Technical Comments

AIAA 81-4048

Comment on "Some Singular Acoustic Signatures Observed in the Cockpit of a Jet Aircraft"

N. R. Keshavan*
Hindustan Aeronautics Limited, Bangalore, India

A PHYSICAL model has been proposed in Ref. 1 to explain the acoustic noise in the cockpit of a jet aircraft. The predominant discrete frequency component in the measured noise at 166 Hz equal to the shaft rotational frequency of the engine at its maximum speed has been attributed in Ref. 1 to the blade tip vortex shedding from blades with excessive tip clearance between the rotor blade and the compressor casing. But a ducted rotor with a few blades having excessive tip clearance alone cannot produce sound efficiently. The larger the number of blades the more closely the rotor approximates a two-dimensional disturbance pattern with subsonic phase speed.[2] From this point of view the model proposed in Ref. 1 is not satisfactory. Mather et al.[3] have proved that a nonidentical bladed rotor interacting with a distorted flowfield produces noise at frequencies related to the shaft speed. The fundamental of this discrete frequency noise occurs at a frequency equal to the number of distortions $\times$ shaft speed and this is a plane wave radiation. A similar situation leading to more serious problems of the failure of the inlet guide vanes has been reported in Ref. 4.

A more appropriate physical model to explain the observed phenomenon of noise radiation at shaft rotation frequency is as follows. A nonidentical bladed rotor with differences in blade camber, angle of incidence, tip clearance or differential twist interacting with a distorted flow containing solitary disturbance around the azimuth produces noise at the shaft rotational frequency. The solitary disturbance in the upstream flow is most probably due to a large atmospheric eddy ingested into the intake of the engine. The pilot's observation reported in Ref. 1 that the intensity of noise heard in the cockpit depends on the altitude of the aircraft also suggests that the atmospheric turbulence is probably the source of distortion in the upstream flow. Hanson[5] has in fact envisaged a similar model of a large atmospheric eddy interacting with an identical bladed rotor to explain the blade passing frequency noise of an identical bladed ducted rotor.

References

[1] Ramachandra, S.M., "Some Singular Acoustic Signatures Observed in the Cockpit of a Jet Aircraft," *Journal of Aircraft*, Vol. 16, Aug. 1979, pp. 513-514.

[2] Morfey, C.L., "Rotating Blades and Aerodynamic Sound," *Journal of Sound and Vibration*, Vol. 28, June 1973, pp. 587-619.

[3] Mather, J.S.B., Savidge, J., and Fisher, M.J., "New Observations on Tone Generation in Fans," *Journal of Sound and Vibration*, Vol. 16, Dec. 1971, pp. 407-418.

[4] Keshavan, N.R., "Acoustic Fatigue Failure of Inlet Guide Vanes Due to Intake Flow Distortions in an Aircraft Engine," *Journal of Sound and Vibration*, Vol. 67, Nov. 1979, pp. 278-279.

[5] Hanson, D.B., "Spectrum of Rotor Noise Caused by Atmospheric Turbulence," *Journal of the Acoustical Society of America*, Vol. 56, July 1974, pp. 110-126.

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*Design Engineer.

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Reply by Author to N. R. Keshavan

S. M. Ramachandra*
Alfateh University, Tripoli, Libya

DR. Keshavan's idea of nonidentical blades with errors in angle of incidence, camber, and twist is interesting and a possible source for noise when coupled with atmospheric turbulence. Atmospheric turbulence eddy ingestion causing this phenomenon should make these observations occasional rather than regular as reported so that the atmospheric turbulence hypothesis may be ruled out. Cockpit observations of the pilot were conditioned by the perceived sound after transmission and en route attenuation and were, indeed, altitude dependent. But, as mentioned in the paper, instrumented acoustic measurements showed the grinding and resonance phenomenon to exist in flight at all altitudes, with the engines running on a stationary aircraft and even during engine test-bed running. Further, compressor blades are gang-milled on profile copy millers and fitted into milled slots on the rotor hub. The assembly is fitted into the compressor casing and clearance checked. Blades are trimmed as required and the entire assembly dynamically balanced. A study of this manufacturing process shows the nonidentical blade hypothesis to be less probable than the nonuniform clearance hypothesis which has also been borne out by the later inspection reports.

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*Professor of Aeronautical Engineering.

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Comment on "Flutter Analysis of NACA 64A006 Airfoil in Small Disturbance Transonic Flow"

H. P. Y. Hitch*
British Aerospace Corporation, Weybridge, Surrey, England

THE crux of the question under consideration by Yang et al.[1] which the author takes to be an assessment of the effect of the so-called supercritical airfoil sections on the flutter behavior of wings, relates primarily to the relative change of C_{L_α} with Mach number compared to the change of C_{M_α} with Mach number. In the first instance, and especially for the 2D-sectional analyses used in the article, the flutter solutions are dominated by the real parts of the aerodynamic derivatives. (Indeed the flutter speeds will be little different if all the non-$\dot{z}$ imaginary terms are omitted.) Putting

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*Research Coordinator, Weybridge-Bristol Division.

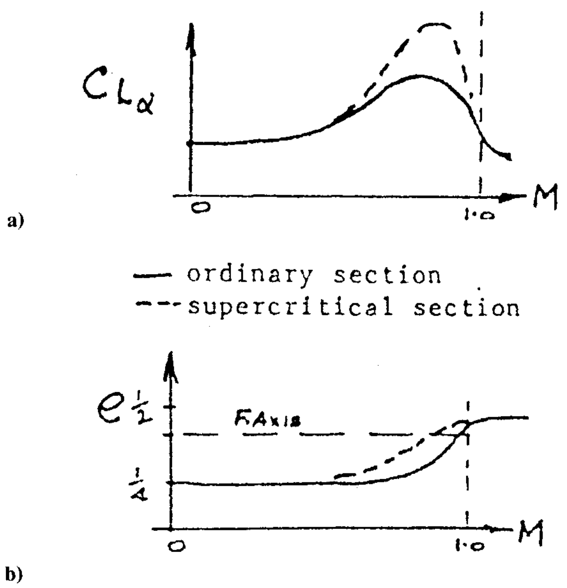

Fig. 1 Mach number vs a) C_{L_α} and b) center of pressure.

$\Re C_{M_\alpha} = \Re C_{L_\alpha} \times e$, which defines e as the center of pressure of the steady incidence loading, the typical shape of $C_{L_\alpha}(M)$ and $e(M)$ is shown in Fig. 1. The supercritical airfoil design-intent relates to steady flow and aims to produce more "aft loading" at the higher Mach numbers, the effect of which can be sketched as shown.

Wing flutter speeds will go down as C_{L_α} increases, and will go up as the CP approaches the flexural axis, i.e., as the CP moves from around ¼ c to around ½ c for a flexural axis near ½C. It would have been helpful had the article presented flutter solutions for these independent variables, e.g., Fig. 7 of Ref. 1 reflects the variation in e, but with an implied variation in mass axis as well. The precise geometry of the dip in flutter speed at high subsonic Mach numbers depends upon the relative effect of these two conflicting influences. The curve will continue to dip under the influence of the increasing C_{L_α} until the CP has moved far enough back to compensate, beyond which further movement aft (coupled with any reduction in C_{L_α}) will cause the flutter speed to rise rapidly.

Wings having supercritical flow, albeit not particularly well arranged, have been in service for some 15 years, and the dip in flutter speed with high subsonic Mach number has been assessed in the U.K. along the preceding lines using, inter alia, data from steady wind-tunnel tests.

The current aerodynamic ability to design wings, advantageously having supercritical flow, implies that C_{L_α} will climb higher and "break" more rapidly at a higher subsonic Mach number, and the CP will move aft at an earlier subsonic Mach number. From the flutter specialists' point of view, the question is whether or not a supercritical wing can be designed with an aft CP shift which is more favorable than the unfavorable C_{L_α} increase, and thereby either increase the flutter margins or reduce the weight of any antiflutter means necessary.

Finally, it is still an open question as to how to assess the additional effect of the interaction between shock position and shock strength with amplitude and character of motion. In this connection, the recent paper by Ashley (Ref. 2 of the article) is very relevant, and the whole phenomenon is reminiscent of the work on "buzz" in the late 1950's, references to which are very relevant.

Reference

[1] Yang, T.Y., Guruswamy, P., Striz, A.G., and Olsen, J.J., "Flutter Analysis of a NACA 64A006 Airfoil in Small Disturbance Transonic Flow," *Journal of Aircraft*, Vol. 17, April 1980, pp. 225-232.

AIAA 81-4051

Reply by Authors to H. P. Y. Hitch

T. Y. Yang,* P. Guruswamy,† and Alfred G. Striz†
Purdue University, West Lafayette, Ind.
and
James J. Olsen‡
Air Force Wright Aeronautical Laboratories
Wright-Patterson Air Force Base, Ohio

THE authors would like to thank Mr. Hitch for his interesting comments. Also, they would like to acknowledge that similar comments were expressed to them by Walter Mykytow at the 21st Structures, Structural Dynamics, and Materials Conference in Seattle, Wash., in May 1980.

Indeed, the variations of ReC_{l_α} and e (distance of center-of-pressure from leading edge, measured in chords) with Mach number for the airfoils studied show trends similar to those pointed out by Mr. Hitch. The resulting plots for the NACA 64A006, NACA 64A010 (Ref. 1 of the original paper), and MBB A-3[1] airfoils are presented in Fig. 1 for $k_c = 0.1$. The authors have tried other k_c-values and found similar trends.

From the data obtained for the three airfoils, it appears that ReC_{l_α} peaks earlier, and the CP aft-shift comes at a lower transonic Mach number for the MBB A-3 supercritical airfoil

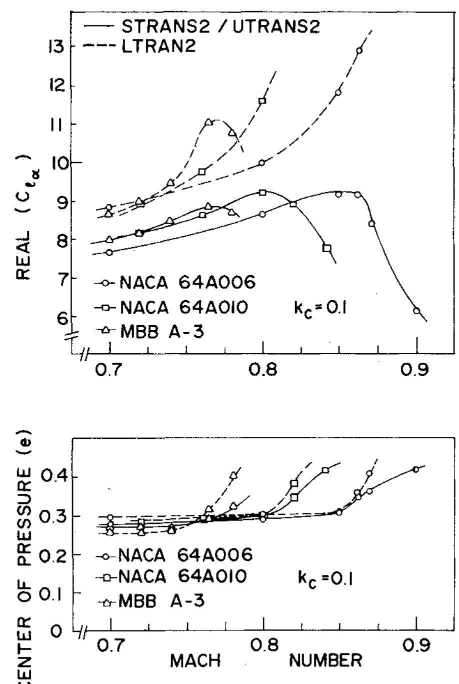

Fig. 1 Effect of Mach number on $Re(C_{l_\alpha})$ and the position of center-of-pressure for $k_c = 0.1$.

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*Professor and Head, School of Aeronautics and Astronautics. Associate Fellow AIAA.

†Graduate Research Assistant, School of Aeronautics and Astronautics. Member AIAA.

‡Assistant for Research & Technology, Structures and Dynamics Division, Flight Dynamics Laboratory. Member AIAA.

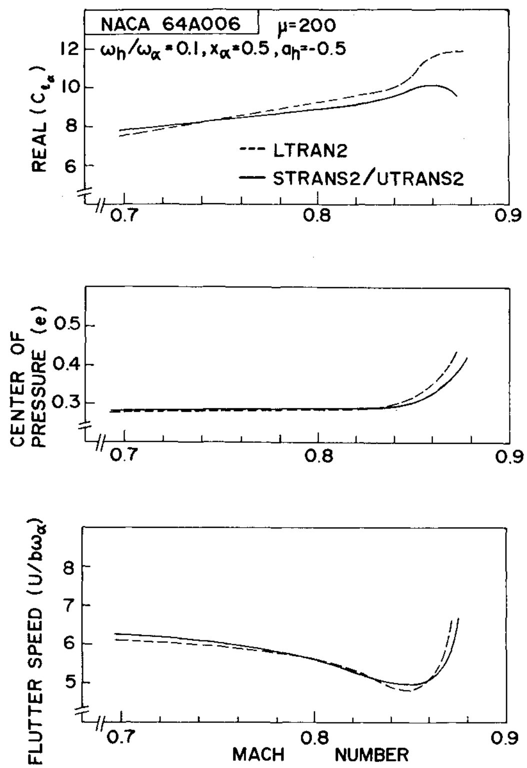

Fig. 2 The compensating effects of $Re(C_{l_\alpha})$ and the position of center-of-pressure on flutter speed.

than for the two conventional airfoils. Also, the peak of ReC_{l_α} for this supercritical airfoil is not as pronounced as those for the NACA 64A006 and NACA 64A010 conventional airfoils.

Figure 2 illustrates the compensating effects of ReC_{l_α} and e on flutter speed for the NACA 64A006 airfoil. As ReC_{l_α} increases, the flutter speed drops at a comparable rate. The e-value remains more or less unchanged up to about $M=0.84$. After that, the e-value increases noticeably, i.e., the center-of-pressure moves aft. The effect of this aft movement appears to increase the flutter speed sharply.

In the original paper, the authors considered the effect of shock strength on flutter results. But, due to the limitations of both the indicial and the harmonic methods, the effect of shock movement on flutter results could not be considered.

Reference

[1] Yang, T.Y., Striz, A.G., and Guruswamy, P., "Flutter Analysis of a Two-Degree-of-Freedom MBB A-3 Supercritical Airfoil in Two-Dimensional Transonic Flow," AIAA Paper 80-0736, *AIAA/ASME/ASCE/AHS 21st Structures, Structural Dynamics, and Materials Conference Proceedings,* Seattle, Wash., May 12-14, 1980, pp. 434-443.

Errata

Analysis and Design of Strake-Wing Configurations

John E. Lamar*
NASA Langley Research Center, Hampton, Va.
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THE following figures should replace Figs. 8 and 9 which appeared on pages 23 and 24, respectively.

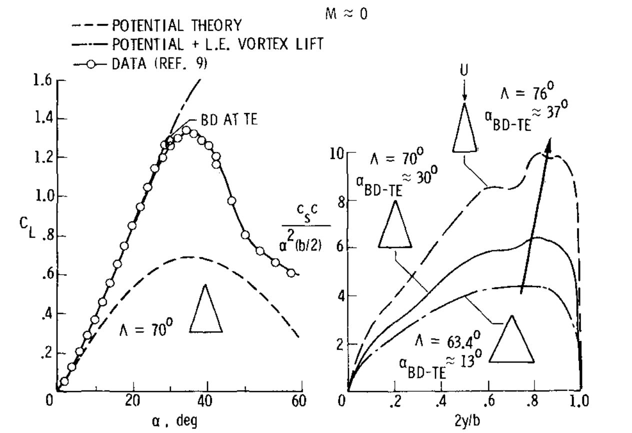

Fig. 8 Delta wing vortex breakdown angle correlation with leading-edge suction distribution, $M \approx 0$.

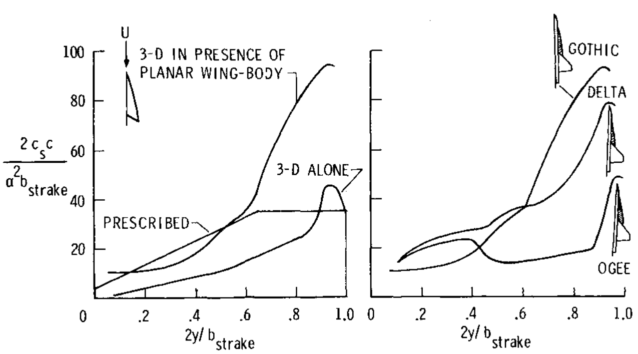

Fig. 9 Strake and strake-wing leading edge suction distributions, $\Lambda = 44$ deg, $M = 0.2, 0.3$.

Received Feb. 4, 1980. This paper is declared a work of the U.S. Government and therefore is in the public domain.
*Aeronautical Research Scientist. Associate Fellow AIAA.