Reynolds number effects on VIV of a splitter plate

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Keywords: VIV, Digital Imaging, PIV

The development of Vortex-Induced Vibration (VIV) with increasing Reynolds number in the wake of a splitter plate has been examined with Particle Image Velocimetry (PIV) and High-Speed Digital Imaging (HSDI). Previous studies e.g. Eloranta et al. (2005) have shown that flow separation from the trailing edge of a splitter plate in a convergent channel involves fluid-structure interactions, modifying the fundamental instability related to vortex shedding. The splitter plate placed in a convergent channel vibrates in a well-defined mode, which is essentially characterized by a standing wave along the plate trailing edge. Under certain conditions, the VIV induces cellular vortex shedding from the trailing edge. The imprint of the vibration mode can be clearly observed in the near wake as a spanwise periodic variation of streamwise mean velocity.

This paper reports measurements on the effects of Reynolds number on plate vibration and the resulting effects on the flow. The objective of this work was to gain more information on the Reynolds number dependency of the VIV system. Experimental work includes HSDI measurements to assess the vibrational response of the plate and PIV measurements to study the effect of vibration to the flow field. Combining data from these techniques, the development of the vibration frequency can be addressed together with the imprint of the vibration mode in the flow properties.

The results show that over most of the Reynolds numbers measured, the plate vibrates in a distinct mode characterized by a spanwise standing wave along the plate trailing edge. The vibration frequency and the spacing between the nodes of the standing wave depend on the Reynolds number. As the Reynolds number is increased, the frequency of the dominant vibration mode does not increase linearly, but in a stepwise fashion. In other words, only certain frequencies i.e. the natural frequencies of the system are amplified by the combined fluid-structure system. The plot of vibration frequency as a function of Reynolds number shows that the vibration frequency of the VIV system tends to lock-in to a rather constant value over a range of Reynolds numbers (Fig. 1). After certain Reynolds number threshold is exceeded the frequency jumps to a new level. The characteristic vibration mode is initiated as soon as the synchronization of the vortex shedding frequency with a natural frequency of the system occurs. In the beginning of the vibration branch the amplitude of vibration increases.
At some point the frequency starts to drift out of the range sustained by the VIV and the amplitude of vibration starts to decay. This development is reflected in the near-wake mean flow pattern too.

1. Experimental set-up and data acquisition

The measurements are carried out in a 2D convergent channel with a rectangular cross-section. Important dimensions, normalized by the trailing-edge thickness (h = 1mm), are presented in Fig. 2. Width of the channel is 120h.

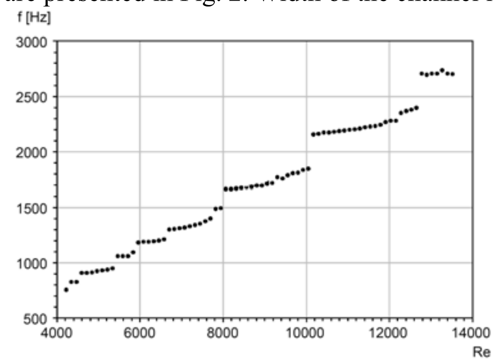

Fig. 1 Vibration frequency of the plate tip as a function of Reynolds number.

The length of the splitter plate is 600h with the last 50h of the plate tapered from the body thickness of 3h to 1h in the trailing edge. The plate is hinged from the upstream end, while the other end is free to move according to flow.

PIV (2D-2C) measurements are performed just after the trailing edge in the x-z -plane. A measurement window with dimensions of 60x30h2 (x-z) is used and vectors are computed to a grid with the size of 80x40 nodes. This results in a spatial resolution of approx. 0.8h, which is the spacing between two adjacent vectors. PIV data is obtained at the wake symmetry line 20h after the trailing-edge. The location of the PIV measurement plane is presented in Fig. 3.

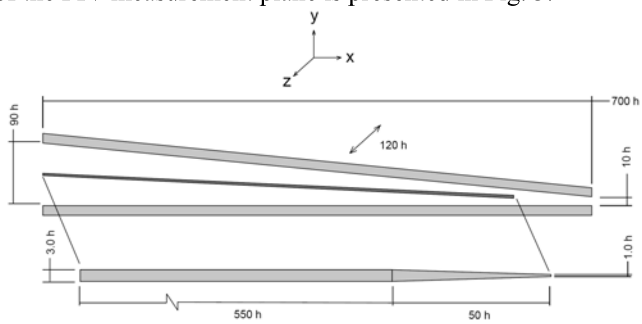

Fig. 2 Dimensions of the flow channel and the splitter plate.

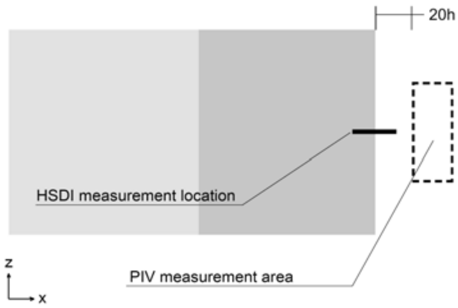

Fig. 3 PIV (dashed) and HSDI (solid) measurement positions in the x-y and x-z –planes.