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Vortex-induced dynamic interaction between two coupled systems using reduced models

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Flow-induced vibration (FIV) is a widespread phenomenon occurring in various natural and engineered systems, including towers, offshore risers, power cables, and tall buildings. When subjected to complex flow environments, these structures often encounter interacting hydrodynamic forces that generate vibrations. Studying FIV behavior enhances understanding of structural performance in relevant engineering applications [4].

Initial research mainly addressed vortex-induced vibration (VIV) in an isolated cylinder, where the response is governed by parameters such as mass, damping ratio, natural frequency, Reynolds number and geometry. VIV develops when the vortex shedding frequency coincides with the cylinder's natural frequency-known as the "lock-in" condition-resulting in increased vibration amplitudes [1, 2].

Here, we deal with the vortex-induced dynamic behavior of a system consisting of two flexibly mounted cylinders interconnected through a nonlinear coupling, Fig. 1. The study focuses on the resonance characteristics arising from the mutual interaction of lock-in regimes, with particular attention to the influence of bistability [3].

The dynamics of the two cylindrical profiles can be described using a linear oscillator model

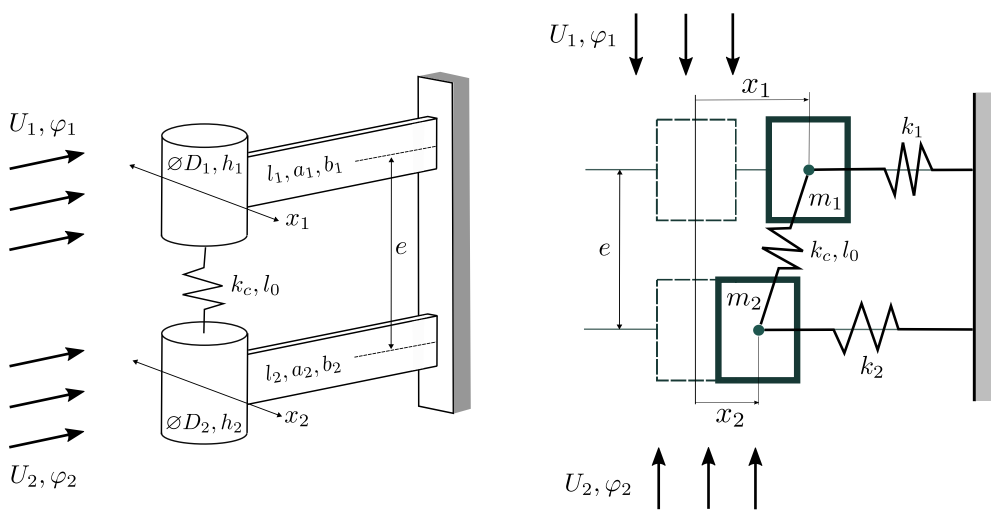

Fig. 1. Two flexible-mounted cylinders in a fluid-flow interconnected by nonlinear flexible coupling: physical model (*left*), reduced computational model (*right*)

subjected to fluid-induced forces, which are modelled by wake oscillators, as follows

$$
\begin{aligned}
&m_1\ddot{x}_1 + b_1\dot{x}_1 + k_{s1}x_1 - \frac{1}{4}\varrho U_1^2 D_1 C_{L0}\varphi_1 = -k_c\left(1 - \frac{l_{0c}}{\sqrt{e^2+(x_1-x_2)^2}}\right)(x_1-x_2),\\
&\quad\ddot{\varphi}_1 + 2D_{a1}\Omega_{a1}(c_{a1}\varphi_1^2-1)\dot{\varphi}_1 + \Omega_{a1}^2\varphi_1 = P\ddot{x}_1,\\
&m_2\ddot{x}_2 + b_2\dot{x}_2 + k_{s2}x_2 - \frac{1}{4}\varrho U_2^2 D_2 C_{L0}\varphi_2 = k_c\left(1 - \frac{l_{0c}}{\sqrt{e^2+(x_1-x_2)^2}}\right)(x_1-x_2),\\
&\quad\ddot{\varphi}_2 + 2D_{a2}\Omega_{a2}(c_{a2}\varphi_2^2-1)\dot{\varphi}_2 + \Omega_{a2}^2\varphi_2 = P\ddot{x}_2,
\end{aligned}
\tag{1}
$$

where m_i, b_i and k_i are mass, damping and stiffness of the i-th profile, respectively, including the added mass, added damping and the forcing is given by the wake oscillators. All geometric parameters are defined in Fig. 1.

Basic characteristics of the system for chosen parameters are plotted in Fig. 2.

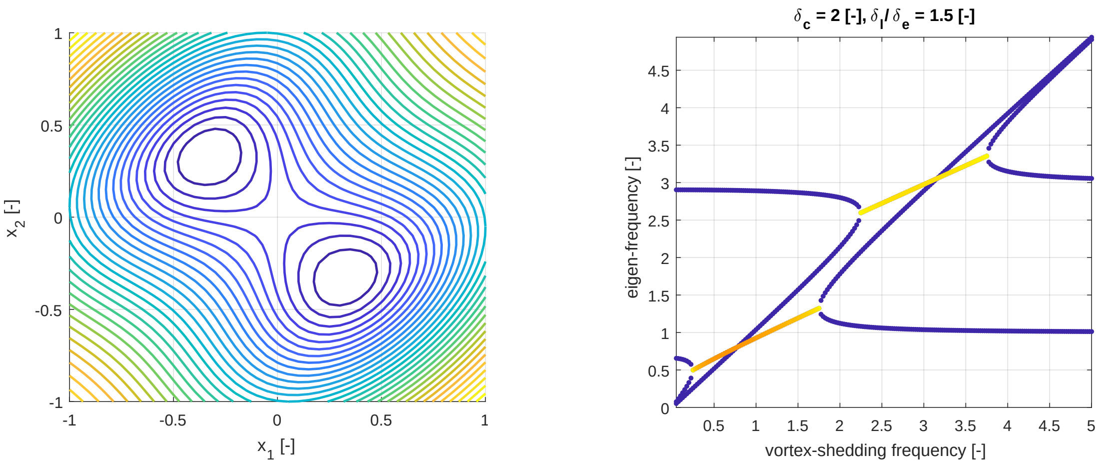

Fig. 2. Deformation energy plot of the structural part (*left*), Campbell diagram capturing the frequency lock-in areas by yellow color (*right*)

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References

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