Socket-Based Coupling of OpenFOAM and Abaqus to Simulate Vertical Water Entry Of Rigid And Deformable Structures

Maximilian Müller, Matthias Haupt, Peter Horst

TU Braunschweig, Institute of Aircraft Design and Lightweight Structures,
Hermann-Blenk-Str. 35, D-38108 Braunschweig,
maximilian.mueller@tu-braunschweig.de, +49 531 391-9919
www.tu-braunschweig.de/ifl

An important element of the process of aircraft certification is the demonstration of the crashworthiness of the structure in the event of an emergency landing on water, also referred to as ditching. Novel numerical simulation methods that account for mechanical fluid-structure interaction (FSI) open up a promising way to model ditching on a high-fidelity level. High demands are placed on those simulation methods due to the strong added-mass effect during ditching [1,2,8].

This work presents a numerical simulation approach combining *OpenFOAM-5.0* and the proprietary finite element structural solver *ABAQUS*. The coupling data is exchanged by using a socket-based communication method as part of the distributed environment *ifls* [4]. A Dirichlet-Neumann approach is applied along with a fixed-point coupling method adopting the simple but yet efficient and robust Aitken accelerator [5]. The socket-based communication between *OpenFOAM* and *ifls* is realized by using an OpenFOAM function object. The modular structure of the function object is shown in figure 1. The structure is based on the function object for conjugate heat transfer analysis described in [7].

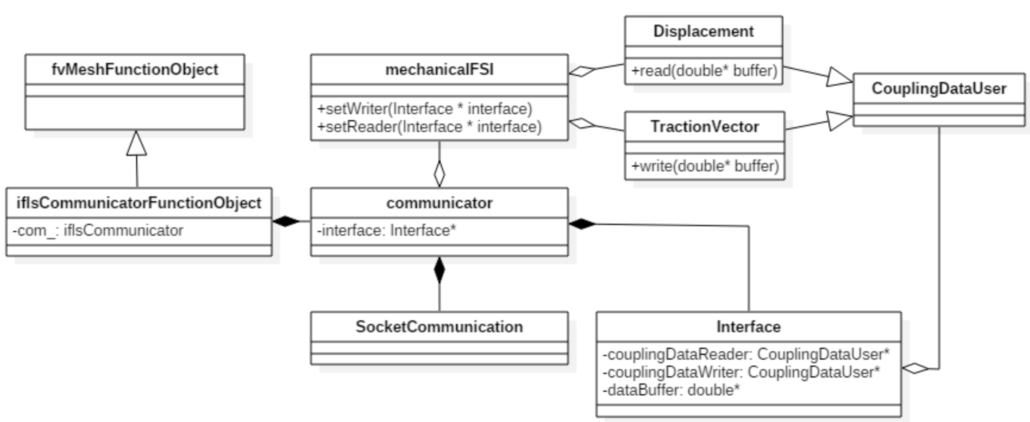

Figure 1: General code structure of OpenFOAM function object for mechanical FSI

The *iflsCommunicatorFunctionObject* class accomplishes the external communication by calling special methods of the *communicator* class at predefined points of the simulation. The *iflsCommunicatorFunctionObject* class is directly derived from the general OpenFOAM *fvMeshFunctionObject* class. The *SocketCommunication* class is used by the *communicator* class to realize the socket-based communication. The *Interface* class contains the fluid-structure interface. The calculation of the fluid forces at the fluid-structure interface as well as the application of the structural displacements to the fluid mesh are realized by the *mechanicalFSI* class.

The developed method is applied to solve the two-dimensional water impact of rigid and deformable circular cylinders as described in [3] and [6]. The calculated results are compared with experimental data. Prospects of extending the presented method to account for both highly nonlinear structural behaviour as well as hydrodynamic effects, thus allowing the ditching simulation of full aircraft configurations, are discussed.

References

[1] P. Causin, J.-F. Gerbeau and F. Nobile, Added-mass effect in the design of partitioned algorithms for fuidstructure problems. *Computer methods in applied mechanics and engineering*, 194(42), pp. 4506-4527, 2005.

[2] C. Förster, W.A. Wall and E. Ramm, Artificial added mass instabilities in sequential staggered coupling of nonlinear structures and incompressible viscous flows. *Computer methods in applied mechanics and engineering*, 196(7), pp. 1278-1293, 2007.

[3] M. Greenhow and W.-M. Lin, Nonlinear-free surface effects: experiments and theory, No. 83-19, Massachusetts Institute of Technology, Department of Ocean Engineering, 1983.

[4] M.C. Haupt, R. Niesner and R. Unger, Computational aero-structural coupling for hypersonic applications. *9th AIAA/ASME Joint Thermophysics and Heat Transfer Conference, AIAA-2006-3252, San Francisco, California*, USA, 2006; 119.

[5] B.M. Irons and R.C. Tuck, A version of the Aitken accelerator for computer iteration. *International Journal for Numerical Methods in Engineering*, 1(3), pp. 275-277, 1969.

[6] H. Sun, O. M. Faltinsen, Water impact of horizontal circular cylinders and cylindrical shells. *Applied Ocean Research*, 28(5), pp. 299-311, 2006.

[7] B. Uekermann, H.-J. Bungartz, L. Cheung Yau, G. Chourdakis, A. Rusch. (2017). Official preCICE Adapters for Standard Open-Source Solvers.

[8] E.H. Van Brummelen, Added mass effects of compressible and incompressible flows in fluid-structure interaction. *Journal of Applied mechanics*, 76(2), 2009