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TOWARDS A UNIVERSAL INDICATOR OF WAKE TRANSITION TO THRUST OF A SINGLE FLAPPING FOIL

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The vast majority of water based animals generate thrust by utilizing oscillatory (flapping) motion. Regardless of the chosen kinematics, forward propulsion (thrust) is achieved when at certain TE amplitude – frequency combinations (expressed as Strouhal number, $Sr = \frac{f * t}{U\infty}$ where f is the frequency, t is the characteristic length scale, U is the freestream speed) the shedding vortices rotate in an accelerating pattern (reverse BvK street) [1]. Additionally, side force is produced through wake deflection by increasing either the amplitude or the frequency of oscillation [2, 3, 6, 7]. This deflection is the result of dipole formation downstream of the TE and although 3D effects are present, it is indicated that the driving mechanisms are 2D [2, 3].

The present study aims to reveal the singular key factor that leads to wake transitions regardless of the underlying kinematics e.g. pure heave, pure pitch, coupled etc. and the type of transition e.g. drag-to-thrust, straight-to-deflected-wake etc. Using two-dimensional numerical simulations of a Boundary Data Immersion (BDIM) solver [4], we examine these transitions for sinusoidal heaving, pitching and coupled motions. For coupled motions, the heave-to-pitch phase and the effective angle of attack are chosen according to the highest propulsive efficiency [5].

In accordance with published data [8], pure heaving motions are observed to reach the transition curves earlier than the pure pitch ones in A_D vs Sr plots (where $A_D = \frac{TE\ amplitude}{Characteristic\ Length}$. On the other hand, the coupled motions follow more complicated patterns influenced by the dominant pure motion (heave or pitch), the phase, the effective angle of attack etc.

Here we will present new results that attempt to unify these different curves. We will examine the utility of maximum swept area of the kinematics as the essential parameter that captures the wake transitions. This parameter can replace the TE amplitude parameter that is widely used in the literature to capture the kinematics. The use of this swept area parameter collapses the neutral lines for pure-pitch and pure-heave motions. We will also present our current progress towards a similar scaling parameter for coupled motions.