Role of stochasticity in the synchronisation characteristics of a pitch-plunge aeroelastic system undergoing stall flutter

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Abstract. Recent wind tunnel experiments on noise-induced stall flutter have pinpointed the presence of phase-flip synchronization characteristics. It remains to be seen as to how the probabilistic markers associated with the stochastic wind can affect this end of finding. To that end, we adopt a semi-empirical aeroelastic model based on Leishman-Beddoes (LB) state-space formulation. The input stochastic wind is modelled via a Kahunen-Loeve expansion (KLE). We systematically investigate the role of noise intensity, time scales and the probabilistic distribution of the input wind over both the stochastic dynamical signatures and the underlying synchronisation characteristics.

Introduction

The study of stall flutter is becoming a vital requirement due to increased interest in high aspect ratio wings, micro aerial vehicles (MAVs) which are highly flexible and operate in low mach number regime. To do the same, an accurate description of the underlying physical mechanism is needed and the synchronisation approach carried out, by the authors [3], assuages this need. Given that the original LB model pertains to larger Mach number regimes, a Leishman-Beddoes state-space formulation based aeroelastic model is used on to which modifications by Sheng *et al.*[2] and dos Santos *et al.*[1] have been incorporated for modelling the dynamic stall onset criteria and trailing edge separation, respectively. Subsequent to the response dynamics, comparison to our wind tunnel experiments [3], we address the role of probabilistic markers in influencing the synchronisation characteristics.

Results and Discussion

Figure 1 presents a comparison of the numerical stall dynamics with our experimental results (see [3]). A close onset of stall flutter is noted. Under stochastic inflows, we come across varying kinds of intermittent oscillations and random LCOs, one such response is shown in Fig. 2. The response exhibits burst type intermittency wherein response randomly alternates between "bursts" of periodic oscillations and aperiodic oscillations. Such type of intermittent responses are characterised by different phase relationships like phase drifting, phase slips[3]. To this end, numerical simulations are being carried out to discern the effect of various parameters such as the noise intensity, time scale of fluctuations and their effect on the ensuing synchronisation characteristics.

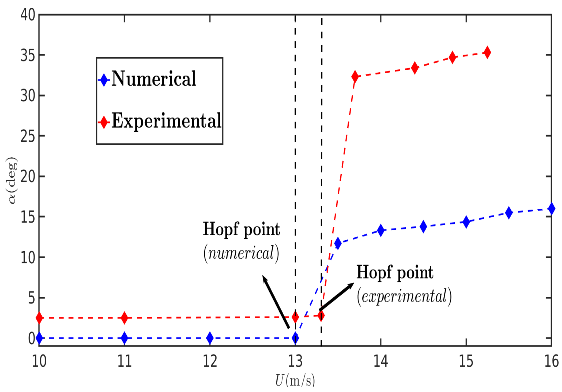

Figure 1: Bifurcation plot when subjected to uniform inflow.

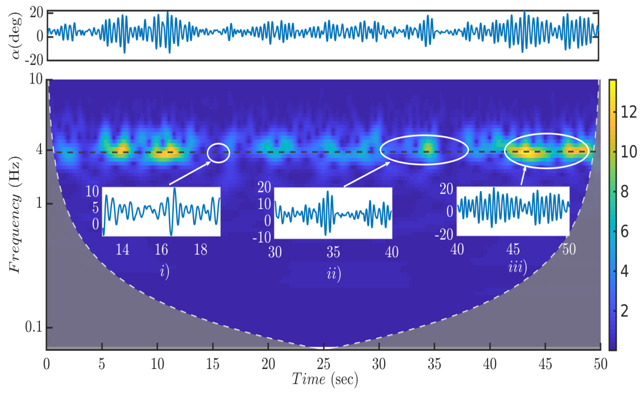

Figure 2: Intermittent pitch response and its scalogram at U = 13.5 m/s when subjected to stochastic inflow.

References

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[3] Tripathi D., Shreenivas R, Bose C., Mondal S., Venkatramani J (2022) Experimental investigation on the synchronization characteristics of a pitch-plunge aeroelastic system exhibiting stall flutter. *Chaos: An Interdisc. J. Nonlinear Sc.*, **32**: 073114.