Parry the Attack of the Simulators: Why Experiments are necessary to validate and complement Numerical Simulations: Fluid-Structure Interaction of a Membranous Structure

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ABSTRACT

Coupled fluid-structure interaction (FSI) problems are nowadays often tackled by simulations applying sophisticated (monolithic/partitioned) methodologies describing the fluid flow, the dynamics of the structure and the coupling effects by the fluid forces and deformation of the structure. Indeed, large effort was put into the development of these tools and a significant progress has been achieved. Thus, sometimes the question arises whether we still need experimental investigations.

The present paper tries to contribute to the answer of this question considering the fluid-structure interaction of a flexible membranous structure within a turbulent flow. For this purpose, a new experimental setup was constructed investigating a thin-walled hemispherical structure exposed to a turbulent boundary layer generated in a wind tunnel using especially designed turbulence generators. The hemispherical model (D = 0.15 m) consists of a thin membrane (thickness t = 0.16 mm) made of silicone and is stabilized by a small gauge pressure. Such air-inflated membranous structures are used for example as a roofing in sport facilities. Three Reynolds numbers are investigated. Various measurement techniques are applied to capture the fluid flow as well as the structure deformation. Particle-image velocimetry (PIV) based on a high-spatial resolution mono-PIV setup using a CCD camera at a maximum sampling rate of 1.67 fps is the main measurement technique to determine the instantaneous flow as well as statistical quantities such as time-averaged velocities and Reynolds stresses. Additionally, a standard hot-film probe is applied to measure the velocity spectra at specific monitoring points close to the surface of the flexible hemisphere at a much higher data rate of 2000 Hz. The structure deformations are determined by a high-speed camera system in a stereoscopic setup based on a digital-image correlation (DIC) algorithm with a frame rate of 250 fps. The measurements allow to characterize the complex FSI between the deformable structure and the fluid flow [1,2]. In parallel, high-fidelity numerical simulations based on large-eddy simulations combined with a FSI coupling algorithm and a FEM solver for the structure were carried out for this case [3].

Besides the validation purpose, the experimental data also serve to better understand the complex physics involved in this FSI case, since the advantages and drawbacks encountered by both simulations and experiments are complementary. For example, the experiments easily allow to record a long time-span which is the basis for accurate time averages (first and second moments) or an appropriate frequency analysis. The simulations on the other hand allow a higher temporal and spatial resolution but for a limited time-span due to CPU-time restrictions. Furthermore, due to different setup requirements of the PIV and DIC techniques, the measurements have to be carried out independently. Contrarily, the simulations synchronously provide data for the fluid and the structure allowing more easily to link both. Thus, experiments and simulations are fully complementary and should not be played off against each other. This point of view will be discussed in the presentation.

REFERENCES

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