Final Mesh Refinement for the hypersonic script in AeroF

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Goal: Verification of the excluded volume and Perfect Gas fluid models for the hypersonic script in AeroF

Vérification of the code :

1- Choice of the initial conditions

2- Training of the computer for the hypersonic case

3- Generation of the mesh

4- Choice of the parameters and the error for the refinement of the mesh

5- Case of the Excluded Volume

6- Results

FINAL MESH REFINEMENT FOR THE HYPERSONIC SCRIPT IN AEROF

Step 1: Choice of the initial conditions

Definition of the initial conditions **under BoundaryConditions{under Inlet}** :

- Inlet Beta : $\beta = 0°$
- Inlet Alpha : $\alpha = 0°$
- Inlet Mach : $Ma = 8$
- Inlet Density : $\rho_{inlet} = 1\ kg/m^3$
- Inlet Pressure : $p_{inlet} = 7.8421 \times 10^4\ Pa$

```
under BoundaryConditions {
   under Inlet {
      Type = External;
      Beta = 0;
      Alpha = 0; // Degrees
      Mach = 8;
      Pressure = 7.8421e+04; // Pa
      Density = 1; // kg/m^3
   }
```

Definition of the initial conditions **under Equations{under Navier-Stokes} :**

- Fluid Model = $PerfectGas$
- Gas Constant : $R_{air} = 287.1\ J/kg \times m^3$

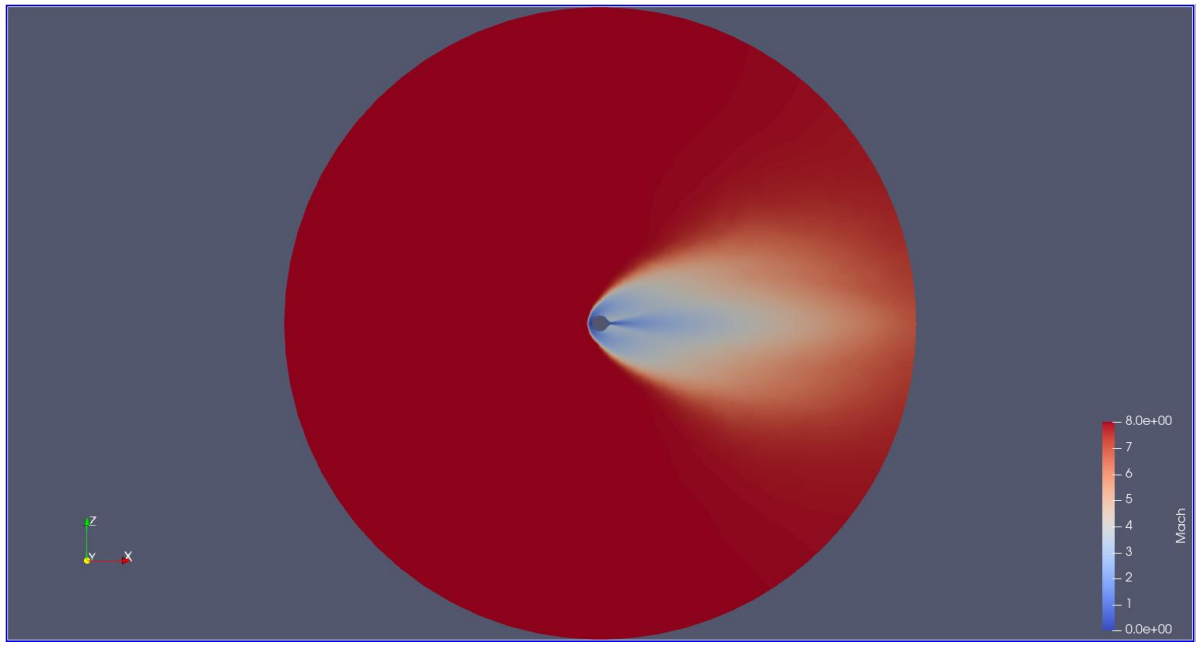
```
under Equations {
   Type = NavierStokes;
   under FluidModel[0] {
      Fluid = PerfectGas;
      under GasModel {
         SpecificHeatRatio = 1.4;
         IdealGasConstant = 287.1;
      }
   }
```

(Parameters equivalence for US3D : $T_{inlet} = 273.15\ K$ and $u_{inlet} = 2.650 \times 10^3\ m/s$)

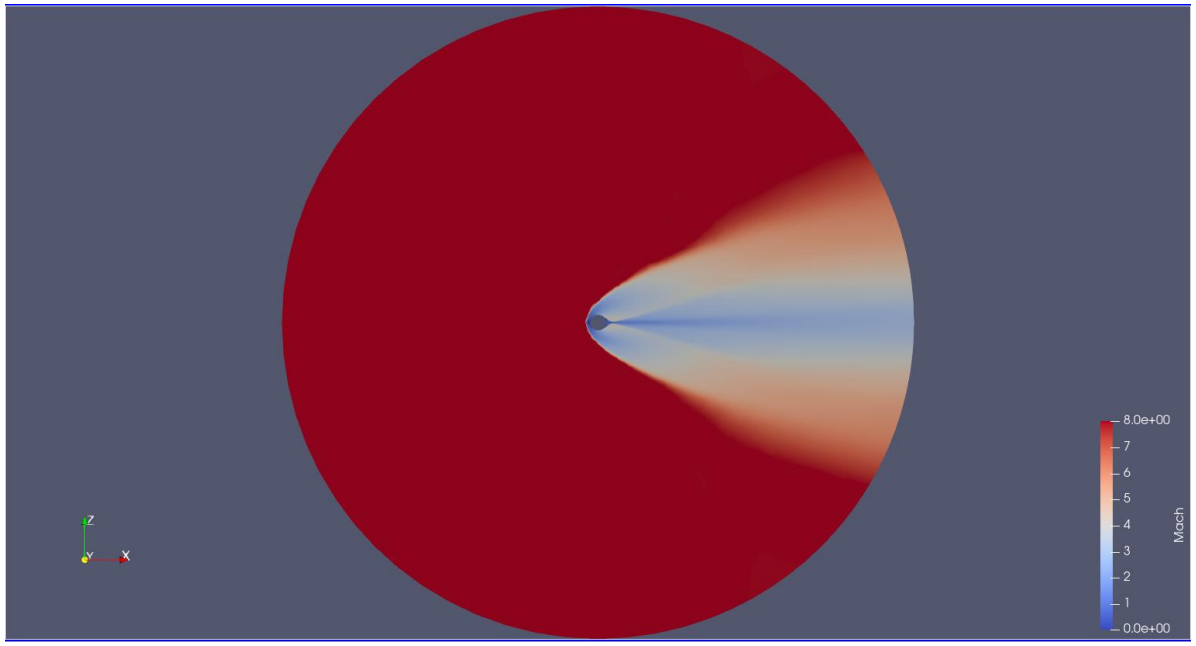
FINAL MESH REFINEMENT FOR THE HYPERSONIC SCRIPT IN AEROF

Step 2: Training of the computer for the hypersonic case

- 5-step process to get more accurate results in the hypersonic case



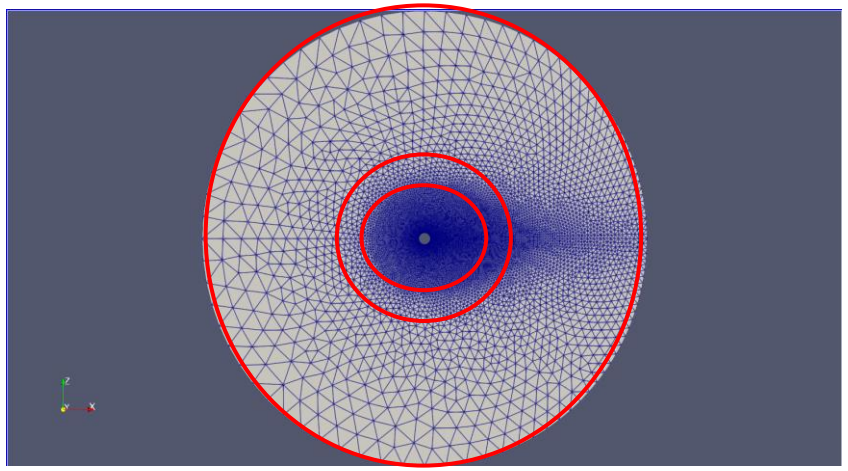
MACH AFTER STEP 1 OF THE HYPERSONIC SCRIPT

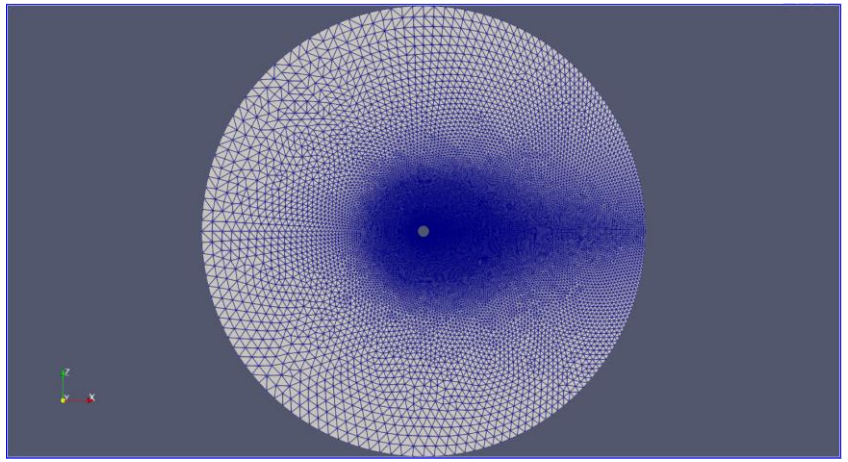


MACH AFTER STEP 5 OF THE HYPERSONIC SCRIPT

FINAL MESH REFINEMENT FOR THE HYPERSONIC SCRIPT IN AEROF

Step 3: Generation of the mesh





Fields of meshes generated

CODE FOR THE FAR FIELD

```
// Far-field

Point(6) = {-Lo, -0.5*dy, 0, clc};
Point(7) = {0, -0.5*dy, Lo, clc};
Point(8) = {Lo, -0.5*dy, 0, 0.2*clc};
Point(9) = {0, -0.5*dy, -Lo, clc};
Circle(5) = {6, 1, 7};
Circle(6) = {7, 1, 8};
Circle(7) = {8, 1, 9};
Circle(8) = {9, 1, 6};
```

CODE FOR THE CYLINDER

```
// Cylinder

Point(1) = {0, -0.5 * dy, 0, clw};
Point(2) = {-0.5*D, -0.5 * dy, 0, clw};
Point(3) = {0, -0.5 * dy, 0.5*D, clw};
Point(4) = {0.5*D, -0.5 * dy, 0, clw};
Point(5) = {0, -0.5 * dy, -0.5*D, clw};
Circle(1) = {2, 1, 3};
Circle(2) = {3, 1, 4};
Circle(3) = {4, 1, 5};
Circle(4) = {5, 1, 2};
```

CODE FOR THE TWO MID-FIELDS

```
// Mid-range (for sizing)

mcr = 0.75*D;
Point(10) = {-mcr, -0.5 * dy, 0, 0.6*clbg1};
Point(11) = {0, -0.5 * dy, mcr, 0.5*clbg1};
Point(12) = {mcr, -0.5 * dy, 0, 0.4*clbg1};
Point(13) = {0, -0.5 * dy, -mcr, 0.5*clbg1};
Circle(9) = {10, 1, 11};
Circle(10) = {11, 1, 12};
Circle(11) = {12, 1, 13};
Circle(12) = {13, 1, 10};

ec = 0*D;
esma = 6.5*D;
esmi = 4.5*D;
Point(14) = {ec, -0.5 * dy, 0};
Point(15) = {ec-esmi, -0.5 * dy, 0, clbg2};
Point(16) = {ec, -0.5 * dy, esmi, clbg2};
Point(17) = {ec+esma, -0.5 * dy, 0, 0.5*clbg2};
Point(18) = {ec, -0.5 * dy, -esmi, clbg2};
Ellipse(13) = {15, 14, 14, 16};
Ellipse(14) = {16, 14, 14, 17};
Ellipse(15) = {17, 14, 14, 18};
Ellipse(16) = {18, 14, 14, 15};
```

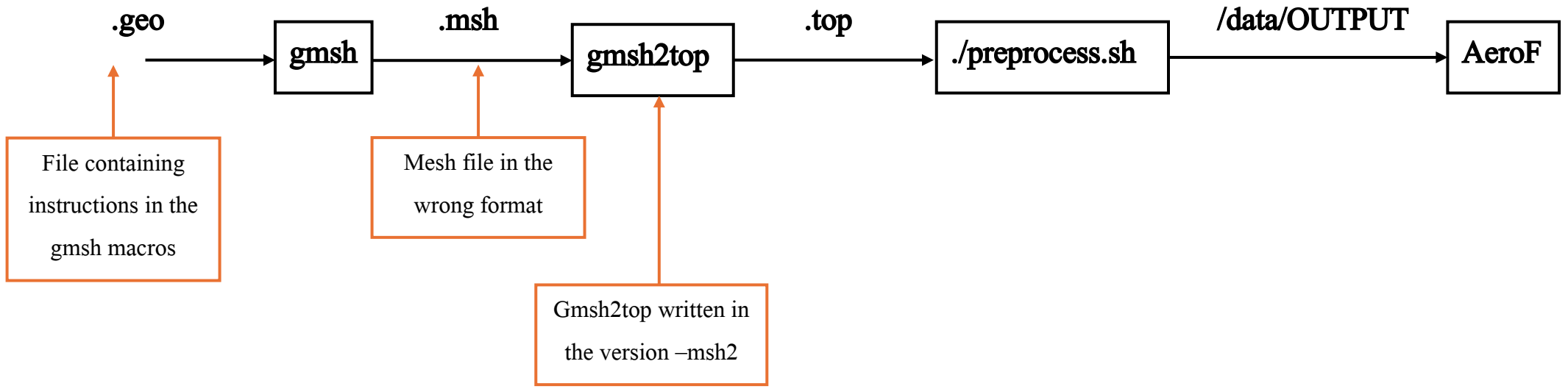
CODE FOR THE PARAMETERS DECLARATION

```
// Geometry parameters
D  = 1;
Lo = 20*D;

// CLW: mesh size near the wall
clw  = 0.01; //0.001;
clbg1 = 0.05;
clbg2 = 0.2;
clc  = 2;

dy = 0.01;

Mesh.Algorithm = 8;
Mesh.Optimize = 1;
Mesh.OptimizeThreshold = 0.6;
Mesh.Smoothing = 10;
```

FINAL MESH REFINEMENT FOR THE HYPERSONIC SCRIPT IN AEROF

Step 3: Generation of the mesh (Part 2)

HOW TO CREATE A NEW DOMAIN :




```
[yelmore@sh03-ln03 login /scratch/users/yelmore/Hypersonic/step4]$ module load math gmsh ^C
[yelmore@sh03-ln03 login /scratch/users/yelmore/Hypersonic/step4]$ gmsh domain.geo -3 -o domain.msh -format msh2 ^C
[yelmore@sh03-ln03 login /scratch/users/yelmore/Hypersonic/step4]$ /home/groups/cfarhat/bin/gmsh2top domain ^C
[yelmore@sh03-ln03 login /scratch/users/yelmore/Hypersonic/step4]$ module load netcdf/4.4.1.1 ^C
[yelmore@sh03-ln03 login /scratch/users/yelmore/Hypersonic/step4]$ /home/groups/cfarhat/bin/xp2exo domain.top domain.exo ^C
```

FINAL MESH REFINEMENT FOR THE HYPERSONIC SCRIPT IN AEROF

Step 4: Choice of the parameters and the error for the refinement of the mesh

CODE FOR THE PARAMETERS DECLARATION

```
// Geometry parameters
D  = 1;
Lo = 20*D;

// CLW: mesh size near the wall
clw  = 0.01; //0.001;
clbg1 = 0.05;
clbg2 = 0.2;
clc  = 2;

dy = 0.01;

Mesh.Algorithm = 8;
Mesh.Optimize = 1;
Mesh.OptimizeThreshold = 0.6;
Mesh.Smoothing = 10;
```

PARAMETERS TO CHANGE

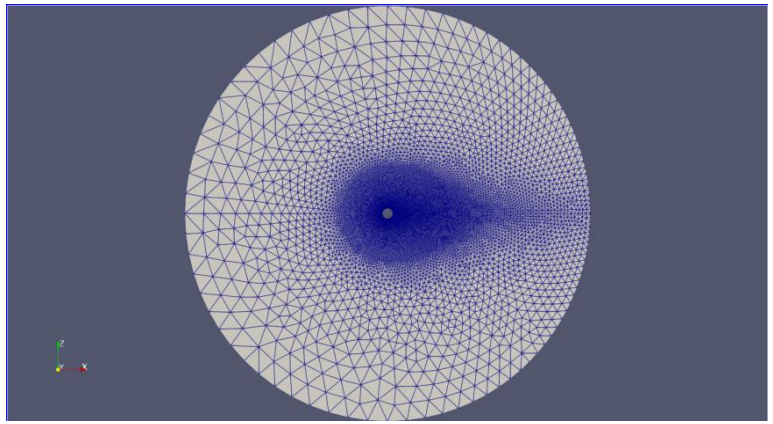
- clw
- clbg1
- clbg2
- clc

ERROR TO CALCULATE

$$\epsilon = \frac{Lift_{cur} - Lift_{cur-1}}{Lift_{cur}}$$

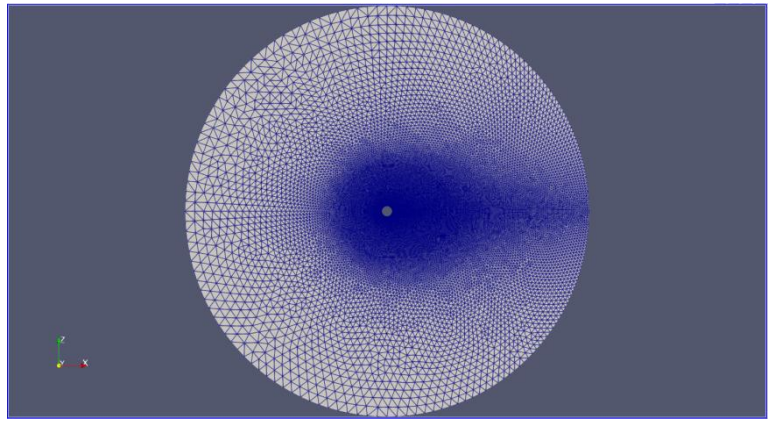
Mesh 1 :

- clw = 0.01
- clbg1 = 0.05
- clbg2 = 0.2
- clc = 2



Mesh 2 :

- clw = 0.01
- clbg1 = 0.025
- clbg2 = 0.1
- clc = 1



FINAL MESH REFINEMENT FOR THE HYPERSONIC SCRIPT IN AEROF

Step 5: Excluded Volume

- Excluded Volume Equation of State: $p = \frac{\rho RT}{1 - \rho b}$
- Internal energy e is still a function of temperature only since $\rho = f(\frac{p}{T})$ (proof using Gibbs equation + Maxwell relations), $e = C_v T$
- For cases with constant specific heats $\gamma = \frac{C_p}{C_v}$, isentropic process is described by $p(\frac{1}{\rho} - b)^{\gamma}$=constant (See Appendix)
- Speed of Sound: $a^2 = \gamma \frac{1}{1 - \rho b} \frac{p}{\rho}$
- Specific Enthalpy: $h = e + p/\rho = e + \frac{RT}{1 - \rho b}$

SLIDE FROM THE PREVIOUS STUDENT

Steps done previously :

- Definition of the excluded volume
- Definition of the generalised Averaged Roe Flux and Steger-Warming Flux
- Verification of the equations

```
under Equations {
  Type = NavierStokes;
  under FluidModel[0] {
        Fluid = ExcludedVolume;
        under ExcludedVolumeModel {
            SpecificCoVolume = 0.001024;
            MixtureGasConstant = 287.1;
        }
    }
```

FINAL MESH REFINEMENT FOR THE HYPERSONIC SCRIPT IN AEROF

What is currently running on the computer :

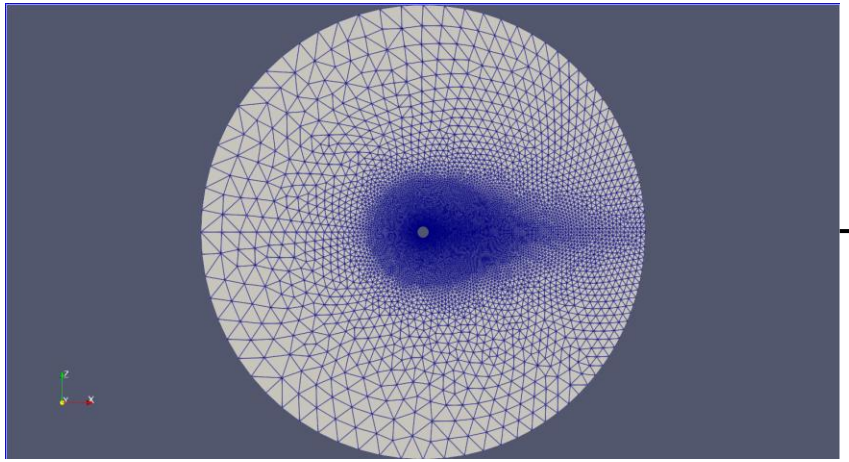
1. Hypersonic script on finer meshes -> long process

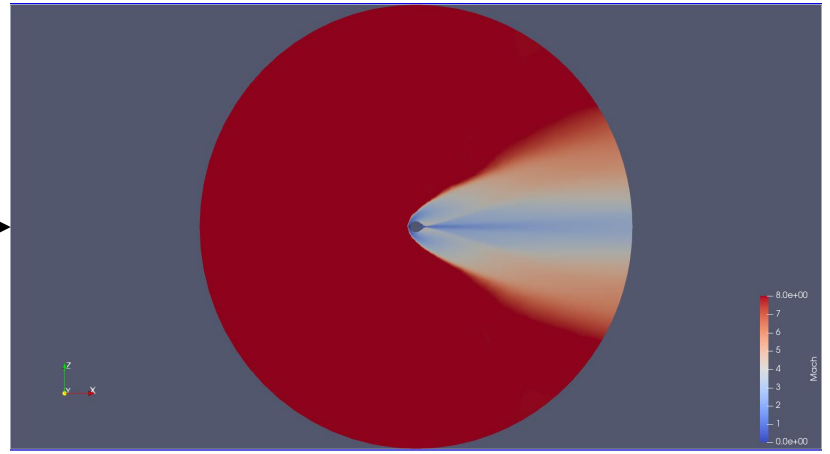
2. The calculus of the error that can be only determined once the fifth step of the hypersonic script is completed -> we can get the lift force from the directory postpro

3. The excluded volume case that is buggy.

Mesh 1 :

- clw = 0.01
- clbg1 = 0.05
- clbg2 = 0.2
- clc = 2

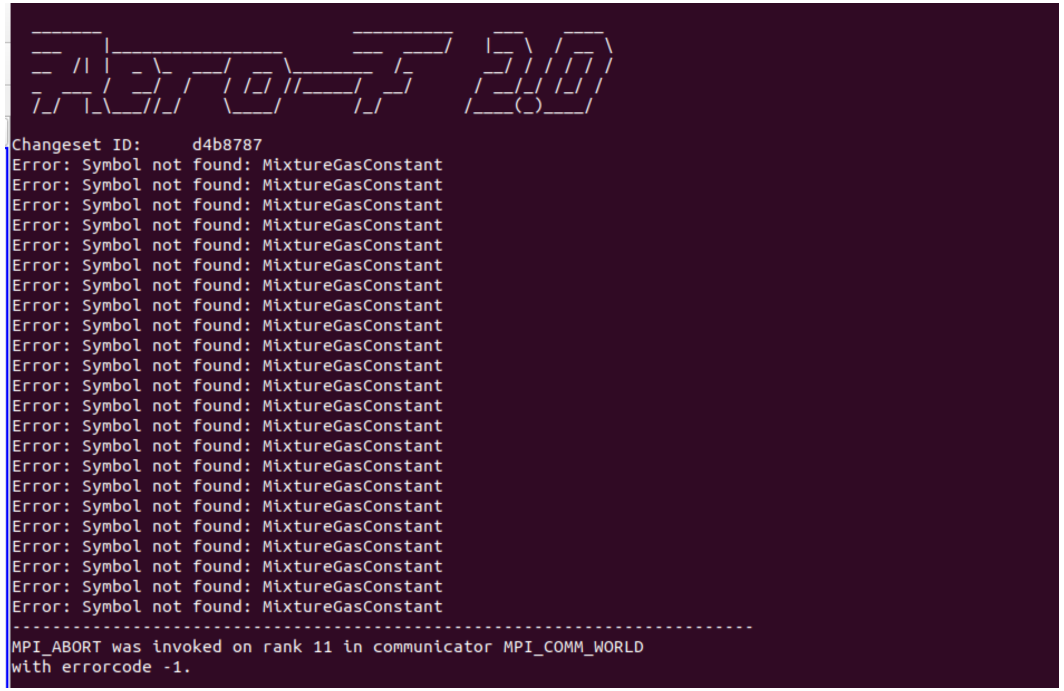




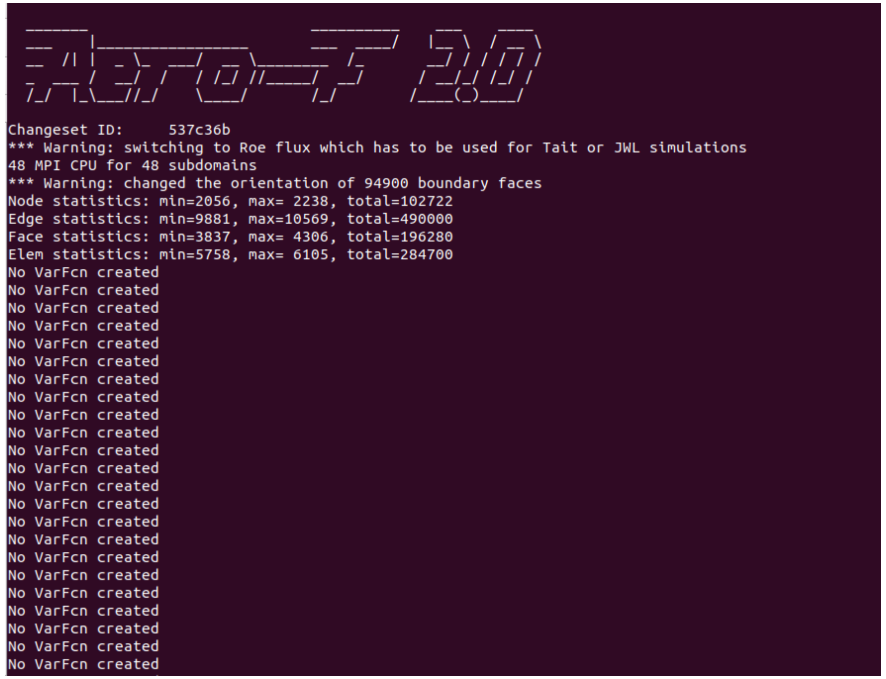
FINAL MESH REFINEMENT FOR THE HYPERSONIC SCRIPT IN AEROF

Step 6: Results

- For the excluded Volume : bug in the source codes form the master branch and hypersonic branch



ERROR FROM THE HYPERSONIC BRANCH



ERROR FROM THE MASTER BRANCH