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Galloping of square cylinders in cross-flow at low Reynolds numbers

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Galloping of square cylinders is studied at low values of the Reynolds number using a two-dimensional finite element method. A sinusoidal quasi-steady model allows determination of the occurrence of galloping and its amplitude. Parameters of this model are obtained via FEM unsteady simulations at different angles of incidence between 0° and 10°. The model efficiency is validated by comparing its predictions to those of unsteady simulations of fluid–structure interaction of a spring mounted square constrained to move in the direction transverse to the flow. Results show that the model yields good predictions of both the onset of galloping and its amplitude as a function of the Reynolds number at high values of the mass ratio. However, the quasi-steady model fails to reproduce the sudden change of amplitudes observed in finite element simulations at mass ratios below a critical value. Modifications to the model are introduced to reproduce this low mass ratio effect.

1. Introduction

Galloping is a flow-induced vibration that differs from the more common and well-known vortex-induced vibration both in its causes and its effects. It is a self-excited instability which may result in high-amplitude and low-frequency oscillations. According to Kaneko et al. (2008), Den Hartog (1956) was the first to provide a theoretical explanation for it. In his study of galloping of iced electric transmission lines, he developed a stability criterion which we will be describe later. Païdoussis et al. (2011) pointed out that the same criterion was developed earlier by Glauert (1919).

Galloping usually happens to long elastic structures of non-circular cross section. The square cylinder in particular is known to be prone to the phenomenon. Galloping of square cylinders is relevant to offshore engineering, where bundles of risers can be sheathed in a square envelope (low values of the mass ratio), and to civil engineering (high values of the mass ratio). Parkinson and Brooks (1961) examined the validity of a polynomial development of forces as a function of the angle of attack for square cylinders; their theoretical explanation was largely bourne out by experimental evidence. Parkinson and Wawzonek (1981) studied mutual effects of vortex-induced vibrations and galloping since they found that under certain circumstances both phenomena could occur simultaneously. In the present paper, we show, by means of an example for a large reduced velocity of 40, that vortex shedding could interfere with galloping while both phenomena are well separated in terms of frequency.

Robertson et al. (2002) carried out a study of both rotational and transverse galloping of rectangular cylinders. Using the Den Hartog criterion, they determined which thickness ratios were susceptible to galloping and validated their assumptions through simulations of fluid–structure interactions (FSI). Barrero-Gil et al. (2009) focused on the transverse

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