SIMULATIONS FOR SOME LOW AND MEDIUM REYNOLDS NUMBER PROBLEMS USING IMMERSED BOUNDARY METHOD IN FOAM-EXTEND

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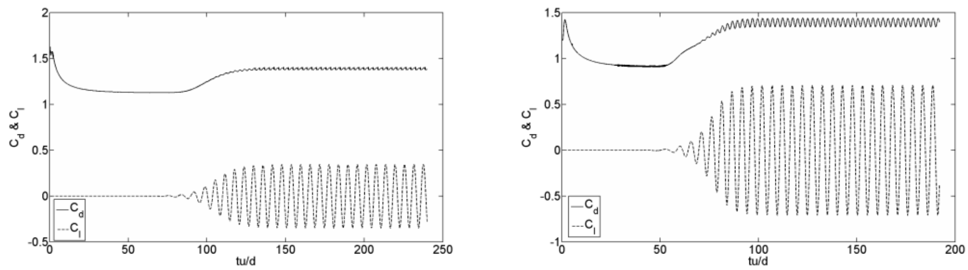
Immersed boundary method was first proposed by Peskin[1,2] for the simulation of human heart. The method was later extended to many fields[3,4]. By using cartesian grids, the immersed boundary method has some advantages in the simulation of complex boundary and moving boundary problems. In this paper, the method employs a discrete force approach which uses two polynomial interpolation combined with weighted least squares method[5,6] for the reconstruction of the flow variables. Space domain was discretized using the finite volume method and time was discretized using Euler method. PISO algorithm was utilized for the couple of velocity and pressure field. Simulations of flow around a two-dimensional cylinder, an oscillating cylinder, a three-dimensional sphere and a two-dimensional fish were conducted to verify the accuracy and fidelity of the solver over low and medium Reynolds numbers covering static and dynamic boundary problems. It can establish foundations for the future handling of more complex problems in the field of naval and bionic hydrodynamics. Results show that those simulations have a high fit degree with relevant references.

Flow around a cylinder

Simulations of flow around a two-dimension cylinder were conducted and compared with the result of Chiu[7] and Xu[8].The Reynolds numbers are 100 and 200 respectively, and the characteristic length is defined as the radius of the cylinder, *d*. The computational domain is 50× 25 *d.*



a **b**

Figure 1: The evolution of drag and lift coefficient at (a): Re =100, (b): Re=200

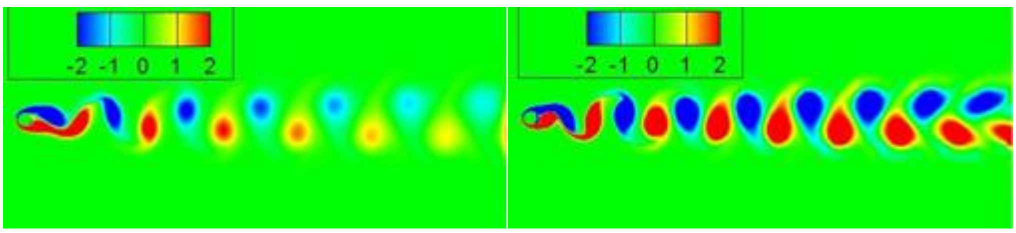


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Figure 2: Vortical structures of flow over a cylinder at (a): Re =100, (b): Re=200

Table 1: Comparation of present results and literature results

	Re	C_d
Current	100	1.38
	200	1.39
Chiu[7]	100	1.35
	200	1.37
Xu S[8]	100	1.42
	200	1.42

Flow over an oscillating cylinder

Simulations of an oscillating cylinder were computed under the Re = 185. The amplitude (Ae) was 0.2d , and the oscillation frequency (fe) are $1f_0$, $1.2f_0$, where f_0 is the vortex shedding frequency. The computational domain was the same as the flow around the stational cylinder.

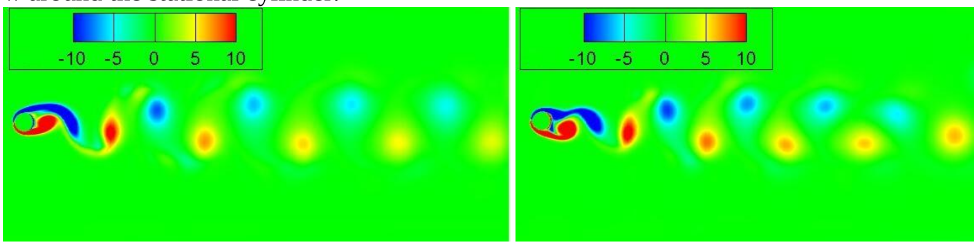

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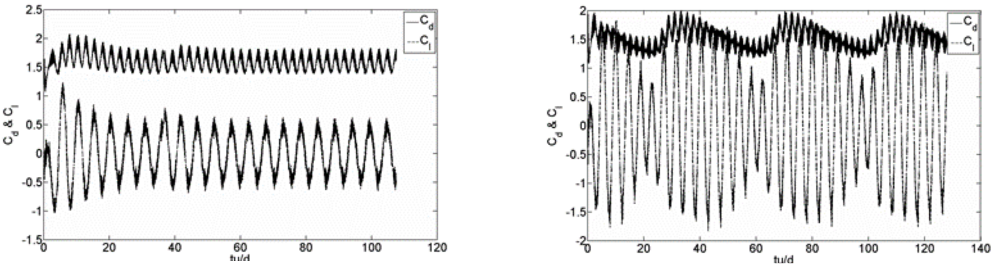
Figure 3: Vortical structures of flow over an oscillating cylinder. (a): fe/f0=1, (b): fe/f0=1.2

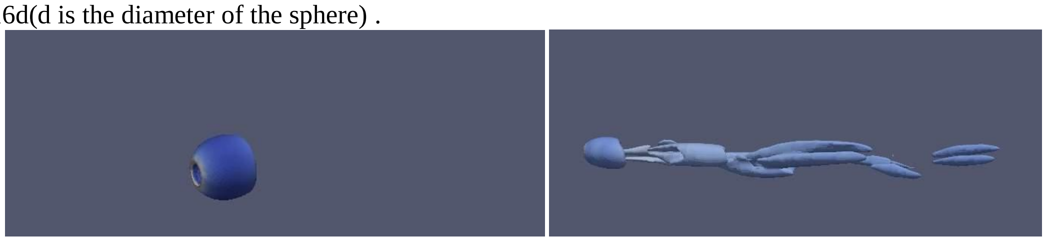


a **b**

Figure 4: The evolution of drag and lift coefficient for the cylinder oscillation. (a): fe/f0=1, (b): fe/f0=1.2

Flow over a 3D sphere

The 3D sphere simulations were conducted under the condition of Re = 100 and 300. The computational domain was 33d×16d×16d(d is the diameter of the sphere) .



a **b**

Figure 5: Vortical structures of flow over a 3D sphere. (a): Re=100, (b): Re=300

Table 2: Comparation of drag coefficient

	Re	C_d
Current	100	1.071
	300	0.692
JungwooKim[9]	100	1.087
	300	0.657
Fornberg[10]	100	1.085
Constantinescu[11]	300	0.655

Simulation of undulatory swimming

The fish body is represented by a NACA 0012 foil, the following motion is selected to resemble the fish-swimming motion observed in nature. The movement equation[12] is described as:

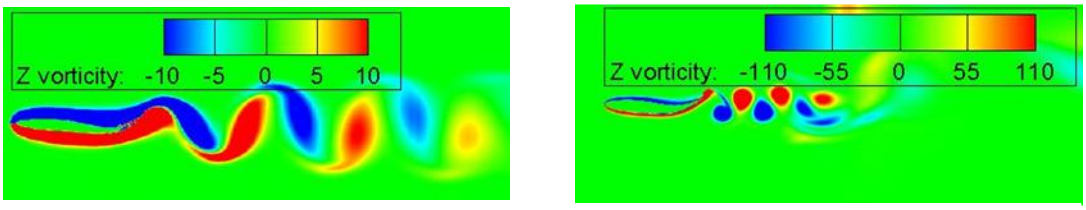
$$h(x,t) = a(x)\, sin\left[2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right] \qquad (1)$$

$$a(x) = L\left[0.351\,sin\left(\frac{x}{L} - 1.796\right) + 0.359\right] \qquad (2)$$

whrerλ is the wavelength, L is the body length, and the Strouhal number is defined by

$$\mathrm{St} = \frac{fA}{U} \qquad (3)$$

The simulations were carried out under the condition of Re=45000, St = 0.23 , 1.18.



a b

Figure 6: Vortical structures of the fish-like movement. (a):St=0.23, (b):St=1.18

Acknowledgements

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