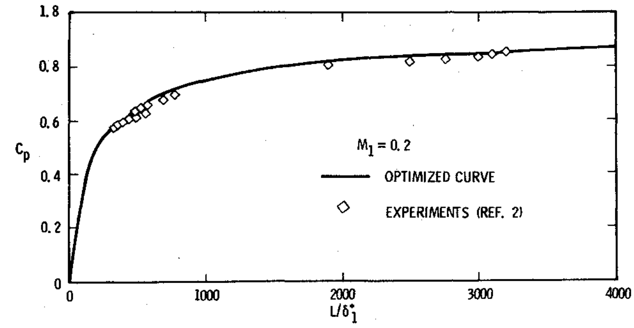

Fig. 4 Comparison between experimental and theoretical optimized C_p values at $M_I = 0.2$ for straight wall channel diffusers.

References

[1]Huo, S., "Optimization Based on Boundary Layer Concept for Compressible Flows," *Transactions of the ASME, Journal of Engineering for Power*, Vol. 97, April 1975, pp. 195-206.

[2]Runstadler, P. W. Jr. and Dean, R. C. Jr., "Straight Channel Diffuser Performance at High Inlet Mach Numbers," *Transactions of the ASME, Journal of Basic Engineering*, Vol. 91, Sept. 1969, pp. 397-422.

[3]Dolan, F. X. and Runstadler, P. W. Jr., "Pressure Recovery Performance of Conical Diffusers at High Subsonic Mach Numbers," NASA CR-2299, Aug. 1973.

[4]Stratford, B. S. and Tubbs, H., "The Maximum Pressure Rise Attainable in Subsonic Diffusers," *Journal of the Royal Aeronautical Society*, Vol. 69, April 1963, pp. 275-278.

Passive Flutter Suppression

Charles W. Ingram*
Systems Research Laboratories, Inc., Dayton, Ohio

and

Walter J. Szwarc†
U.S. Naval Air Station, Moffett Field, Calif.

Nomenclature

V_f = flutter velocity, fps
ΔV_f = change in flutter velocity, fps
α_0 = static angle of attack, deg
α_s = static stall angle of attack, deg

Introduction

LUGT[1] and Daniels[2,3] found that the auto-rotation of a flat plate and cruciform fins could be controlled or eliminated through the use of spanwise slots. Comparison of the flowfield about an airfoil in a bounded flutter oscillation, via smoke flow visualization,[4] revealed similarities in vortex shedding patterns between that of the auto-rotating flat plate and cruciform fins. Hence, it was felt that a spanwise slot could possibly increase the flutter velocity of an airfoil. This fact was proved in subsonic wind tunnel tests conducted on an NACA 0012 airfoil. The details of this experimental program are given in Ref. 5; only the major results are presented in the following section.

Received April 21, 1976. The authors express their appreciation to P. Daniels, U.S. Naval Surface Weapons Center/Dahlgren Laboratory, for his suggestion of slot utilization.

Index categories: Nonsteady Aerodynamics; Aeroelasticity and Hydroelasticity.

*Senior Scientist, Aerosystems Research Division, formerly Assistant Professor, University of Notre Dame. Member AIAA.

†Lt. (JG.), Pilot, U.S. Navy, VP-19, formerly Graduate Research Assistant, University of Notre Dame. Member AIAA.

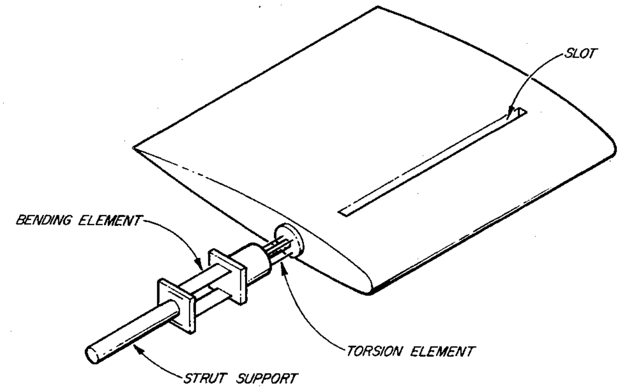

Fig. 1 Slotted airfoil and support system.

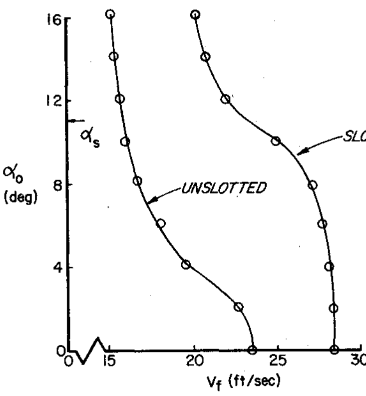

Fig. 2 Flutter velocity vs angle of attack.

Test Results

The NACA 0012 airfoil section used for the flutter tests, the type of spanwise slot considered, and the support system are shown in Fig. 1. The airfoil model is completely rigid; the two-degree-of-freedom flutter support system (details are given in Ref. 4) allows separation of the bending and torsional modes. This support system facilitates independent variations of either the torsional or bending structural characteristics. Bending and torsional elements were employed which possessed linear structural restoring and damping characteristics.

The slot is a spanwise cut completely through the airfoil section. The area of the slot is approximately 0.20 of the surface area of the airfoil. The flexural axis and the slot are located at the quarter chord position.

The flutter velocity, V_f, as a function of static angle of attack, α_0, i.e., the angle between the chord line and the wind tunnel velocity vector are presented in Table 1. These values were repeatable to within one percent. This data clearly shows that the slot does increase the flutter velocity. A plot of this data as a function of α_0 (Fig. 2) better defines the trends. A maximum increase in V_f, 57.8%, occurs at $\alpha_0 = 8°$, just prior

Table 1 Flutter velocity vs angle of attack

α_0 (deg)	V_f (fps) Unslotted	Slotted	ΔV_f (fps)	% Increase
0	23.5	28.6	5.1	21.7
2	22.8	28.2	5.4	23.7
4	19.3	27.8	8.5	43.1
6	18.0	27.2	9.2	51.1
8	16.6	27.0	9.6	57.8
10	15.8	24.8	9.0	57.0
12	15.6	21.8	6.2	39.7
14	15.4	20.7	5.3	35.4
16	15.2	20.1	4.9	32.2

to the onset of static stall, $\alpha_s = 11°$. It is interesting to note that the unslotted airfoil had a more severe decrease in V_f with increasing α_0 than the slotted airfoil, for $\alpha_0 < \alpha_s$. The slotted airfoil shows a more drastic reduction in V_f than the unslotted airfoil, as α_0 passes through and above α_s.

The slot's effect on the flowfield causing the increased V_f, or its effects on airfoil efficiency are not known at this time. However, the data presented in this Note does demonstrate that passive flutter suppression is possible.

References

[1]Lugt, H. J., "Self-Sustained Spinning of a Cruciform Fin System," *Proceedings of the Fifth United States Navy Symposium on Aeroballistics*, Naval Ordnance Laboratory, White Oak, Md., 1961.

[2]Daniels, P., "Fin Slots vs Roll Lock-In and Roll Speed-Up," *Journal of Spacecraft and Rockets*, Vol. 4, March 1967, pp. 410-412.

[3]Daniels, P., "A Flow Visualization Study of Free Rolling Cruciform Fins in Crossflow," U.S. Naval Weapons Laboratory, Dahlgren, Va., NWL TR 3053, Nov. 1973.

[4]Batill, S. M. and Ingram, C. W., "On an Investigation of Unsteady Aerodynamics on an Oscillating Airfoil," AIAA Paper 73-318, Williamsburg, Va., March 1973.

[5]Szwarc, W. J., "An Investigation of Aerodynamic Flutter," Master Thesis, University of Notre Dame, Notre Dame, Ind., May 1974.

Airborne Windmills and Communication Aerostats

M.S. Manalis*
University of California at Santa Barbara, Santa Barbara, Calif.

Introduction

ELECTRICAL generation from airborne windmills has been studied in both the United States and the Soviet Union. One Southern California aircraft corporation investigated the subject during the mid-1930's. TCOM Inc. of Columbia, Maryland had looked into the possibility of using windmills for communication aerostats by the late 1960's. These investigations were on a general basis and did not consider the matter in detail. In what may be the first attempt to use an airborne windmill to produce electricity, Sheldahl Inc. of Northfield, Minnesota, placed a French-made aerogenerator on a tethered ballon.[1] This fourbladed windmill was 6.8 ft in diameter and produced about 350 W. Vaynshteyn[2] of the Soviet Union has described an aerostat-system to be placed in the tropopause for communication purposes and environmental sensing. Power for the dirigible was to be generated from a wind-wheel coupled to a three-phase 35 KW electric generator.

Within the last year, there have been a few proposals submitted to the National Science Foundation and the Energy Resources Development Administrtation to investigate this matter.[3] These proposals have been denied funding in the United States for two major reasons. One, they propose a hazard for aircraft and two, they are not economical.

Presented as Paper 75-923 at the AIAA Lighter Than Air Technology Conference, Snowmass, Colo., July 16-17, 1975 submitted Sept. 11, 1975; revision received March 15, 1976. The author wishes to acknowledge helpful conversations with H. J. Stewart of the Graduate Aeronautical Laboratories at the California Institute of Technology in Pasadena, California, and R. Kaplan of the Department of Aerospace Engineering at the University of Southern California, Los Angeles, California.

Index category: Electric Power Generation Research.

*Environmental Physicist, Quantum Institute and Environmental Studies Department.

Communication aerostats are placed in areas such as the Bahamas, the Middle East, Africa, South America, India and Indonesia where air traffic is minimal. Presently, electricity is supplied to these aerostats from onboard gasoline generators. It will be shown that windmills can replace enough of this fuel to be useful without the addition of unnecessary weight.

A power source for communication purposes must be reliable. We are considering gasoline generators to be the primary power source with auxilary power supplied by windmills. The windmill and generator must be synchronous to supply power with optimum reliability and economics. The question naturally occurs: how reliable are the windmills? This can best be answered by previous experience with aerogeneration. Jacobs[4] produced tens of thousands of aerogenerators in the United States between 1930 and 1960. Some of these aerogenerators were used near the South Pole and Africa and have had reliable performance under extreme weather conditions for two decades with minimal maintenance. This leads the author to believe that windmills in the kilowatt range can be produced to run reliably for ten to twenty years with minimum maintenance.

Discussion

Aerostats currently in use are sixty ft in diameter, 175 ft long and have a helium capacity of one quarter million ft^3. The aerostat has approximately 1000 lb. of net lift and can carry a maximum of 1200 lb. of fuel. The tethering cable which is now being used weighs about 260 lb/1000 ft of cable with a breaking strength of over 20,000 lb. The cable has an outer metallic shield to protect it from lightning and to ground the system.[5] Placed on the aerostat are three Wankel generators of approximately five kw capcity each at an altitude of 10,000 ft. Nine pounds of fuel are consumed in one hour to produce five kw of electricity. This is equivalent to electricity at the rate of 15 cents per kw/hr. An airborne windmill could most likely produce electricity competitive with this price.

In order that airborne windmills be practical, they must be economical, and they must produce the required power with minimal drag. These two criteria must be satisfied without increasing the aerostat's weight. This is accomplished by trading the windmill weight for reduced fuel capacity. A simple, two-bladed, variable pitch windmill is suggested for this purpose. The windmill must be feathered in order to reduce drag at higher wind speeds. Multi- or counter-rotating blades increase the weight far more than is justified by the small increase in performance that they may add to the system.

The weight of an airborne windmill was estimated to be approximately 35 lb per kw for peak power in the range of 5 to 25 kw. Rotor blades and the hub were found to weigh 15 lbs per kw. Generators used with ground-based windmills are slow turning and weigh in the neighborhood of 100 lb per kw, much too heavy for airborne applications. Aircraft generators in the neighborhood of 20 kw and related equipment weigh about ten lb per kw. These generators rotate at a much higher frequency than the windmills thus necessitating the use of gearing. From Ax,[6] it was estimated that the generating gear system compatible with the windmill would weigh no more than 10 lb per kw. The efficiency, ϵ, for producing electricity in this manner would be about 70%. Finally, 10 lb per kw were allowed for support and miscellaneous.

The power in kw, which can be converted to electricity by a windmill is given by Eq. (1). For an ideal windmill, θ equals 1. We take a realistic value of θ to be 0.6 at a wind speed of 30 mph. The overall electrical conversion efficiency, ϵ, for airborne applications was then to be 0.7. Thus, approximately 25% of the energy in the airstream is converted to electricity by the windmill. This is an obtainable estimate. The reader will notice that the power output is a very sensitive function of wind speed. Communication satellites rest at an altitude of approximately 10,000 ft where wind speeds are considerably