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A NEW STRATEGY FOR SOLVING STORE SEPARATION PROBLEMS USING OPENFOAM

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Abstract. The ability of OpenFOAM to solve the store separation problem has been evaluated using an overset method for an industry-class test case. The major challenges have been highlighted. To tackle these challenges, a new strategy has been proposed and implemented using completely open-source tools. The obtained results are compared to the wind tunnel experiments.

1 INTRODUCTION

Safe separation of stores is a critical mission for many air vehicles. Predicting the path which the store will take (to decide the safe separation envelop) can be done using wind tunnel testings [1] and flight tests [2]. However, both methods are costly and raise safety issues. The recent developments in computer hardware as well as parallel Computational Fluid Dynamics (CFD) algorithms have made simulations possible and more feasible. This reduced the need for the first two methods.

There are two CFD approaches to solve this problem, which are inherited from the wind tunnel testing [3]: the off-line (or grid survey method [4]) and the on-line (or captive trajectory simulation [5]) approaches. In the first approach, an aerodynamic database of forces and moments are obtained by solving the flow fields (as a steady-state case) over a static mesh for different scenarios. The scenarios (or grid test matrix) are mixture of different Mach numbers, altitudes, angle of attacks, side angles and store positions.

Finding the optimum scenarios is normally obtained using the Modern Design of Experiments (MDOE) method [3]. After creating the aerodynamic database, a six degrees of freedom (6 DOF) solver is used to obtain the linear displacements, linear velocities, angular displacements and angular velocities. For the second approach, transient simulation which utilizes a dynamic mesh technique is required. Since the resulting deformations are normally large, the suitable dynamic mesh techniques are either based on the deformable mesh (with re-meshing capabilities) [6] or overset/chimera [7] techniques. At each time step, the flow fields are computed, the forces and moments are calculated, and using a 6 DOF solver, the displacements and velocities are calculated. Finally, the mesh is moved (or deformed/re-meshed) according to these displacements.

Practically speaking, If the required number of cases to decide the safe separation envelop is enormous for the same geometry, using the first approach by generating large database will be efficient. However, if the number of cases are not so many, and for different geometries, the second approach can be more efficient. In this work, the second approach (on-line) will be used.

Although OpenFOAM [8] is a very popular open-source platform for CFD, it has been rarely used for solving the store separation problem. The work of Wadibhasme [9] can be mentioned. He used the Mesquite dynamic mesh library [10] which was available under OpenFOAM in earlier releases. However, he ran only a sample projectile case using an incompressible solver (pimpleDyMFoam) for demonstration. The reasons that OpenFOAM is not used widely in store separation problems are: Firstly, store separation analysis is normally required at transonic and supersonic regimes, whereas in OpenFOAM, there is a well-known limitation in it's standard compressible solvers, such that there are no density-based coupled compressible solvers which are normally used in these regimes. Secondly, the OpenFOAM dynamic mesh libraries have limited capabilities.

2 Problem Statement

The problem involves solving transient, compressible Euler equations while a solid body moves within the computational flow domain. The motion of the body is the result of solving the 6 DOF equations by considering all the applied forces and moments.

3 Present Work

In this paper, a new strategy for solving the store separation problem within the OpenFOAM platform is proposed, implemented and validated.

After evaluating the standard OpenFOAM capabilities to solve this problem, two main limitations have been observed:

- The flow solver: More accurate and stable compressible solver is required

- The overset mesh-to-mesh addressing algorithm: More efficient (faster) and robust (can classify the cells accurately for complex cases) algorithm is required. Having a correct cell classification (calculated, hole or interpolated) will enable the use of higher orders interpolation schemes. Thus, more accurate results can be obtained

3.1 THE FLOW SOLVER

HiSA [11] is an external (non-standard OpenFOAM) open-source and free solver which utilizes the OpenFOAM libraries. It is density-based and coupled solver which can solve both transient and steady-state cases. It has been developed at the Council for Scientific and Industrial Research, South Africa (CSIR) [12]. HiSA solver has been verified and used here together with overset method. The code is also parallelizable through OpenFOAM parallel library.

3.2 THE OVERSET MESH-TO-MESH ADDRESSING ALGORITHM

Under the OpenFOAM platform, there is an alternative open-source overset library in the foam-extend fork [13]. The algorithm is more robust and faster than the standard OpenFOAM overset library. This library has been tested then ported to OpenFOAM in order to be used with the HiSA solver.

3.3 VALIDATION

Eglin [1] is by far the dominating test case for codes validation for the store separation problem. That can be attributed to the availability of the geometry and the experimental test reports. The three test objects (wing, pylon and store) are shown in Fig. 1.

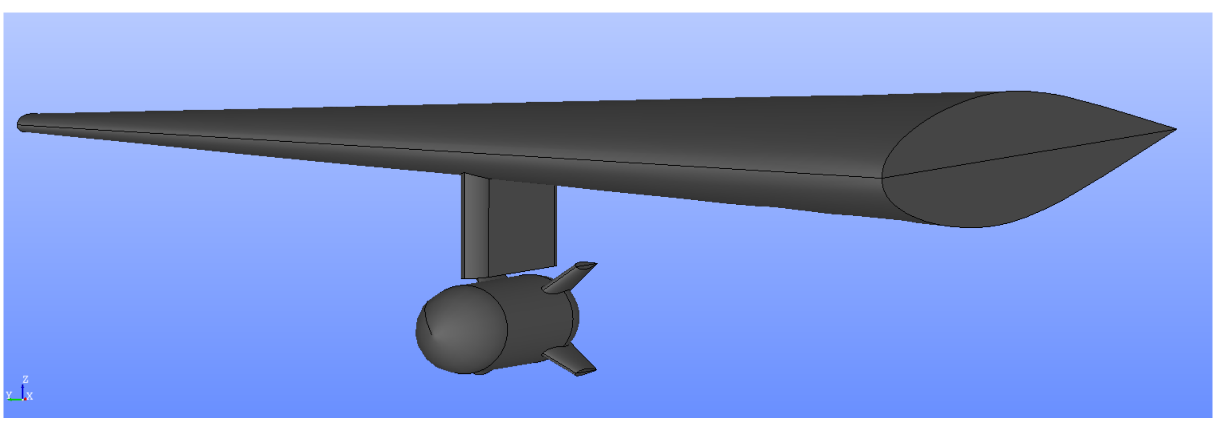

Figure 1: Eglin case full-scale geometry

snappyHexMesh [14] (unstructured, octree-based and hexa-dominant) open-source meshing tool has been selected for mesh generation. A slice from the coarse mesh is shown in Fig. 2.

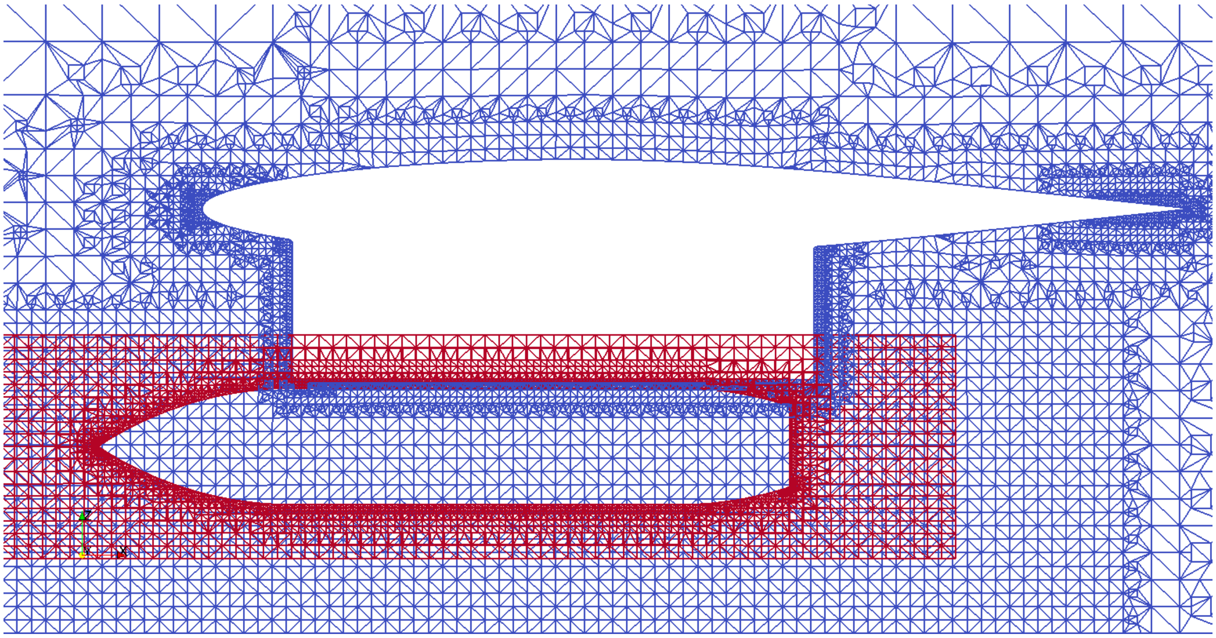

Figure 2: slice from the coarse mesh (0.58M cell), the background mesh in blue and the overset mesh in red

3.4 TO BE PRESENTED

The results obtained with the current approach will be presented at the conference, demonstrating the superiority of the new approach of choosing better libraries for the problem at hand. The parallel efficiency of the method will be studied. Comparisons with wind runnel experiments will be made.

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