speed. The significant results of these studies is the fact that, for turbulent boundary layers, the volume drag coefficient varies but little for wide variations of the five geometric profile parameters. The "Akron"[3] still yields one of the lowest aerodynamic drag coefficients, at par with the best U. S. Navy Series 58 Model 4176.[4] Parametric studies against fineness ratio, from Hess[5] to Young,[6] substantiate the above.

It can be concluded that means other than body shaping alone are needed to reduce propulsion power. Mention is made by Curtiss, Hazen, and Putman[1] of modern interest in BLC airships, which can reduce friction drag at constant volume with much lower fineness ratios, without allowing concomitant flow separation and high pressure drag. It should be pointed out that a significant attempt to integrate hull design, boundary-layer control, and stern jet propulsion was presented by Goldschmied,[7] on the basis of wind-tunnel tests reported by Cerreta.[8] Further wind-tunnel work was carried out in recent years, with a substantial reduction of the minimum suction flow requirements; these results have been presented by Goldschmied.[9]

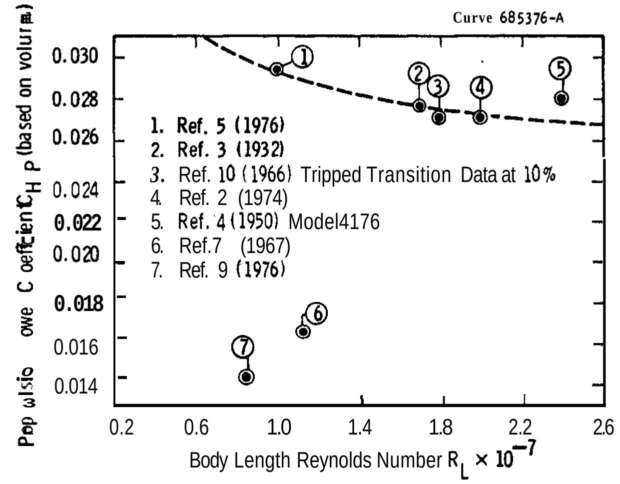

Fig. 1 Propulsion power assessment for all-turbulent vehicles.

A general assessment of the situation can easily be made, as shown in Fig. 1, by plotting the power coefficient C_{hp} (based on volume) against the Reynolds number (based on length). The guidelines are as follows: 1) laminar/turbulent transition is always triggered or assumed at 5% or 10% length from the nose; 2) an additional drag $\Delta C_D = 0.003$ is imposed on all bodies to account for the empennage resistance; c) stern wake-propeller efficiency of 85% is assumed for bodies 1 through 5;

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and 4) an impeller efficiency of 90% is assumed for bodies 6 and 7.

It is seen that propulsion power is reduced in half by the Goldschmied vehicles; considerably better results may be obtained yet from a system optimization study which would produce the best possible match between the hull profile, the single suction-slot, the impeller stage, and the stern propulsive jet.

Mathematical models for the several components are available and can be combined into a system. For instance, five parameters may be allocated to the hull profile, two parameters to the suction-slot, two parameters to the impeller stage, and one parameter to the propulsive jet; the ten parameters then may be simultaneously optimized by the methods of Ref. 2. A suitable experimental verification could be carried out in the NASA Ames 40 x 80-ft wind tunnel, with a 300 ft^3 model of 6-ft diam and 18-ft length. The length Reynolds number would be 3.75×10^7 and the estimated power to the impeller would be 52 hp at 230 mph, with transition triggered at 5%.

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