CFD ANALYSIS OF VERTICAL CHIMNEY

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1. Basic Mesh

The first mesh is generated by following steps and iteration:

Steps for Mesh generation

1. Generate the default mesh donot give any input in mesh sizing, the mesh wil be generated by the software as shown below

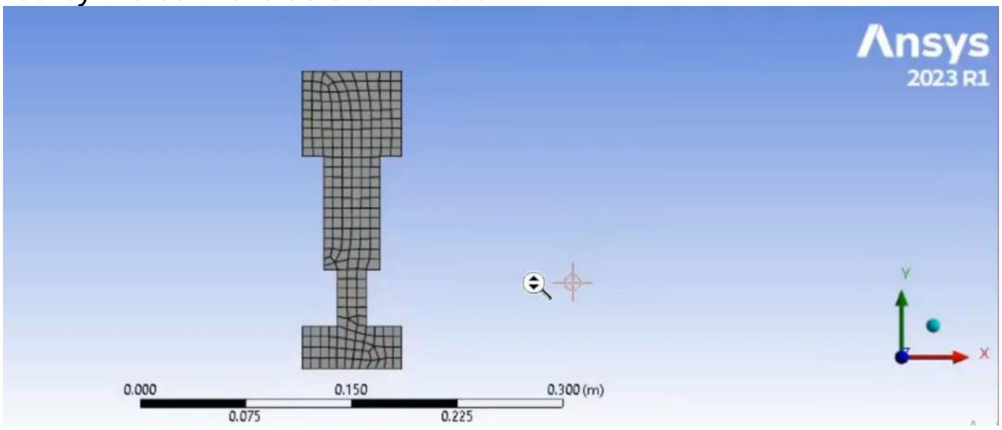

Figure 1 Default mesh generated by ANSYS

2. Mesh Sizing: Step element size is kept 3.5 mm

   In this step, the size of element is reduced to fine the mesh, the size of element is kept as factor of 70 using mesh sizing. The generated mesh is shown below.

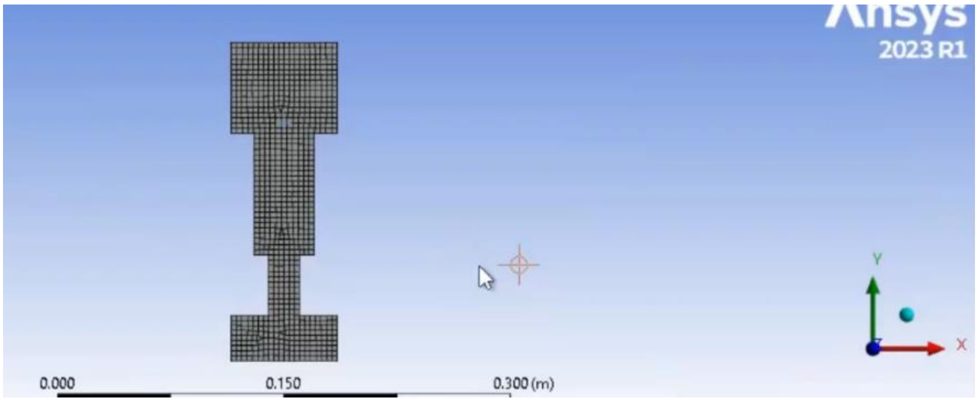

Figure 2 Mesh generated using element size of 3.5 mm

The generated mesh is uniform mesh with quad as element shape. In the next step, the mesh near inlet and outlet is fined.

Step 3. Edge sizing at inlet and outlet using No. of division.
The number of divisons for each edge is given as shown below:

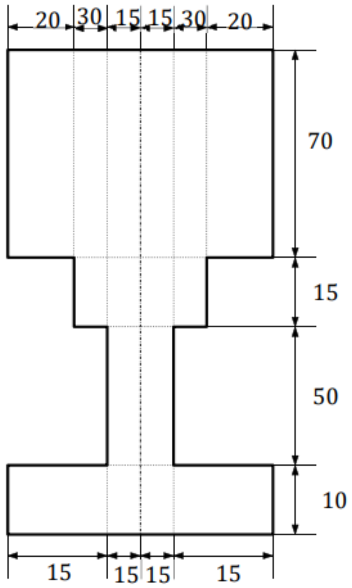

Figure 3 Number of division for each edge

Step 4. Other Inputs

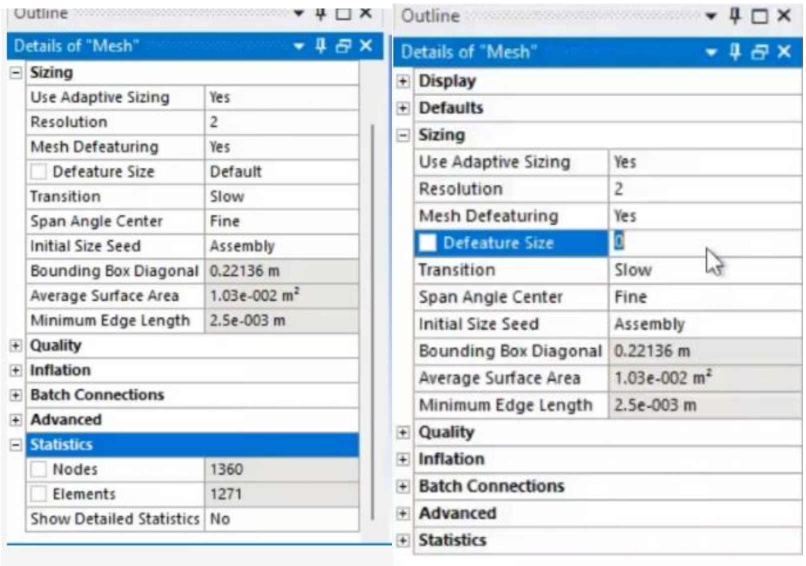

Figure 4 Other Inputs for mesh generation

Step 4. Final mesh as Basic Mesh

The mesh generated using above shown steps is given below :

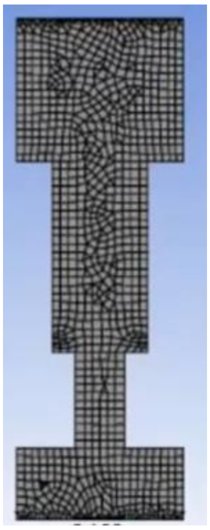

Figure 5 Basic Mesh

Mesh Metrics

The number of element for the basic mesh is 1271 and the quality is shown below.

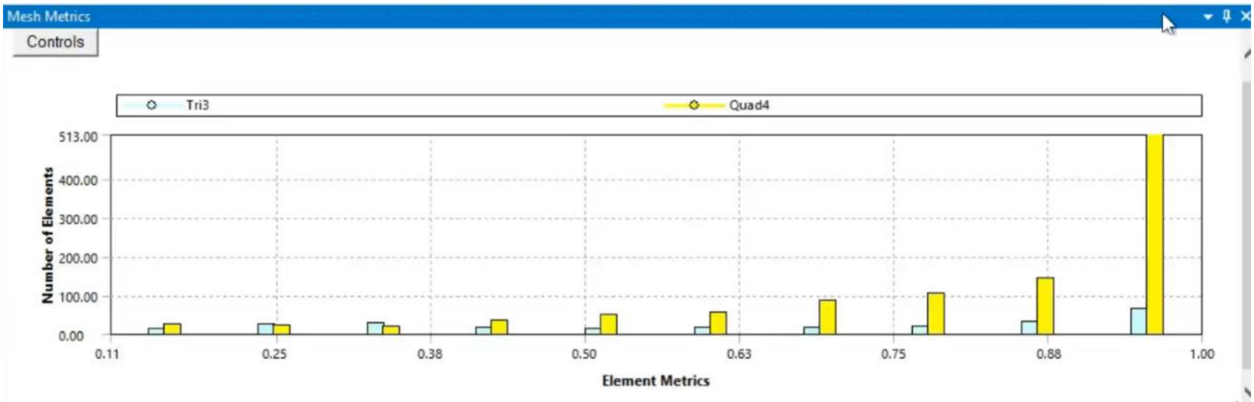

Figure 6 Element Quality distribution

2. Basic Simulation

The basic mesh is used for setting the physics and solver input as per given inputs. The Ra number is 7.63 e+6 for following properties. The relatshipship used for Ra is

$$Ra = \frac{g\beta\Delta T\ L^3}{\vartheta.\alpha}$$

Table 1 Input for Ra calculation

$g(m/s^2)$	9.81
β	0.0033
ΔT	10
L	0.21
ϑ	1.79E-05

α	2.20E-05

Results

The result for the basic simulation is shown in this subsection

Temperature Contour

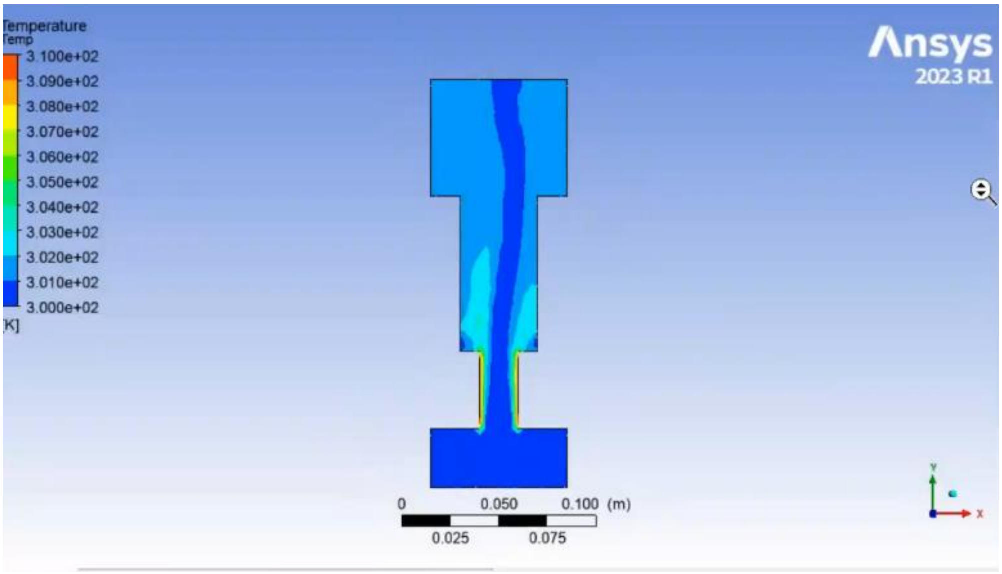

Figure 7 Temperature map

Temperature map shows that maximum temperature is near the hot wall as it is the hottest wall, the temperature rise takes place in vertical upward direction which is the direction of air also. There is temperature stratification in vertical direction in the entire chimney. The temperature at the core is low as compare to the surrounding.

Velocity Streamline

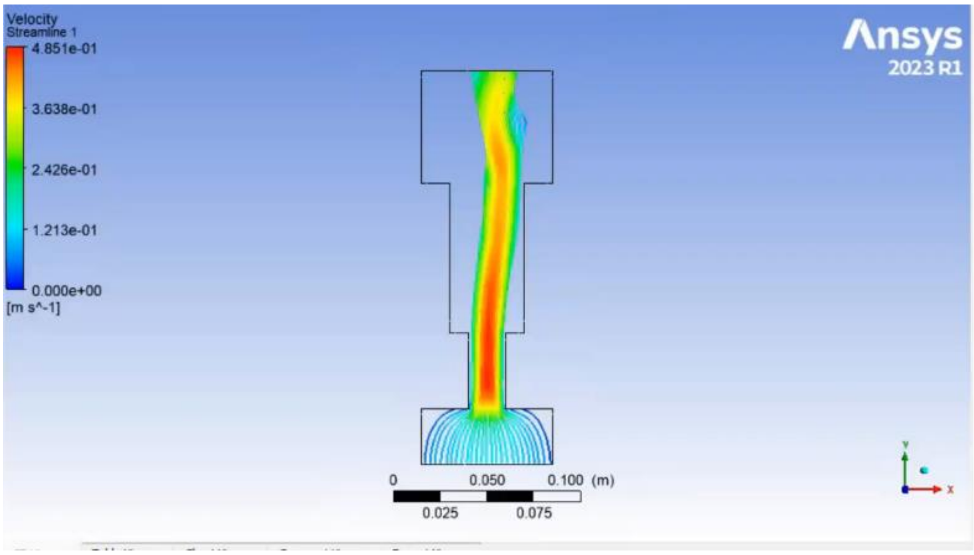

Figure 8 Velocity Streamline

The velocity is maximum at core near hot wall. The maximum velocity at the core 0.485 metre per second. It shows flow is streamlined and does not spread in lateral direction.

Maximum air-velocity at core

The maximum velocity at the core **0.485 metre per second.**

3. Solver

A pressure-based solver can handle natural convection induced by temperature variations even when density is assumed constant because it focuses on solving the momentum equations rather than directly solving for density. In natural convection, fluid motion occurs due to density differences caused by temperature variations, leading to buoyancy forces. However, in many cases, the change in density with temperature is relatively small, allowing for a simplification where density is treated as constant.

The gas state equation, which relates pressure, density, and temperature for an ideal gas, is not needed in this case because the solver does not directly calculate density based on temperature. Instead, it uses the constant density assumption and solves for the pressure field, which indirectly accounts for the effects of temperature through the momentum equations.

When a density-based solver is used, the Boussinesq approximation is not needed because the solver directly calculates changes in density based on temperature variations. The Boussinesq approximation is typically used in fluid flow problems where density variations are small except for buoyancy effects, allowing density to be treated as constant except in the buoyancy term of the momentum equations. However, in a density-based solver, density variations are explicitly considered, making the Boussinesq approximation unnecessary.

Using a density-based solver may not be convenient when the problem can be adequately solved within the framework of the Boussinesq approximation because density variations are small and do not significantly impact the flow behavior. In such cases, using a density-based solver would introduce unnecessary computational complexity without providing substantial benefits in accuracy. The Boussinesq approximation simplifies the equations by assuming constant density except in buoyancy terms, making it a more efficient approach for problems where density changes are negligible outside of buoyancy-driven flows.