Measurements of sound-flow interaction at a bias flow liner

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Purpose

Optimization of sound absorbing bias flow liners in aircraft engines or gas turbines [3] demands a deeper understanding of the damping mechanism of those liners. A bias flow liner is a perforated sheet with a cavity behind, where an air flow is driven through the perforation in order to interact with the acoustic field, which leads to the damping of the propagating sound wave [1]. However, the interaction of sound and flow has not yet been understood completely.

For this reason, contactless measurements of both the acoustic particle velocity (oscillation due to sound field) and the flow velocity field at a bias flow liner are required. To capture the complex interaction phenomena, multi-component and multi-dimensional velocity measurements are necessary. Since the acoustic particle velocity is typically in the range of a few mm/s, a low measurement uncertainty (< 10 mm/s) is demanded. In addition, velocity spectra with a Nyquist frequency up to 20 kHz are needed to analyze the energy transfer from sound to vortex field in order to enhance the understanding of the sound absorption mechanisms.

Results

In this paper, laser optical measurements of the acoustic particle velocity using FM-DGV (Doppler global velocimetry with sinusoidal laser frequency modulation) are presented. FM-DGV offers a velocity measurement rate up to 100 kHz and a low uncertainty of 5 mm/s at a measurement duration of 80 s and, thus, meets the requirements for the measurement task [2].

The application of FM-DGV at an aeroacoustic duct with a maximum flow Mach number of 0.25 is presented: Firstly, the measurement of the acoustic particle velocity using FM-DGV is successfully validated by reference data obtained with a well-proven microphone measurement technique at a sound-reflecting surface. Thereby, a good agreement with the micro-phone technique and the acoustic particle image velocimetry (A-PIV) was achieved.

Secondly, a measurement of three velocity components at a bias flow liner with grazing flow and sinusoidal acoustic excitation was conducted using FM-DGV. The measured mean flow velocity field contains both the bias flow jet and the grazing flow of both Mach 0.1. The flow velocity oscillation field shows amplitudes up to 2.5 m/s which comprise not only the acoustic particle velocity but also an acoustically induced hydrodynamic velocity oscillation (vortex field). To analyze the energy transfer from the sound field to the vortex field in more detail, a spectral analysis of the flow velocity was carried out.

As a result, there is a spectral power increase of the velocity near the liner for high frequencies (cf. Figure 1), when the acoustic excitation (frequency 1122 Hz) is turned on. This supports the assumption of acoustically induced small scale vortex generation. Since there is a power loss in the low frequency range, also an acoustically induced large scale vortex collapse is indicated here. Future investigations are required to explain these interaction phenomena better in order to gain a deeper understanding of the damping mechanisms at bias flow liners.

![Figure 1: Increase and decrease of spectral velocity power above the central orifice of the liner in case of acoustic excitation (frequency 1122 Hz)](image)

Conclusion

The FM-DGV system was applied to investigate the sound flow interaction at a bias flow liner. First measurements reveal the potential of FM-DGV for capturing acoustically induced flow velocity fluctuations at a generic bias flow liner with grazing flow. In order to enhance the understanding of the damping phenomena at bias flow liners, the energy transfer has to be identified and completely quantified. Therefore, an extension of the FM-DGV system towards three-dimensional measurements is obligatory.

References