Unsteady aerodynamic forces on accelerating and pitching avian wings

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A better understanding of the aerodynamic forces and flow physics surrounding bird flight can lead to an improved understanding of their evolutionary history and development. One aspect of bird flight which has received relatively little attention in the literature is the landing. The ability to land from flight would have supplied strong evolutionary pressures as the consequences of an inability to do so safely could be fatal. Birds necessarily decelerate as they land, but have also been observed to rapidly pitch their wings to high angles of attack. These motions create unsteady flow around the wings and likely augment the lift and drag forces beyond their steady state values, allowing for improved landing performance. Here, we present results from a parametric exploration of the effects of acceleration, pitch rate, and their combined motion on the resulting aerodynamic forces. The wings tested are a flat plate (thickness 5% of chord), a seagull (*Larinae*), and duck (*Mergus merganser*) wing. The bird wings are created from scans taken from the actual birds and then printed from a carbon fibre infused nylon filament (PPA-CF) and reinforced with stainless steel struts. Tests are performed in a water channel at Reynolds number of 10^4 - 10^5, a range relevant to birds. A 3m belt-driven traverse translates the wing in the streamwise direction and a separate motor controls the pitch about the quarter chord. Non-dimensional accelerations of 0.1 - 1.0 and non-dimensional pitch rates of 0.05 - 0.5 are tested for each wing. For the combined motions, the pitching is synchronised with the acceleration and is tested across the same range of values. For a single test case, the effect of offsetting the pitching motion from the acceleration whilst maintaining the same non-dimensional acceleration and pitch rate is also explored. The resulting forces are compared with their steady state values to assess the effect of these unsteady motions. These findings provide insight into the effects of wing geometry and kinematics on the resulting aerodynamic forces and how this may impact the landing behaviours of birds.

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