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Numerical simulation of exploring fish motion by a series of linked rigid bodies

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Present work is mainly based on numerical simulation of solving fish motion problem by using multi-body dynamics algorithm. The fluid solver employs the commercial software ANSYS Fluent 15.0. it is based on finite volume method. Basic theory used in Fluent is by discretising transport equation:

$$\frac{\partial}{\partial t}\int_V \rho\phi dV + \oint_A \rho\phi V dA = \oint_A \Gamma_\phi \nabla\phi dA + \int_V S_\phi dV$$

A first order implicit time marching scheme is used for time transient. Second-order upwind scheme is employed for diffusion term discretization. Pressure-velocity coupling can be achieved by the Fractional Step scheme. The first case two-element flapping wing was carried out to check the algorithm accuracy. The second one was about exploring fish motion by given prescribed angular motion.

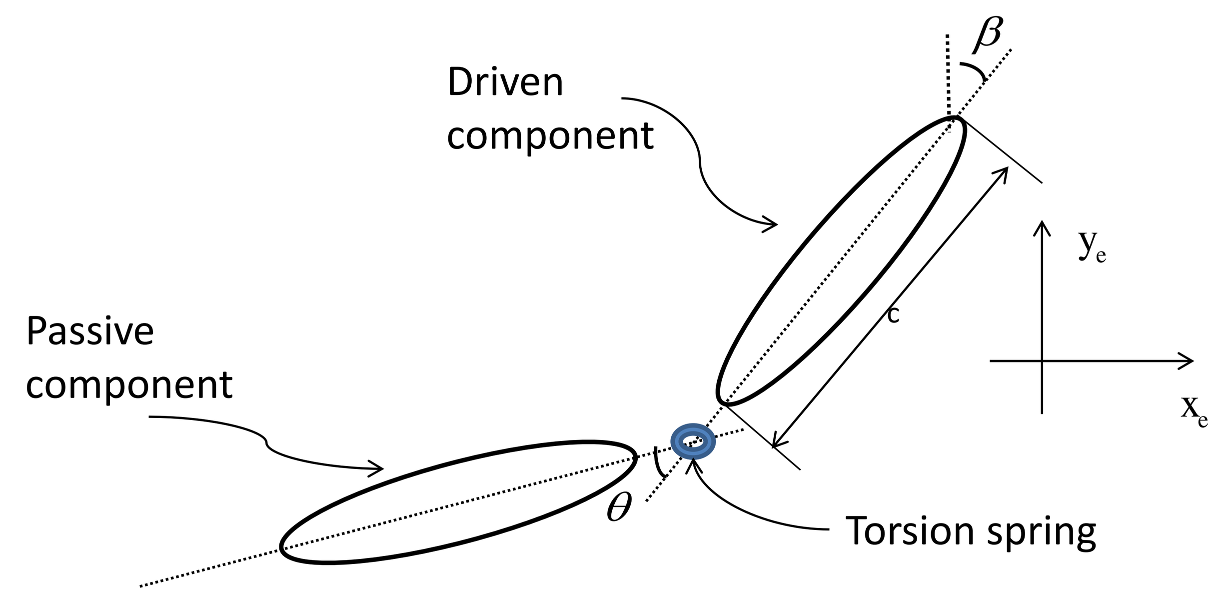

Fig 1. Geometry of two-element flapping wings

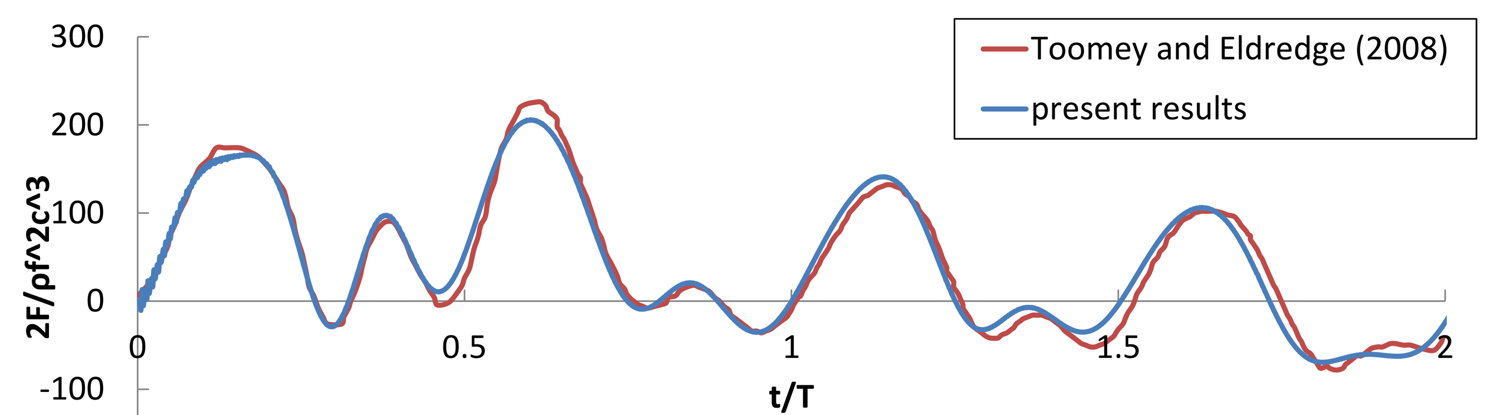

Fig 2. Forces comparison

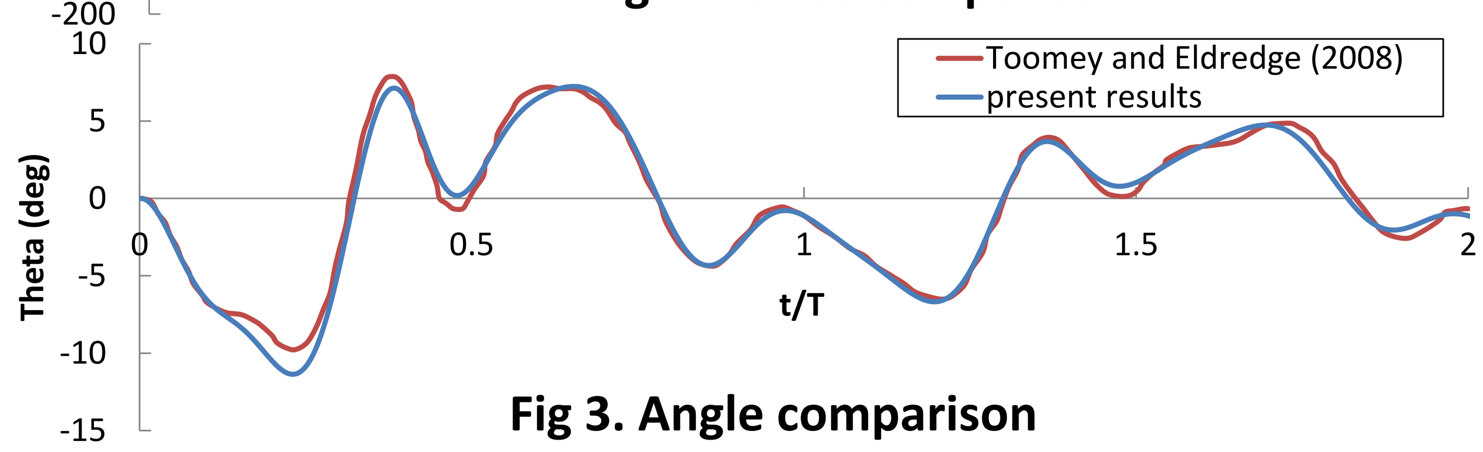

Fig 3. Angle comparison

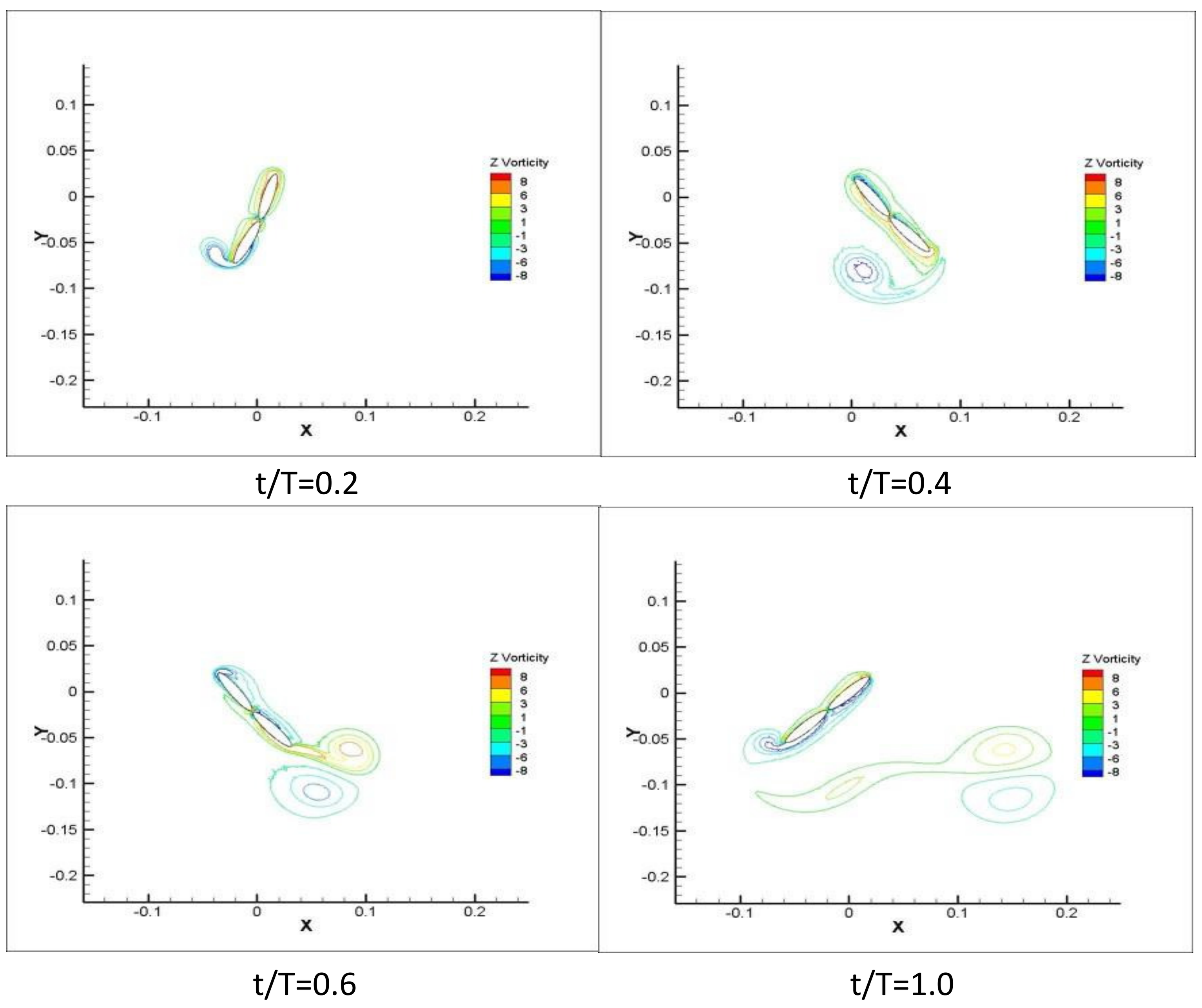

Fig 4. Contours of two elements flapping wings at t/T=0.2,0.4,0.6 and 1

Fig 1. shows the geometry of two elements, connecting with an given stiffness and damping ratio spring. Driven component and passive component is given. Prescribed translational and rotational motion is added on the driven component. Force and angle comparisons are shown in Fig 2 and 3. The results are comparable with previous results. Fig 4. is the contours presentation at t/T=0.2, 0.4, 0.6 and 1.

Jonathan Toomey and Jeff D. Eldredge. "Numerical and experimental study of the fluid dynamics of a flapping wing with low order flexibility." *Physics of Fluids (1994-present)* 20.7 (2008): 073603.

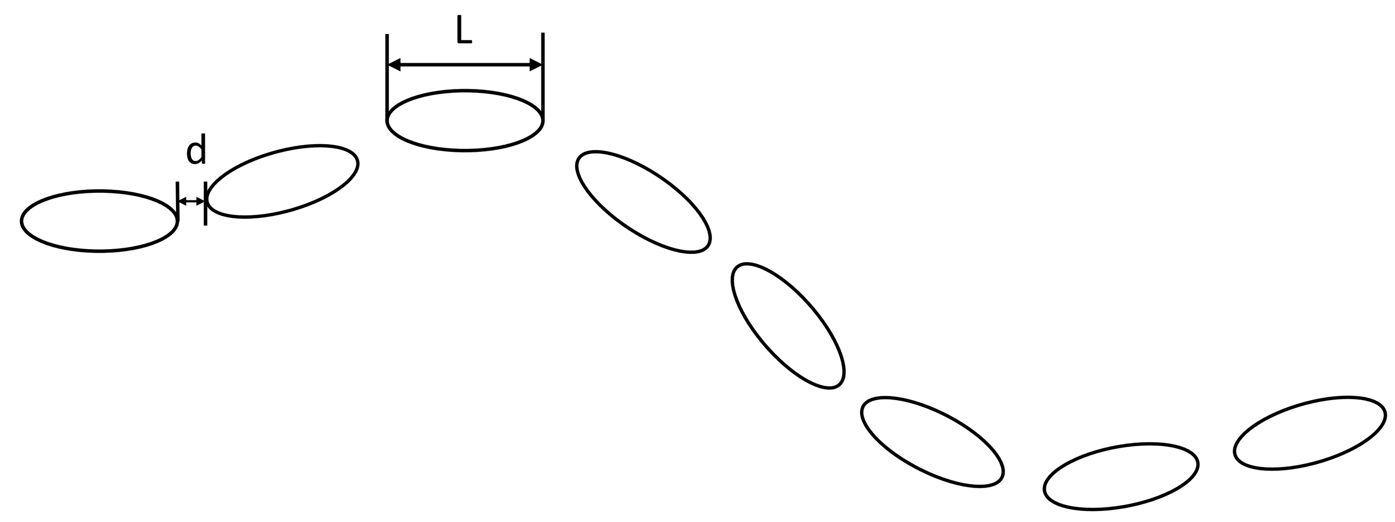

Fig 5. Geometry of eight-element fish model

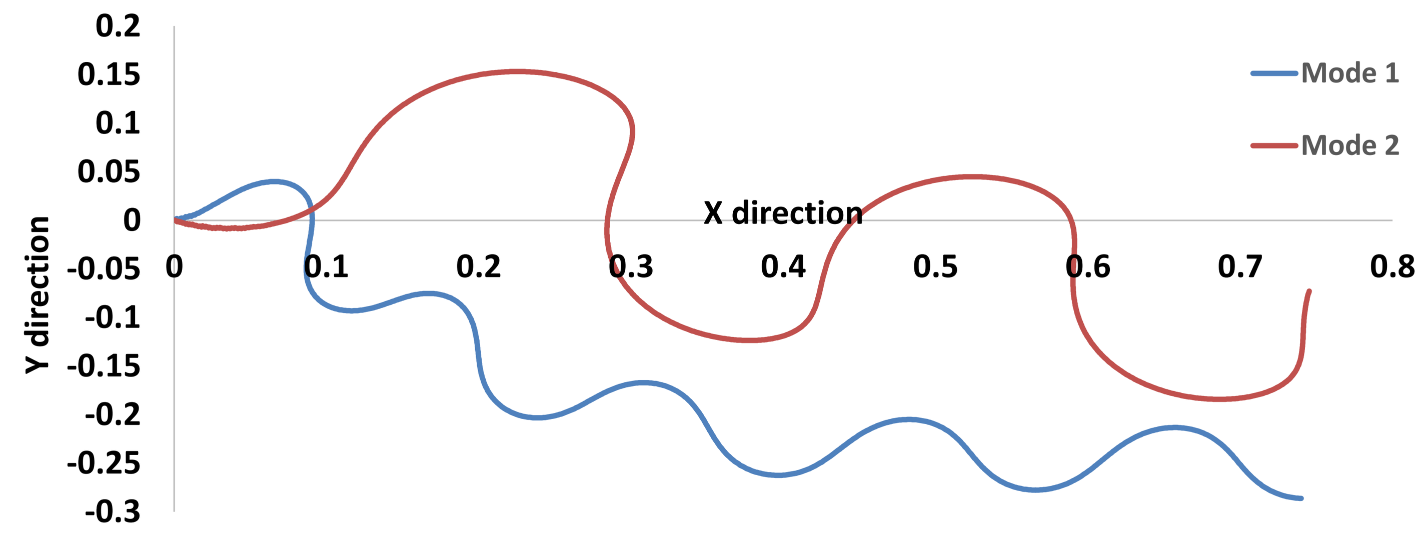

Fig 6. Predicted two different trajectories by varying swimming amplitude and tail beating frequency

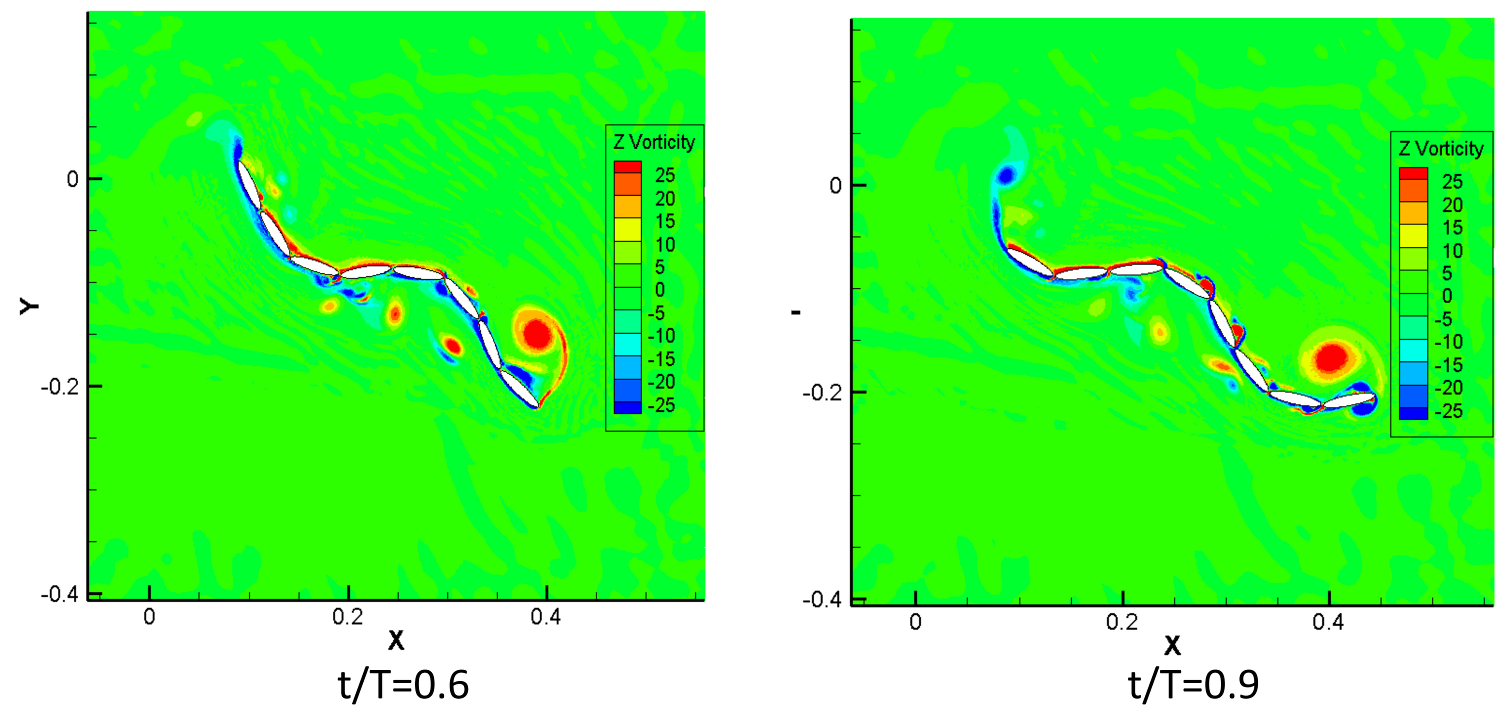

Fig 7. Contours of Mode 1 at t/T=0.6 and 0.9

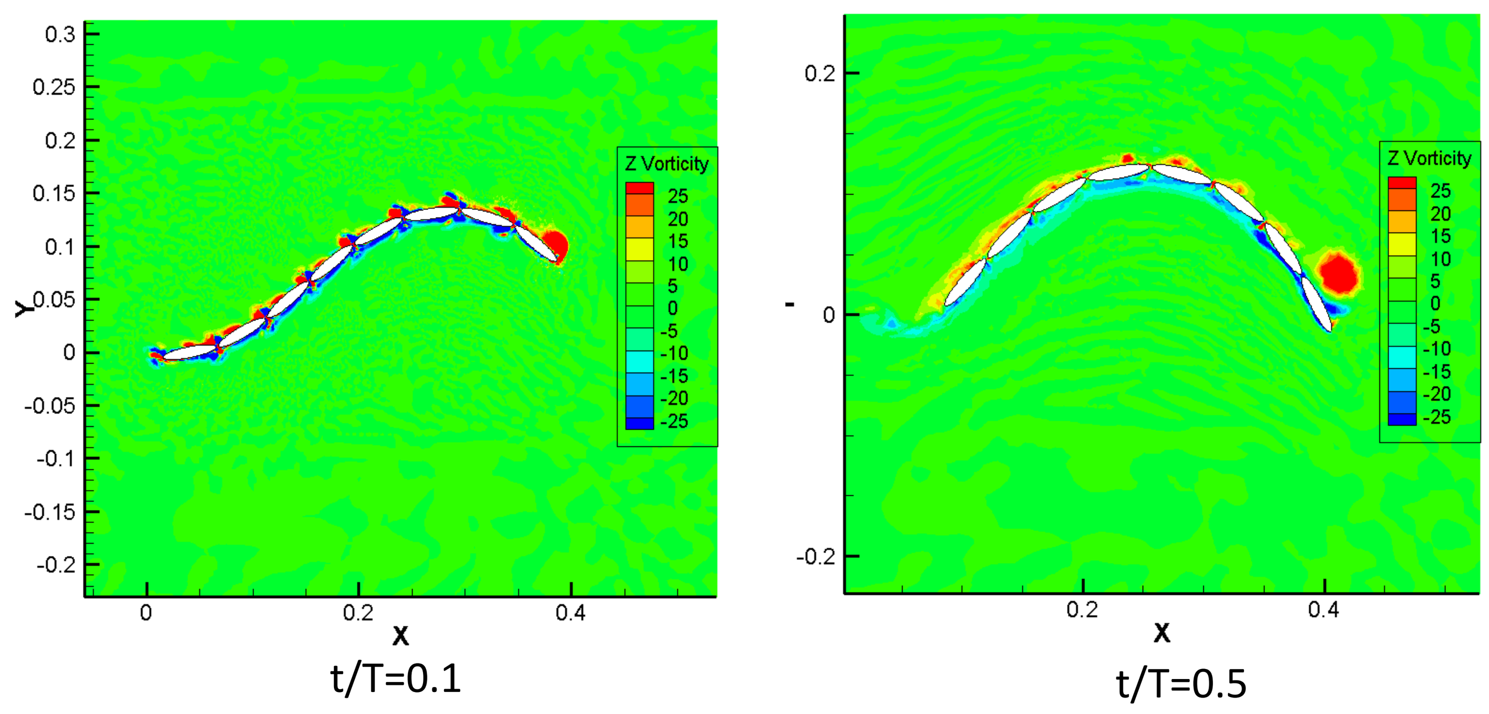

Fig 8. Contours of Mode 2 at t/T=0.1 and 0.5

This eight-element model is shown in Fig 5. All the elements are identical and the gap between each element is equal as well. Two modes are simulated and Fig 6. gives the path lines for each mode. The angular motion on each hinge is prescribed. Fig 7 and 8 show the contours of two modes at different time. These two modes can stand for two different swimming conditions of fish.

Porez, Mathieu, Frédéric Boyer, and Auke Ijspeert. "Improved Lighthill fish swimming model for bio-inspired robots-Modelling, computational aspects and experimental comparisons." *International Journal of Robotics Research* (2014): 1-34.

ARCHIE-WeSt

Results were obtained using ARCHIE-WeSt High Performance Computer (www.archie-west.ac.uk).