On Reliability of Higher-Order FEM in Fluid-Structure Interaction Problems

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In this paper we are concerned with numerical methods for fluid-structure interaction (FSI) problems, as well as with their verification and validation. The interaction of fluid flows with elastic structures plays an important role in many technical disciplines – aerospace industry (e.g., wings deformations), blade machines (turbines, compressors, pumps), civil engineering (stability of bridges), etc. We consider a coupled two dimensional model involving incompressible viscous fluid and an elastic structure. The problem is solved with the aid of the Finite Element Method (FEM). Numerical results are compared to relevant benchmark problems and experimental data.

The fluid flow is mathematically described by the incompressible Navier-Stokes equations (INSE). For the numerical approximation, several sources of instabilities have to be treated. First, the coupling of finite elements for velocity and pressure needs to satisfy the Babuška-Brezzi (BB) condition in order to guarantee the stability of the scheme. Furthermore, flows with high Reynolds numbers require the application of a additional suitable stabilization for the FEM discretization. We will discuss a stabilization procedure for higher-order finite elements based on Galerkin-Least squares method (GLS). Performance of the method will be studied on several problems whose solution will be compared to experimental data.

The choice of the structural model depends on the underlying technical application. We discuss two models of the motion of the structure: First we use a low-dimensional motion based on a few degrees of freedom (e.g., flexibly supported airfoil which can vertically oscillate and rotate around its elastic axis). The fluid approximation on moving meshes is treated with the aid of the Arbitrary Lagrangian-Eulerian (ALE) method. Second, the elastic body is described by the Lamé's equations of elasticity and solved with the aid of adaptive *hp*-FEM. A performance comparison of the *hp*-FEM with the standard lowest-order FEM will be shown.

Finally, the weak, strong, and monolithic approaches for the coupling of the fluid and structure models is discussed. Numerical results are validated using NASTRAN as well as on experimental data.