

EXPERIMENTAL STUDY OF RIGID FLAPPING WING IN QUIESCENT WATER

Abstract

In the present study, flow field around rigid flat plate rectangular wings of aspect ratio 1.0 and 1.5 executing main flapping motion at 1.5 and 2.0 Hz frequency has been studied in quiescent water. Velocity field was obtained using phase-locked two dimensional particle image velocimetry (PIV) and normal force by using load cell. Main flapping motion is a single degree of freedom motion in which the wing undergoes pure flapping with a pivot/hinge point located at a fixed distance from the wing root. The wing chord wise pitch is zero degree and the wing has zero deviation from stroke plane while flapping. Out of total six cases studied, four cases are with no winglet and two cases with winglet.

The first part of the study involves wing without winglet in which velocity field, vorticity and λ_2 criterion have been investigated for the complete flapping cycle in great detail. Based on this a hypothesis has been proposed which identifies the phenomena of organized vortex sheet formation along the locus of the wingtip during downstroke (vortex filamentation) followed by a weak vortex sheet formation which culminates in dispersed and disintegrated vortex structures during upstroke (vortex fragmentation). This symmetry breaking of vortex sheet occurs primarily due to the 3:1 angular asymmetry of the flapping kinematics about the horizontal plane and unequal time spent by the wing during downstroke and upstroke. This asymmetry also leads to normal force generation. Wingtip vortex, bound vortex, spanwise flow, residual or wake flow, wake capture, added mass, etc have been systematically observed. Evolution of peak vorticity & its spatial distribution, kinetic energy of the flow field, circulation, rate of strain, rate of rotation and enstrophy have been studied to identify the effect of nominal change in aspect ratio and flapping frequency. The second part of the study involves winglet. Birds have feathers in the outboard portion of their wings which are deployed as deformable winglets to augment performance and maneuverability. This motivated use of winglets in fixed wing aircrafts to reduce induced drag. However, effect of winglet is not well studied in flapping wings. Taking note of the above points, flow field characteristics around a square planform wing with winglet was investigated in the present study. It was observed that presence of winglet modifies the vortex filamentation and fragmentation phenomena; reduces kinetic energy content of the flow field and localizes it in the proximity of the wing and reduces added mass effect. From load cell measurement it was observed that wing with winglet produces normal

forces comparable with wing without winglet using lesser power and therefore provides superior performance, especially for low aspect ratio wing.

Keywords: Flapping motion; flapping wing; winglet; PIV measurements; force.