Investigations on a Backward-Facing Step by Means of a Microphone Array and IR-Thermography

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Aspects of the flow of a space transportation system are investigated by means of a generic, planar wind tunnel model with backward-facing step at Mach 6 and a unit Reynolds number of $16 \cdot 10^6\,\mathrm{m}^{-1}$ in the hypersonic wind tunnel Cologne (H2K) with respect to the flow effects in the base. In this region, typical space transportation configurations feature an abrupt geometry change from the base to the nozzle, which is characterized by the effects of a separating-reattaching flow. The two-dimensional backward-facing step is chosen due to the similarity in the shear layer instability process to an axisymmetric step (Ref.[1]) and the improved accessibility for a number of measurement techniques. The combined measurement results of a microphone array and IR-thermography are studied with regard to static and dynamic behavior like the reattachment length, streamwise structures induced by centrifugal instabilities, dominant frequencies and coherences and corresponding modes that are correlated to flapping and shedding.

The results presented below are an excerpt of the measurement results of the planned paper. Fig. 1 shows an isometric view on the backward-facing step visualized with the combined measurement results from IR-thermography and the microphone array. The microphones are located on each intersection of the depicted grid. The temperature distribution indicates with the blue color (representing the lower temperature) a detached flow region. Downstream from that region, the pattern of various patches elongated in the streamwise direction reveal vortices in the reattachment mechanism. These vortices are very likely to be caused by the Dean instability due to centrifugal forces in the convex streamlines of the reattaching flow. The microphone signals on the array are analyzed here with respect to the skewness of the probability distribution function and reveals noticeable features with respect to the unsteady behavior of the reattaching flow. Positive values of skewness occur if large positive pressure fluctuations are more frequent than negative ones.

Fig. 2 shows the power spectral density (PSD) of the microphones on the centerline of the array in the streamwise direction. The PSDs reveal a highly dynamic behavior in the recirculation region with several distinct tonal pressure peaks that widen to a broadband signal further downstream close to the reattaching flow. This information is used to average the pressure signals over one phase for the determination of the dominant modes.

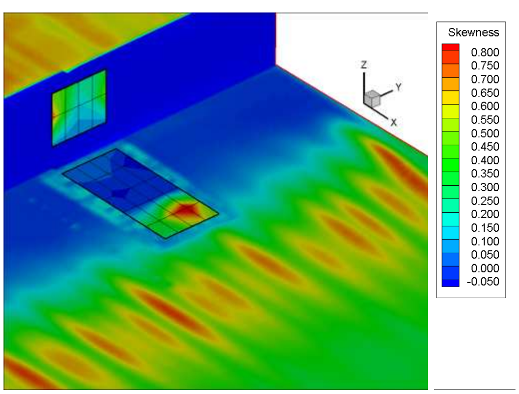

Figure 1. Joined measurement results showing an IR-image and the skewness of the PDF for each microphone

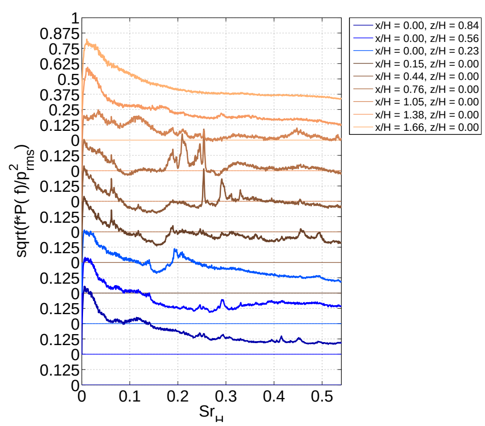

Figure 2. PSD of the microphones along the centerline of the array (at $y = 26.1\mathrm{mm}$)

References

[1] Deck, S. and Thorigny, P., "Unsteadiness of an axisymmetric separating-reattaching flow: Numerical investigation," *Physics of Fluids,* **19**, 2007.

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