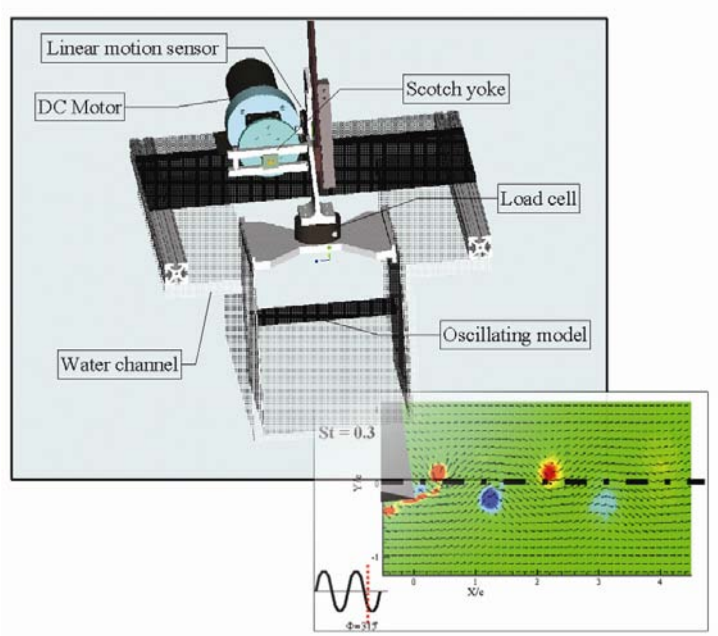
PIV Measurements of the Asymmetric Wake of a Two-dimensional Heaving Airfoil

Application Note PIV-011

Owing to possible applications in the efficient propulsion of small-scale marine vehicles, there has been a recent surge of interest in oscillating airfoil flow. Here, the pure heaving motion of an airfoil, which oscillates at zero angle of attack in a direction perpendicular to the plane of its planform, is studied. At lower Strouhal numbers, the positions of the vortical structures in the flow are symmetrical about the mean heave line. However, starting at St ≈ 0.6 this symmetry is lost. Here, phase-locked PIV measurements are used to quantify this effect and to track the motion and strength of vortices shed by the oscillating airfoil.



The investigation of the asymmetric wake of a 2D heaving foil was performed with the 4MP camera (4 million pixels) and the ***INSIGHT* 3G** software. The measurements were taken phase-locked with the oscillations so that the wake deflection angle could be obtained.

High resolution PIV measurements are made using a TSI PowerView™ Plus 4MP (2048 × 2048 pixels) 12-bit camera. A 60 mm focal length lens is used to image a 200 x 200 mm^2 area of the flow at a magnification of M = 1/13.3 and f/# 2.8. The flow is seeded with 11 µm hollow glass spheres (specific gravity of 1.1 gm/cm^3) and the PIV laser light sheet illumination is provided by using a 532 nm Nd:YAG pulsed laser system.

The Strouhal number $St = fA/U_\infty$ is varied by changing the oscillation frequency f of the foil; the freestream velocity U_∞ and heave amplitude are held constant. For each phase of the forcing cycle 50 velocity fields are acquired. The vector fields are determined using a CDIC deformation algorithm (Wereley & Gui 2003) combined with the Hart correlation method. The processing scheme is available in TSI's ***INSIGHT* 3G** software. This four-pass method used an interrogation region of 32 × 32 pixels with 75% overlap (final size). The vector fields were validated using standard velocity range criteria and a local median filter. Finally, any missing vectors were interpolated using a local mean technique.

The wake deflection angle was calculated from the phase-locked averages by averaging the position of maximum velocity over the complete heaving cycle at each position. Between measurements, the orientation of the asymmetry reverses itself at random. While the sign of the wake deflection angle was not observed to switch while the airfoil is in motion, it seems to make its preference during start up, and then remain that way for the duration of the its motion. It also is found that as the Strouhal number is increased the wake deflection angle decreases and the virtual origin shifts upstream.

Reference

K. D. von Ellenrieder, S. Pothos, "PIV measurements of the asymmetric wake of a two-dimensional heaving airfoil," *13th Int. Symp. on Appl. Laser Techniques to Fluid Mechanics*, Lisbon, Portugal, June 26–29, 2006.

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