Analysis and Optimization of Dragonfly Wing

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Introduction: Dragonflies are nature's wonderful creature. 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 main idea behind writing this paper is to explore the complexities of Dragonfly's flight. This paper includes the literature as well as analytical results using simulation of the wing.

In this work, a 2-D model of a NACA-2415 airfoil is taken as a wing first and then two airfoils moving out of phase with each other are tested in COMSOL MULTIPHYSICS 5.2 software using Fluid-Structure Interaction (FSI) module.

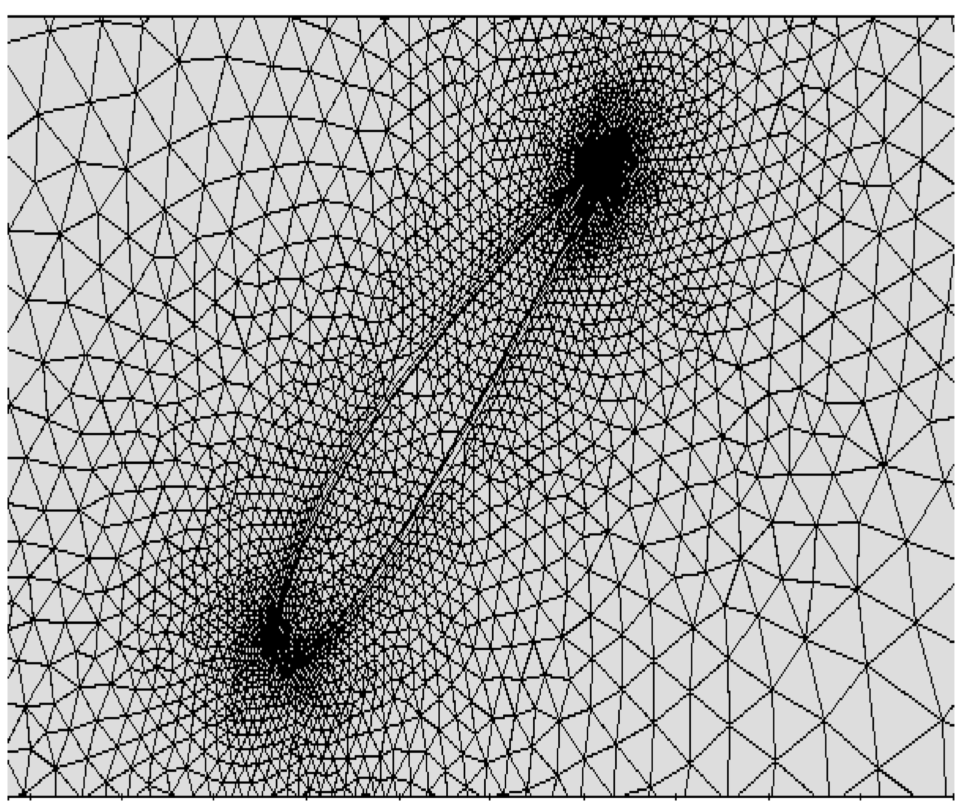

Figure 1. Shows the meshed airfoil

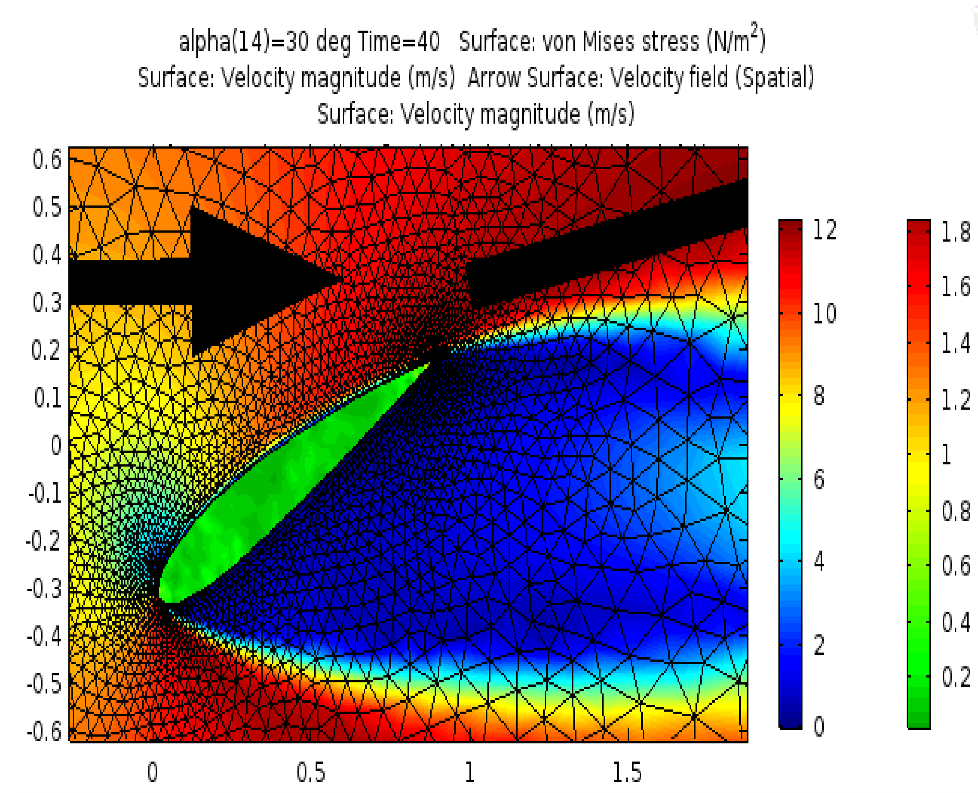

Figure 2. Shows the pressure and velocity magnitude for an airfoil

Computational Methods: Considering the flow around the wings to be compressible, the equations used by the solver are Navier Stokes equations as stated below:

$$\rho\frac{\partial u_{fluid}}{\partial t} + \rho(u_{fluid}.\nabla)u_{fluid} = \nabla.\left[-p\boldsymbol{I} + \mu - \frac{2}{3}\mu(\nabla.u_{fluid})\boldsymbol{I}\right] + F$$

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho u_{fluid}) = 0$$

$$\frac{\rho\partial^2 u_{fluid}}{\partial t^2}\text{-}\nabla.\sigma = Fv$$

The flow is also characterized by low Reynolds number which is given by:

$$R_e = \frac{\rho u L}{\mu}$$

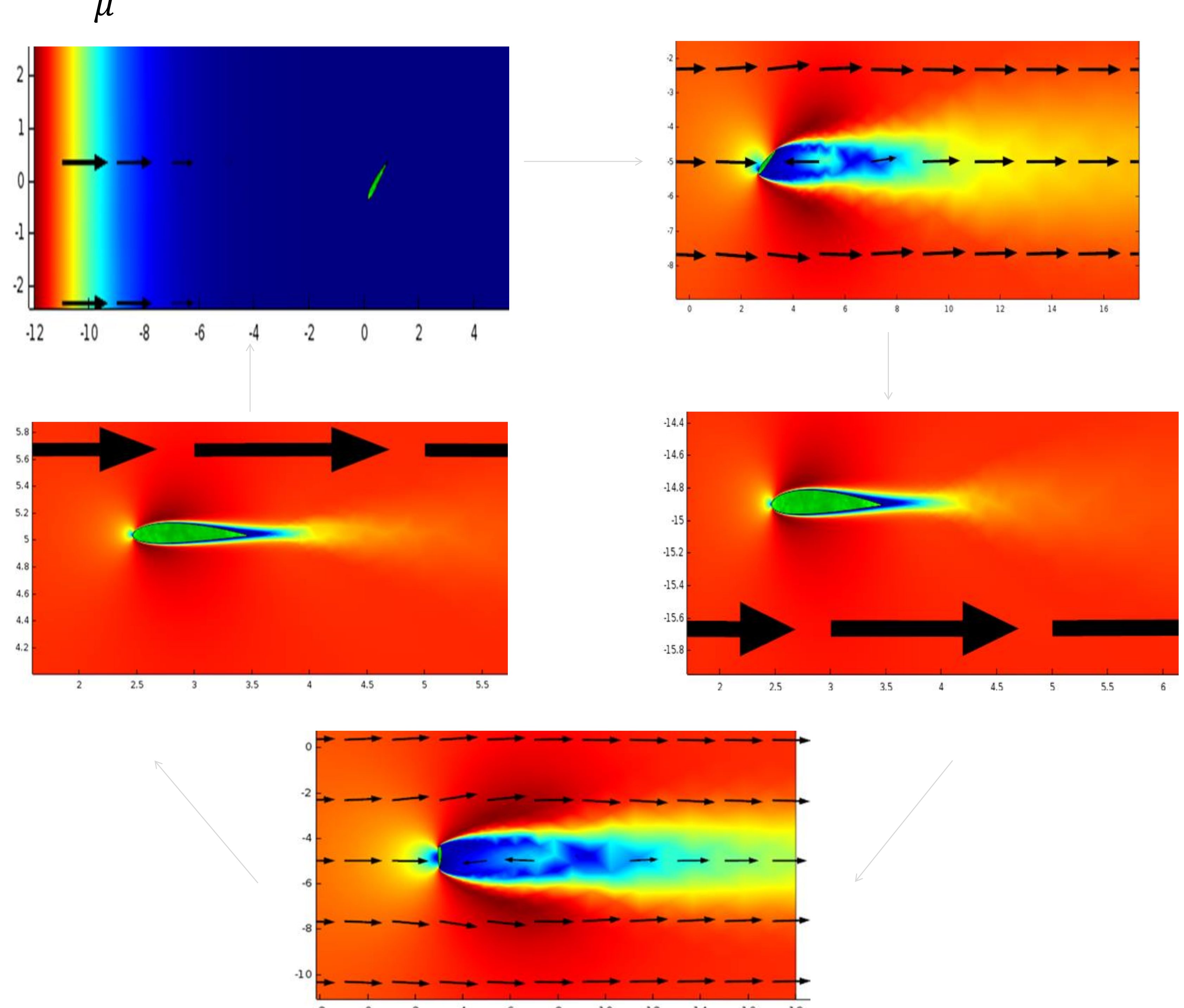

Figure 3. Shows position of single airfoil at t= 0,5,15,25,35s in clockwise sense

Results: The figures 1&2 shown below depict the flow visualization and plots of lift and drag for a single wing and two wings at different time intervals.

The plot (Figure 1) shows that for a single wing most of the lift is generated in the first 10s of the motion which is the downward inclined stroke.

The plot (Figure 2) shows that for two wings, most of the lift is generated in the first (0-10s) and the third (20-30s) segments of the motion which are the downward inclined strokes of the fore and the hind wings respectively. The dip in the lift curve is due to the flow disturbance when they cross each other.

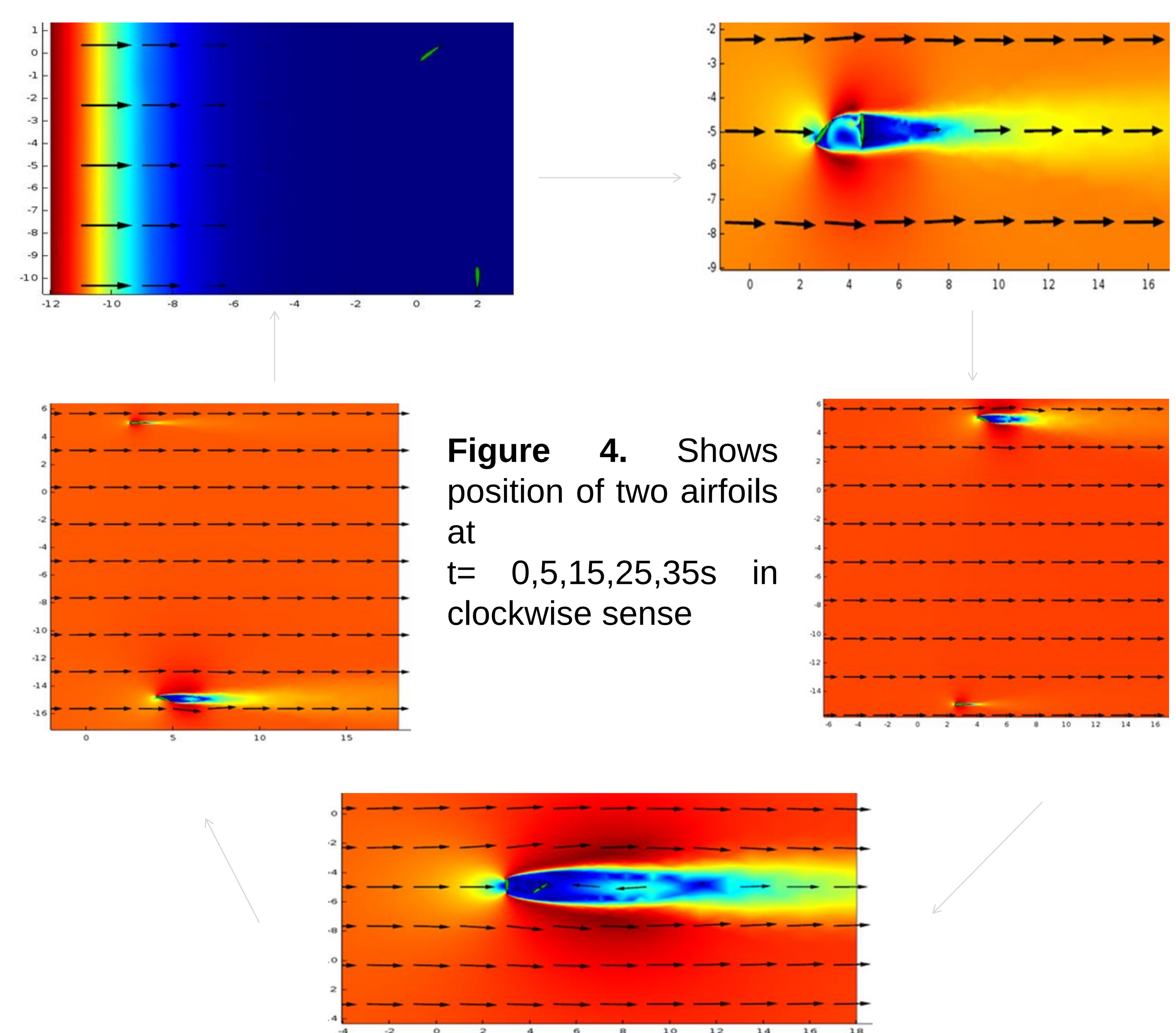

Figure 4. Shows position of two airfoils at t= 0,5,15,25,35s in clockwise sense

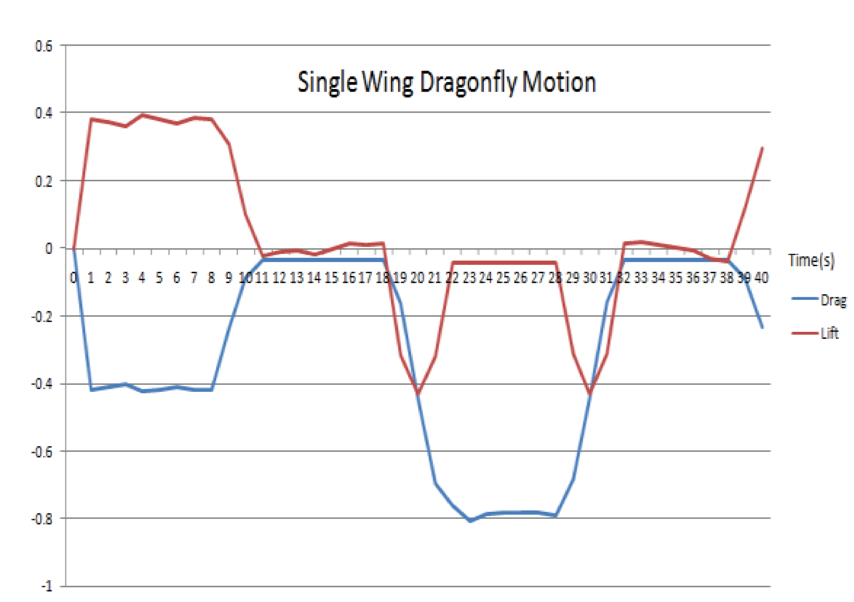

Figure 5. Lift and Drag curves for single wing. The airfoils changes its angle of attack from -45º (0-10s), 0º (10-20s), 90º (20-30s), 0º (30-40s)

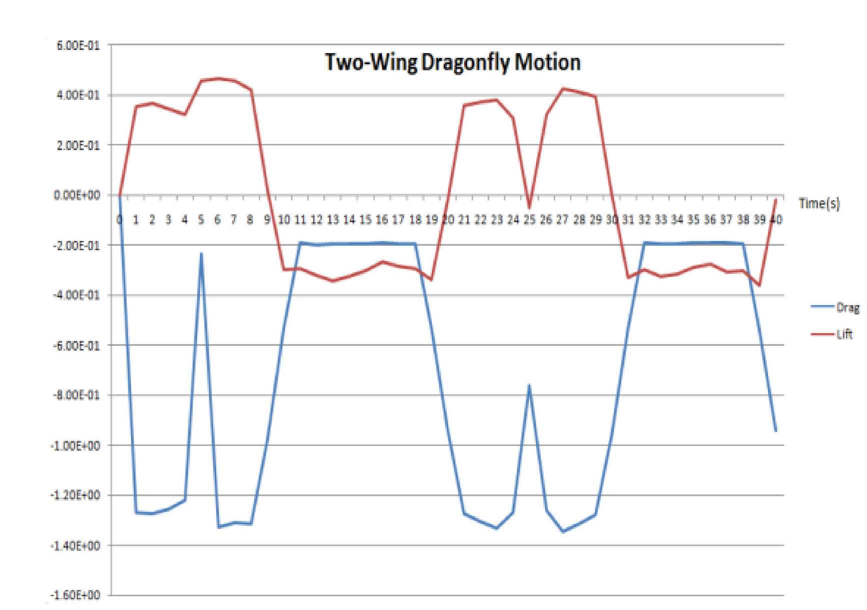

Figure 6. Lift and Drag curves for two wings. The airfoils changes its angle of attack from -45º (0-10s), 0º (10-20s), 90º (20-30s), 0º (30-40s)

Conclusions: In this study, it is shown that the application of the second wing increases the total lift generated in one cycle as compared to single wing. The complex wing motion of the dragonfly is successfully simulated using COMSOL.

Future studies may include the inclination of the path with the horizontal axis, and/or changing the angle of attack of the wing in the various segments.

References:

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