Accepted Manuscript

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PII:	S0045-7930(14)00416-2
DOI:	http://dx.doi.org/10.1016/j.compfluid.2014.10.011
Reference:	CAF 2715
To appear in:	*Computers & Fluids*
Received Date:	7 October 2013
Revised Date:	28 August 2014
Accepted Date:	21 October 2014

Please cite this article as: Hasheminejad, S.M., Jarrahi, M., Numerical simulation of two dimensional vortex-induced vibrations of an elliptic cylinder at low Reynolds numbers, *Computers & Fluids* (2014), doi: http://dx.doi.org/10.1016/j.compfluid.2014.10.011

Numerical simulation of two dimensional vortex-induced vibrations of an elliptic cylinder at low Reynolds numbers

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Abstract- Flow-induced vibrations (FIV) of an elastically supported rigid elliptical cylinder, which is free to move in cross-flow and in-line directions, with equal natural frequencies in both directions, is numerically simulated. Laminar flow regime (60 < Re < 400) for selected cylinder cross sectional aspect ratios and inclination angles ($a/b = 0.5,1,2$; $\alpha = 0,45,90^{\circ}$), with a low non-dimensional mass (m^* = 10), are considered. Also, to enhance high amplitude oscillations, the structural damping coefficient is supposed to be zero ($\xi = 0$). The natural structural frequency of the oscillator is assumed to match the associated vortex shedding frequency of a stationary cylinder with zero inclination angle at Re = 100. The unsteady fluid/cylinder interactions are accurately captured by implementing the moving mesh scheme via integration of an in-house developed User Define Function (UDF) into the main code of the commercial finite volume solver Fluent. The temporal discretization is based on the computationally efficient non-iterative Fractional Step time marching procedure. Numerical results reveal the decisive effects of cross sectional aspect ratio and inclination angle on the cylinder VIV characteristics (i.e., transverse/in-line response amplitudes, aerodynamic coefficients, Strouhal number, phase portrait, time response, orbital trajectory, and wake mode pattern). In particular, it is observed that the fluid/structure interaction effects notably amplify with the decrease (increase) in the cylinder cross sectional aspect ratio (inclination angle), linked to the decrease in the added mass effect. The validity of the simulations is established by comparison with the available experimental/numerical data.

Keywords: Nonlinear fluid-structure interaction; self-excited oscillations; CFD modeling; hysteresis; soft lock-in; desynchronization.

1. Introduction