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Aerodynamic Force Measurement on Caret and Delta Wings at High Incidence

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1. Introduction

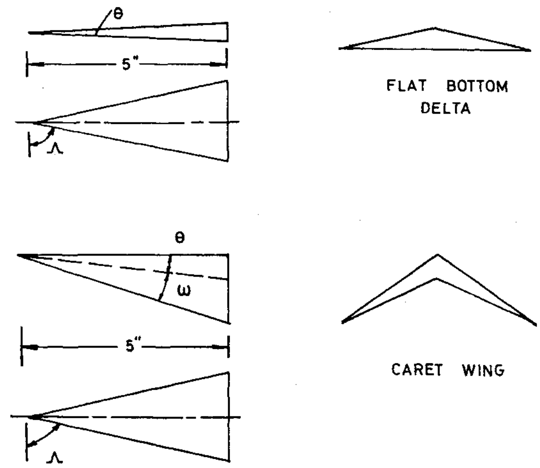
THE space shuttle program has focused attention on high lift re-entry vehicles such as flat-bottom delta wing configurations. The caret wing is also of interest because of its higher lift coefficient in comparison with the delta, due to the containment of a two-dimensional shock at its design incidence and the associated lack of flow spillage (assuming that heating considerations do not dictate blunted leading edges). The advantage of the caret wing in cruising flight was shown by Opatowski,[1] but there was a lack of information on its behavior under re-entry conditions until Rao[2] performed tests at $M = 12.2$ in the Imperial College No. 1 Gun Tunnel. These tests suffered from the effects of tunnel blockage and were repeated by Carr[3] with more success. The investigation described herein was conducted in the larger Imperial College No. 2 Gun Tunnel at $M = 9$ using the same models and balance. The results provide further insight into the behavior of lifting re-entry configurations at high angles of incidence.

2. Experimental Details

The tests were made using a three component force balance in the Imperial College No. 2 Gun Tunnel[4] which uses nitrogen as the test gas. The models (Fig. 1) had a preset angle of 30° between the balance sting and the windward surface and windward ridgeline, respectively, for the flat delta and caret wing.

3. Results and Discussion

Measurements of normal and axial forces and pitching moment were taken for both the flat bottom delta and caret wing model in the incidence range $30° \leqslant \alpha \leqslant 60°$, where α is the angle between the flow direction and the windward surface or windward ridgeline, respectively, for the flat delta and caret wing. The upper limit (60°) is higher than in previous tests. The test conditions are given in Table 1, where the subscript o, w, ∞ refer to reservoir, wall, and freestream conditions, respectively, and L' is the center chordlength of the models.



MODEL	Λ	θ	ω
FLAT DELTA	75°	6°	–
CARET WING	75°	6°	10°

Fig. 1 Details of the models.

Table 1 Test conditions

M_∞	Re_∞/in.	T_o °K	T_w °K	T_∞ °K	$Re_{L'}$
8.96	0.31×10^6	1070	295	65.5	1.55×10^6

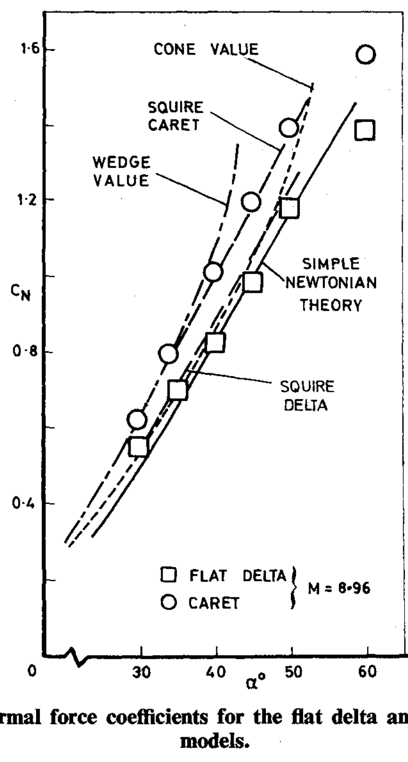


Fig. 2 Normal force coefficients for the flat delta and caret wing models.

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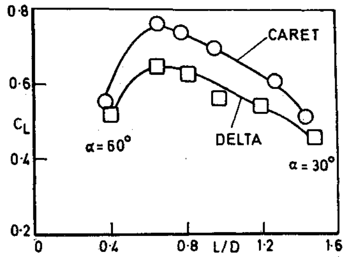

Fig. 3 Lift coefficients.

The experimental data has been tabulated by Coleman.[5]

The measurements of normal force coefficient, C_N, for the flat delta and caret wing models are compared with each other and with some theoretical predictions in Fig. 2. The caret wing develops significantly higher values of C_N than does the flat delta. Near the caret design incidence ($\alpha = 34°$) the experimental values agree well with the two-dimensional (wedge) prediction whereas, at the same incidence, C_N for the delta wing corresponds more closely to the cone value. Similar comments were found to apply to the measured shock wave angles. Simple Newtonian theory ($C_p = 2\sin^2\alpha$) also gives a good estimate of C_N for the flat delta over the incidence range considered, but tends towards underestimation at low α and overestimation at high α. The agreement of Squire's prediction[6] for the caret wing is striking, but for the flat delta his method is less successful.

The lift coefficients (C_L) developed by the two models are compared in Fig. 3; the superiority of the caret wing over the entire incidence range is clear. Both shapes develop maximum lift around 50° incidence, corresponding to $L/D \simeq 0.7$.

4. Conclusions

Tests have been conducted at a Mach number of 9 to compare the performance of a flat-bottomed delta and a caret wing model at high angles of incidence appropriate to lifting re-entry conditions. The distinct advantage of the caret wing over the incidence range considered has been clearly shown. Comparisons between the data and a few prediction methods for the normal force coefficient have been made and particularly good agreement has been found between the data and Squire's theoretical curve for the caret wing.

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Viscous Damping Characteristics of Dacron Parachute Suspension-Line Cord

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Introduction

A KEY element in the analytical study of parachute inflation dynamics is the calculation of loads exerted on the towing vehicle by the inflating parachute. Recent analyses[1,2] have shown that suspension-line elasticity and viscous damping can have an important effect on the magnitude of the opening load exerted on the vehicle.

This Note presents results obtained from a test program conducted to determine the force-strain characteristics of Type 52, 220-denier, 880-lb minimum tensile strength dacron suspension-line cord under quasi-static loading conditions and at strain rates ranging up to 210%/sec. Average force-strain curves were obtained, and viscous damping coefficient curves approximating the change in response attributed to dynamic loading conditions were calculated. The calculated damping coefficient was observed to be a nonlinear function of both strain and strain rate. Rupture loads measured during the test program were observed to decrease with increasing strain rate.

Test System Description

The basic Type 52 dacron cord was first cut into sections, which were then heat sterilized according to Viking specifications. After sterilization, the sections were formed into test samples having Chinese-finger end loops and a pin-to-pin length of 15 in.

Quasi-static tensile tests were performed on an Instron tensile-testing machine. Dynamic tensile tests were performed by using a hydraulically-driven ram mechanism which is sketched in Fig. 1. Samples were attached to pin-type fittings on the ram head and on a rigid base by using the Chinese-finger end loops. Ram-head displacement was measured by using a steel-cable-driven potentiometer: dynamic effects on the steel cable were considered to be negligible. Force

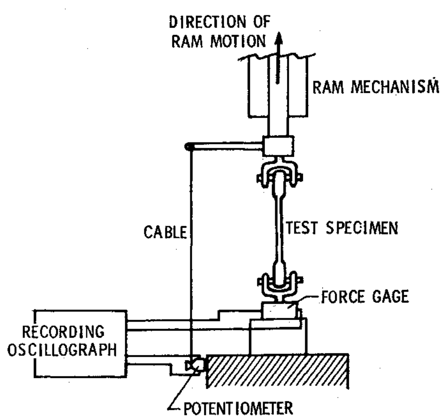

Fig. 1 Sketch of test system configuration.

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