8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

OpenFOAM mesh motion using Radial Basis Function interpolation

*** F.M. Bos[1], D. Matijašević[2], Z. Terze[2], B.W. van Oudheusden[1], H. Bijl[1]**

[1] Delft University of Technology
Aerospace Engineering
Kluyverweg 1, P.O.Box 5058
2600 GB, Delft, the Netherlands
f.m.bos@tudelft.nl
www.lr.tudelft.nl/aerodynamics

[2] University of Zagreb
Faculty of Mechanical Engineering
and Naval Architecture
Ivana Lučića 5
10 000 Zagreb, Croatia.
dubravko.matijasevic@fsb.hr
www.fsb.hr/aero

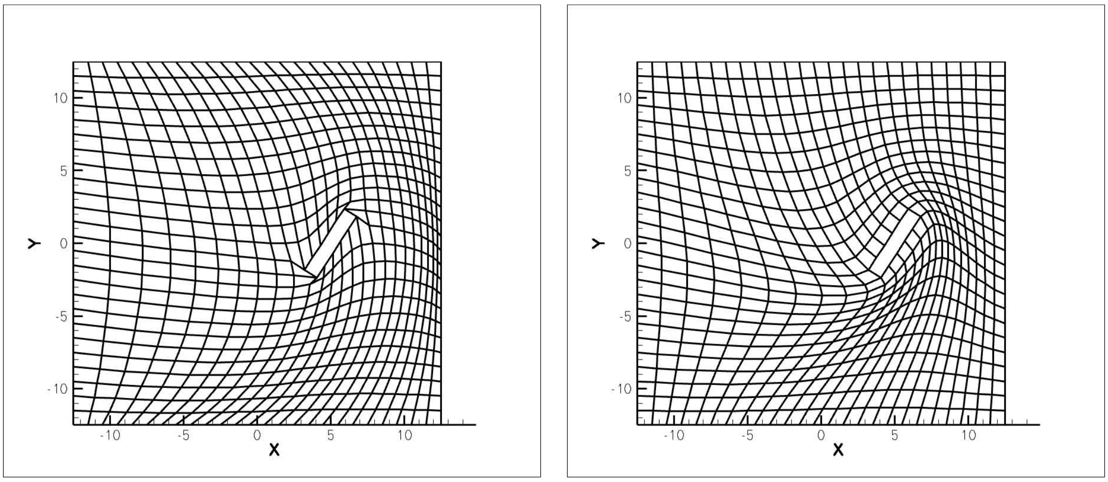
Key Words: *Computational Fluid Dynamics, OpenFOAM, mesh motion/deformation, Radial Basis Functions, flapping wings.*

ABSTRACT

In the design, development and optimisation of Micro Air Vehicles (MAVs) the knowledge of insect aerodynamics can be very helpfull to understand wing performance for flapping wings at very small scales. The performance of insect flight, in terms of energy consumption, is closely related to the aerodynamic forces generated by the flapping wings[1],[2] at these low Reynolds numbers. In order to capture the flow in the near wake with sufficient accuracy, there is need for moving and deforming meshes to accommodate for the high translation and rotation rates of a flapping wing. The OpenFOAM (Open Field Operation And Manipulation) toolbox[3],[4],[5] is used as the flow solver, but existing mesh motion techniques within OpenFOAM are not capable of maintaining high mesh quality at large rotations. This can be solved using a new mesh motion algorithm based on Radial Basis Function (RBF) interpolation.

This algorithm uses Radial Basis Functions to interpolate the displacement of boundary nodes onto the whole mesh[6]. To obtain the interpolation coefficients, we invert the matrix of correlations between boundary nodes, then every inner mesh point can be correlated to the boundary points through the obtained coefficients to create the interpolation matrix. This interpolation matrix is used to evaluate the Radial Basis Function at each internal mesh node to calculate its displacement at every time step. Large transformations, rotations and deformations can be handled by this method.

The fastest method is by calculating the RBF interpolation matrix only once, at the beginning of a simulation, but large mesh deformations can be handled by determining this matrix again at every time step. The choice of Radial Basis Function influences the mesh quality, but also the efficiency of the method. It was found[6] that best accuracy and robustness are obtained by using the thin plate spline which has global support. The disadvantage of a RBF with global support is that a full non-sparse system needs to be solved to obtain the interpolation matrix. By making a proper choice of RBF with local support the efficiency can be drastically improved.



(a) (b)

Figure 1: Deformed mesh around a two-dimensional plate at extreme translation position. (a) Laplacian method, (b) RBF method.

An overview is presented about the relative performance of different mesh motion algorithms within the OpenFOAM framework. The new RBF mesh motion is compared with two currently available methods: 1) Solving the Laplacian of mesh velocity field, 2) Solving the solid body rotation stress equations for the mesh displacement field. It will be shown that the RBF method leads to superior mesh motion in terms of mesh quality, especially in cases with large rotations, see figure 1. However, as this RBF mesh motion is rather computationally expensive, methods to improve efficiency will be considered. Additionally, the lift of a flapping wing will be used to investigate the accuracy of the flow solver using all three mesh motion solvers.

REFERENCES

[1] Z.J. Wang, and M.B. Birch, and M.H. Dickinson, "Unsteady forces and flows in low Reynolds number hovering flight: two-dimensional computations vs robotic wing experiments". *J. Exp. Biol.*, Vol. **207**, 461-474, 2004.

[2] F.M. Bos, D. Lentink, B.W. van Oudheusden, H. Bijl, "Influence of wing kinematics on aerodynamic performance in hovering insect flight". *J. Fluid. Mechanics.*, Vol. **594**, 341-368, 2008.

[3] H. Jasak. *Error analysis and estimation for the finite volume method with applications to fluid flows*, PhD Thesis, Imperial College, London, 1986.

[4] H. Jasak, Ž. Tuković "Automatic mesh motion for the unstructured finite volume method". *Trans. Famena.*, Vol. **30**, 1-18, 2007.

[5] H.G. Weller, G. Tabor, H. Jasak, C. Fureby "A tensorial approach to computational continuum mechanics using object-oriented techniques". *Computers in Physics.*, Vol. **12**, 620-631, 1998.

[6] A. de Boer, M.S. van der Schoot, H. Bijl "Mesh deformation based on Radial Basis Function Interpolation". *Computers & Structures.*, Vol. **85(11-14)**, 784-795, 2007.