A Numerical Analysis on Interaction Problems between Fluid and Multi-body Using CIP Method

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SUMMARY

The phenomena of fluid-structure interaction (FSI) have frequently occurred in our daily life. The examples are the noise in automobile ventilation system, air flow around windmill and aircraft, and the blood flow in a blood vessel and a mechanical heart. In the past, most of researches on FSI were only performed for the behavior of structure without a fluid effect. This is due to a limitation of computer performance and numerical algorism. So the predicted solution has a large difference to the real phenomena. In recent years, a number of engineers have required more accurate solution in the design problem.

Generally two kinds of difficulties can be occurred in the numerical analysis of FSI problem. The difficulties have been mainly due to the interface problem between the different phases. The first difficulty is the accurate search of the interface between the various phases because of inaccurate searching algorithm. The second difficulty is the solving algorithm on dealing with the different phases in the same matrix solver due to the dissimilar scales of solution between the various phases.

Particularly, these difficulties are frequently occurred in the problem on the nonlinear physical phenomena such as phase change, porosity, and rubber characteristic. In this case, it is very difficult to satisfy the conservation law on the physical quantity. Also the dynamic analysis with the implicit time marching scheme has been always required in order to analyze the flow around moving structure. However, most of researchers use the one-way effect in the flow analysis around moving structure. After the fluid analysis, the result is explicitly used in the structure or dynamic analysis. This method leads to the large error in the solution. So the new method dealing with two-way effect is needed, that is the main concern in recent study. Also another difficulty is occurred on the conservation of the physical quantities due to simply interpolate the properties of the phase interfaces. So it is very important to overcome the above mentioned problems in order to gain the accuracy of FSI analysis.

The free surface flow has been generally analyzed by interface tracking method or interface capturing method. In the interface tracking method, the computational grid point is moved directly. The merit of interface tracking method is that the phase interface can be clearly divided by grid point. However grid generation is very difficult for discontinuous flow. In the interface capturing method, the computational grid point is always fixed with searching the phase surface. In spite of the difficulty of interface searching, interface capturing method is widely used for discontinuous flow or free surface analysis.

The interface capturing method is classified into VOF, Level set, and CIP method. In VOF (Volume of fluid) method, the interface is captured by volume fraction of a phase in a cell. The PLIC (piece linear interface calculation) VOF method, which is used for improving mass conservation of general VOD method, is very complex in the geometrical calculation for the interface reconstruction. In LS (Level set) method, the LS function is defined as a signed distance from the interface. This method can accurately calculate the interface curvature by using the continuous LS function. However computational process is more complicated than process in the VOF method. So the CIP (Cubic Interpolate Propagation) method is introduced for overcome the shortcoming of VOF and LS. The CIP method was developed by Takewaki et al. and uses the solution of the wave equation

The CIP method has the special advantage to reduce the numerical diffusion for a large density difference by using the cubic interpolation

In particular, CIP method can be applied for multi-phase flow, phase change, the fluid flow problem with the simultaneous consideration of incompressible and compressible flow. These types of fluid flow and heat transfer can greatly increase numerical diffusion due to a sharp interface. Yoon et al. did analyze the compressible flow, free surface flow using CIP method. In their research, staggered grid and predictor-Corrector method was adopted.

In this study, the analytic program has been developed for the purpose of the complicate geometries application. So the non-staggered, non-orthogonal, and unstructured grid system can be also used for the various geometries in the program. For validating CIP solver, the lid-driven cavity flow and solitary wave propagation flow are carried out. The lid-driven cavity flow is performed with a variety of Reynolds number for unstructured and non-orthogonal test. The solitary wave propagation flow is performed for phase moving boundary test. The research was performed on the flow problem around torpedo and log and the flow problem in a tank in order to analyze the three phase flow problem with solid, liquid, and gas.

Test results show a good agreement with the proved results. And dynamic solver was used for the behavior of moving body. Interface process between the two solvers is introduced. Although the comparison to the verified results was not quantitatively performed, the trend of the results was reasonable.

The next plan is to validate the developed solver for FSI problem. And also the application a many of application field is future work.