Falcon

Foreseeing the next generation of Aircraft

D2.3. 1st Report on the validation of FSI solvers on academic and industrial test cases focusing on stability, efficiency and accuracy

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List of acronyms	
CA	Clean Aviation
EC	European Commission
EU	European Union
FSI	Fluid-Structure Interaction
FEM	Finite Element Model
GDPR	General Data Protection Regulation
IPR	Intellectual Property Rights
KERs	Key Exploitable Results
KPIs	Key Performance Indicators
LBM	Lattice Boltzmann Methods
PEDR	Plan for Exploitation and Dissemination of the project Results
R&I	Research & Innovation
WP	Work Package

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2. ESPRESO, VSB-TUO, IT4Innovation

ESPRESO library is a highly parallel library for solving engineering problems of structural mechanics. In the FALCON project, it is coupled with the OpenLB library to provide an open-source and scalable suite for FSI simulations. During the first two years of the project, we implemented an interface to the open-source coupling library PreCICE [1], integrated the pressure computed with the fluid solver for non-matching grids, and verified ESPRESO on two examples provided by the community. The newly implemented features are described in detail in the sections below.

2.1. Coupling with PreCICE

PreCICE is an open-source coupling library for partitioned multi-physics simulations. It was chosen for use by the open-source branch of this project to couple ESPRESO with OpenLB libraries. Using this library instead of the direct connection brings the advantage of generality and easier utilization of both libraries by the community. The implementation of the PreCICE interface enables the integration of tools developed within the FALCON project with other software for physical simulations. Hence, increase the project's impact.

In coupling, the PreCICE tool serves as a middle-layer between the solvers. It is responsible for exchanging data, mapping simulated parameters from one solver to another, and orchestrating the simulation. Once a solver implements the PreCICE interface, it can be coupled with all other software that also supports PreCICE.

2.2. Implementation in ESPRESO

The PreCICE wrapper in the ESPRESO library was implemented for physical solvers of transient structural mechanics problems. It implements all the functions required by the PreCICE library for both explicit and implicit coupling. In particular, the wrapper implements methods *advance*, *read* and *write*, and also *checkpoints*. From a general perspective, it was crucial to implement a wrapper that does not affect non-FSI runs. Hence, two versions of the wrapper exist. The first is a dummy wrapper that always keeps the simulation untouched, i.e., the advanced method does not change the time step, and the

computation is never restarted from a previous checkpoint. The second, the real wrapper, is activated only when the FSI simulation is performed. Then, the wrapper modifies the time step and restarts the computation as controlled by the PreCICE library.

2.3. Non-matching grids

The PreCICE library offers numerous mapping functions for parameters between solvers. However, during the initial experiments, we were unable to achieve a satisfactory exchange of the force parameter for non-matching grids. All tested mapping functions were dependent on the discretization used. Hence, we developed a manual integration of the force in the ESPRESO library.

3. OpenLB-ESPRESO – KIT

Within task 2.5, a FSI software suite consisting of the FEM solver ESPRESO (IT4I@VSB) and the LBM solver OpenLB (KIT) is to be developed. In order to orchestrate the coupling between both frameworks, preCICE, a coupling library for partitioned multi-physics simulations is utilized. Each solver maintains a separate mesh for solid (ESPRESO) resp. Fluid (OpenLB) and information is exchanged at the frontier between both. Specifically, OpenLB computes surface forces via momentum exchange, communicates those forces to ESPRESO where they are used as boundary conditions for the FEM structure mesh, displacements are computed and communicated back to OpenLB. The exact sequence of information exchange and processing is controlled by preCICE which offers a selection of different (explicit and implicit) coupling algorithms.

4. LaBS-Nastran Cosimulation

In the first half of the project, we mainly exchanged with people of Hexagon to identify the technical needs of both software. Our main concern is about exchanging data between LaBS and CoSim in the heavily parallelized environment of LaBS.
The principle of the LaBS/CoSim coupling is quite simple, coupling is ported by surfaces, LaBS will send the force applied at each center of triangle and Cosim will send back the new position of each vertex. But there is some particularity due to parallel execution.

5. CoSim coupling strategy

MSC Software had developed and commercialized the CoSim engine aimed to couple 2 different solvers in a strong coupling strategy. Prior to Falcon, the CoSim tool was only interfaced with MSC Software solutions like Nastran. With Falcon, the objective was to extend the interface to non-MSC solutions by supporting the development of a connection in LaBS and extend also the mapping and connecting strategies to match to Fluid-Structure Interaction problems planned in Falcon.