is, at collapse the symmetry about the cutout is lost (see Fig 3). This loss of symmetry is due to the larger radial displacements, hence the larger moments With the greater radial displacements, the bending stiffness matrix (D matrix) has a greater effect Therefore, the D_{11} and D_{22} will have an effect on the displacement pattern A further review of the history of the displacement pattern and the plots of eigen vectors were given in Ref 8

Figure 4 shows the contours of the radial displacements at collapse load (131.2 lb/in) for the $[0, +45, -45, 90]_s$ panel The collapse displacement function for the $[0, -45, +45, 90]_s$ panel is the mirror image of that shown in Fig 4 It can be seen that with a 4 × 4 in cutout the displacement pattern at collapse is more symmetric about the circumferential and longitudinal axis than the panel with a 2 × 2 in cutout This is because the larger cutout produces the bending effects earlier and the moment change is more spread out; therefore, a more symmetric displacement pattern However, the slight amount of nonsymmetry shown at the center of the cutout's vertical edges can be seen to change sides when the ply layup is changed by switching the 45 deg plies The same phenomenon was experienced with the smaller cutouts The w component eigenvector contour plots of the 4×4 in cutout panels and the physical interpretation of results were contained in Ref 8

Conclusions

The following statements and conclusions are based on the analysis presented in this paper

1) Collapse characteristics of composite panels are dependent on the ply layup and the size of the cutouts

2) The 2×2 cutouts (less than 5% of the panel surface area) have a displacement pattern at the collapse load that is different than the larger cutouts. The 2×2 cutouts displacement pattern build symmetrically about the cutout and at the collapse load, snap into the displacement pattern of the eigenvector. The 4×4 cutout had a displacement pattern that stayed fairly symmetric at collapse and was close to the isotropic collapse pattern

3) The load bearing capability of a composite panel is very sensitive to the presence and size of a cutout

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Flutter Characteristics of High Aspect Ratio Tailless Aircraft

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Introduction

ONE of the examples of high aspect ratio slender wing aircraft is sailplanes In the next context of their continuing development a tailless design study[1] at Cranfield has claimed an overall performance gain of 10% over conventional types achieved mainly from reduction in the parasite drag Sailplanes, because of their high aspect ratios and slender wings, are prone to aeroelastic problems such as flutter, even at low speeds Furthermore the complexity increases in the absence of a tail when the damping in pitch becomes very low This makes the longitudinal dynamics of the aircraft a formidable problem because it involves an aerodynamic coupling of the rigid body motion with the elastic modes of distortion Using the basic data for the class of tailless sailplanes given in the design study[1] at Cranfield, this Note investigates such interactions from a selection of extracted results from Ref 2

The particular class of tailless sailplane under investigation is called the Ricochet[1 2] and a major section of results is compared with those of an existing class of tailed sailplane the Kestrel-22m Figure 1 and Table 1 together give the basic details of the two aircraft, whereas Fig 2 shows the structural and aerodynamic properties of their respective wings

Method of Analysis

The use of generalized coordinates in flutter analysis has been reported earlier by a number of authors [3 6] The same method involving normal modes is implemented herein to express mass, stiffness and aerodynamic matrices of the aircraft in terms of the generalized coordinates The finite element method[7] is used to obtain the mass stiffness matrix and the normal modes, whereas strip theory based on Theodorsen expressions[3] for unsteady airfoil motion is employed to form the aerodynamic matrix. The flutter matrix is formed by algebraically summing the generalized mass, stiffness, and aerodynamic matrices

The solution of the flutter determinant is a complex eigenvalue problem because the determinant is primarily a complex function of two unknown variables, the airspeed and the frequency The method used selects an airspeed and evaluates the real and imaginary parts of the flutter determinant for a range of frequencies The process is repeated for a range of airspeeds until both the real and imaginary parts of the flutter determinant vanish completely Once the flutter speed and frequency are established, the corresponding vector, i e , the flutter mode is found in the classical way by deleting one row of, say, the nth order determinant and solving for $(n-1)$ of the coordinates in terms of the nth

Results of Computation

The first few wing modes in the symmetric motion obtained from PAFEC[7] analysis are shown for the Ricochet (four

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modes) and the Kestrel (six modes), respectively, in Fig 3 Apart from the inclusion of two symmetric rigid body modes namely heave and pitch, the elastic modes shown in Fig 3 for the respective aircraft all are included in the analysis to describe their symmetric flutter The mode shapes shown include fundamental bending and torsional mode in both cases In Fig 3, the first elastic mode for the Kestrel at 11 8 rad/s is the fundamental bending mode, whereas its fifth elastic mode at 112 1 rad/s represents a pure torsional mode These two modes were established at 11 3 and 94 9 rad/s, respectively, by ground resonance test [2] Following the eigensolution procedure described in the previous section, the flutter speeds for the Ricochet and Kestrel are located at 38 8 and 70 6 m/s respectively The corresponding frequencies at flutter are found to be 8 7 and 53 8 rad/s

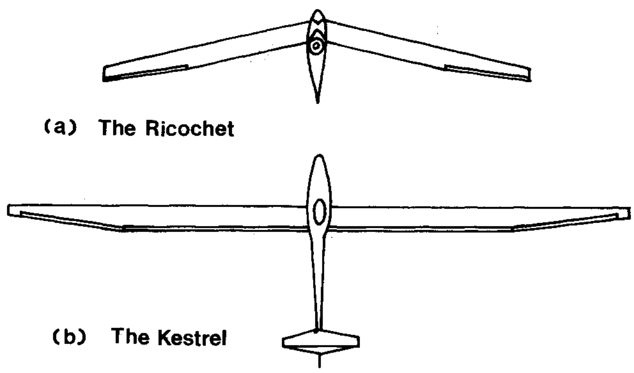
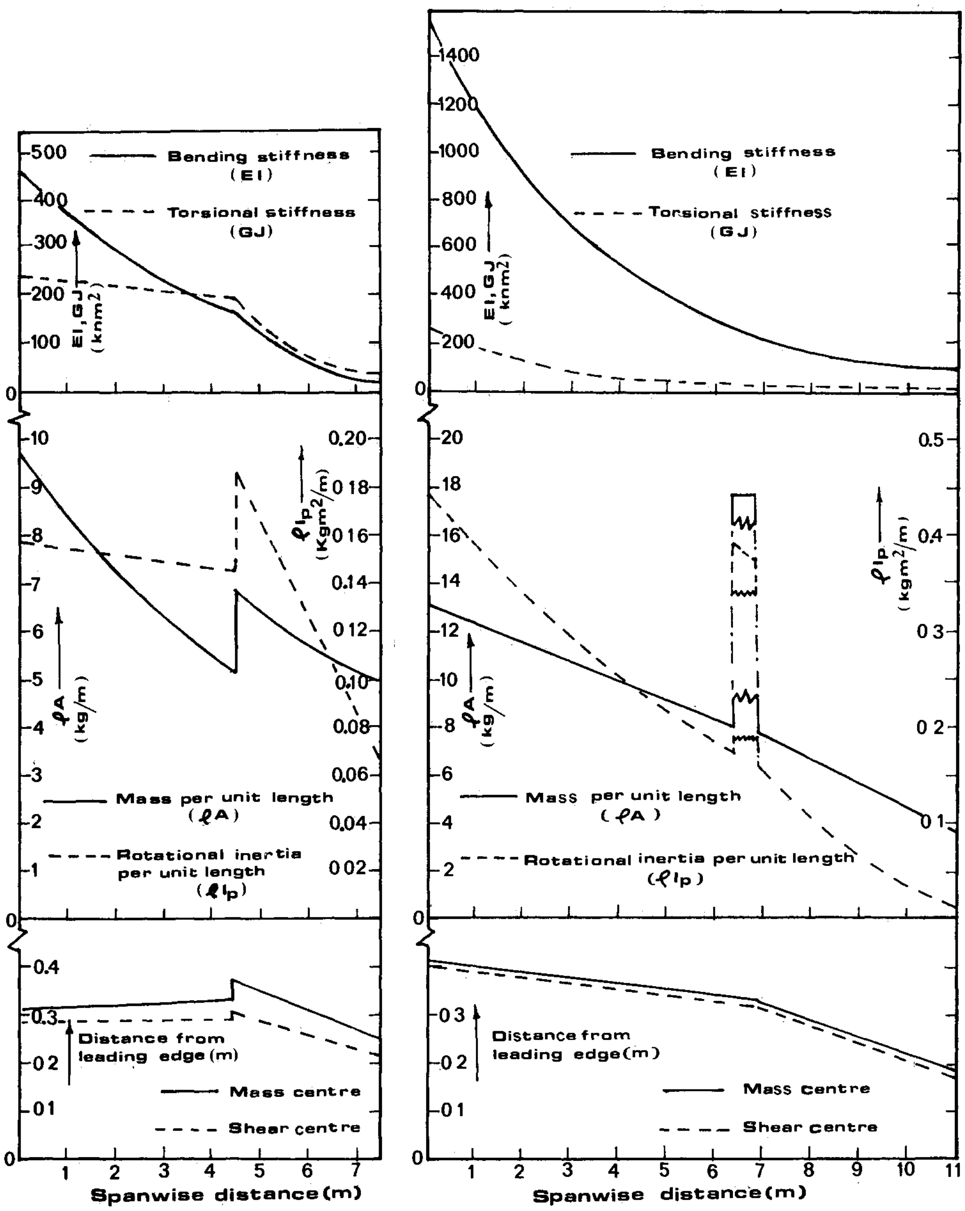


Fig 1 General layout of tailless and tailed aircraft

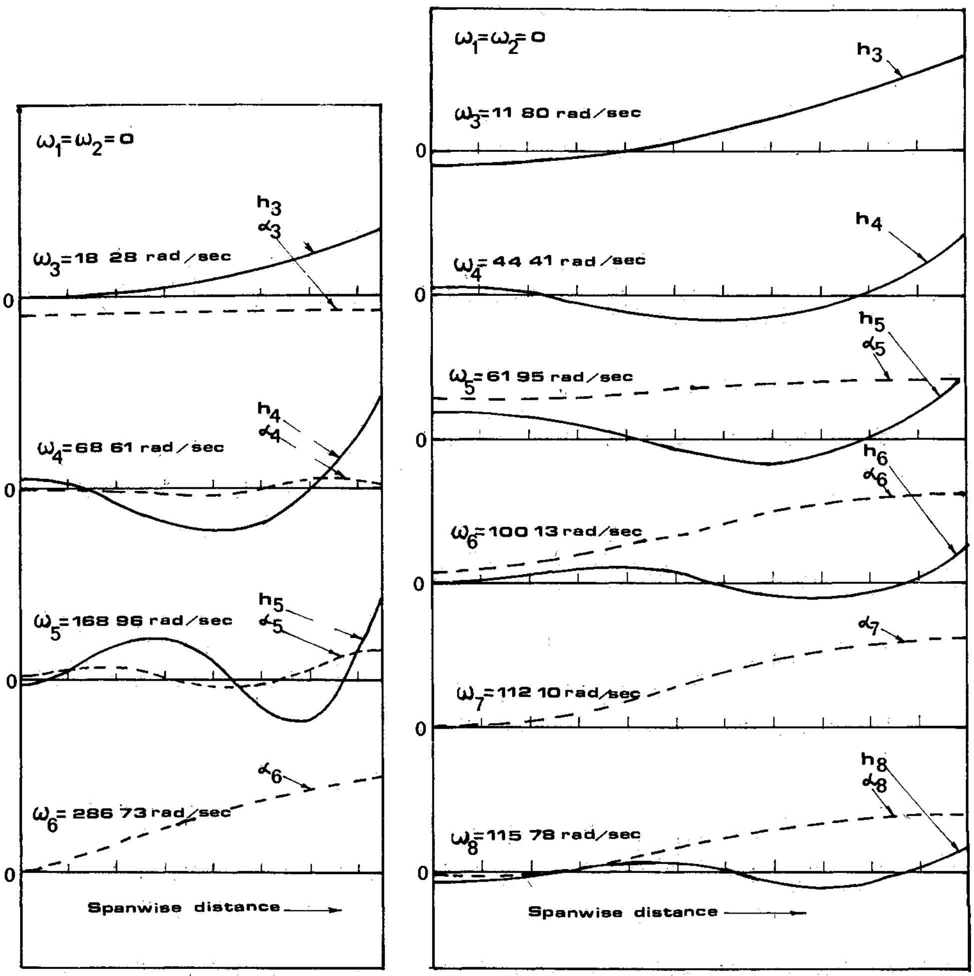
Having found the flutter speed of the Ricochet very low at 38 8 m/s, which is far below the estimate of 150 m/s given in Ref 1, a parametric study varying c g position angle of sweep, and pitching moment of inertia has been undertaken without altering the basic design of the aircraft The c g of the pilot fuselage assembly is moved forward and aft to a maximum of 12% of the original distance from the leading edge The corresponding analysis shows that the forward c g decreases the flutter speed by 6%, whereas the flutter speed increases by 13% for the aft position The improvement observed in the aft c g case is still not within acceptable limits The angle of sweep then is changed gradually from the initial value of 13 deg to a minimum of 5 deg, which resulted into a maximum improvement of 3% The parameter which is found to have the most significant effect on the flutter speed is the pitching moment of inertia of the aircraft The variation



a) The Ricochet

b) The Kestrel

Fig. 2 Wing properties of Ricochet and Kestrel



a) The Ricochet b) The Kestrel

Fig 3 Modes shapes for Ricochet and Kestrel wings, ___ vertical displacement, h_i; – – – –pitching rotation, α_i

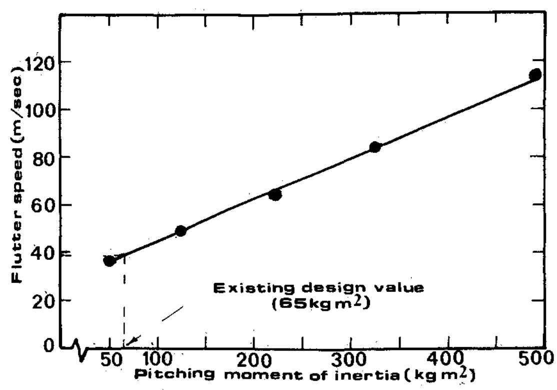


Fig 4 Variation of flutter speed of Ricochet against pitching moment of inertia of pilot fuselage assembly

Table 1 Particulars of the Ricochet and Kestrel

Parameter	Ricochet	Kestrel 22m
Material of construction	Aluminum alloy (6061 T6)	FRP
Span m	15	22
Wing area m^2	10 26	15 44
Aspect ratio	22 93	31 35
Wing root chord m	0 73	0 90
Wing tip chord m	0.50	0 36
Sweep angle deg	13	0
Mass of each wing kg	50	115
Fuselage mass with equipment kg	65	180

of flutter speed against the pitching moment of inertia of the pilot fuselage assembly is shown in Fig 4 and the results as shown indicate a linear trend (It may be noted that a 25% increase in the fuselage mass has not shown any appreciable improvement in the flutter speed [2])

Discussion of Results

The calculated flutter speed of the Ricochet is unacceptable, whereas that of the Kestrel is in close agreement with pilot report and flight test results [2] An inspection of the flutter modes indicates that the flutter of the Ricochet is unusual with large deflections at the wing root, whereas the flutter of the Kestrel wings is a distinct example of classical bending torsion flutter with the tip having maximum displacement and the root being almost stationary The Ricochet flutter is influenced mainly by the two rigid body motions and also by the fundamental wing bending mode, whereas the rigid body modes do not play any role in the flutter of Kestrel wings The flutter modes also indicate that the Ricochet flutters in a very unconventional way where an upward movement of the fuselage is accompanied by a downward movement of the wing tip The type of instability seems to be an overall in stability giving rise to a flapping motion The flutter behavior of the Kestrel is quite normal In both cases the pitching rotation (torsion) lags the vertical displacement (bending) as expected. The only significant parameter that can improve the flutter characteristics of the Ricochet is found to be the pitch ing moment of inertia provided mainly by the pilot fuselage assembly Figure 4 clearly indicates that the Ricochet has low flutter speed because of its inadequacy in the value of the pitching moment of inertia An increase in the fuselage mass alone did not improve the flutter characteristics to any ac ceptable standard nor did the c g position or the angle of sweep It is unlikely that other than major modifications of the Ricochet within the scope of the tailless layout can provide an adequate pitching moment of inertia to increase the flutter speed to an acceptable level

Concluding Remarks

The symmetric flutter speed obtained for the tailless sailplane Ricochet is very low and the instability results from the coupling between the short period oscillation and the first bending mode of the aircraft The results of the parametric study indicate that the small value of the pitching moment of inertia of the aircraft, in the absence of a tail, is primarily responsible for its low speed instability The scope for modification in the aerodynamic parameters such as the angle of sweep, aspect ratio, wing chord, and taper ratio is rather limited if the aircraft has to remain within this particular class of sailplanes The relative positions of the mass and shear center of the wing sections are unlikely to be able to be altered sufficiently to affect the flutter speed because of the small chord of the high aspect ratio wing However, from an inspection of the relative magnitude of the bending and torsional stiffnesses of the wings (see Fig 2), there seems to be an important area of improvement where the metallic wings of the Ricochet can be replaced by FRP with possible carbon fiber spar reinforcement, which will increase the flexural stiffness quite significantly This could possibly provide a remedy because of the large part the flexural mode plays in the flutter mode of the Ricochet Further analysis is required to authenticate whether the inadequacy of the pitching moment of inertia can be compensated by this change

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