Flow induced sound radiated by a forward facing step with different geometries

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The perturbation of the flow over the exterior surface of airplanes by small steps plays an important part in the generation of aeroacoustic noise. Those steps appear at skin lap joints, window gaskets and other flow perturbing obstacles. Due to manufacturing imperfections, step heights in the range of 0.8 mm to 5 mm are produced due to skin-joint mismatches and glassing contours.

Therefore, the precise understanding of the correlation between fluid and acoustic quantities for this kind of geometry is of relevance. The physics behind the noise generation process is quite complicated and still not fully understood for this simplified geometry.

![Fig. 1 Basic flow configuration: forward facing step](image)

The strategy of our investigations was to combine the numerical and experimental tools at the University of Erlangen-Nuremberg. This presentation is focused on the experimental part of the investigations. For the experiments in a low noise wind tunnel environment we made use of synchronous measurement techniques and a microphone array to identify relevant regions which were responsible for the noise generation. Correlation analysis was applied to the wall pressure fluctuations and velocity characteristics of the flow in respect to the recorded far-field sound pressure.

Measurements were carried out in an aeroacoustic wind tunnel which is integrated into an anechoic chamber. The chamber has a lower cut-off frequency of 300 Hz. The anechoic environment allows for the measurement of the directional pattern of the radiated sound.

Different measurements have been taken using flows with Reynolds numbers (based on step height) ranging from 8000 to 24000 which relate to flow velocities from \( U_0 = 10 \) m/s to \( U_0 = 30 \) m/s. The step height \( H \) was always 12 mm. Investigations at \( \text{Re}=8000 \) were carried out with a laminar boundary layer while at \( \text{Re}=24000 \) a tripping tape was used to generate a turbulent boundary layer at the inflow. The flow induced noise field of the forward facing step was recorded at a distance of 1 m at an angle of 45° and 90° relative to the plate with microphones placed outside of the flow. The results displayed in Figure 2 illustrate the broadband nature of the radiated noise of the step. Hereby the cross spectrum between the simultaneously recorded signals at an angle of 45° and 90° was evaluated in order to suppress uncorrelated noise between these two microphones and thereby yielding a higher ratio between the signal of interest and background noise.

![Fig. 2 Cross spectra of flow induced noise of forward facing step with sharp edge using microphone](image)

The sound generated by the forward facing step had broadband nature radiating significant amounts of noise in the frequency range of 2 kHz to 10 kHz (at \( \text{Re}=24000 \)). Extensive investigations were performed by using the correlation technique. The objective was to get a better understanding of the mechanics of flow induced sound concerning the forward facing step. The results show that only in the closed region in front of and around the sharp edge a connection between velocity distribution and local wall pressure to the far-field sound pressure can be found. This region contained a large two-dimensional vortex structure. Behind the step the flow was three dimensional. The spatial correlation of wall pressures in lateral direction to the mean flow was less correlated. The turbulent flow pattern underwent transition into an isotropic structure.

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