Flemming, F.; **Williamson, C. H. K.**
Vortex-induced vibrations of a pivoted cylinder. (English) Zbl 1065.74020
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Summary: Much of the research into vortex-induced vibrations has been dedicated to the problem of a cylinder vibrating transverse to a fluid flow (Y-motion). There are very few papers studying the more practical case of vibration in two degrees of freedom (XY-motion), or the case where there is variation of amplitude along the span of a body. The present two-degree-of-freedom pivoted cylinder apparatus represents the simplest configuration having a spanwise variation of amplitude. A central question concerns how well the results from Y-motion studies carry over to the case of a body in two degrees of freedom, and also how effective the quasi-uniform assumption is when there is spanwise amplitude variation.

In a manner comparable with the Y-motion cylinder, the principal dynamics of the pivoted body are transverse to the flow. For moderate values of the product inertia-damping or $(I^*\zeta)$, the system exhibits two amplitude response branches, and for sufficiently low $(I^*\zeta)$, three response branches appear, in strong analogy with previous results for Y-motion bodies. The response branches for the bodies with low $(I^*\zeta)$ correspond with both the 2S mode (two single vortices per cycle) and 2P mode (two vortex pairs per cycle) of vortex formation along the span. We also observe a clear 2S-2P hybrid mode, similar to that found for vibrating tapered cylinders by *A. H. Techet* et al. [J. Fluid Mech. 363, 79–96 (1998; Zbl 0967.76510)]. These different modes correspond well with the *C. H. K. Williamson* and *A. Roshko* [J. Fluids Struct. 2, 355 ff (1988)] map of modes in the plane of amplitude and frequency, so long as the streamwise vibration is small. However, when the inertia of the body is sufficiently small, the correspondence with the map of modes for the upper branch is not close. The response branches cross over each other in this map, and one has to introduce a third dimension to represent streamwise amplitude. This three-dimensional plot shows that the two response branches exist in quite different parameter spaces. The upper branch with the higher streamwise motion corresponds to a new vortex formation mode, which comprises two co-rotating vortices each half-cycle, defined as a '2C' mode. We present the principal three-dimensional vorticity structures corresponding to each vortex wake mode. Vortex dislocations and vortex merging are characteristics of these complex three-dimensional structures. We introduce equations of motion for the case of the pivoted cylinder with two degrees of freedom, and thereby deduce that a critical inertia, I_{crit} exists analogous to the 'critical mass' of *R. Govardhan* and *C. H. K. Williamson* [J. Fluid Mech. 420, 85–130 (2000; Zbl 0988.76027); 473, 147–166 (2002; Zbl 1024.76507)], below which the pivoted body is predicted to have an infinitely wide regime of flow velocities where resonant oscillations will occur.

MSC:

74F10 Fluid-solid interactions (including aero- and hydro-elasticity, porosity, etc.)

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