Engineering Notes

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Effects of Flexibility on Stability of Small Ribbon Parachutes

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Introduction

IN previous studies[1,2] it was noted that small (12-in.-diam), 20% geometric porosity, textile, ribbon parachutes flew at stable trim angles of ±12 deg and exhibited a region of static instability (positive $dC_M/d\alpha$) for angles of attack between ±5 deg. Full-size parachutes of this type would normally fly at a stable trim angle of 0 deg. Reference 3 reported a rigid model of a ribbon parachute which exhibited a stable trim angle of ±22 deg and an unstable trim angle of 0 deg. The variation of moment coefficient with angle of attack for this rigid model was qualitatively similar to that exhibited by the small textile parachute models.[4]

Heinrich and Hektner[5] have shown that small parachute models are generally much less flexible in relation to their size than their full-scale counterparts and that this difference in flexibility causes differences in opening force characteristics and steady-state drag coefficients. Since the performance of the rigid model was similar to that of the 12-in. textile models, it was hypothesized that model stiffness might also cause the differences in the stability characteristics between the small parachute models and larger parachutes of the same design.

In order to examine this hypothesis, several ribbon parachute models of the same geometric porosity but different flexibility were constructed and tested in the University of Minnesota Wind Tunnel. Moment coefficients were calculated for each model; however, no correlation was found between model flexibility and stability characteristics. Further study of the data indicated that the stability characteristics may depend on the Reynolds number of the flow through the slots in the parachute.

Parachute Models

Three parachute cloths of varying weaves and densities were selected for model construction: cloth A, a uniform weave nylon, cloth B, also a uniform weave nylon, and cloth C, a rip-stop nylon. Parachute models were cut with a hot knife. Acetate reinforcing ribbons ¼ in. in width were stitched in between the gores; and suspension lines the length of the parachute nominal diameter were attached to the reinforcing ribbons at the skirt.

The flexibility of the models was determined using a technique suggested by Heinrich and Hektner.[5] The models were laid flat on a table, then lifted by the suspension lines and shaken. The diameter of the parachute suspended in this manner was measured and stiffness index was defined as $\eta = D/D_0$, where D_0 is the nominal diameter and D is the diameter of the uninflated parachute when lifted by its suspension lines. Heinrich and Hektner also included the ratio of the canopy weight to the weight of an equal area of the parachute cloth in the stiffness index to help account for mass effects during opening. Since the present study is concerned only with the steady-state performance of the models, the weight ratio was not included in the stiffness index.

The parachute model construction parameters are listed in Table 1 along with the stiffness index for each model.

Instrumentation and Test Procedure

The aerodynamic coefficients were measured in the closed test section of the University of Minnesota Low Speed Horizontal Return Wind Tunnel. An electric, three-component strain gage balance was used to determine the aerodynamic forces.

The parachute models were attached to the balance, which was in turn attached to a turntable mounted in the wind tunnel. This turntable allowed the orientation of the parachute to be changed relative to the direction of flow, and thus aerodynamic coefficients could be measured at different angles of attack. Measurements were made at intervals of angle of attack of 2.5 deg. Tests were run to produce eight data points at each angle of attack. The parachutes were then inverted and the tests repeated to eliminate any effects of construction asymmetries. The data for each model at each angle of attack were averaged and plotted.

Results

A typical graph of moment coefficient vs angle of attack is shown in Fig. 1. The moment coefficient, C_M, is zero at 0- and ±10-deg angle of attack, α; and $dC_M/d\alpha$ is positive between ±4 deg and negative for larger and smaller values angle of attack, indicating that a trim angle of 0 deg is statically unstable and that trim angles of ±10 deg are statically stable. This result is typical of all the small parachutes tested.

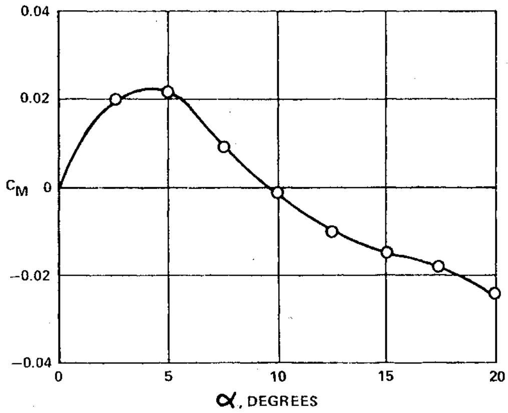

Fig. 1 Moment coefficient of typical model vs angle of attack ($D_0 = 12$ in., $N_g = 12$, $\eta = 0.67$).

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Table 1 Model construction parameters

Model	D_0, in.	N_g	Cloth	Cloth area Density, g/m^2	D, in.	η
1	12	12	A	84.25	8.04	0.67
2	12	12	B	80.05	5.64	0.47
3	12	12	C	37.34	3.96	0.33
4	15	12	C	37.34	4.35	0.29
5	15	24	A	84.25	9.90	0.66
6	15	24	C	37.34	4.35	0.29

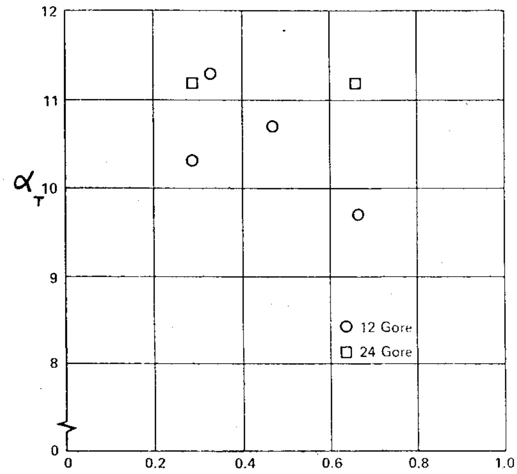

Fig. 2 Trim angle of attack vs stiffness index.

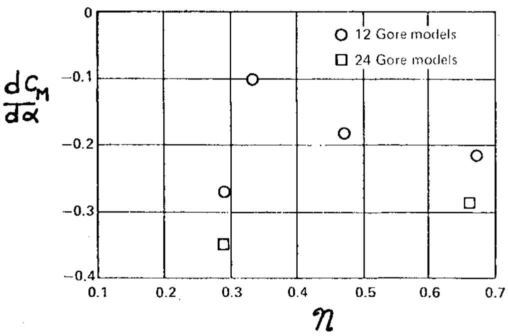

Fig. 3 $dC_M/d\alpha$ at trim vs stiffness index.

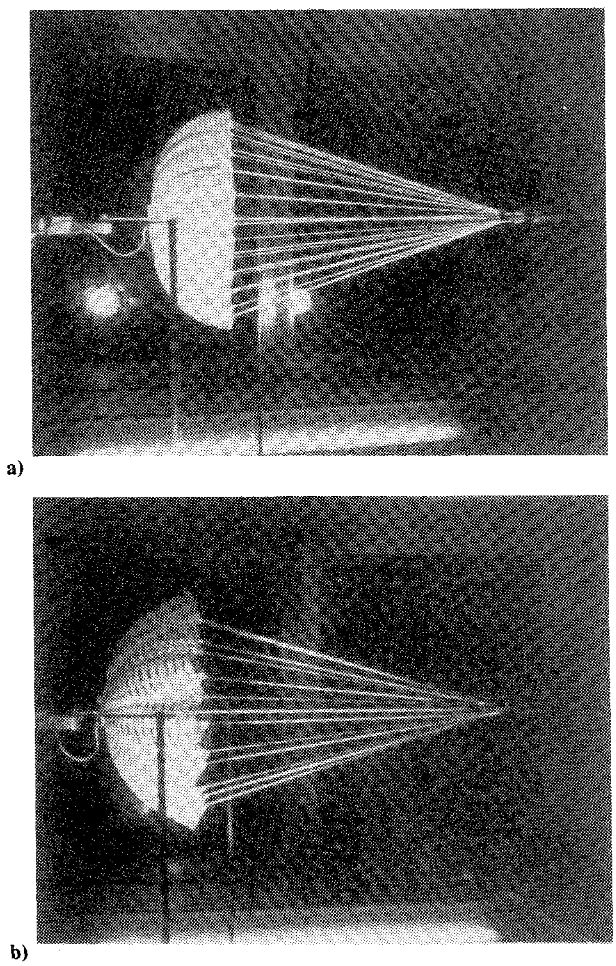

Fig. 4 Inflated shapes of 15-in.-diam models: a) 24 gores, $\eta = 0.29$; b) 12 gores, $\eta = 0.29$.

None of the parachute models exhibited a stable trim angle of 0 deg. Still-air drop tests were conducted in a hangar to determine if balance wake interference might cause the deviation of the trim angle of attack from zero. The payload weights which would result in the same steady-state velocity as used in the wind tunnel tests were calculated and these weights were attached to the model parachutes. The models were dropped indoors in still air a distance of approximately 30 ft. All models were observed to have a trim angle of attack other than 0 deg. This confirmed the wind tunnel test results and indicated that the balance wake was not the primary factor contributing to the nonzero trim angle of attack observed in the wind tunnel.

The stability characteristics of the parachute models as a function of stiffness index are illustrated in Figs. 2 and 3. The trim angle of attack does not decrease with stiffness index. In fact there is some indication that the model parachutes behave more like full-size parachutes as the stiffness index increases. The more flexible parachutes exhibited considerably more flutter and buffeting than did the stiffer parachutes, and unsteady aerodynamic effects may be the cause of seemingly anomalous behavior of the small parachute models. A number of 22-in.-diam ringslot parachutes of very stiff construction were flown in the wind tunnel and while it was impossible to quantitatively determine the force and moment coefficients with apparatus available to the investigators, qualitatively the performance of these very stiff models was similar to their full-scale counterparts.

The number of gores, N_g, proved to be an important parameter in determining the inflated shape of the models (Fig. 4). The parachutes with larger numbers of gores looked more like full-size parachutes when inflated; however, analyses of N_g effects on stability proved inconclusive.

Large model parachutes exhibit performance similar to that of full-scale parachutes. For example, a 24-gore, 1.5-m nominal diameter model ribbon parachute, constructed in the same manner as the small models, described in this study, flew at a stable angle of attack of 0 deg in the wind tunnel and behaved in all respects like a large ribbon parachute. Since the slot size is larger in large parachutes, it was hypothesized that slot geometry or size somehow affects parachute performance, perhaps by reducing the effective porosity of the models if the slot is too small. A slot Reynolds number was defined and the trim angle $dC_M/d\alpha$, and tangent force coefficients were determined as a function of this Reynolds number.[4] For a slot Reynolds number greater than 10^4, the stability characteristics of the model ribbon parachutes approximated those of full-size parachutes.[4] These results are still tentative, however, and more study is required before definitive statements about the effect of the slot Reynolds number on stability can be justified.

Conclusions

Several important model design parameters emerged from this study. It was found that the number of gores was a dominant factor influencing inflated canopy shape. The stiffness of the parachute did not strongly influence stability characteristics, and, in fact, stiffer models appeared to perform more like full-size parachutes than did more flexible models. Finally, the Reynolds number obtained by using slot height as the characteristic length appears to affect the stability characteristics of the models. This may be due to a reduction in the effective porosity of the parachute, and further studies should be focused on slot Reynolds number effects.

Acknowledgment

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References

[1] Heinrich, H.G. and Schmitt, J.C., "Aerodynamic Coefficients of a Twin Parachute Cluster," *Proceedings of the AIAA 6th Aerodynamic Decelerator and Balloon Technology Conference,* Houston, Tex., March 1979, pp. 356-362.

[2] Weber, T. and Garrard, W.L., "Aerodynamic Coefficients of 20% Geometric Porosity Ribbon Parachutes," Sandia Laboratory Contract 07-4328 Technical Report, Department of Aerospace Engineering and Mechanics, University of Minnesota, Minneapolis, Minn., July 31, 1979.

[3] "Performance of and Design Criteria for Deployable Aerodynamic Decelerators," AFFDL-TR-61-579, Dec. 1963.

[4] Weber, T. and Garrard, W.L., "The Effects of Flexibility on the Steady State Performance of Small Ribbon Parachute Models," AIAA Paper 81-1923, Oct. 1981.

[5] Heinrich, H.G. and Hektner, T.T., "Flexibility as a Model Parachute Performance Parameter," *Journal of Aircraft,* Vol. 8, Sept. 1971, pp. 704-709.

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U.S. Marine Corps AV-8A Maintenance Experience

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Introduction

THE Hawker Siddley Harrier, AV-8A, is the free world's only operational V/STOL (vertical short takeoff and landing) jet aircraft. The rigorous operational demands imposed by V/STOL operation, especially with a payload greater than the empty weight, would lead one to expect an airframe requiring excessive maintenance downtime and massive expenditures to maintain its structural integrity and flight worthiness, but this is not the case. Maintenance data show that this aircraft is as good as most Naval aircraft. Although it is as reliable as other aircraft, the lightweight design of the aircraft along with its operational and maintenance idiosyncrasies have created some airframe problems.

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The AV-8A

The AV-8A (Fig. 1) is a single-fanjet engine, single-seat, high-wing monoplane with conventional monocoque fuselage and built-up empennage, all of 2000 series ALCLAD aluminum. Both wing and stabilator have anhedral with the wing tips having support ribs for outrigger landing gear. The fuselage has retractable bicycle-style landing gear with brakes on only the dual wheel main landing gear. The fanjet engine has a bifurcated inlet with peripheral, airload operated, auxiliary air doors and four rotatable exhaust nozzles. The two forward (cold) nozzles located just under and forward of the wing, on either side of the fuselage, exhaust over 60% of total engine airflow (430 lb/s in V/STOL). The remaining fan air, after passing through the turbine, is exhausted through the aircraft's two rotatable (hot) nozzles located again on either side of the fuselage below and slightly forward of the wing rear spar. All four nozzles are mechanically connected, synchronized, and driven by a dual air motor through torque shafts, gear boxes, and chains, from a full aft (0 deg) position to a maximum forward (98 deg) position called "braking stop." This system, although it weighs only 120 lb, can rotate the nozzles through their full travel in under 1 s and do this while the aircraft is in flight at up to 450 knots airspeed. As the nozzles go past the 16-deg position, a valve begins opening to pressurize the reaction control system (RCS) with eighth-stage compressor bleed air which permits nonaerodynamic aircraft attitude control via the reaction control valves (RCVs), which are mechanically connected to the normal flight control system. With a weight of only 200 lb, this system transmits and controls up to 10% of engine airflow, which in the form of hot compressor air approximates 3000 hp over distances of 20 ft.

Maintenance

The Navy has three levels of aircraft maintenance: organizational (O), intermediate (I), and depot (D). O-level maintenance is performed by the aircraft user and, aside from servicing and flying the aircraft, consists of aircraft and engine inspection and maintenance. This includes the removal and replacement (R&R) of various bolted components including both wing and engine. It should be noted that the O level performs the majority of high power runups which are

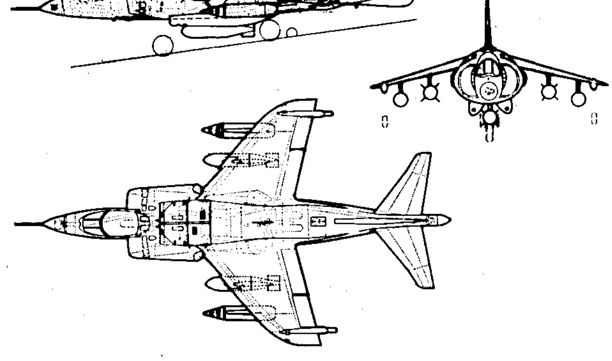

Fig. 1 AV-8A Harrier.