Noise Control on Flap Side Edge

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ABSTRACT

Efficient aircraft noise reduction is a major factor for continuing growth of civil aviation. In addition to low noise flight procedures it is essential to reduce the noise directly on the source. Within the last decades large effort has been spent to successfully reduce the engine noise contribution. During landing approach, however, airframe noise is of comparable importance as the engine noise. Therefore, further noise reduction studies consider also the major airframe sources, i.e. landing gears and high lift devices. High lift device sources are usually differentiated in to the slat sources and the flap side edge source, latter being the main focus of the present paper. Studies have been performed within the last years on the mechanisms and the modelling of high lift device noise sources, providing a number of numerical, semi-analytical modelling approaches for the local flow unsteadiness, which is the drive of the farfield acoustics. Also remarkable reductions of flap side edge noise at the source have been demonstrated by designs such as e.g. flap fences or porous side edges in model scales. The present work shall provide a novel low noise flap side edge tested in a parametric wind tunnel study.

Keywords: Flap Side Edge

1. INTRODUCTION

In the frame of the European Project “RAIN, 1999” the side edge of a deployed flap were identified as a dominant airframe noise source by microphone array measurements in a aeroacoustic wind tunnel study (figure 1).

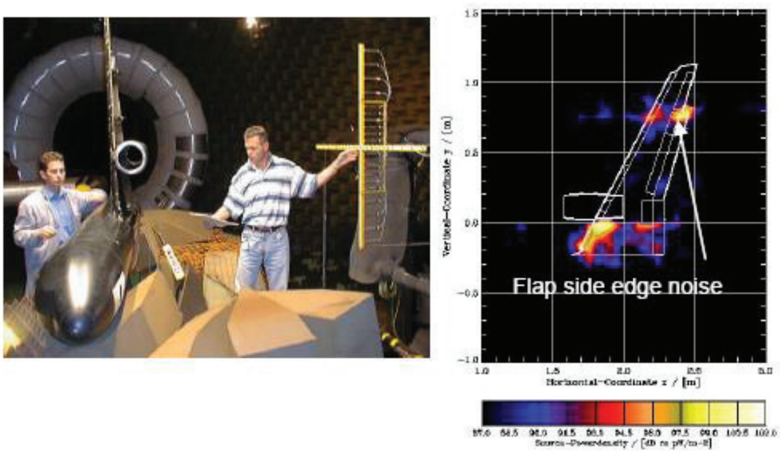

Figure 1 – Flap Side Edge Noise identified by microphone array technique in the wind tunnel

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In the last decade noise reduction measures for a flap side edge were developed [1, 2, 3]:

- Porous flap side edge (figure 2a)
- Profile fence (figure 2b)
- Microperforations
- Toothed trailing edges of a profile
- Acoustic liners (figure 2c)

a) Porous side edge   b) Profile fence   c) Acoustic liner

Figure 2 – Noise reduction measures

The objectives of the present study are the development of a novel side edge which is **silent and aerodynamic efficiently**.

2. NOISE SOURCE MECHANISMS

The tip vortex generation is caused by the static pressure difference between upper and lower flap surfaces. The vortex system is particularly characterized by the fact that in the flap upstream region two separate vortices are generated, one at the lower edge of the flap side contour, one at the upper edge of the flap side contour. With increasing chord the lower vortex is following the mean stream lines and moves upward. It is passing the upper edge of the flap side contour and interacts and merges with the upper vortex. This leaves a single side edge vortex which is continuously fed with vorticity from the shear layer emanating from the lower edge of the flap side contour, producing a strong jet-like flow in the vortex core with high streamwise velocities.

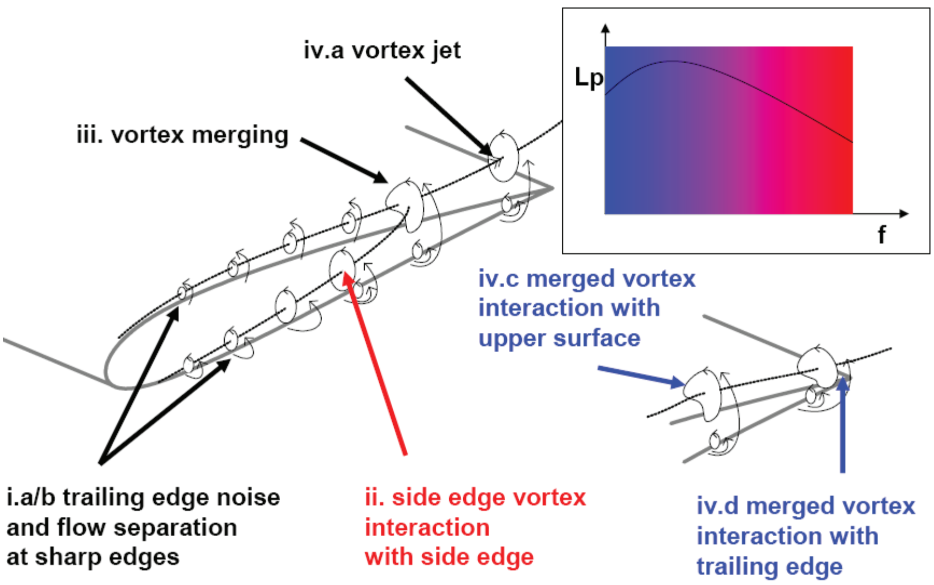

Figure 3 – Simplified scheme for the flap side edge local flow field.

From these described local mean flow fields (figure 3) following possible noise generation mechanisms may be derived:

i. Trailing edge noise and flow separation at the sharp edges. (a.) The turbulent boundary layer on the pressure side of the flap is traveling across the lower flap side edge. Comparable to trailing edge noise mechanisms the flow pressure fluctuations are partly converted into acoustically radiated noise by passing this discontinuity. This mechanism is present for the entire flap chord region. (b.) The turbulent boundary layer on the side of the flap is travelling across and separating at the upper flap side edge.

ii. The side edge vortex pressure fluctuations are interacting with the flap side surface and the upper sharp side edge. Hereby, the vortex is continuously fed by shear instabilities emanating from the lower side edge which may provide an oscillating and rotating vorticity field. This mechanism is present at the mid chord region, for a merging location close to the trailing edge this region may be extended up to the trailing edge too.

iii. The two vortices merge.

iv. The merged vortex pressure fluctuations are interacting with the flap suction side and the upper sharp side edge. (a.) In case that the merged vortex is moving quite soon upwards this mechanism is limited to a small region slightly downstream of the merging location, however, in addition a jet-like noise generation in the accelerated vortex core may play a certain role. (b.) In case of a vortex breakdown this mechanism is replaced by the vortex breakdown itself as noise source. (c.) In case that the merged vortex stays close to the upper surface the instable vortex interacts with the flap suction side and the upper side edge. (d.) In case that the merged vortex also passes the trailing edge the additional interaction with the trailing edge corner must be considered.

3. NOVEL FLAP SIDE EDGE

The novel flap side edge represented in figure 4 reduces the generation of the side edge vortices, those are responsible for

a) the flap side edge noise
b) the aerodynamic lift and drag

This geometry shape is used for example successfully in the world of birds. For the application of this concept target functions are to be defined and the design parameters resulting from it to be determined. In an aeroacoustic and aerodynamic wind tunnel test this new concept was successfully tested.

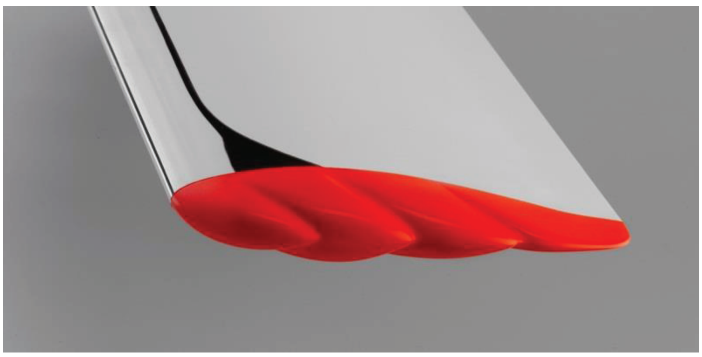

Figure 4 – Novel flap side edge

3.1 Wind Tunnel Test

The acoustics of a generic flap model as reference and modified side edge were measured in the aeroacoustic wind tunnel (AWB, DLR Braunschweig) with microphone arrays and far field microphones (figure 5). The flap has a chord length of 135 mm, span 400 mm and height of 20 mm.

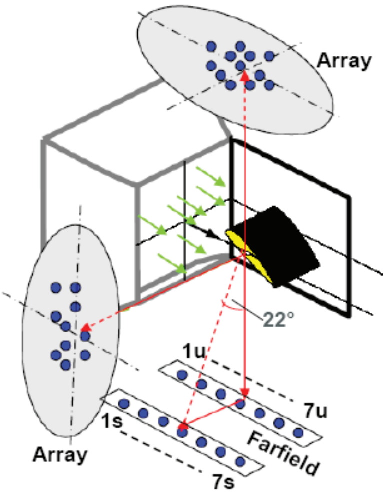

Figure 5 – Aeroacoustic wind tunnel with the test setup.

3.2 Acoustic Results of Measurement

The modified side edge was optimized on an angle of incidence of alpha 5°. The measurements were carried out for wind velocity (40, 50 and 60 m/s) and an angle of attack from -20° to +20° in 5°-steps. A noise reduction of 5 dB was reached (figure 6),

- dependent on the angle of attack, whereby alpha 5° shows best noise reduction (figure 7)
- independently of the flow velocity
- works in the frequency range from 200 Hz to 16 kHz

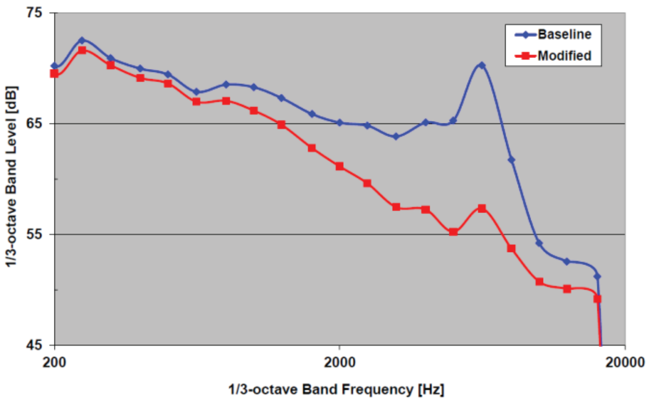

Figure 6 – Noise reduction potential by means of low noise side edge with flow velocity 50 m/s, alpha =5°, 1/3-octave-band sound pressure spectrum with the microphone array measured.

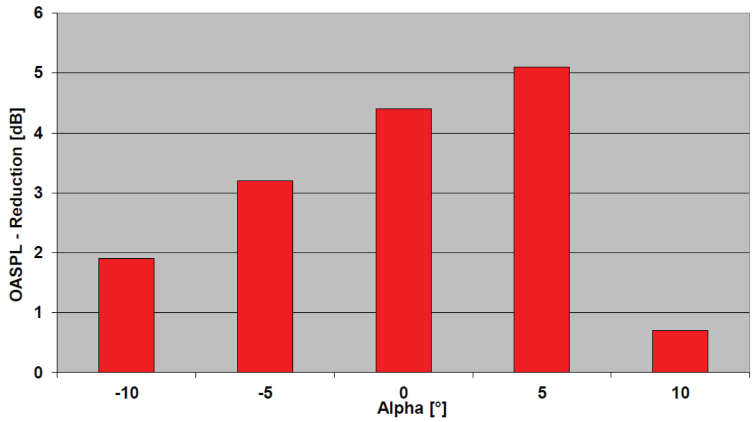

Figure 7 – Reduction of the total sound pressure level dependent on the angle of incidence alpha.

This new flap side edge concept was tested also in die aerodynamic wind tunnel (Technical University Munich) and shows a significant increase of the lift and reduction of the drag.

4. CONCLUSIONS

The presented novel flap side edge shows a significant noise reduction on the side edge and in the farfield. Aerodynamic tests show also drag reduction and lift increase.

Possible applications are:

- Flap side edge
- Winglet
- Wing tip
- Landing gear
- Pylon (interaction)
- Rotor blade tip
- Fan blade tip

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