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FURTHER VALIDATIONS OF PENALIZATION AND VIC BASED METHODS FOR AERONAUTIC APPLICATIONS

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The fluid-solid interaction method proposed in this work is formulated for a laminar flow modeled by the incompressible Navier-Stokes equations in which we consider the presence of rigid (possibly moving) solids S^i. The model is formulated inside an immersed boundary method (IBM) based on a penalization technique to account for rigid bodies [3]. Most of IBMs need to compute the intersections of the grid with the boundary of S^i. Penalization is quite different; the velocity field is extended inside the solid body. The boundary of S^i is computed from a level set function, the signed distance function to S^i. The flow equations are then solved with a penalization term to enforce rigid motion inside the solid as proposed by Cottet *et al.*[1] . The velocity vector of the rigid moving body is obtained either by an imposed body motion, or a flow governed body motion computed by solving the forces acting on the body S^i. To solve our governing equations, we choose the following strategies:

1. A vortex formulation of our governing equations is derived: this formulation is especially adapted to study vortex shedding behind bluff bodies.
2. A vortex in cell (VIC) scheme is coded to solve the equation: this scheme offers less CFL restrictions.
3. A time splitting algorithm allows to consider each part of the equation with specific requirements; for example the implicit treatment of the penalization term for accuracy purpose.

This approach has been validated against imposed body motion, as the flapping wing depicted in figure (1) . We model an oscillating wing with a NACA0015 airfoil experiencing simultaneous pitching and heaving motions [1].

The goal of the paper is to compute the aerodynamic force and moment using a control volume formulation proposed by Noca *et al.* [2] and extended to momentum calculation [4]. The paper validates the computed lift, drag and moment coefficients around airfoil by comparison with other results from literature. The cases of a static airfoil at low Reynolds number and a pitching airfoil in pitching and heaving motions are studied. Results agree well with literature, thus enabling computation of power extracted by airfoil pitching and heaving motions. In the next step, the penalization and VIC method will be used to study airfoil geometry effect on power extraction efficiency.

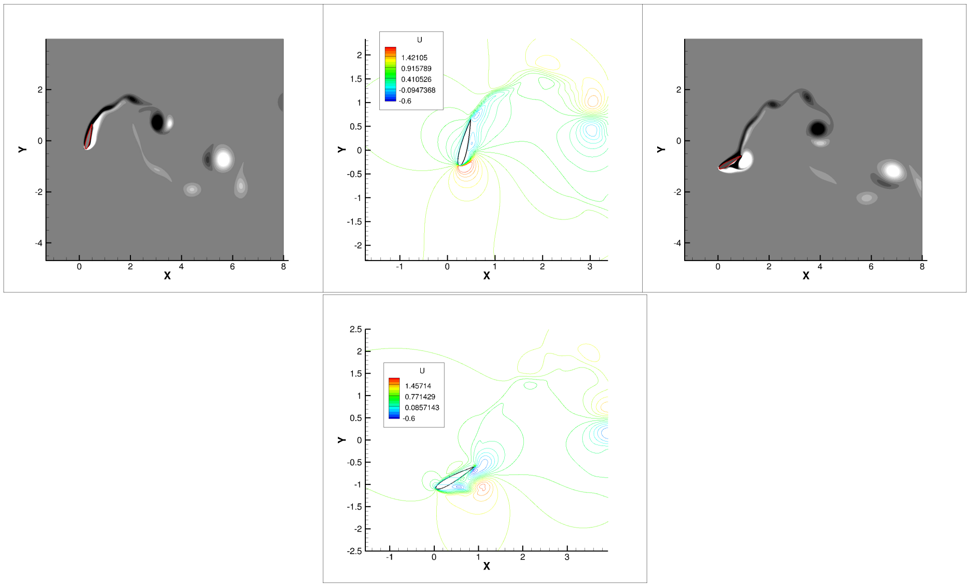

Figure 1: Contours of vorticity (white for positive and black for negative) and velocity u at two instants in the cycle of an oscillating flapping wing.

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