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IDENTIFYING THE ROUTE TO CHAOS FOR A DIPTERAN FLIGHT SYSTEM

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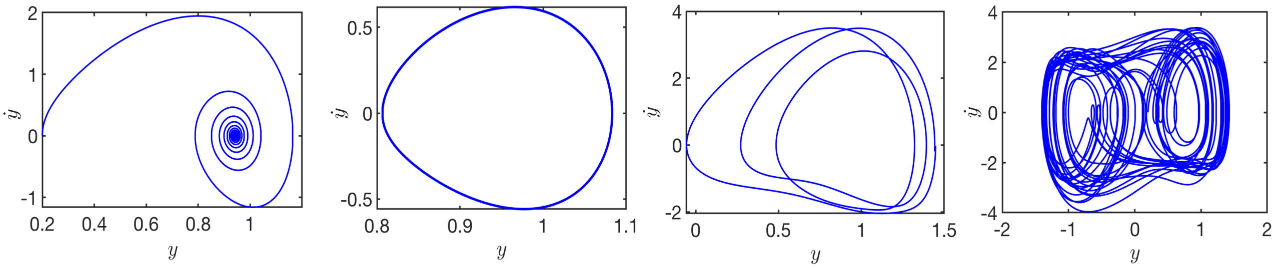
Natural flyers such as birds, insects and bats fly by exploiting the unsteady flows around their flapping-wings and this has been an inspiration in the development of flapping-wing Micro Air Vehicles (FMAVs) [1]. The secret to their flight has been attributed to different wing kinematics and the associated wake patterns. Usually in flapping wing studies, a sinusoidal kinematics is considered. However in reality, a flexible flight motor system dictates the motion of the wing. The bistable “click” mechanism is one of the most popular modelling approaches for representing the muscle-wing interactions in the insect flight motor during Dipteran flight [2]. The kinetic energy of the wing is stored as elastic energy while deforming the muscle elements in the flight motor during one stroke of flapping and gets recovered in the reverse stroke. The present work investigates the nonlinear dynamical behaviour of a Dipteran flight motor system immersed in a steady incompressible flow. An in-house fluid-structure interaction (FSI) solver has been developed by combining an existing forced Duffing oscillator model with an Immersed Boundary Method (IBM) [3] based Navier-Stokes solver. A bifurcation study has been performed using the coupled FSI solver considering the amplitude of wing actuation force as the control parameter at a low Reynolds number flight regime ($Re = 100$). The system response damps down and sinks to a stable spiral solution when no actuation forcing was applied; see Fig.1(a). At this parametric value the phase space consists two stable sinks and the fate of a trajectory depends on the choice of initial condition. On the other hand, at high forcing amplitudes, the system response exhibits a chaotic behaviour (see Fig.1(d)). As the forcing amplitude is varied gradually in between above two cases, different periodic states such as period-1 (see Fig.1(b)), period-3 (see Fig.1(c)), period-5 oscillations and so on are observed. This kind of bifurcation analysis will help in understanding the underlying physics behind the periodic to chaotic transition in Dipteran flight, which can be useful in developing efficient flight control algorithms for futuristics FMAVs.



(a) (b) (c) (d)

Figure 1. Phase-portraits for the system response: (a) stable fixed point, (b) period-1 oscillation, (c) period-3 oscillation, and (d) chatioc regime.

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