Kinematics Vortex dynamics of flapping foils

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Abstract

A flexible foil undergoing pitching oscillations is studied experimentally in a wind tunnel with different imposed free stream velocities. The chord-based Reynolds number is in the range 1600–4000, such that the dynamics of the system is governed by inertial forces and the wake behind the foil exhibits the reverse Benard-von Karman vortex street characteristic of flapping-based propulsion. Particle Image Velocimetry (PIV) measurements are performed to examine the flow around the foil, whilst the deformation of the foil is also tracked. The first natural frequency of vibration of the foil is within the range of flapping frequencies explored, determining a strongly-coupled dynamics between the elastic foil deformation and the vortex shedding.

Cluster-based reduced order modelling is applied on the PIV data in order to identify the coherent flow structures. Analysing the foil kinematics and using a control-volume calculation of the average drag forces from the corresponding velocity fields, we determine the optimal flapping configurations for thrust generation. We show that propulsive force peaks occur at dimensionless frequencies shifted with respect to the elastic resonances that are marked by maximum trailing edge oscillation amplitudes. The thrust peaks are better explained by a wake resonance, which we examine using the tools of classic hydrodynamic stability on the mean propulsive jet profiles.

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