Flow-induced vibrations of a rectangular cylinder at low mass ratios

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This study examines the features concerning the cross-flow response of a rectangular cylinder with an aspect ratio $L/W = 1.5$. The interest in this particular section stem from the fact that it has been observed[1] to be particularly prone to the interaction between vortex-induced vibration and galloping instability[2]. It was shown that the interaction can occur in a range of aspect ratio varying from *0.6* to *3.5* approximately, and for system damping levels such that the quasi-steady galloping onset velocity, U_0, approach the resonance one, U_r (or even lower than this value). Given the higher density of the fluid a low mass ratio is readily available[3].

The interaction was investigated during the past decades almost entirely referring to square cylinders, with some exceptions[4-5] concerning comprehensive studies for several different section types, aimed in defining the quasi-steady galloping dynamical characteristics. However none for the studies on the square section with low values of mass ratios were investigated[6-7-8]. Recently the interaction was approached with a square section in water at several angles of attack[9] (α).

In the water channel facility (FLAIR - Monash university), a rectangular cross-section rigid cylinder model made from anodized aluminium tubing with a final side depth of $W = 24.75$ mm and a side width of $L = 37.45$ mm has been tested: the lowest mass ratio has been $m^* = 2.24$ with a system damping ratio $\zeta = 2.47‰$. The model is set free to oscillate in the transverse direction being it connected to an air bearing system through a force balance which measure the forces exerted by the flow via 4 strain gauges. In the vibration direction the model is connected to the system with a variable number of springs allowing different natural frequencies.

The study shed a deeper insight on the responses describing precisely the evolution of the different mechanisms at play. A wide range of parameters were carefully varied making it possible to investigate amplitude response with varying both the mass ratio of the cylinder and the angle of attack. When the interaction occurred the amplitude response branch had the characteristics of galloping instability, developing at $U^* = U_r$: it has been observed, in particular for the lowest mass ratios, the violation of this usual "empirical rule", with galloping response starting from a reduced velocity much higher than U_r and showing a sub-harmonic resonance bell which got wider as the mass ratio got lower.

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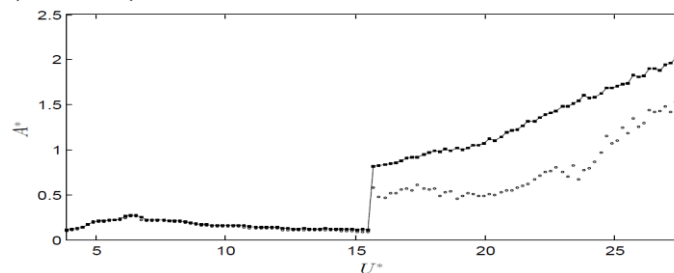
Figure 1: hydro-elastic response of the model for m* = 2.24 and α = 0. filled squares: mean of the top 10% of the peaks; empty circles: mean of the peaks.

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