Analysis and Optimization of Dragonfly Wing Using COMSOL Multiphysics® Software

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Abstract

Introduction
This paper presents the motion and pressure distribution acting on the wings of the dragonfly. Dragonfly flight, as with general insect flight, is a rich field of research. Dragonflies are heavy-bodied, strong-flying insects that hold their wings horizontally both in flight and at rest. In general, large dragonflies have a maximum speed of 10-15 meters per second (22-34 mph) with average cruising speed of about 4.5 meters per second (10 mph). The wing of a dragonfly follows path "8" along with changing the angle of attack during the course of motion. Using Fluid-Solid Interactions (FSI), any phenomena can be modeled where a fluid and deform-able solid affect each other.

Using this model the [1] forces such as lift and drag which are responsible for the flight of dragonfly and also the pressure distribution are visualized (Figures 1, 2). A proper movement of wing is reproduced by defining several functions in both space and time. [2]The study is further progressed with the simulation of two airfoils (dragonfly wings) simultaneously (Figure 3, 4). [3] A 3-D simulation of a thin plate wing is also achieved, enhancing the study and flow visualization.

Use of COMSOL Multiphysics®
Our approach to simulate wing motion requires the use of multiphysics along with advanced features of COMSOL® software in which structural mechanics is used to move the solid geometry with large distortions in surrounding fluid domain and fluid mechanics to simulate the motion. An important aspect is the moving mesh ALE and re-meshing to solve the FSI.

A 2-D model of an NACA-2415 airfoil is taken as a wing (with aluminium material as a prototype model). As specified earlier, the wing of the dragonfly is modeled as an airfoil undergoing displacement in fluid (air). Several properties such as incoming velocity, prescribed velocity have been specified. With the time varying study, the motion of the wing is analysed. As the wing displaces in the fluid, continued re-meshing is required due to large displacements, the mesh distorts.

Result
The results show the flow and stress, and pressure variations in the fluid surrounding the wing at different intervals of its overall motion. The focus is on the relationship between

the fluid flow and wing and the pressure variations over the wing to find lift and drag (Figures 1, 3).

Conclusions
We visualize and study the aerodynamics of the wing during the flight of a dragonfly. With more calculations and study, we would be able to generate data for the development of aerospace industry.

Reference

[1] Z. Jane Wang, Dissecting Insect Flight, Annu. Rev. Fluid Mech. 2005.37, 183-210 (2005)
[2] Z. Jane Wang, Dragonfly Flight , Physics Today (2008)
[3] David Baker Russell, thesis on Numerical and Experimental Investigations into the Aerodynamics of Dragonfly Flight, ResearchGate (August 2004)
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Figures used in the abstract

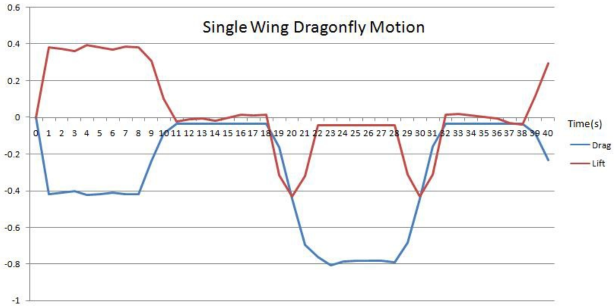

Figure 1: Shows the lift and drag on the airfoil (2D wing) with time. The airfoil changes its angle of attack from -45deg (0-10s), 0deg (10-20s), 90deg (20-30s), 0deg (30-40s).

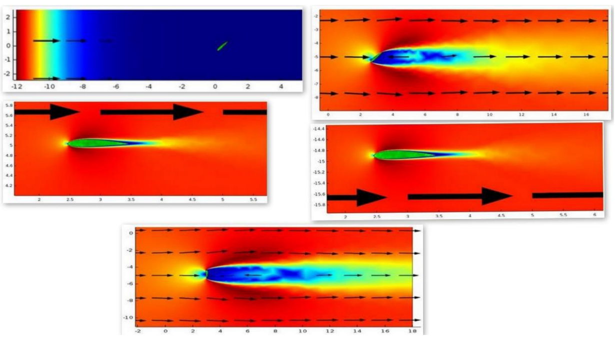

Figure 2: Shows position of the single airfoil at t = 0,5,15,25,35s in clockwise sense.

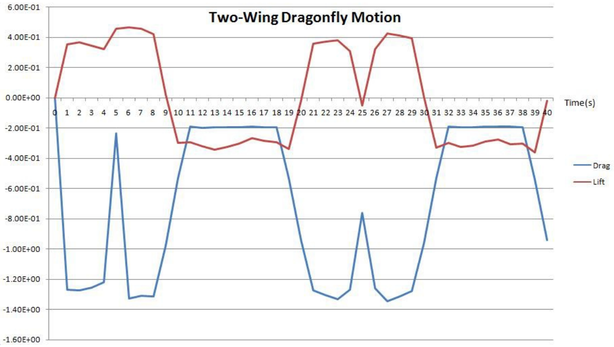

Figure 3: Shows the lift and drag vs time on two airfoils (2D wings) at a phase difference of 180deg in the motion. The airfoils changes its angle of attack from -45deg (0-10s), 0deg (10-20s), 90deg (20-30s), 0deg (30-40s).

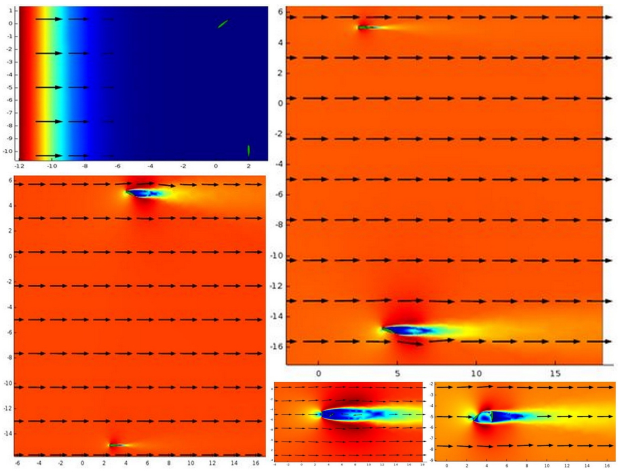

Figure 4: Shows position of the two airfoils at t = 0,5,15,25,35s in clockwise sense.