



**SYRACUSE
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& COMPUTER
SCIENCE**

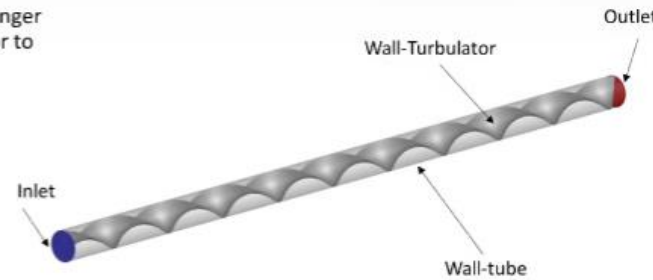
HEAT TRANSFER ENHANCEMENT USING USING A TURBULATOR

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PROBLEM DESCRIPTION (Turbulator and without Turbulator) SAME CONDITIONS:

- The model consists of a single tube of a heat exchanger system. The tube has a twisted tape type turbulator to enhance the heat transfer:
 - Tube length: 750 mm
 - Tube Diameter: 30 mm
 - Turbulator Twist Ratio*: 0.4
- The fluid moving through the tube is water:
 - $\rho = 998.2 \text{ kg/m}^3$
 - $c_p = 4182 \text{ J/(kg} \cdot \text{K)}$
 - $k = 0.6 \text{ W/(m} \cdot \text{K)}$
 - $\mu = 0.001003 \text{ kg/(m} \cdot \text{s)}$
- The surroundings are modeled through thermal boundary conditions:
 - The heat from the steam surrounding the tube is modeled as a constant temperature wall boundary condition.
 - Transfer of heat from one side of the turbulator to the other is accounted using a coupled thermal boundary condition



*Twist Ratio = Length to twist by 180° / Tube diameter

FIG A1 – Problem Description

- Boundary conditions:
 - Inlet:
 - Mass-flow Inlet with 0.15 kg/s mass flow rate and constant total temperature of 288 K
 - Outlet:
 - Pressure outlet at 0 Pa gauge pressure and 330 K backflow temperature
 - Wall-tube:
 - No-slip wall at constant temperature of 373.15 K
 - Wall-turbulator (and shadow):
 - No-slip wall with coupled thermal condition
- A steady-state solution is obtained using the pressure-based solver in Ansys Fluent

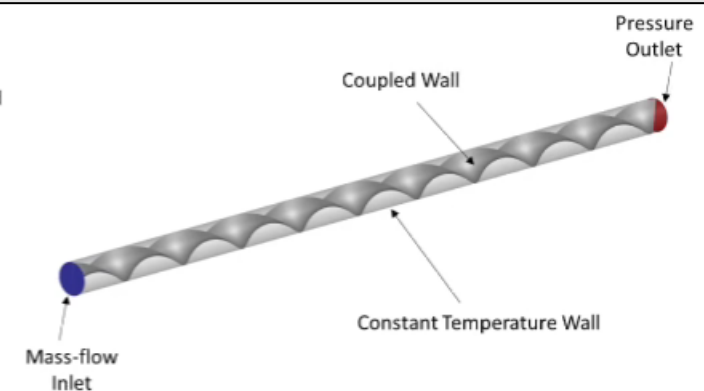


FIG A2 – Problem Description - Boundary Conditions

MESH FOR TUBULATOR:

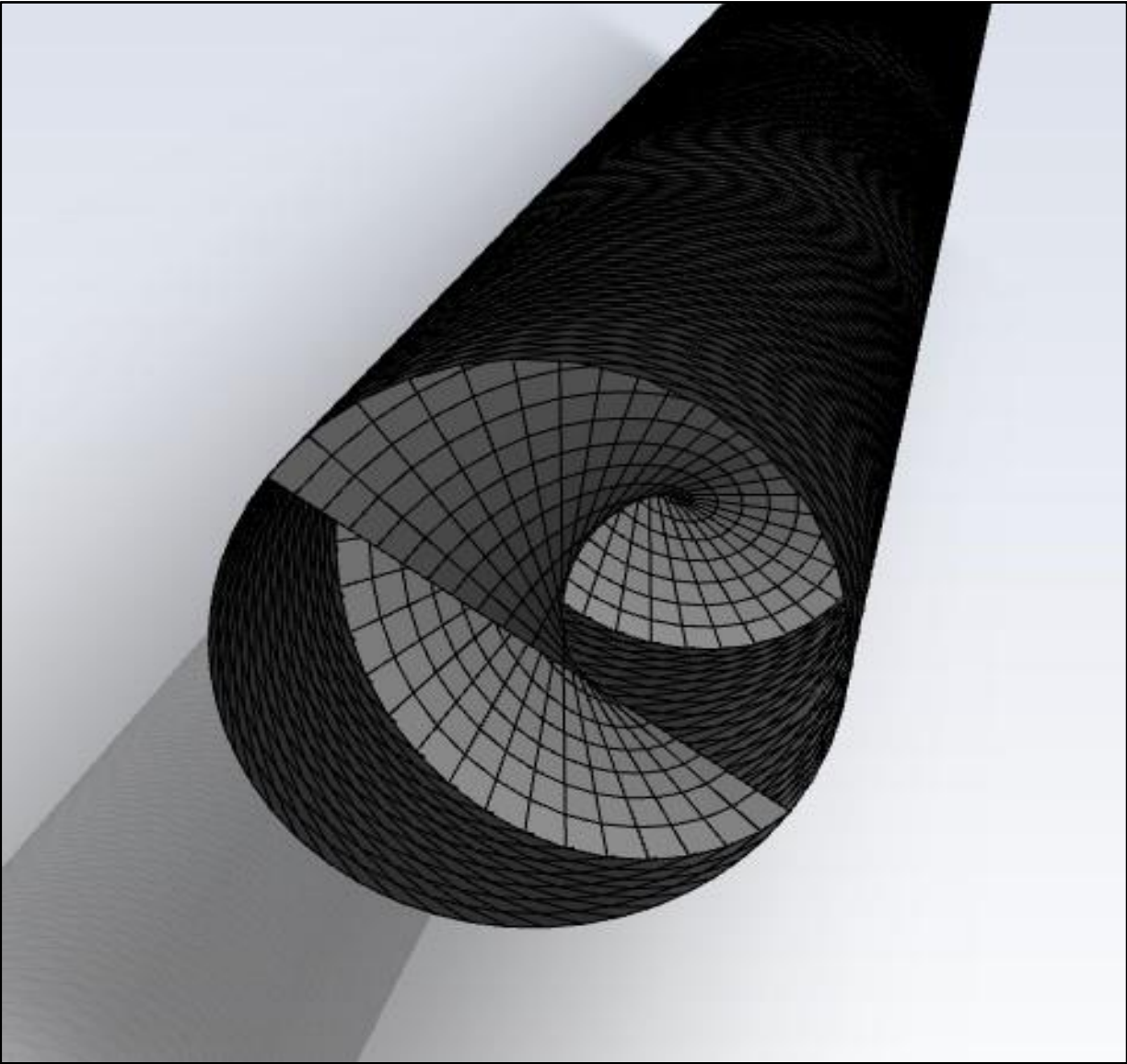


Fig B1: Mesh for tubulator

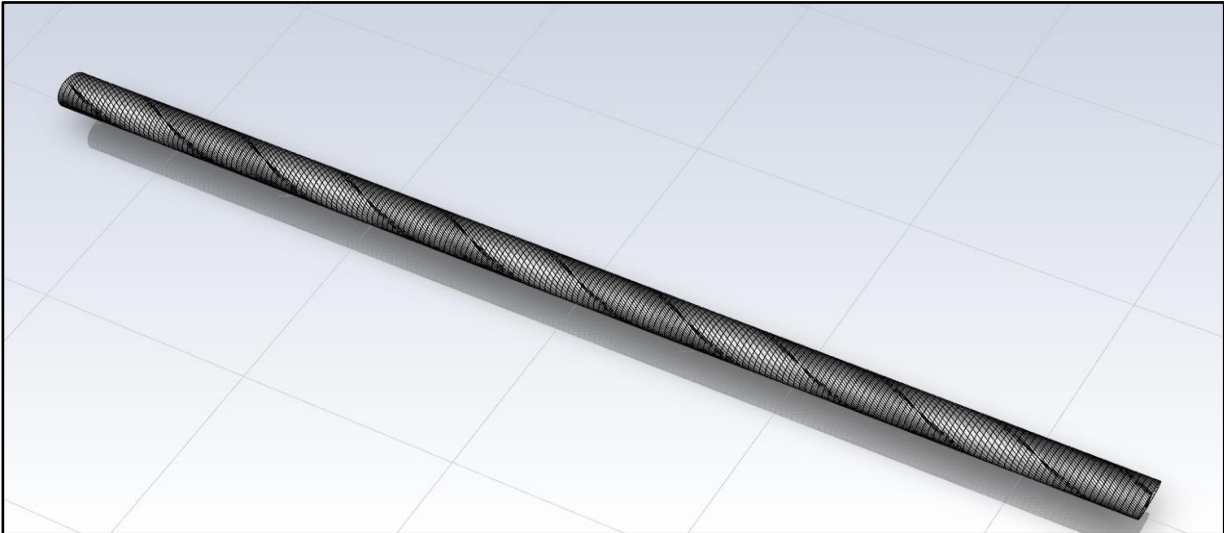


Fig B2: Mesh for tubulator

```
Console
.....
maximum face area (m2): 1.397135e-05
Checking mesh.....
Done.

Mesh Quality:

Minimum Orthogonal Quality = 1.47507e-01 cell 12197 on zone 5 (ID: 466997 on pa
(To improve Orthogonal quality , use "Inverse Orthogonal Quality" in Fluent Mesh
where Inverse Orthogonal Quality = 1 - Orthogonal Quality)

Maximum Aspect Ratio = 4.97807e+02 cell 12189 on zone 5 (ID: 463196 on partitio
```

Fig B3: Mesh Quality

MESH WITHOUT TUBULATOR:

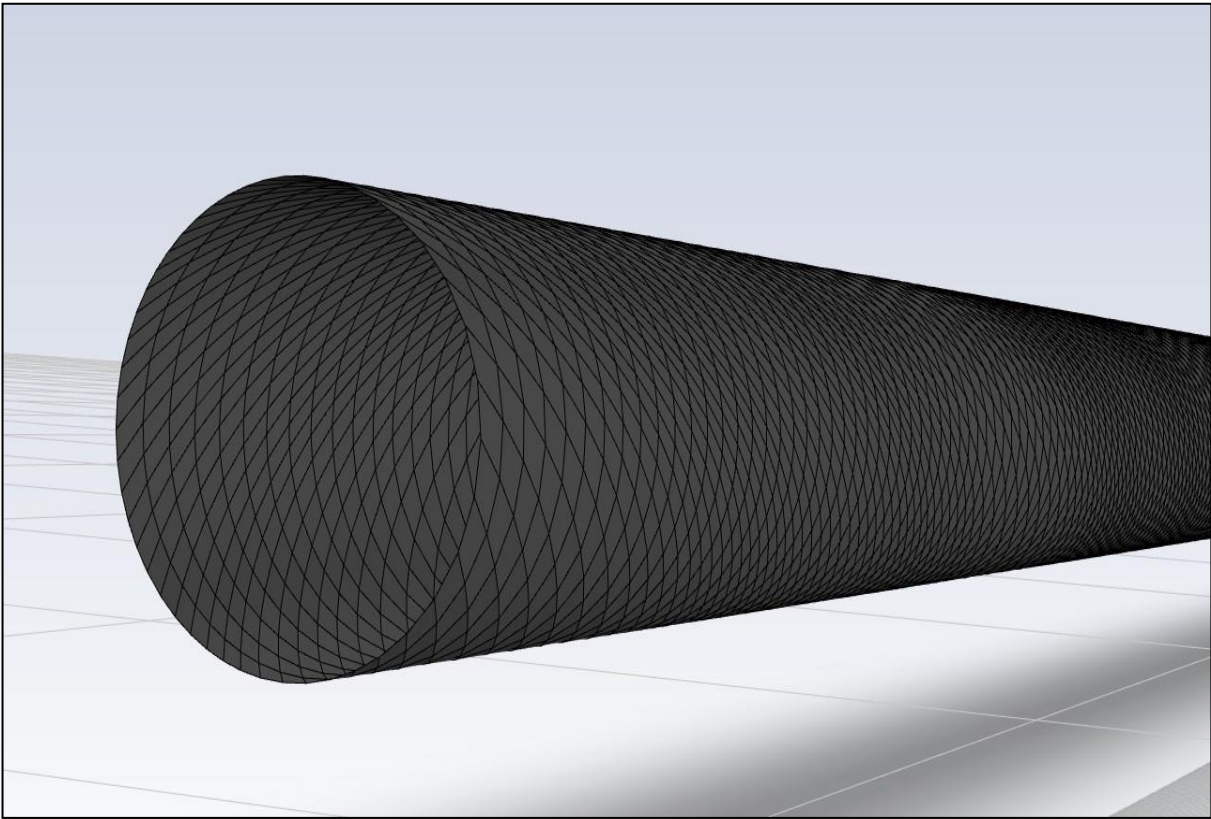


Fig C1: Mesh without tubulator

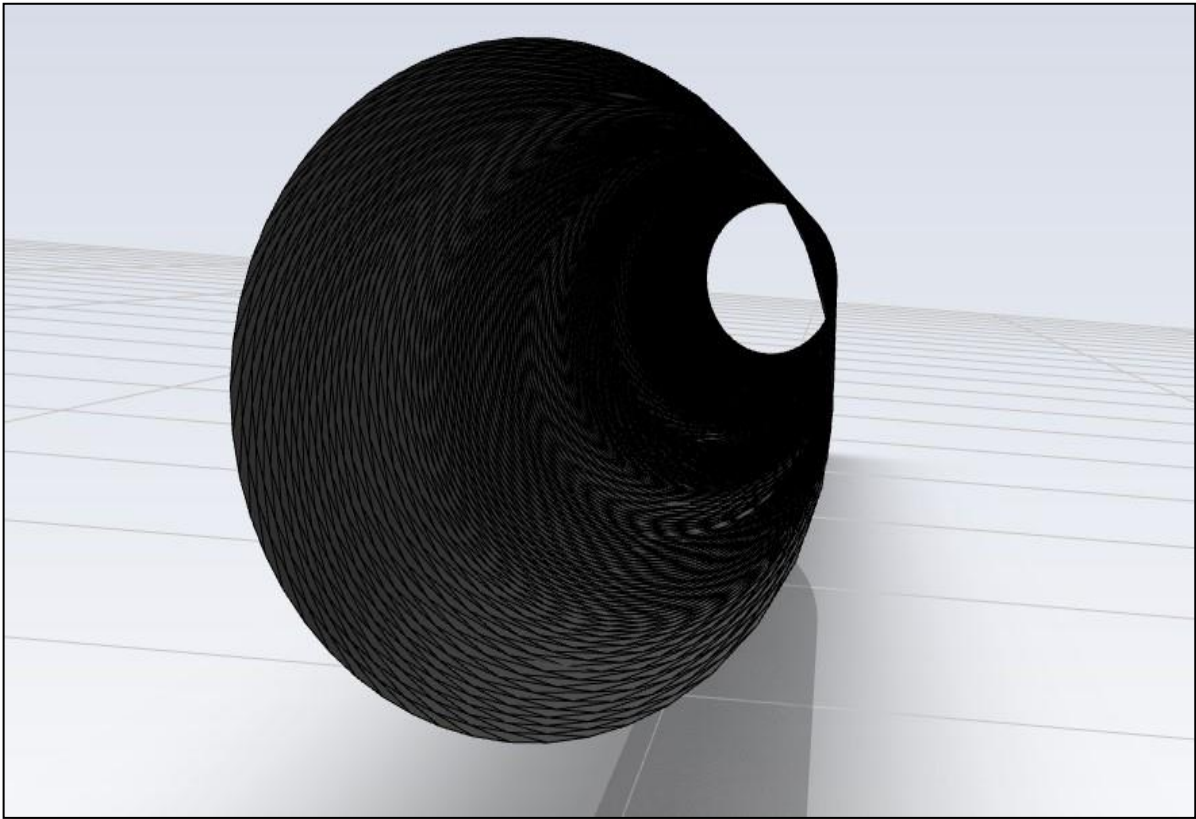


Fig C2: Mesh without tubulator

```
Console
maximum face area (m2): 1.322294e-05
Checking mesh.....
Done.

Mesh Quality:

Minimum Orthogonal Quality = 1.73702e-01 cell 76249 on zone 4 (ID: 254012 on partition: 0) at location (-1.42560e-02, 7.93096e-01, 4.37229e-03)
To improve Orthogonal quality , use "Inverse Orthogonal Quality" in Fluent Meshing,
where Inverse Orthogonal Quality = 1 - Orthogonal Quality)

Maximum Aspect Ratio = 4.64103e+02 cell 76183 on zone 4 (ID: 255597 on partition: 2) at location (-9.59318e-03, 1.48689e+00, -1.13302e-02)
```

Fig C3: Mesh Quality

VISCOUS MODEL CONDITIONS FOR BOTH:

Viscous Model

Model

☐ Inviscid
☐ Laminar
☐ Spalart-Allmaras (1 eqn)
☐ k-epsilon (2 eqn)
☒ k-omega (2 eqn)
☐ Transition k-kl-omega (3 eqn)
☐ Transition SST (4 eqn)
☐ Reynolds Stress (7 eqn)
☐ Scale-Adaptive Simulation (SAS)
☐ Detached Eddy Simulation (DES)
☐ Large Eddy Simulation (LES)

k-omega Model

☐ Standard
☐ GEKO
☐ BSL
☒ SST

k-omega Options

☐ Low-Re Corrections

Options

☐ Viscous Heating
☐ Curvature Correction
☐ Corner Flow Correction
☐ Production Kato-Launder
☒ Production Limiter

Transition Options

Transition Model none

Model Constants

Alpha*_inf

Alpha_inf

Beta*_inf

a1

Beta_i (Inner)

Beta_i (Outer)

User-Defined Functions

Turbulent Viscosity
none

Prandtl Numbers

Energy Prandtl Number
none

Wall Prandtl Number
none

OK

Cancel

Help

Fig D1: Viscous Model

Create/Edit Materials

Name:

Material Type:

Order Materials by: ☒ Name ☐ Chemical Formula

Chemical Formula:

Fluent Fluid Materials: **Fluent Database...**

Mixture:

GRANTA MDS Database...

User-Defined Database...

Properties

Density [kg/m³]: **Edit...**

Cp (Specific Heat) [J/(kg K)]: **Edit...**

Thermal Conductivity [W/(m K)]: **Edit...**

Viscosity [kg/(m s)]: **Edit...**

Change/Create **Delete** **Close** **Help**

Fig D2: Material Conditions

THERMAL & MOMENTUM – OUTLET AND INLET:

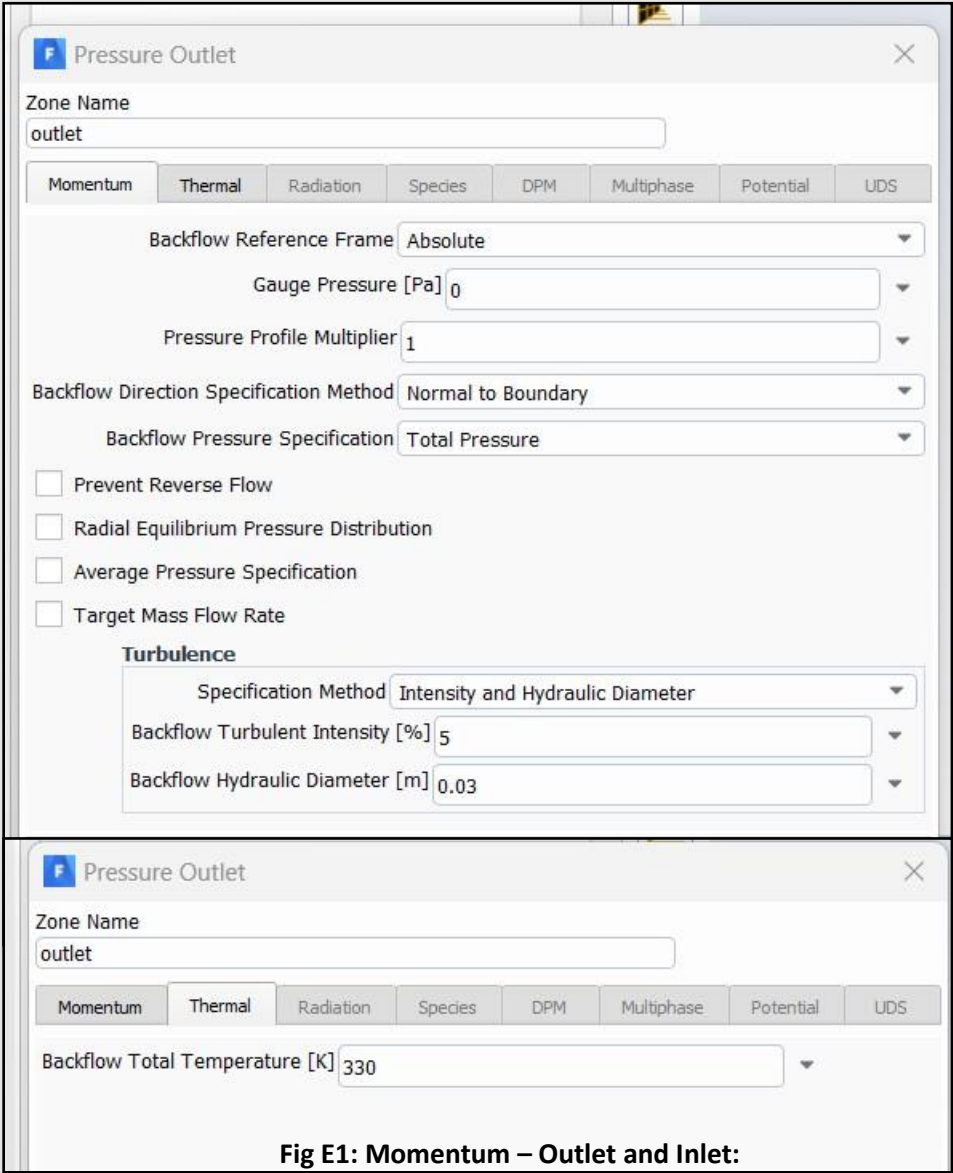


Fig E1: Momentum – Outlet and Inlet:

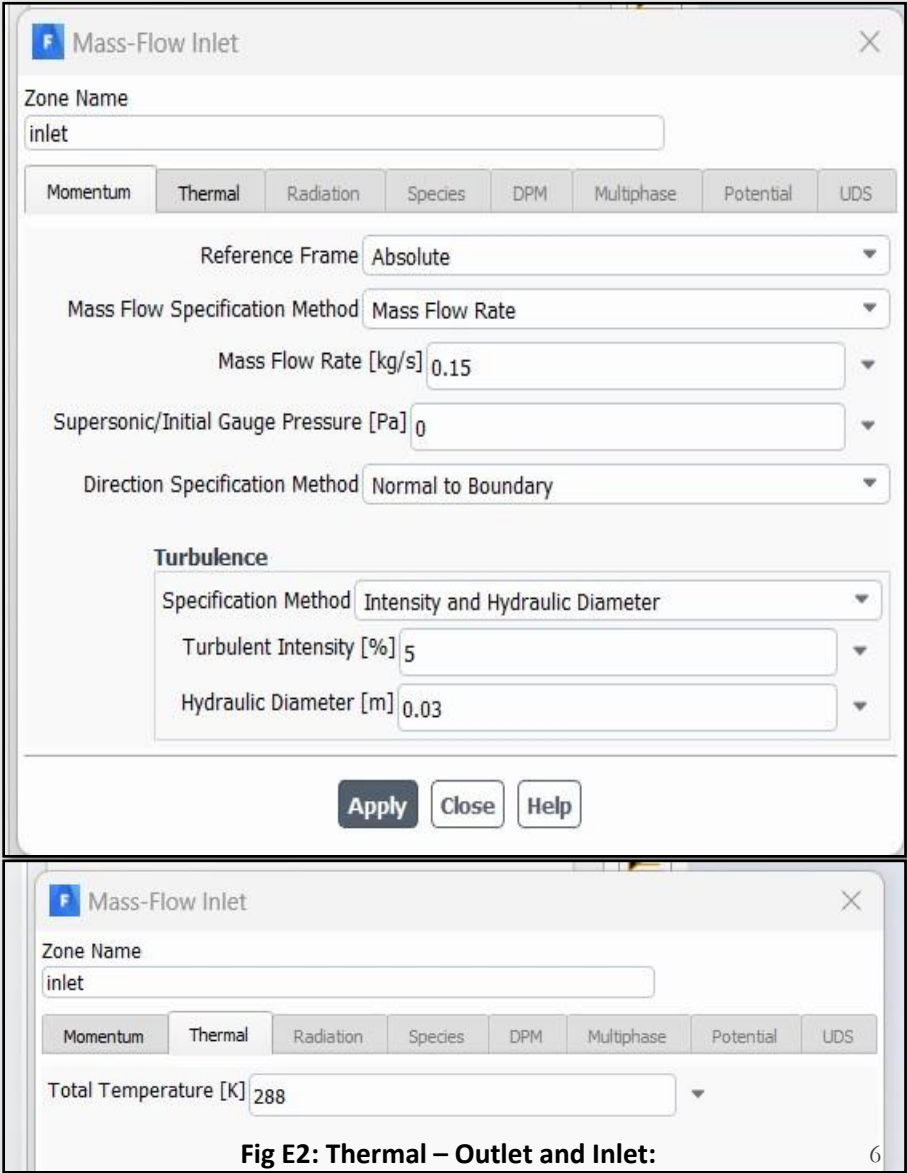


Fig E2: Thermal – Outlet and Inlet:

WALL CONDITIONS:

Wall

Zone Name
wall-turbulator

Adjacent Cell Zone
fluid

Shadow Face Zone
wall-turbulator-shadow

MomentumThermalRadiationSpeciesDPMMultiphaseUDSPotentialStructure

Wall Motion

☒ Stationary Wall

☐ Moving Wall

☒ Relative to Adjacent Cell Zone

Shear Condition

☒ No Slip

☐ Specified Shear

☐ Specularity Coefficient

☐ Marangoni Stress

Wall Roughness

Roughness Models

☒ Standard

☐ High Roughness (Icing)

Sand-Grain Roughness

Roughness Height [m]0

Roughness Constant0.5

Wall

Zone Name
wall-tube

Adjacent Cell Zone
fluid

MomentumThermalRadiationSpeciesDPMMultiphaseUDSPotentialStructure

Wall Motion

☒ Stationary Wall

☐ Moving Wall

☒ Relative to Adjacent Cell Zone

Shear Condition

☒ No Slip

☐ Specified Shear

☐ Specularity Coefficient

☐ Marangoni Stress

Wall Roughness

Roughness Models

☒ Standard

☐ High Roughness (Icing)

Sand-Grain Roughness

Roughness Height [m]0

Roughness Constant0.5

Wall

Zone Name
wall-tube

Adjacent Cell Zone
fluid

MomentumThermalRadiationSpeciesDPMMultiphaseUDSPotentialStructure

Thermal Conditions

☐ Heat Flux

☒ Temperature

☐ Convection

☐ Radiation

☐ Mixed

☐ via System Coupling

☐ via Mapped Interface

Temperature [K]373.15

Wall Thickness [m]0

Heat Generation Rate [W/m³]0

☐ Shell Conduction1 LayerEdit...

Material Name

aluminumEdit...

Wall

Zone Name
wall-turbulator

Adjacent Cell Zone
fluid

Shadow Face Zone
wall-turbulator-shadow

MomentumThermalRadiationSpeciesDPMMultiphaseUDSPotentialStructure

Thermal Conditions

☐ Heat Flux

☐ Temperature

☒ Coupled

Wall Thickness [m]0

Heat Generation Rate [W/m³]0

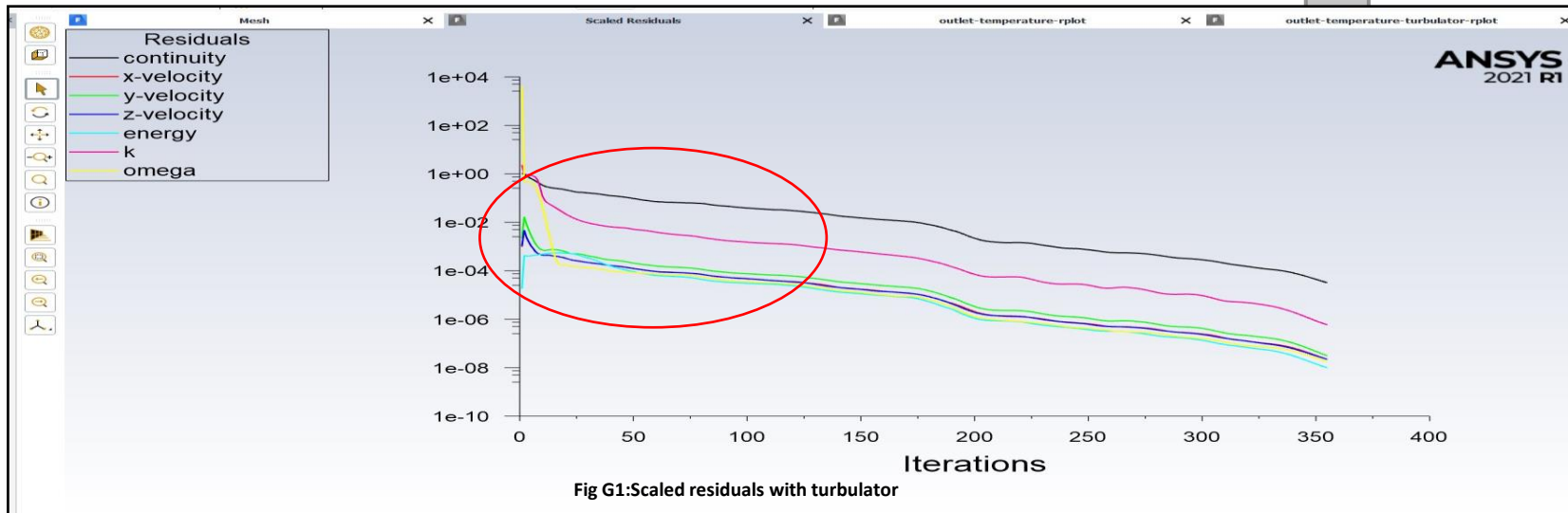
☐ Shell Conduction1 LayerEdit...

Material Name

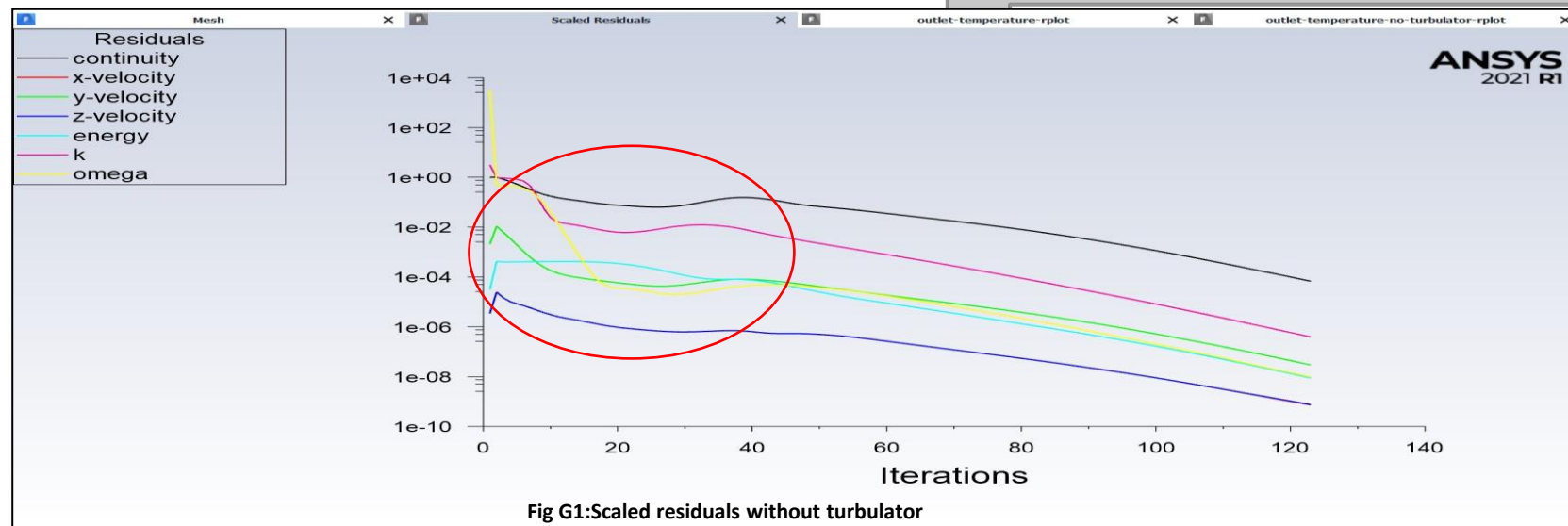
aluminumEdit...

Fig F1: Wall Conditions

SCALED PLOT:



- The distinction between the two graphs illustrating the improvement due to the turbulator is evident.
- The variations in flow irregularities are demonstrated across iterations, highlighting their non-constant nature.



GRAPHICAL PLOT:

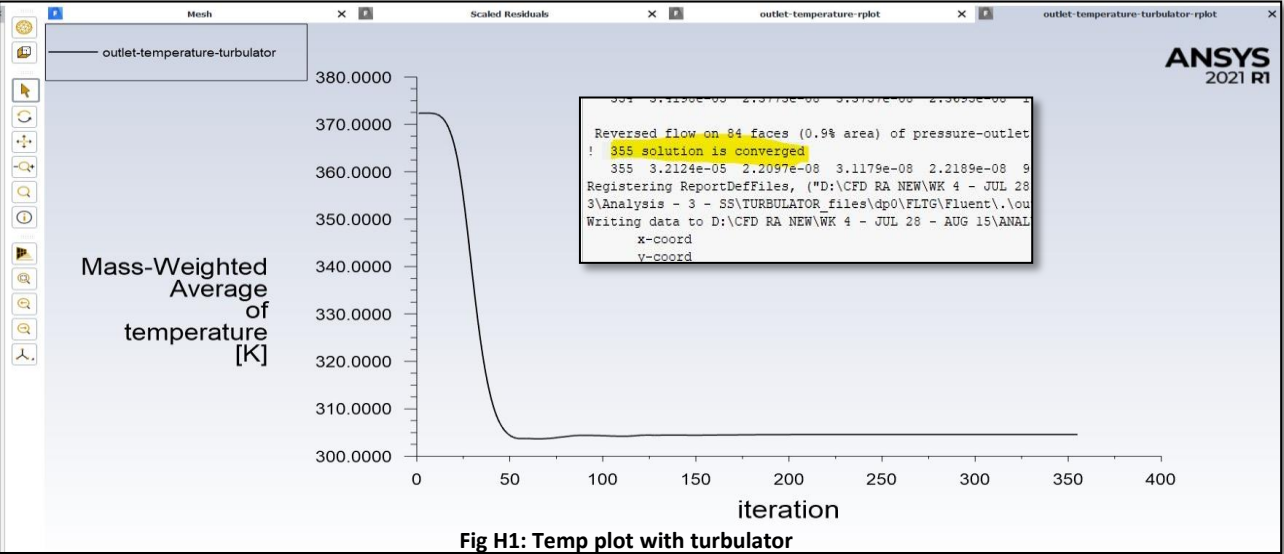


Fig H1: Temp plot with turbulator

- Conducting iterations provides clear evidence of the fluctuations, showcasing superior enhancement when utilizing the turbulator.
- Convergence becomes distinctly observable as the iterations progress, resulting in parameters that undergo notably reduced fluctuations.

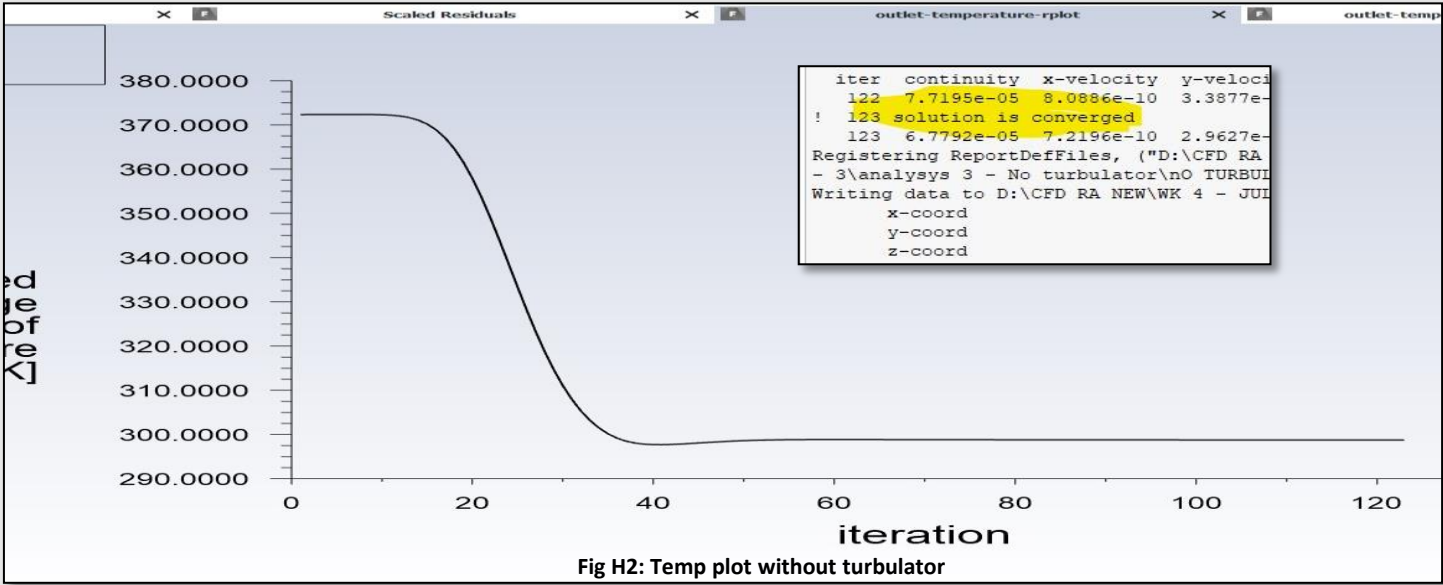


Fig H2: Temp plot without turbulator

VELOCITY CONTOUR:

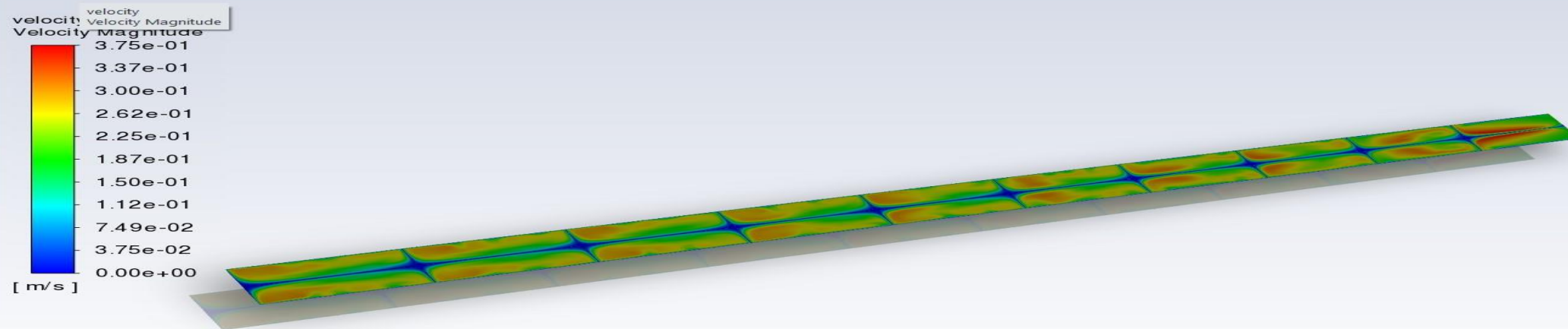


Fig I1: Velocity contour with turbulator

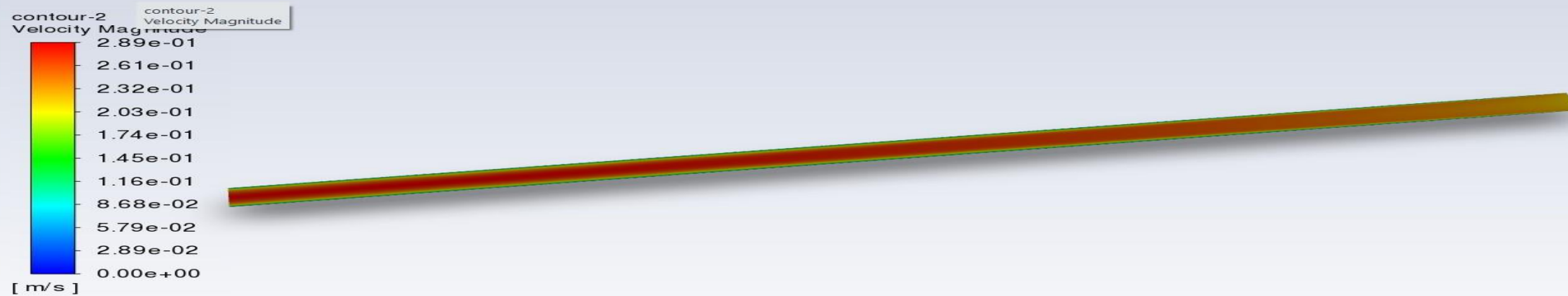
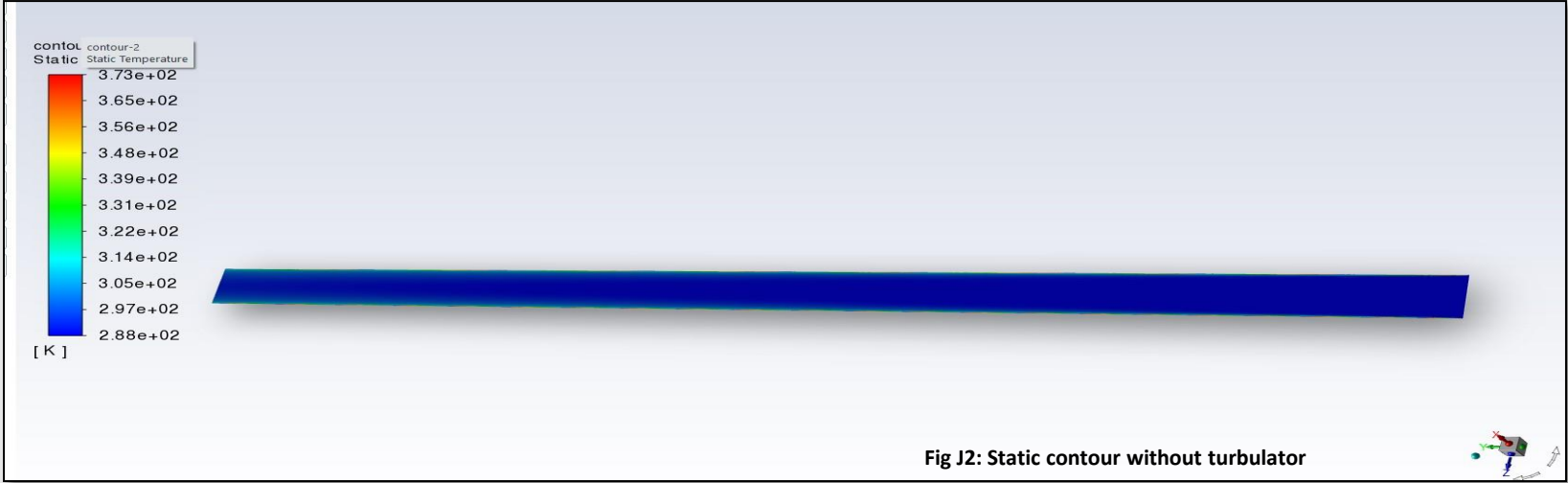
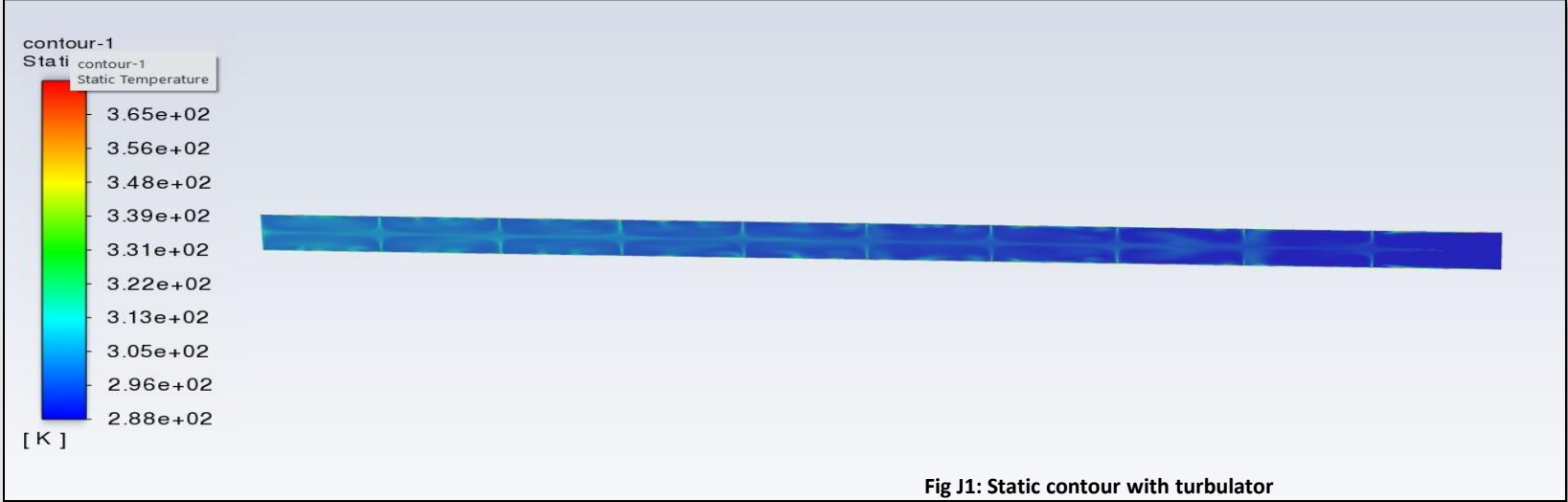


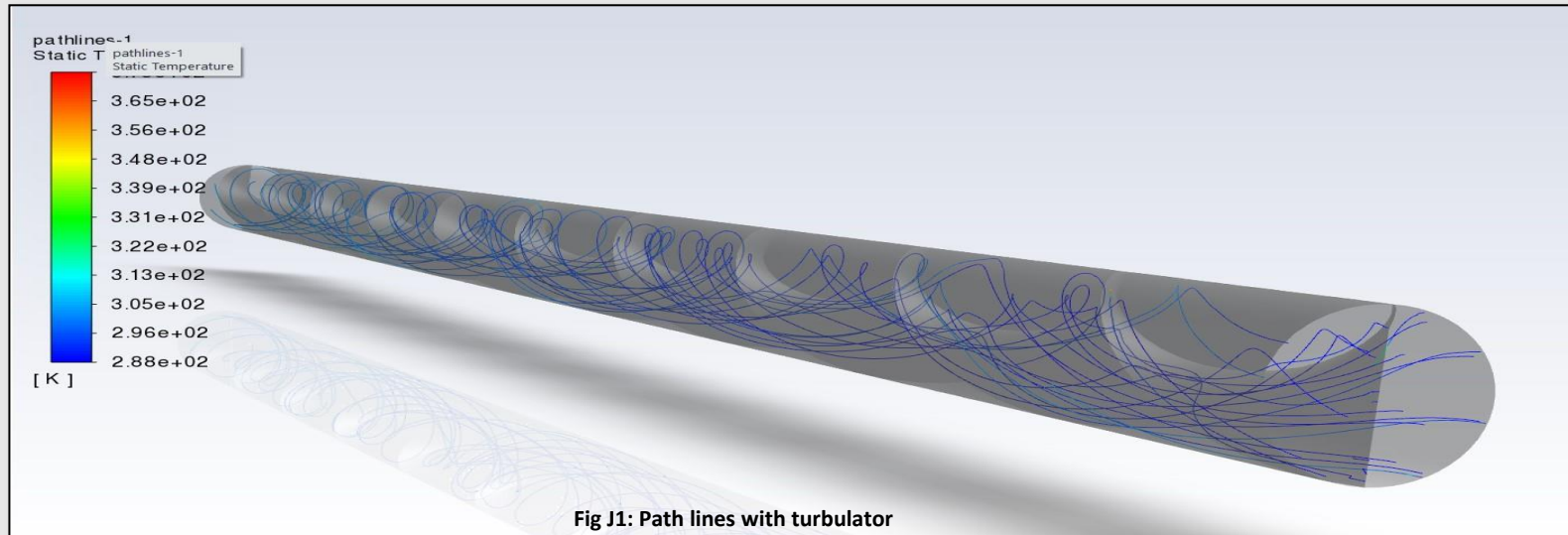
Fig I2: Velocity contour without turbulator

STATIC CONTOUR:

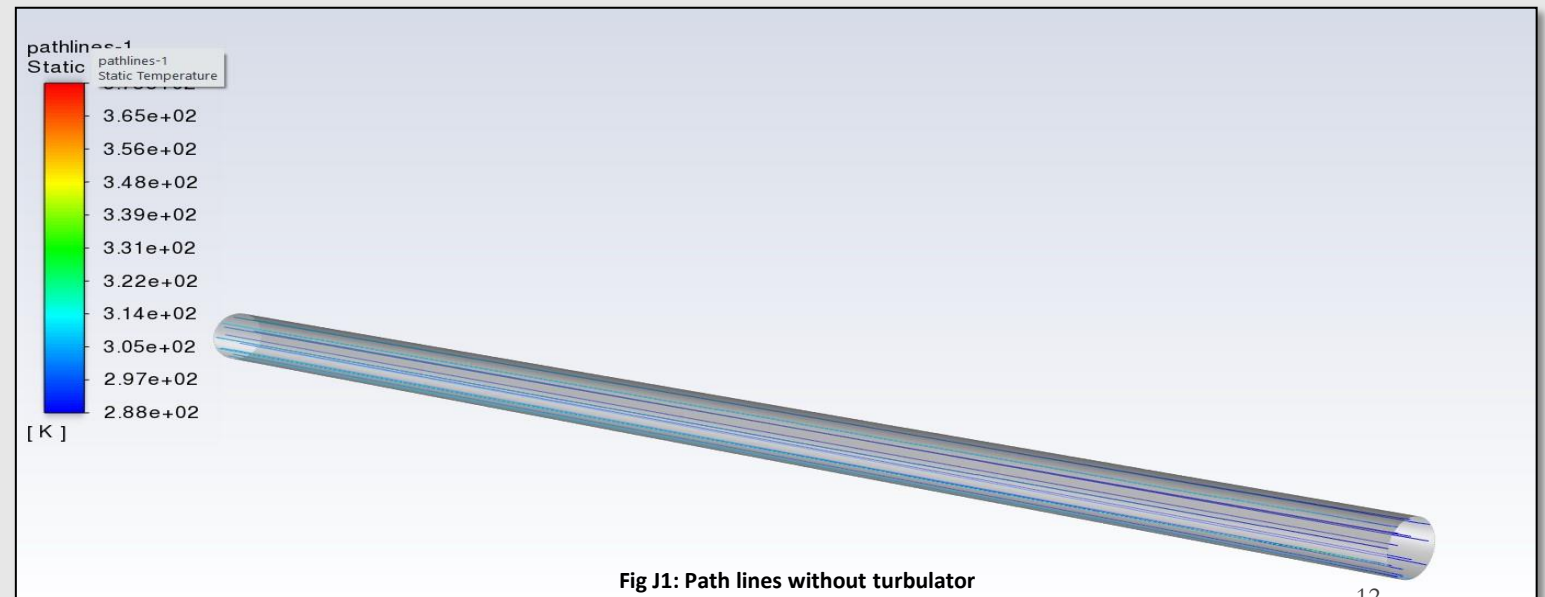


- The static temperature contours provide a compelling depiction of the transformative impact achieved by incorporating a turbulator. This alteration is evident in the thorough reshaping of the temperature profile. The introduction of fluid swirl intensifies heat transfer, resulting in accelerated heating of the water along the tube's length.
- Notably, the simple tube configuration yields an outlet mean temperature of approximately 298.8 K. In contrast, with the incorporation of the turbulator, the fluid reaches the outlet at a notably higher mean temperature of around 304.8 K.

STATIC TEMPERATURE – PATHLINES:



- The tubular introduces a swirling motion within the tube, inducing a secondary flow that generates a tangential velocity component.
- This augmented velocity near the wall significantly boosts the overall fluid movement.
- It is this mechanism that amplifies heat transfer through convection, constituting the fundamental principle behind the effectiveness of this particular heat transfer enhancement configuration.



FLUX REPORTS WITH TURBULATOR:

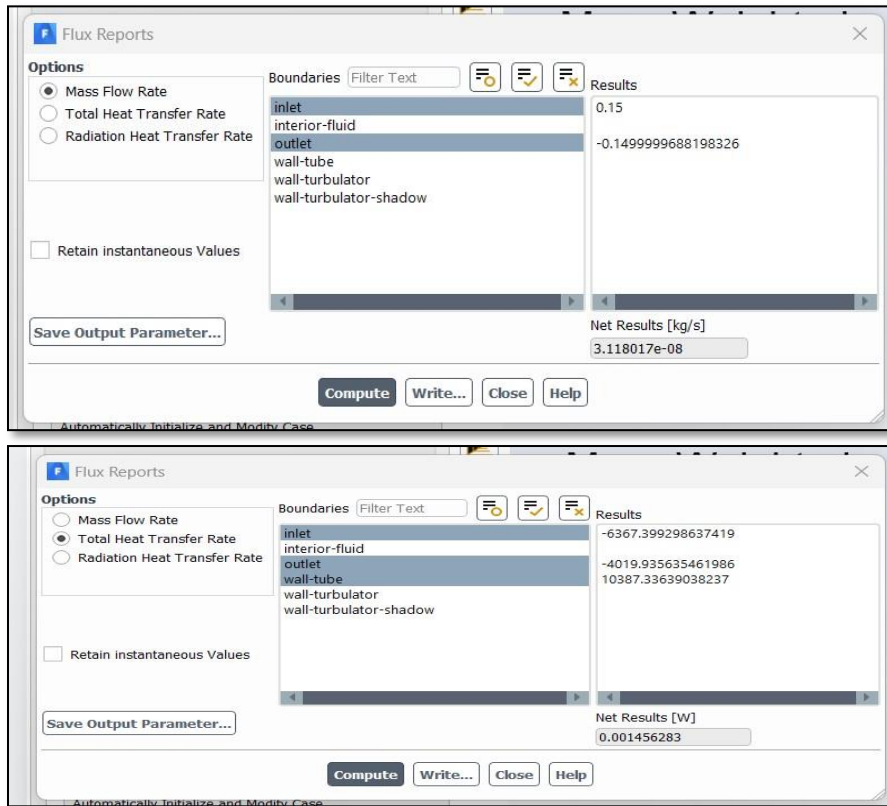


Fig K1: Flux reports with turbulator

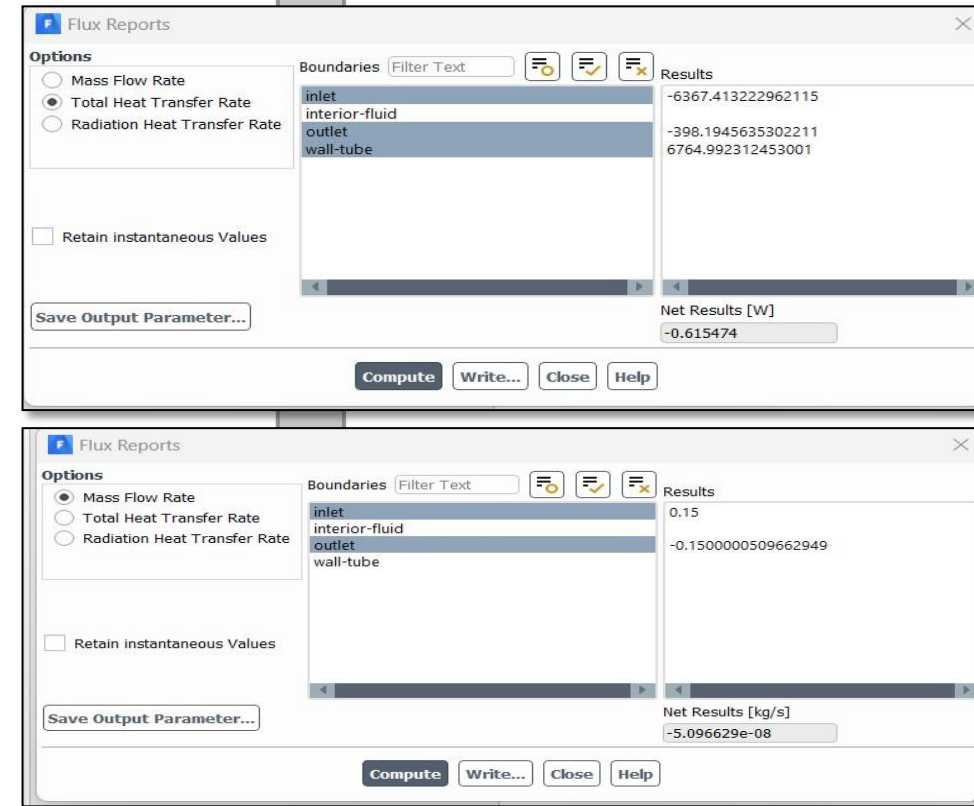


Fig K2: Flux reports without turbulator

- Upon evaluating the cumulative heat transfer resulting from forced convection, as depicted in the provided image, it becomes evident that the utilization of a turbulator yields a substantial enhancement in heat transfer efficiency.
- Specifically, employing a tube equipped with a turbulator leads to a remarkable 47.3% increase in heat transfer effectiveness compared to employing a basic, unmodified straight tube.

THANK YOU!