

## SIMULATIONS OF THE THREE-DIMENSIONAL HYDRAULIC TRANSIENT PROCESS OF FRANCIS TURBINE WITH AN IMMERSED BOUNDARY METHOD

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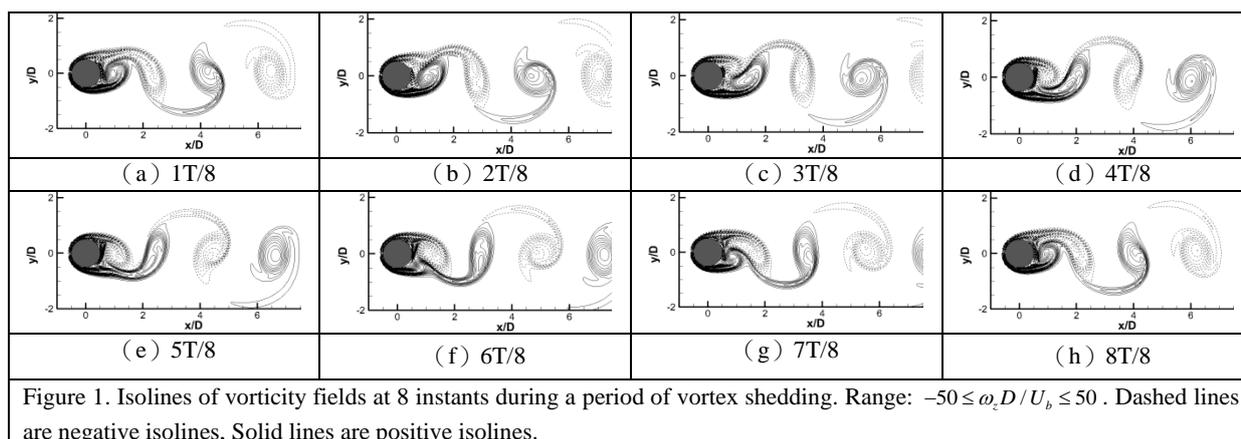
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From the immersed boundary (IB) method point of view, the solid part may mainly act as elastic body or rigid body. Traditionally, the IB approach for fluid and rigid body interaction or fluid dynamics with complex geometry and boundary conditions has been divided into two main categories: the feedback forcing approach and the direct forcing approach. In the direct-forcing IB approach, the body force term is directly deduced from the momentum equation by setting the velocity at IB points to the desired velocity using interpolation/distribution functions. In this manner, the boundary conditions are satisfied on IB points of solid. The direct-forcing IB method has been used successfully by many researchers in various applications. For example, Kim et al [1] developed a new second-order linear or bilinear interpolation scheme to satisfy the no-slip velocity on the immersed boundaries. Elias Balaras [2] presented a novel interpolation scheme which is applicable to boundaries of arbitrary shape. In this method, the velocity field at the grid points near the interface is reconstructed using the momentum forcing without smearing the sharp interface and thus it allows the accurate imposition of the desired boundary conditions. Latter, Yang et al [3] combined the reconstructed interpolation method and large eddy simulation to model turbulent flows interacting with moving boundaries. In this method, several complicated geometric procedures were eliminated without sacrificing the overall accuracy. Ji et al[4] introduce an improved body force distribution function which transfers the body force in the discrete volume of IB points to ambient Cartesian grids totally. Comparison between the computational results predicted by the full distribution forcing strategy which distributed the body force both inside and outside of the immersed boundary and those predicted by the half distribution forcing strategy which spreads the body force just inside the immersed boundary shows that the full distribution forcing strategy has better performance(???check here). Shu et al. [5] suggested correcting the velocity on the Cartesian grids near the immersed boundary directly to the boundary conditions on the fluid–solid interface, instead of using the

interpolation/distribution functions. However, for complex industrially fluid problems, it is still a challenge to apply the IB method accurately and efficiently. .

This paper presents application of an IB method to the industrial flows involving complex geometric configurations. Our aim is to describe the main features of the IB method, and then to introduce an improved method for distribution function which transfers the body force in the discrete volume of IB points to ambient Cartesian points totally. To reduce the computational expense of a full-resolved direct numerical simulation, a direct velocity correction method which transfers the body force in the discrete volume of IB points to the velocity of surrounding Cartesian grids is presented. The accuracy and capability of the present method is firstly validated by performing a flow past a cylinder. Then a three dimension hydraulic transient process of Francis turbine is simulated using the IB method for an industrially application. The present application shows that the IB method is an easy-to-use, inexpensive and accurate technique, and thus can be taken as an important step towards the application of computational fluid dynamics to industrially relevant problems.

Fig.1 is the vorticity fields at 8 instants for a flow past a cylinder during a period of vortex shedding. It shows that this method can accurately capture the vortex structure behind the cylinder and that the vorticity isolines are very smooth. Therefore, the IB method in this paper is reliable.



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