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Flow Characteristics of a Flat Plate Airfoil Resembling Spinning Samara using PIV

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Abstract

The single-winged seed, also known as a samara, is a unique method of seed dispersal established by nature that functions similarly to a helicopter in an autorotation state. Upon separation from the parental plan, the seed enters a transitional phase and then begins steady-state rotation about the vertical axis. The steady-state rotation of the samara is distinguished by a low descent velocity, delaying the impact time with the ground, and allowing it to disseminate by the approaching wind gust. The steady-state local flow around the samara is characterized by the formation of a Leading-Edge Vortex (LEV) [1], which enhances its lift coefficient, like in insect flight. This 3D rotational motion of the samara involves complex flow physics, which is not well understood. These samara function within the Reynolds number range of 1000 to 5000, and their local angle of attack spans from about 90º at their root to a minimum of 10º at their wing tips. In previous studies [2], the majority of researchers have focused on the range $10^4 < Re < 10^5$ as the low Reynolds number at an attack angle just before stalling. In these regimes, a Laminar Separation Bubble (LSB) strongly dominates the flow, followed by a transition to turbulent flow at the re-attachment point. In contrast, at $Re < 10^4$ (Ultra low Re), the flow seems to be entirely laminar and completely separated from the trailing edge, even at the low angle of attacks [3]. Although the flow around the spinning samaras is entirely three-dimensional, it is necessary to characterize the cross-sectional flow physics to fully comprehend its behavior. The present work is carried out to characterize the flow around the flat plate aerofoil in a vertical wind tunnel mimicking the condition similar to spinning samaras. The chord-based flat plate Reynolds number is kept at 2,000 and the angle of attack was set from 0º to 90º. The velocity field data around the flat plate aerofoil is obtained using Particle Image Velocimetry (PIV) technique. The lift and drag forces are calculated from obtained velocity field data using control volume analysis and their corresponding aerodynamic coefficients are derived using non-dimensionalization. In the complete paper, the experimental techniques, flow physics around the flat plate airfoil, and methods used to calculate the aerodynamic coefficient will be described in detail.

References

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