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NONLINEAR FLAPPING DYNAMICS: EFFECTS OF FLEXIBILITY AND KINEMATICS

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ABSTRACT

The majority of experimental and numerical studies related to flapping flight have been explored the relation of the thrust coefficient and propulsive efficiency to the wing geometry and kinematics. Wing flexibility and the interplay between kinematics and flexibility has received less attention, and as of today, it remains unclear if they can be exploited to achieve a better performance during low Reynolds-number flapping flight. To bridge this gap, building on earlier work [1, 2], simulations of a two-dimensional, two-component wings connected by a hinge with a torsion spring have been carried out here to study the associated nonlinear dynamics. The lead body has prescribed harmonic kinematics and the associated nonlinear fluid-structure interactions are computationally studied by using direct numerical simulations with an immersed boundary scheme.

One of the primary outcomes of this work is that nonlinear resonances play an important role in determining the performance of a flapping wing system, mainly through the formation of leading, trailing edge, and end of stroke vortices and interaction among them. For the considered flexible profile, it is shown that the mean values of lift and drag forces, and the ratio of lift to drag are enhanced when the system is excited in the nonlinear resonance region. As the Reynolds number is increased, the periodic structure gives way to an aperiodic structure. This is illustrated in Figure 1, where the results obtained for the Reynolds number values of 75 and 250 are plotted. The qualitative changes observed in the vortex structure with respect to a quasi-static variation of the Reynolds number are discussed, and the importance of these changes for system design are explored.

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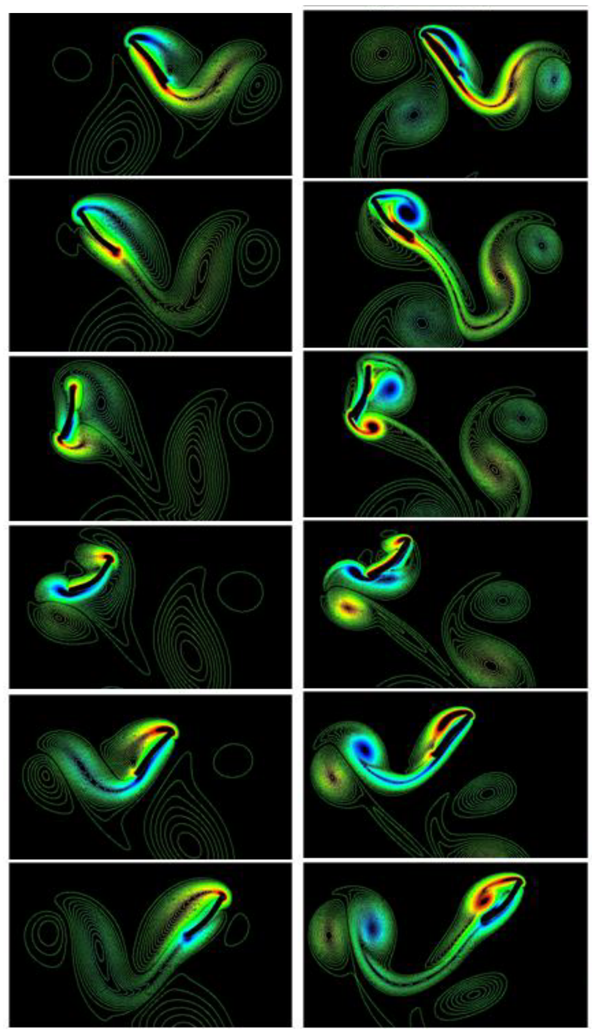

Figure 1: Vorticity contours observed over one period when the system is forced at 1/3 of the natural frequency of the structural system. Column 1 on the left corresponds to Re = 75, and Column 2 on the right corresponds to Re = 250.