8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

COUPLED ANALYSIS OF HIGH-SPEED FLOW AND LARGE-DEFORMABLE STRUCTURE USING PARTITIONED SOLUTION METHOD WITH LEVEL SET FUNCTION

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Key Words: *Fluid-Structure Interaction, Large Deformation, Partitioned Solution Method, Level Set Function.*

ABSTRACT

It is one of important research subjects to solve fluid-structure coupled problems, e.g., airbag and parachute deployments, where a large-deformable thin structure moves in a high-speed flow fields. Many fluid-structure coupling methods based on ALE (Arbitrary Lagrangian-Eulerian) moving mesh [1] has been so far implemented for various coupled problems. However the ALE method is not suitable for tracking an interface with large deformation and movement. The reason is that a remeshing algorithm for avoiding the mesh distortion becomes complicated. It might cause marked increase of computational time.

In this study, a partitioned fluid-structure coupling algorithm based on Eulerian fixed mesh with level set function, named Signed Distance Function (SDF) [2], is constructed in consideration of the above drawback of the ALE method. A large-deformable interfacial geometry moving as Lagrangian description can be easily expressed as zero level set in an Eulerian fluid domain [3] [4]. Then, it is important to update the level set isosurface according as movement of the interfacial geometry and address kinematical conditions at the interface. In this study, a novel interface treatment using a virtual particle with level set function and structure velocity component is proposed in order to settle these problems. The virtual particles are generated in the normal direction of structure nodes on the interface at equal intervals. In addition, a partitioned solution method, where fluid and structure variables are separately solved by finite element method and they are computed iteratively in each time step, is constructed in consideration of the interface treatment using the virtual particles and future application to large scale fluid-structure interaction problems.

The governing equations for fluid are assumed to be compressible, inviscid, and adiabatic. The continuity equation, the equations of motion, and the energy equation are handled as the conservation laws. The fluid system is closed by the equation of state. The advection phases of these equations are computed using CIP (Constrained Interpolation Profile) –FEM [5]. On the other hand, the governing equations for structure are assumed to be compressible and elastic. The equations of motion are solved with the constitutive equation of St. Venant-Kirchhoff material. Furthermore the kinematical and kinetic conditions are imposed on the interface in consideration for slip

in the tangent direction.

We analyze two coupled problems of flow and thin elastic structure to accuracy and capacity of the present method. Firstly, we analyze water flow in a channel with outlet closed by a structure, which is solved by Legay, Chessa, and Belytschko [3]. Numerical solutions are compared with results obtained from an ALE based coupling method and validity of the present method is quantitatively shown. Secondly, the coupled problem of a high-speed air flow and a thin elastic structure, which is set up from the calculation data of the airbag deployment anlayzed by Cirak and Radovitzky [4], is solved. When an air flow with higher density and pressure enters thin elastic container, the container expands gradually because of aerodynamic force acting on the wall (see Fig.1). As the results, it is confirmed that the present method has capability for analyzing large deformation and movement of the structure. Application of the present method to three-dimensional practical problems is future work.

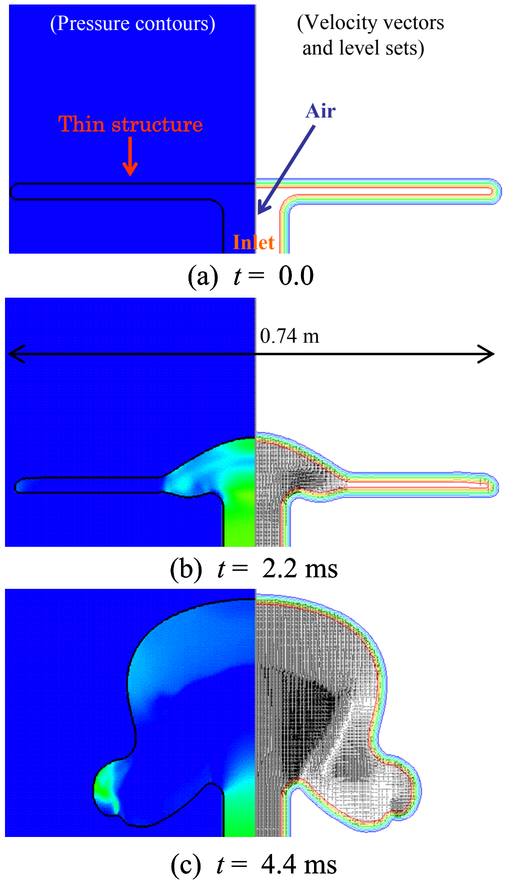

Fig.1 The numical results of coupled analyis of air flow and thin structure

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