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Engineering Notes

Effect of Microtab on Reduction of Noise Due to Aircraft High-Lift Devices

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I. Introduction

DEFINED as the "nonpropulsive noise of an aircraft in flight" in [1], noise produced by airframe components becomes significant during the approach-to-land phase of aircraft operations. Research efforts on identifying and understanding the noise sources associated with the individual airframe components, in particular, high-lift systems, have been undertaken by many researchers [2]. It has been confirmed experimentally in [3–5], and analytically by using empirical methods [6], that both leading-edge slats and trailing-edge flap side edges are the most important noise contributors from the high-lift systems to overall noise levels of an aircraft in approach.

The high-lift noise, intuitively thinking, is configuration dependent. Any increase in the deflection angle of slat and flap will lead to an increase in overall noise level. The larger the deflection angles are, the higher the noise level will be. This is due to the fact that the high-lift components are more loaded when their deflection angles are increased, generating what is referred to as the loading noise. Further, higher deflection angles may induce stronger vortex shedding and turbulent wake downstream which causes higher noise. Such intuitions were supported by experiments conducted at NASA Langley Research Center in 1998 and 2002 [7], which revealed that slat noise is generated due to its configuration setting angles. Khorrami et al. [8] hypothesized with 2-D unsteady computation that the vortex shedding at the slat trailing edge was responsible for the additional high-frequency spike observed only at higher slat angles. An acoustic whistling mechanism at the slat gap due to vortex shedding was later proposed by Tam and Pastouchenko [9] and Agarwal [10]. The theory supported that the simple vortex shedding and feedback mechanism resonating with gap tone frequency caused noise amplification and propagation. Similar observations were made for flap noise, as reported in [11,12]. Both references reported that the measured noise level at higher flap deflection angles exceeded the predicted noise level, which suggests that there might be an additional source contributor, most likely vortex instabilities, as a result of its interaction with the nearby flap upper surface. It may be noted that such phenomenon was not seen at lower settings of flap angles. These observations may infer that high-lift device noise level is directly affected by the configuration setting angles of slats and flaps. In general, high-lift device noise sources are present at wide frequency ranges of low-to-mid and mid-to-high. At a fixed observer location, under a constant flow speed, slat noise is dominant in the low-to-midfrequency range, and flap side-edge noise is dominant at the mid-to-high-frequency range as shown by both Guo and Joshi [13] and Guo et al. [14]. In this study, the proposed technique uses reduced deployment angles of both high-lift devices simultaneously to achieve the most effective noise reduction in different frequency domains. Aerodynamics performance also has to be carefully monitored to ensure no significant loss is present.

The objective of the current Note is to examine the effectiveness of a microtab device in airframe noise reduction. Reducing deployment setting angles of both slats and flaps, the associated noise can be alleviated. Loss in aerodynamic lift, as a result of the reduced high-lift settings, is compensated by use of a microtab device. The microtab device can be viewed as a small spanwise strip located at the pressure side of flap near the trailing edge, similar to a Gurney flap (Fig. 1). While deployed normal to local airfoil surface, the microtab device alters the local flowfield which leads to increased effective camber, and hence improves lift-to-drag ratio, similar to that of a Gurney flap introduced by Liebeck [15]. In the present work, a three-dimensional numerical analysis is presented and compared to sound pressure level (SPL) of the proposed microtab configuration at a specified far-field location to that of the baseline, that is, conventional configuration in approach, to see if any reduction in noise can be achieved.

II. Computational Study

The computational aeroacoustics simulations of a three-element high-lift wing derived from a Boeing 737 with and without microtab are studied. Detailed simulation procedures and models are presented as follows.

A. Acoustic Analogy

A Ffowcs Williams and Hawkings (FW-H) solver is embedded to the flow solver to calculate acoustic contents emitted to specified far-field observer locations. The time-accurate simulation was started with a nondimensional time step of 0.002 (scaled by freestream velocity and the stowed chord length) and was continued until

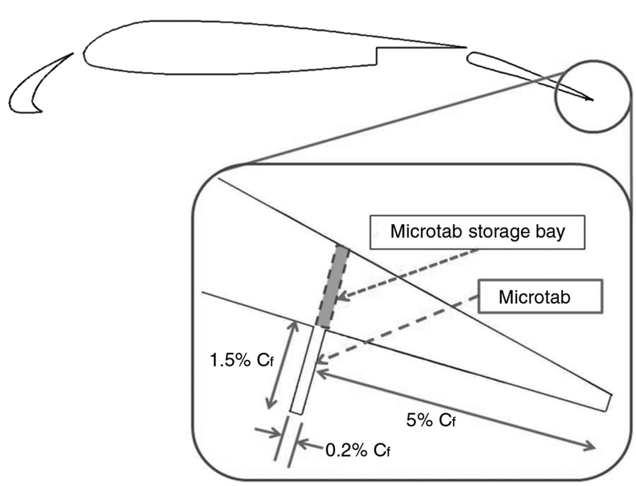

Fig. 1 Conceptual diagram of microtab device in the current study.

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