Comment on "In-Flight Measurement of Static Pressures"

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REFERENCE 1 includes some very interesting in-flight measurements of the steady and fluctuating trailing-edge pressures on an A310-200 aircraft at high speeds. However, Ref. 1 includes two remarks which could mislead some readers.

When discussing the measured pressure spectra (Ref. 1, Fig. 11) it is noted that "The harmonics of torsion can be detected up to eighth order. Such *excitation* indicates strong *buffet* motion." It is true that the peaks in the spectra indicate motion (better "response" or "buffeting" as defined in Ref. 2). The peaks cannot represent "excitation" (buffet) at those frequencies. The separations concerned are incipient and of very small scale. Hence, these are unlikely to be modifying the excitation. These motion-induced pressures should be related directly to the aerodynamic damping. It would be interesting to reanalyze the data to see if there are any changes in the phase of the trailing-edge pressures with respect to the wing motions as C_Z increases at constant Mach number.

Later in the article there is a curious reference to buffet frequencies of 45–70 Hz for aerofoils and Ref. 3 is cited. Such discrete excitation (buffet) is determined by a frequency parameter based on the aerofoil chord (only 0.25 m in Ref. 3). With respect to a local chord of about 3.8 m at 71% semispan on the aircraft, the frequency parameter of Ref. 3 would imply frequencies of about 3–5 Hz for flight at sea level. Therefore, the reference to "f_b = 25 Hz" at $M = 0.73$ is unhelpful. Attribution of the lower frequencies observed to "three-dimensional flow at flight conditions" is wrong. It is well known that the excitation on aerofoils and high-aspect-ratio swept wings is, in fact, similar in character (e.g., Ref. 4).

References

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[2]Mabey, D. G., "Some Aspects of Aircraft Dynamic Loads Due to Flow Separation," *Progress in Aerospace Sciences*, Vol. 26, Pt. 2, 1989, pp. 115–151.

[3]Lee, B. H. K., and Ohman, L. H., "Transonic Buffeting of a Supercritical Airfoil," *Journal of Aircraft*, Vol. 21, No. 6, 1984, pp. 439–444.

[4]Roos, F. W., "The Buffeting Pressure Field of a High-Aspect-Ratio Swept Wing," AIAA Paper 85-1609, 1985.

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Reply by the Author to D. G. Mabey

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MABEY's comments are appreciated as he is a reknowned expert in the field of unsteady transonic flow and buffeting criteria. This knowledge, however, is based mainly on NACA 6 sections and generic three-dimensional models with rectangular wings.[1] For modern transonic wings his hypothesis has to be rethought in some respect, and there are also other authors who do not agree with his conclusions.[2]

Comment No. 1

There is no definite statement in the article saying that the peaks represent excitation. The peaks in Fig. 11 were denoted as "harmonics of strong buffet motion," i.e., that the pressure fluctuations at the trailing-edge are induced by an oscillation of the shock wave. Buffeting is then the dynamic response of the structure as a result of the aerodynamic excitation arising from the load changes on the wing due to the shock-induced separation. The result is a plunging and pitching motion of the wing with corresponding incidence variations which can also be detected as harmonics in the spectrum of the pressure fluctuations. Contrary to the comment of Mabey, it has to be noted that the cited test results obtained in a wind-up turn with progressively increasing lift up to $C_L = 0.9$ (which is close to $C_{L\max}$) is combined with a large shock-induced separation extending from the shock foot to the trailing edge. It is a well-known fact for transport wings with supercritical airfoils, that high-speed stall and buffet-onset are close together. Through the correlated shock-wave amplitudes and corresponding reattachment/separation-cycles, the excitation may well be modified.

A reanalysis of the data to see a phase change of the trailing-edge pressure with respect to the wing motion would, of course, be interesting. Unfortunately, no separate measurement of the wing motion by accelerometers was available on the aircraft.

Comment No. 2

Mabey's hypothesis that the reduced frequency $\nu_{red} = 2\pi \cdot f \cdot c/U_\infty$ from the two-dimensional results of Ref. 3 has to be transposed to the three-dimensional wing would of course lead to 2.95–3.32 Hz for the 3.506-m chord and 35,000-ft altitude of the A310 test case. It may be that Mabey derives his assumption from his own tests on a NACA 64A010 section and a simple unswept rectangular wing of the same section.[1] This type of flow does not seem to be relevant at buffet onset on swept supercritical transport wings. Moreover, Benoit and Legrain[2] performed tests with a similar setup, including sweep variation and a more realistic transport aircraft wing, and could not explain their results with Mabey's hypothesis.

Shock-wave oscillations on airfoils are more stable and quasiperiodic in contrast to wings, where the shock location is influenced by the pressure field of the inboard and tip regions which may still exhibit attached flow. This may explain smaller shock amplitudes and hence, a higher reduced frequency in three-dimensional flow. Note that the observed "buffet" frequency on the A310 of 25 Hz is equivalent to $\nu_{red} = 2.56$, whereas, the two-dimensional test from Ref. 3 showed values of $\nu_{red} = 0.3–0.34$. Therefore, the wording in Ref. 1 where absolute frequencies were compared may have been misleading.

References

[1]Mabey, D. G., Welsh, B. L., and Pyne, C. R., "A Summary of Measurements of Steady and Oscillatory Pressures on a Rectangular Wing," *Aeronautical Journal*, Vol. 92, No. 911, 1988, pp. 10–28.

[2]Benoit, B., and Legrain, I., "Buffeting Prediction for Transport Aircraft Applications Based on Unsteady Measurements," AIAA 5th Applied Aerodynamics Conference, Monterey, CA, Aug. 17–19, 1987.

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