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Bifurcation and Stability Analysis with the Role of Normal Form Symmetries on the Harmonic Streamwise Forced Oscillation of the Cylinder Wake

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Abstract

The dynamics of the cylinder wake subjected to harmonic inline oscillation is investigated in this work. Two-dimensional numerical computations are performed for Re=200 to find the effect of inline sinusoidal oscillation on the flow pattern leading to the variation of cylinder lift, drag and wake shedding frequency. Two complex primary modes of the *v*-velocity field, resulting from a proper orthogonal decomposition (POD) analysis, are considered to model and predict the nonlinear forced wake dynamics governed by the interaction of vortex shedding modes. The equivariant bifurcation theory in the presence of normal form symmetry $O(2)\times S^1$ is employed to classify the mode interaction solution branches with respect to lower order symmetries. The coupled amplitude equations are developed with the frequency saturation information included by the addition of complex coefficients. The symmetry-based model is expanded up to 7th power thus including spatio-temporal effects. The coefficients of the model are obtained from CFD simulations. The novelty of this work is that the amplitude equations are derived purely from the mode symmetries and not from a Galerkin reduction of the Navier Stokes equations.

The inline cylinder oscillation effect on the wake dynamics is captured by bifurcation analysis of this model under the variation of the two linear coefficients. As the oscillation amplitude increases, two limit cycles of the model undergo a symmetry-breaking bifurcation leading to a quasi-periodic state. For amplitude-

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