Simulation of Fighter Aircraft in sonicFoam

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Abstract:

The fighter aircraft Sukhoi Su 30 MKI is meshed in snappyHexMesh and solved using sonicFoam for a laminar, compressible supersonic flow regime in the OpenFOAM software.

Keywords: OpenFOAM, snappyHexMesh, Supersonic, Fighter, sonicFoam

INTRODUCTION

OpenFOAM is a open source software which is majorly used for solving numerical and CFD problems. The CFD simulation of Fighter aircraft in supersonic regime is carried out using the software with appropriate utilities to aid the solution.

METHODOLOGY

1. Import the CAD models as .stl files
2. Create the mesh with appropriate blockMesh, edgeMesh from stl file through surfaceFeatureExtract and snappyHexMesh for the model.
3. Select appropriate solver for the flow conditions and validate the choice by a test run on cylinder.
4. Set the solver for the fighter case and simulate the case
5. Extract results from postprocessing and document the case

PROCESS AND PROCEDURE:

1) Geometry:

The CAD model of the fighter aircraft is obtained from grabCAD[1] and is stored in the triSurface directory. General specifications of the model is listed below:

Sukhoi Su 30MKI[2]

Length: 22 m Wingspan: 15 m Height: 6 m

The model is scaled at 1:10 ratio to obtain the model at “1.5 m * 0.5 m * 2. 2 m”.

2) Mesh:

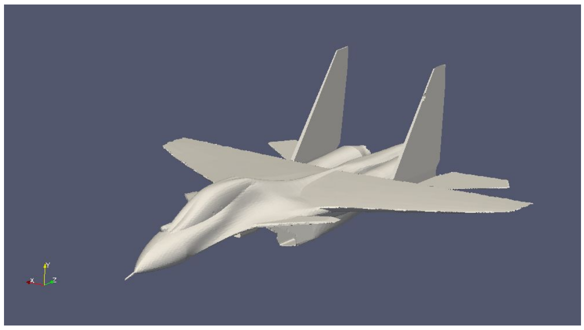

Fig a Mesh of SukhoiSu 30MKI

The case directories 0, constant, system are created with appropriate sub-directories (triSurface with the .stl file in constant directory) and dictionaries (blockMeshDict, snappyHexMeshDict surfaceFeatureExtract Dict in system directory) .

The blockMesh:

Domain Specifications:

A domain size of “5 m * 5 m * 12.5 m” is designed around the model as a single block. The domain is designed with the convention[3] of 10x * 10x *(5x+15x), where x is the minimum dimension in the windward side.

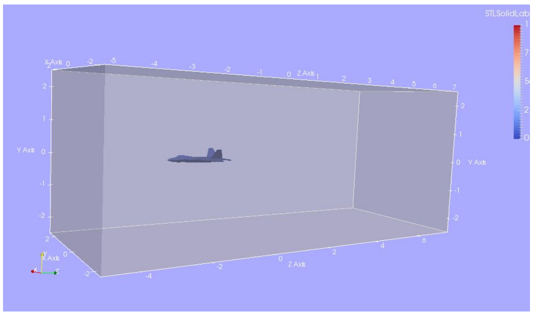

Fig b Domain of SukhoiSu 30MKI

Grading and refinement:

The domain is graded so as to have fine mesh around the model with AR=1 and courser mesh near the periphery of the domain. The grading[4] and division are done with care on smooth transitions all over the domain.

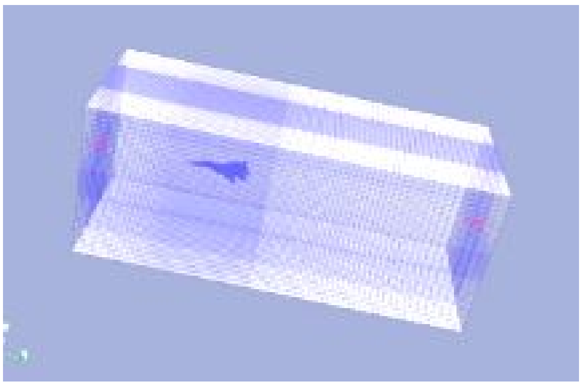

Fig c Grading of Domain

Patches and Boundaries:

The sides, top and bottom are modelled as symmetryPlane while the inlet and outlet faces are modelled as patch.

The complete code can be viewed in the blockMeshDict[5] in system directory.

The snappyHexMeshDict:

The snappyHexMesh is used with the surfaceFeatureExtract utility to mesh the underlying model by following operations:

1) The edges are extracted from the .stl file through the surfaceExtractFeature and is stored as sukhoi.eMesh in the triSurface directory. To run the feature, the surfaceFeatureExtractDict[5] is specified with the .stl file to operate and the settings are tuned to extract all the edges in the .stl file i.e., the model.

2) The domain detects the model and uses casteled Mesh to coarsely remove the blocks that are contained within the model’s outline. This is further refined upto the level specified. The refinement surfaces is set to the eMesh generated, to detect the edges, through which the casteled mesh is generated upon.

3)The sHM dictionary is set with refinements of level 4 to obtain intricate contours of aircraft.

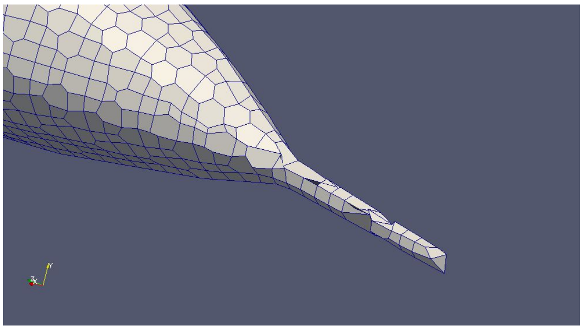

Fig d Meshing of intricate geometry

4)The sHM is carried out in steps of casteledMesh, snap and addLayers so as to check compatibility of mesh.

The code for significant operations for the snappyHexMesh and surfaceFeatureExtract can be found in respective directories.

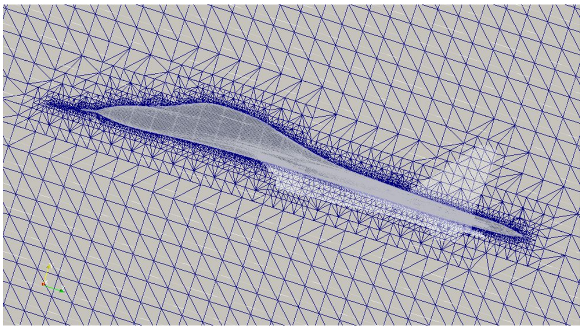

Fig e Cut section of Sukhoi Mesh

checkMesh:

The mesh is generated and the checkMesh command is run to locate illegal faces of the mesh, if any. The result returned as MESH OK. The mesh had nonOrthoFaces which were negligibly small and thus were not considered as error.

Mesh Command set:

Set up the files.

blockMesh

surfaceFeatureExtract

snappyHexMesh

Move the polyMesh into constant

Remove all time files

checkMesh

3) Solver

The Mesh for Sukhoi Su 30 MKI is generated. The mesh is set to be solved with with following initial conditions:

Flow Model : Compressible/Laminar/Transient

Mach Regime : Supersonic/ 1.5 Mach

Fluid Model : Air at STP

Solver Chosen : sonicFoam

4)Validation of solver

The solver is validated for the compatibility to run with the specified conditions by simulating a similar case in a cylinder.[6]

5) Solution

The system folder is updated with the fvSchemes and fvSolution files from sonicFoam cylinder reference case[7] and controlDict is written with **time step 1e-6** and force coefficient functions.

The transport properties and turbulence Properties are also updated in constant folder with **nu 1e-5** and **laminar** simulation respectively. The 0 directory is created with the following boundary conditions:

Boundary	Pressure	Velocity	Temperature
Inlet	TotalPressure 372518 Pa	zero Gradient	FixedValue 300
Outlet	zero Gradient	zero Gradient	InletOutlet 300
Top Bottom Sides	symmetry Plane	symmetry Plane	InletOutlet 301
Sukhoi	zero Gradient	noSlip	zero Gradient
Internal	101325 Pa	0 m/s	300 K

Table 1 Boundary Conditions

The case directory is opened through terminal and **sonicFoam** command is run in **nohup** mode as the simulation takes longer computation time.

6)Postprocessing

The simulation is run and the post processing is done through ParaView.

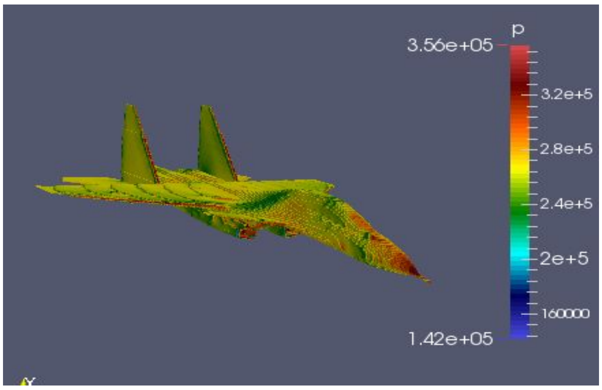

Fig f Pressure Contour

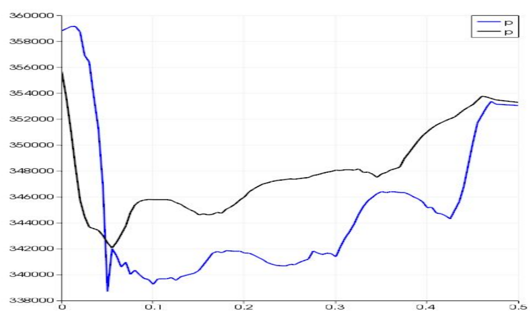

Fig g Pressure plot over the wing

The plots indicate that the simulation is in coherence with the general aspects of flight. The simulation is to be updated for further studies on compressible aerodynamics of the fighter aircraft.

CONCLUSION

The case being a 3D Supersonic Case, the computation time is long.

After the completion of updated simulation, plots on drag forces shall be obtained and validated.

The case can also be developed to compare with a similar simulation of other fighter aircraft and efficiency of one over other can be studied.

References

[1] https://grabcad.com/

[2]https://en.wikipedia.org/wiki/Sukhoi_Su-30MKI

[3] Rocky Patel, Satyen Ramani,

Determination of Optimum Domain Size for 3D Numerical Simulation in ANSYS

[4] OpenFOAM User Guide

[5]OpenFOAM Tutorials >incompressible >simpleFoam>Motorbike>system

[6] Vishish Behera, Simulation cylinder in supersonic flow regime, CFD FOSSEE.

[7] Case Studies > Cylinder at Supersonic Flow.