Presentation

on

Thermal and Acoustic Analysis of a Muffler

Group – VII

Subject : IC ENGINE

School of Mechanical Science

Indian Institute of Technology Bhubaneswar

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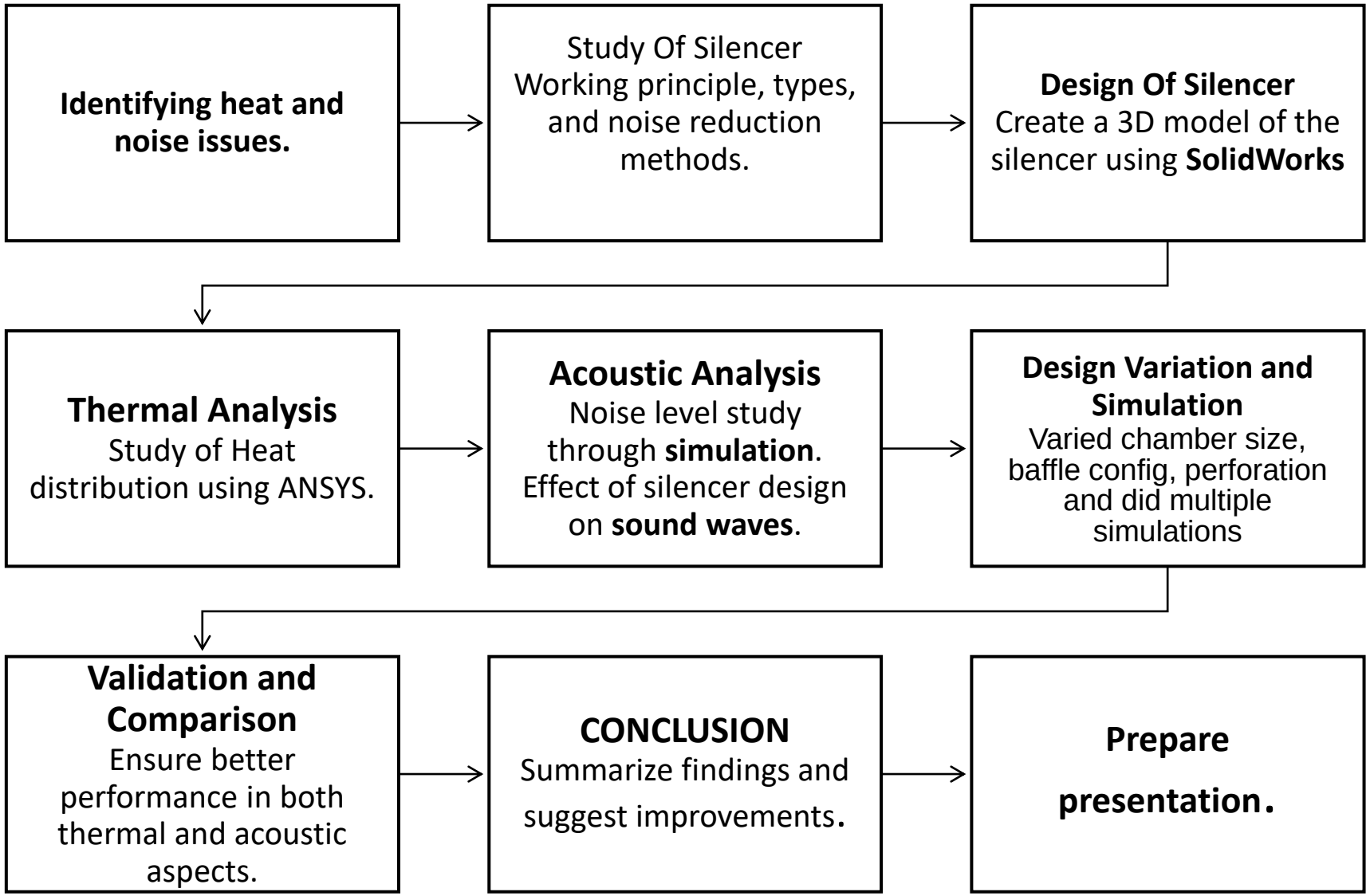
WORKFLOW…


Identifying heat and noise issues.
Study Of Silencer
Working principle, types, and noise reduction methods.
Design Of Silencer
Create a 3D model of the silencer using SolidWorks
Thermal Analysis
Study of Heat distribution using ANSYS.
Acoustic Analysis
Noise level study through simulation.
Effect of silencer design on sound waves.
Design Variation and Simulation
Varied chamber size, baffle config, perforation and did multiple simulations
Validation and Comparison
Ensure better performance in both thermal and acoustic aspects.
CONCLUSION
Summarize findings and suggest improvements.
Prepare presentation.

Thermal Aspect:

•Exhaust gases make the silencer extremely **hot**.

•High surface temperatures can cause **burns and injuries** if touched.

•Proper thermal analysis helps in:

- Understanding **temperature distribution** along the silencer.
- Selecting **heat-resistant materials**.
- Improving **heat dissipation** for better safety.

Acoustic Aspect:

•Engine combustion and **gas flow create noise**.

•Without a silencer, noise levels can **exceed legal limits**.

•Acoustic analysis helps in:

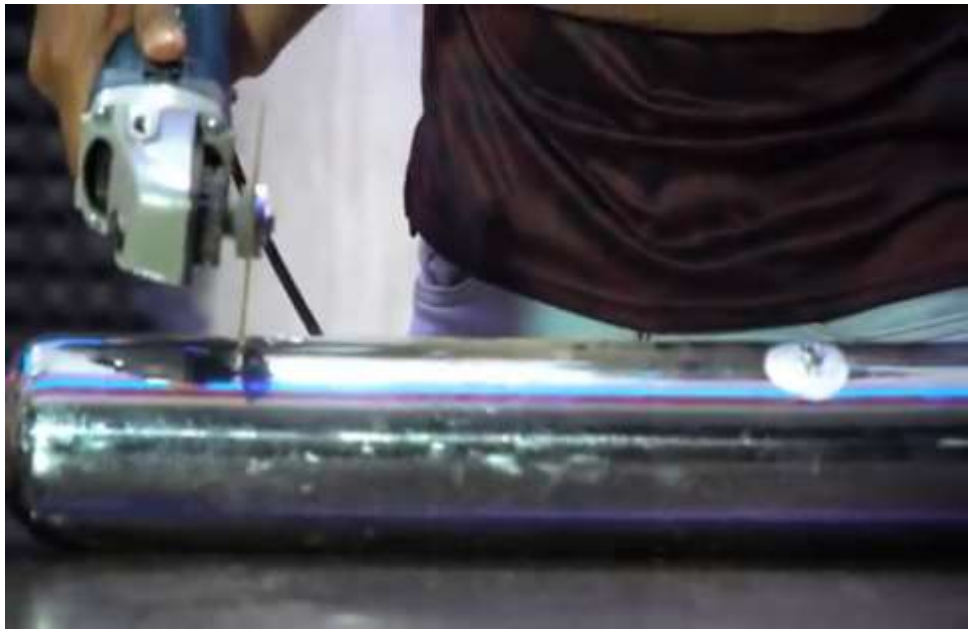
- **Measuring and reducing noise levels**.
- Designing silencers using **sound absorption and reflection techniques**.
- Improving **rider comfort** and **reducing noise pollution**.

SILENCER & IT'S IMPORATANTS

A **silencer** (**Muffler**) is a device attached to the exhaust system of a motorcycle to **reduce noise** and control the **flow of exhaust gases**.

Importance Of Silencer:-

- It helps in **minimizing sound pollution** while also ensuring efficient exhaust gas expulsion
- Without a silencer, the engine's exhaust produces extremely **loud noises**..
- Helps in **enhancing engine efficiency** by controlling backpressure.
- Improves **rider comfort** and reduces noise-related fatigue.



https://www.youtube.com/watch?v=KFI9HTytUyk

Types of Silencers and Their Working

1. Reactive Silencers:

- Use chambers and perforated tubes to reflect and cancel sound waves, reducing overall noise.
- The reactive mufflers normally work on the **principle of destructive interference**.

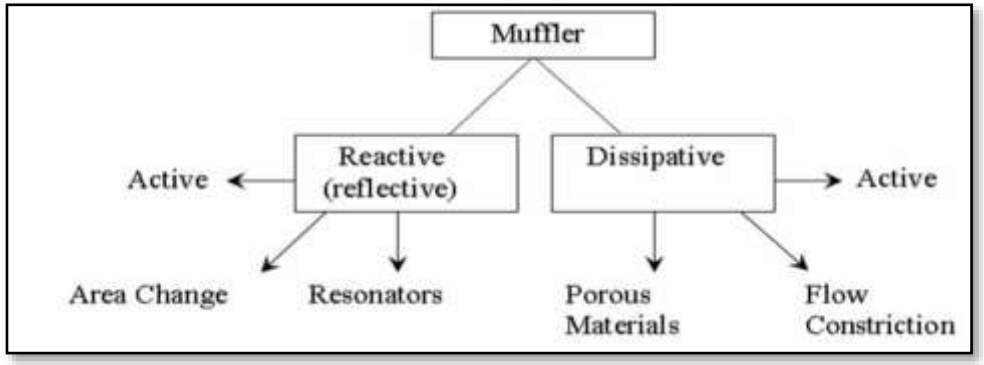
2. Dissipative Silencers:

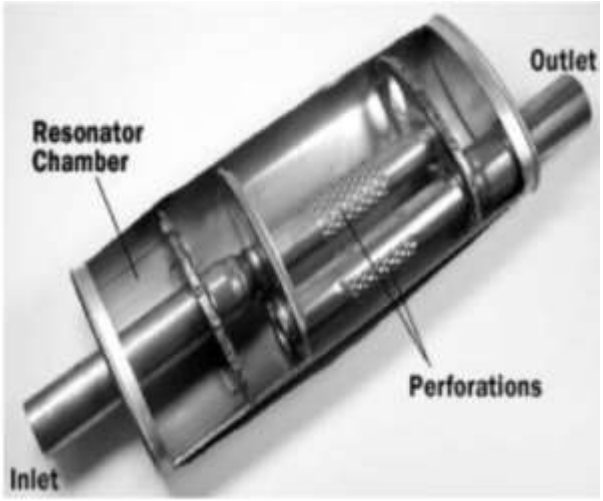
- Use sound-absorbing materials (eg. Glass wool) to reduce noise levels.
- The dissipative or Absorptive mufflers uses the **principle of absorption** as a way to reduce the sound energy

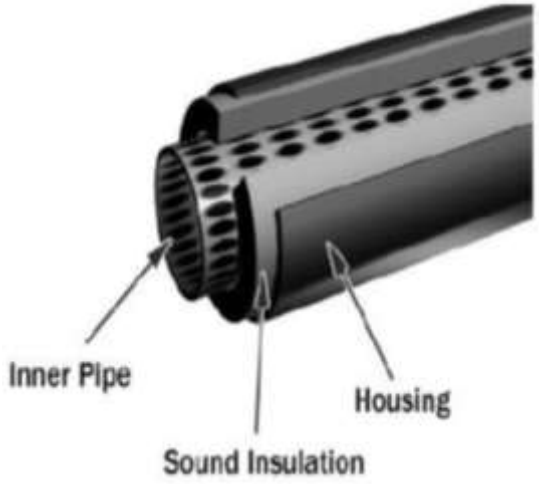
3. Hybrid Silencers:

- Combine reactive and absorptive techniques for better noise control.

Design Features: Typically include baffles, perforated tubes, expansion chambers, and packing materials to reduce noise efficiently.







https://www.researchgate.net/publication/350981205_Method_for_design_and_evaluation_of_ICE_exhaust_silencers

Sound Generation in Exhaust Systems

[Combustion inside the Cylinder]

↓

[High-Pressure Gas Release]

↓

[Exhaust Valve Opens Suddenly]

↓

[The **high-speed flow of exhaust gases** creates Shock Waves & High-pressure waves ,Turbulence]

↓

[Pressure Waves Travel in Exhaust]

↓

[Pressure Waves Exit Muffler/Exhaust]

↓

[Sound is Heard as Exhaust Noise]

Sound Levels with and without Silencer:

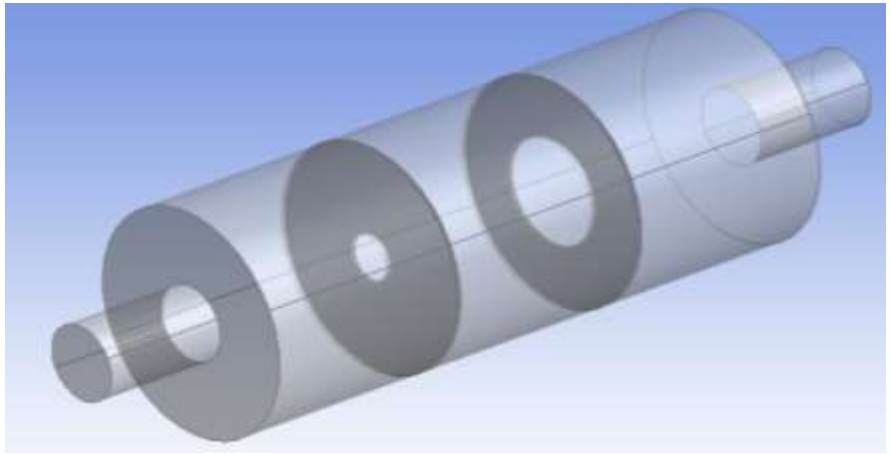
- Without Silencer: Can reach **100-120 dB**,
- With Silencer: Typically reduced to **70-90 dB**, depending on design and material.

https://www.youtube.com/watch?v=rYYppUNSSE8&t=12s

Baffles and Perforations in a Muffler

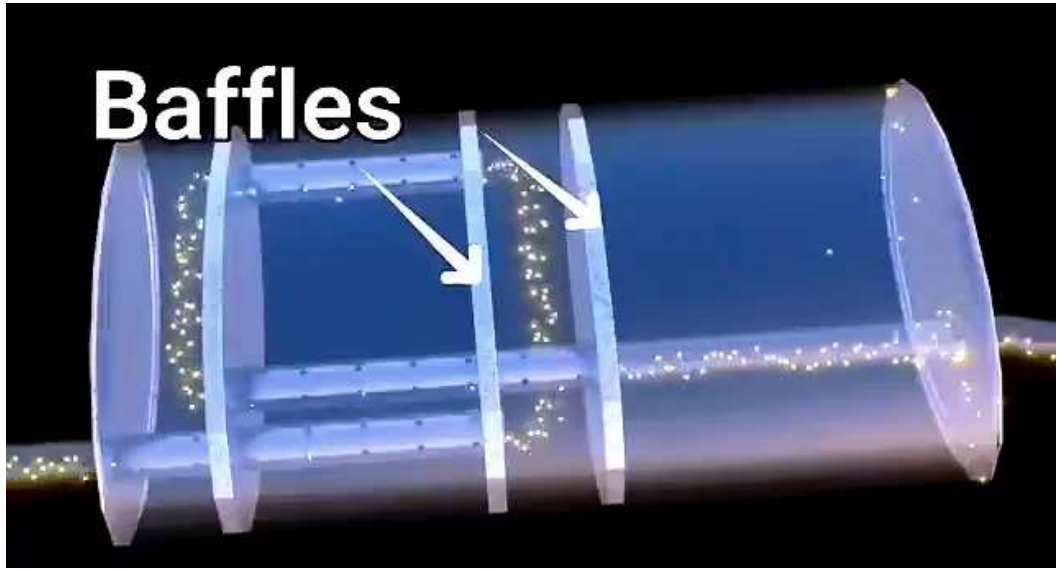
Baffles

- Baffles are internal components placed inside the muffler to control and direct the flow of exhaust gases.
- Their primary function is to reduce noise by reflecting and dissipating sound waves.



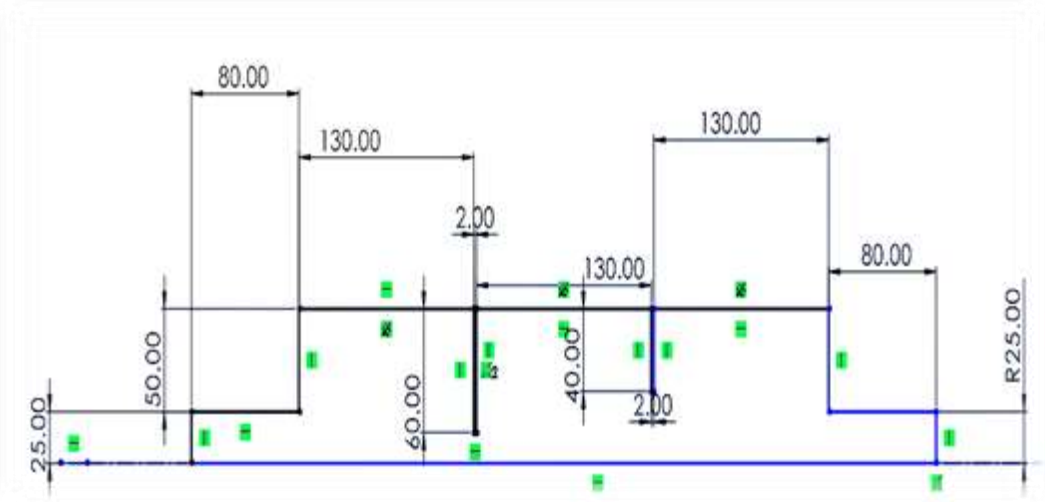
Perforations on Baffles

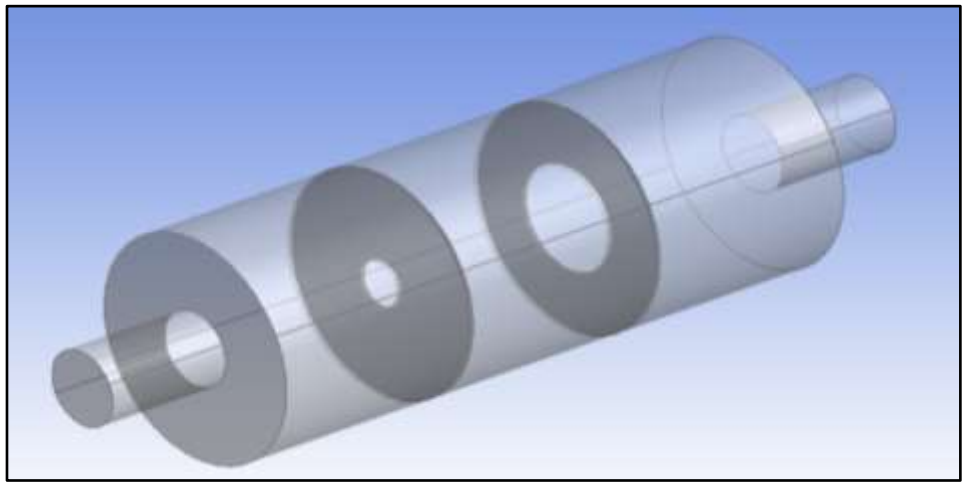
- Baffles with holes that allow partial gas flow, improving noise attenuation and reducing pressure variations.
- Perforations improve acoustic performance by increasing sound absorption inside the chamber.



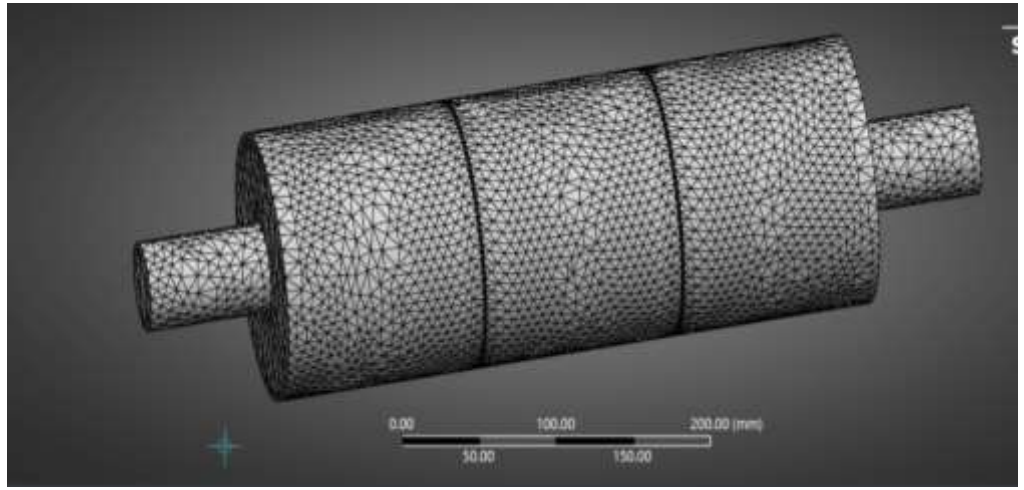
https://youtu.be/RcuwmaIIdQ8?si=X9bAf8qRXl4zbais

Model with Dimensions





Mess Sizing



Details of "Mesh"

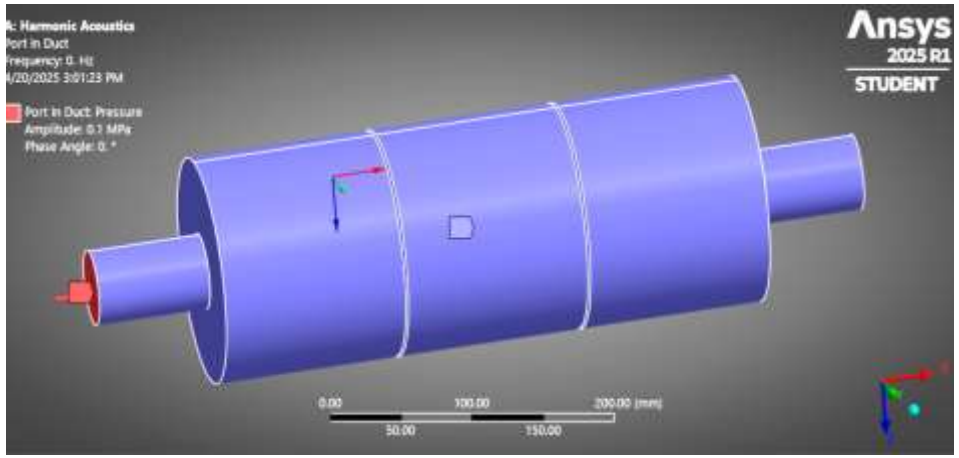
Element Size	8.0 mm
Sizing	
Quality	
Inflation	
Advanced	
Automatic Methods	
Sheet Body Method	Quad Dominant
Sweepable Body Method	Sweep
Statistics	
Nodes	54566
Elements	31108
Show Detailed Statistics	No

Acoustic Analysis

Boundry Conditions:

1. Analysis Settings: Max Frequency: 1500 Hz
2. Port In Duct-inlet Port:
    - •Wave Type: Circular Duct
    - •Pressure: 0.2 MPa
    - •Radius: 25 Mm
3. Port In Duct-outlet Port:
    - •Wave Type: Circular Duct
    - •Radius: 25mm
4. Surface Velocity: I. Inlet Velocity: 40 m/s

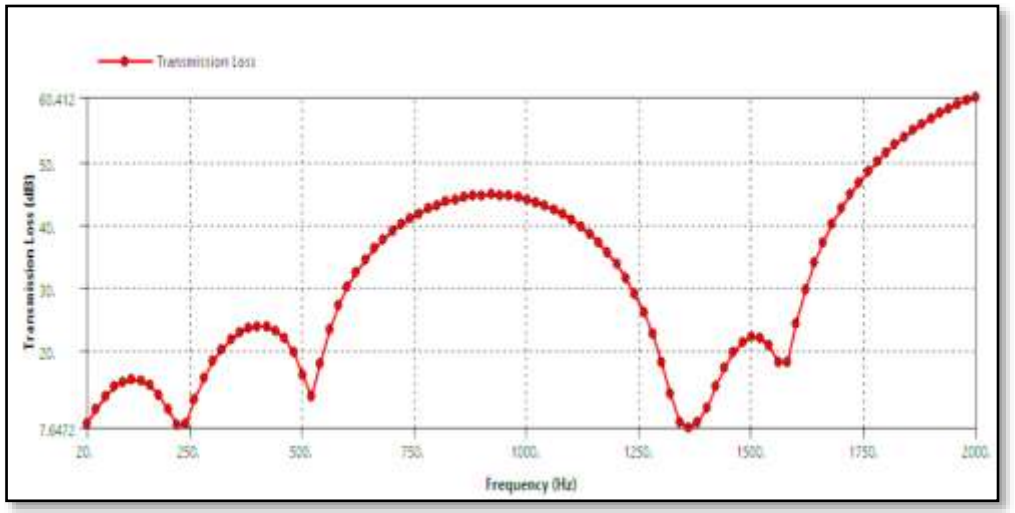
Solve For Transmission Loss And Sound Pressure Level

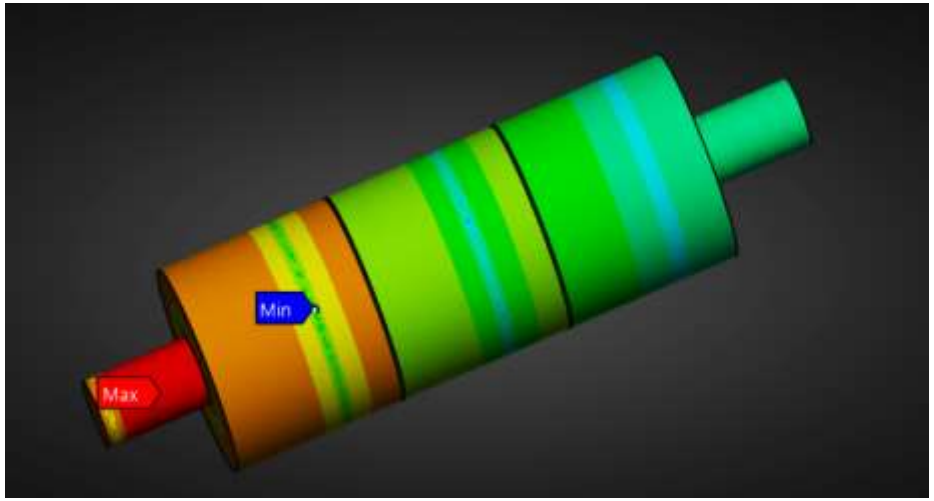


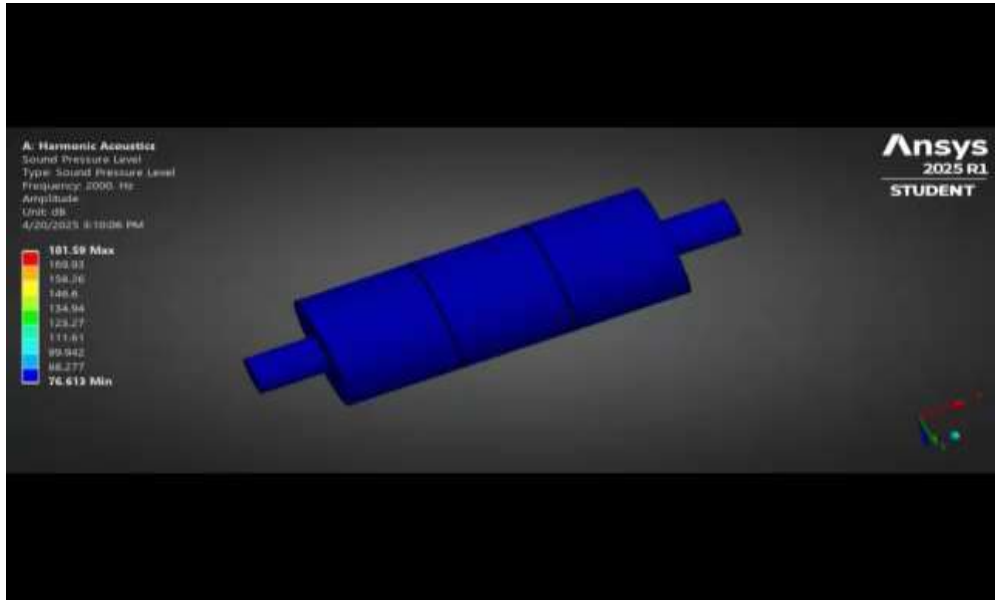
Details of "Analysis Settings"	
Step Controls	
Multiple Steps	No
Options	
Frequency Spacing	Linear
Range Minimum	0. Hz
Range Maximum	2000. Hz
Solution Intervals	100
User Defined Frequencies	Off
Solution Method	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Scattering Controls	

Results

- **Transmission Loss (TL)** varies significantly across the frequency range **20 Hz to 2000 Hz**
- The silencer performs well (TL > 30 dB) across most of the **750–1250 Hz** and **1750–2000 Hz** bands.
- Maximum TL (~60.4 dB) Achieved near **2000 Hz**, showing **excellent noise attenuation** at high frequencies







Thermal Analysis

Boundry Conditions:

Thermal Inlet:

- velocity : 40 m/s
- Pressure : 0.2 MPa
- Temperature : 473 K

Outlet Condition:

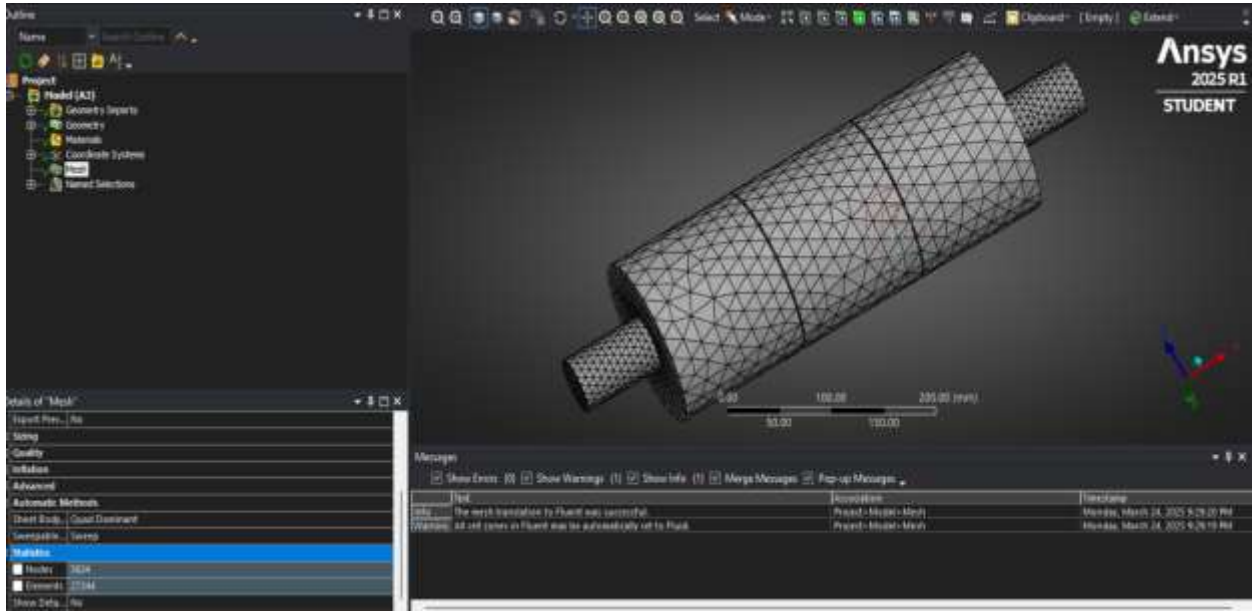
- Ambient condition : T = 300 k

Wall Condition :

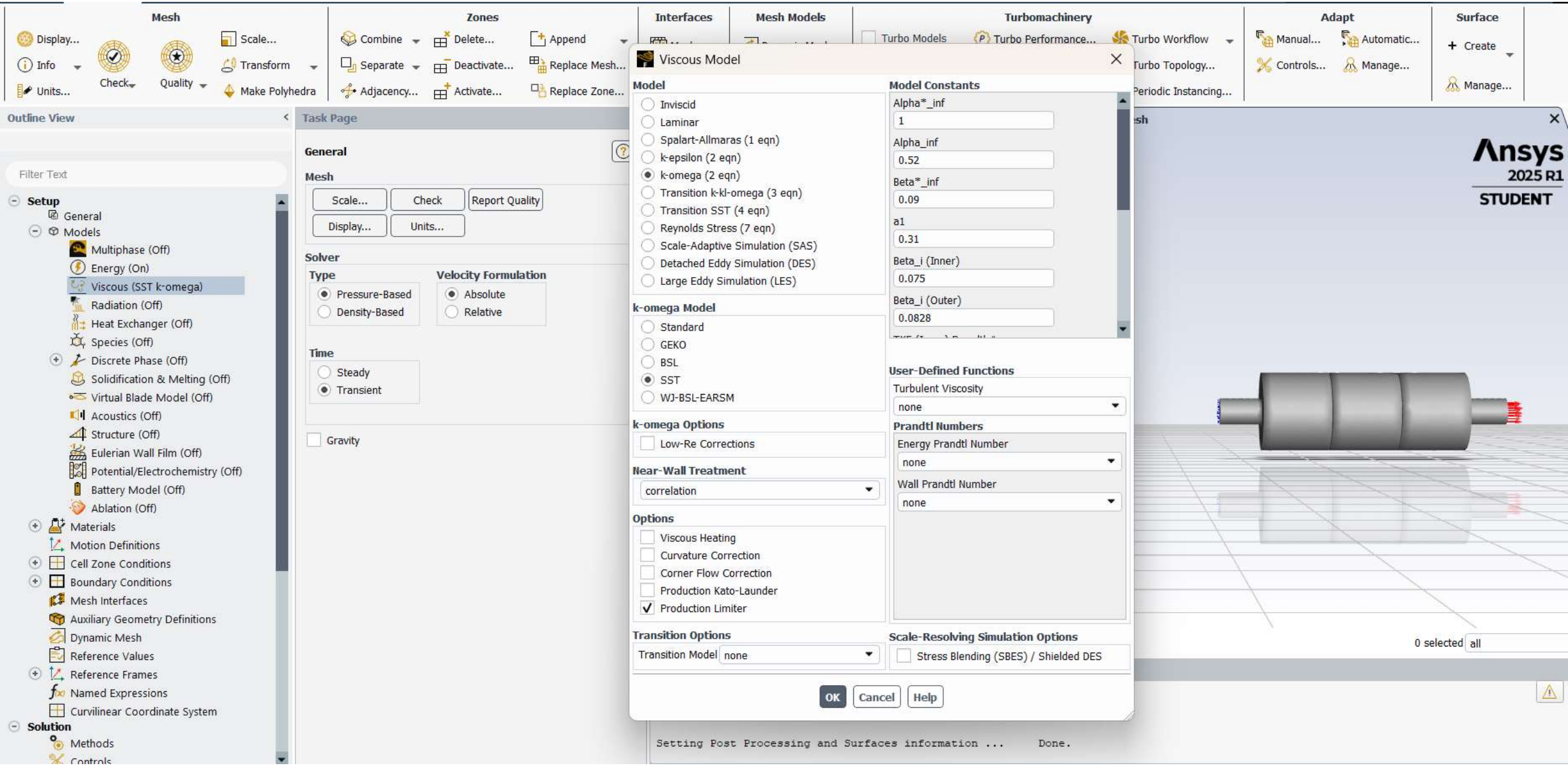
- Stationary wall condition: No slip

Convection :

- Heat transfer coefficient(h) : 80 W/m2.k
- Free stream temperature : 300 k
- Wall thickness : 0.75 m
- Wall material : Stainless Steel 304
- Material density : 7930 kg/m3
- Material Thermal Conductivity : 16.2 W/m.K
- Material Specific Heat : 500 J/kg.K



Meshing


Mesh
Display...
Info
Units...
Check
Quality
Scale...
Transform
Make Polyhedra
Zones
Combine
Separate
Adjacency...
Delete...
Deactivate...
Activate...
Append
Replace Mesh...
Replace Zone...
Interfaces
Mesh Models
Turbomachinery
Turbo Models
Turbo Performance...
Turbo Workflow
Turbo Topology...
Periodic Instancing...
Adapt
Manual...
Controls...
Automatic...
Manage...
Surface
Create
Manage...
Outline View
Filter Text
Setup
General
Models
Multiphase (Off)
Energy (On)
Viscous (SST k-omega)
Radiation (Off)
Heat Exchanger (Off)
Species (Off)
Discrete Phase (Off)
Solidification & Melting (Off)
Virtual Blade Model (Off)
Acoustics (Off)
Structure (Off)
Eulerian Wall Film (Off)
Potential/Electrochemistry (Off)
Battery Model (Off)
Ablation (Off)
Materials
Motion Definitions
Cell Zone Conditions
Boundary Conditions
Mesh Interfaces
Auxiliary Geometry Definitions
Dynamic Mesh
Reference Values
Reference Frames
Named Expressions
Curvilinear Coordinate System
Solution
Methods
Controls
Task Page
General
Mesh
Scale...
Check
Report Quality
Display...
Units...
Solver
Type
Pressure-Based
Density-Based
Velocity Formulation
Absolute
Relative
Time
Steady
Transient
Gravity
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
WJ-BSL-EARSM
k-omega Options
Low-Re Corrections
Near-Wall Treatment
correlation
Options
Viscous Heating
Curvature Correction
Corner Flow Correction
Production Kato-Launder
Production Limiter
Transition Options
Transition Model
none
Model Constants
Alpha*_inf
1
Alpha_inf
0.52
Beta*_inf
0.09
a1
0.31
Beta_i (Inner)
0.075
Beta_i (Outer)
0.0828
User-Defined Functions
Turbulent Viscosity
none
Prandtl Numbers
Energy Prandtl Number
none
Wall Prandtl Number
none
Scale-Resolving Simulation Options
Stress Blending (SBES) / Shielded DES
OK
Cancel
Help
Ansys
2025 R1
STUDENT
0 selected
all
Setting Post Processing and Surfaces information ... Done.

Initialization and Calculation Setting

Initialize using the hybrid initialization method.

Checking case topology...

- This case has both inlets & outlets
- Pressure information is not available at the Boundaries.

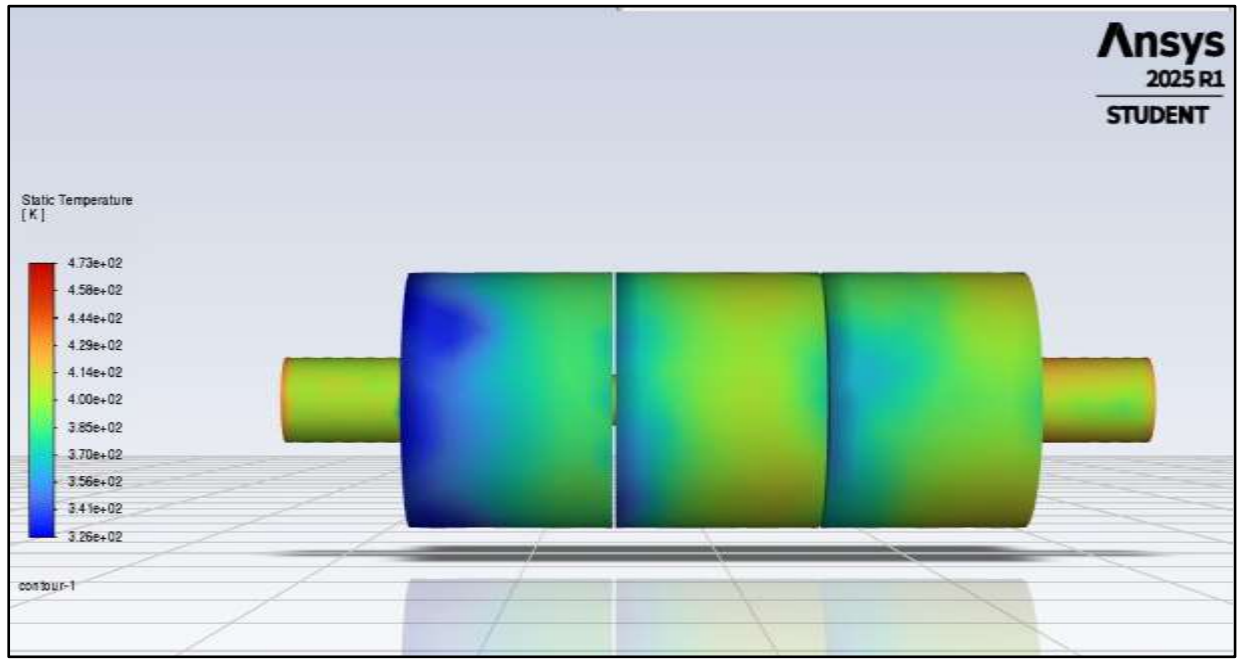
Case will be initialized with constant pressure

Hybrid initialization is done.

iter	scalar-0
1	1.000000e+00
2	5.901652e-04
3	1.059959e-04
4	3.295305e-05
5	9.452262e-06
6	3.268837e-06
7	1.056386e-06
8	3.580275e-07
9	1.314097e-07
10	4.830457e-08

Thermal Analysis Result

- Temperature inside the muffler ranges from **326 K to 473 K**.
- Highest temperature observed at the **inlet** due to entry of hot exhaust gases.
- Gradual temperature drop across the chambers indicates **effective heat dissipation**.
- Overall, **uniform temperature distribution** observed across the muffler body.
- **Minor hot spots** near the inlet suggest a need for **additional thermal insulation** for better safety and performance.



Additional Thermal Insulation

Details of "Mesh"

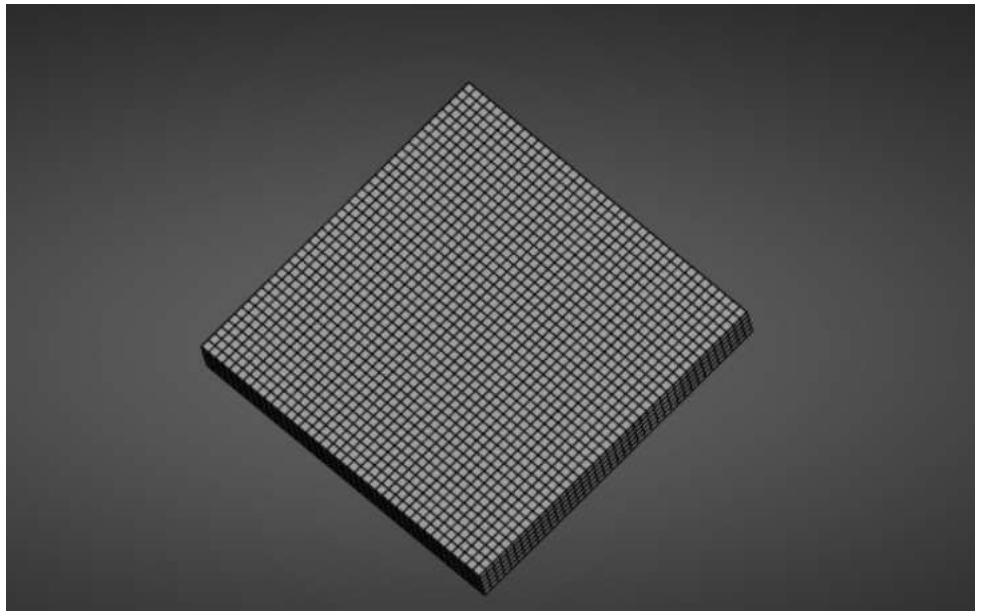
Element Size	2.0 mm
Sizing	
Quality	
Inflation	
Advanced	
Automatic Methods	
Sheet Body Method	Quad Dominant
Sweepable Body Method	Sweep
Statistics	
Nodes	38171
Elements	8000
Show Detailed Statistics	No

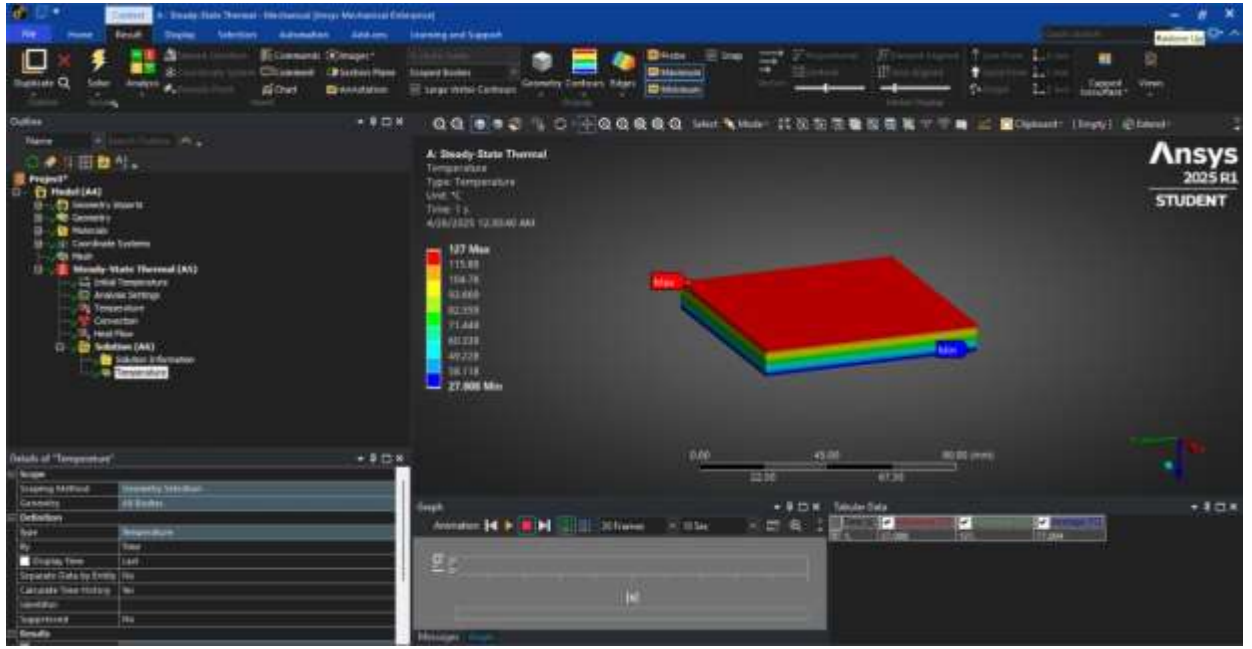
Outline of Schematic A2: Engineering Data

	A	B	C	D	E
1	Contents of Engineering Data		Source		Description
2	Material				
3	glass wool				
4	Structural Steel				Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material				

Properties of Outline Row 3: glass wool

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	60	kg m^-3		
4	Isotropic Thermal Conductivity	0.04	W m^-1 C^-1		
5	Specific Heat Constant Pressure, C_p	850	J kg^-1 C^-1		





Design Variation and Simulation

TL depends on various factors

1. Design of Muffler
2. Materials

Design Variations for Optimization

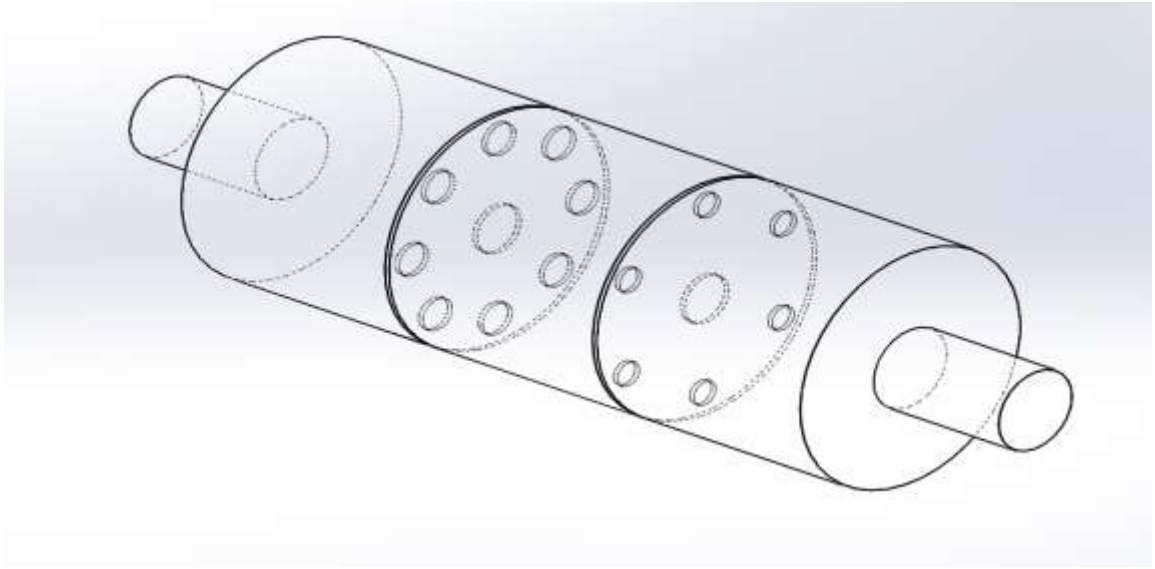
Parameters varied:

- Inlet/outlet diameter
- Chamber dimensions
- Baffle number, position, shape
- Perforation size
- Material selection

Design Variation – 1

Changes made in the model:

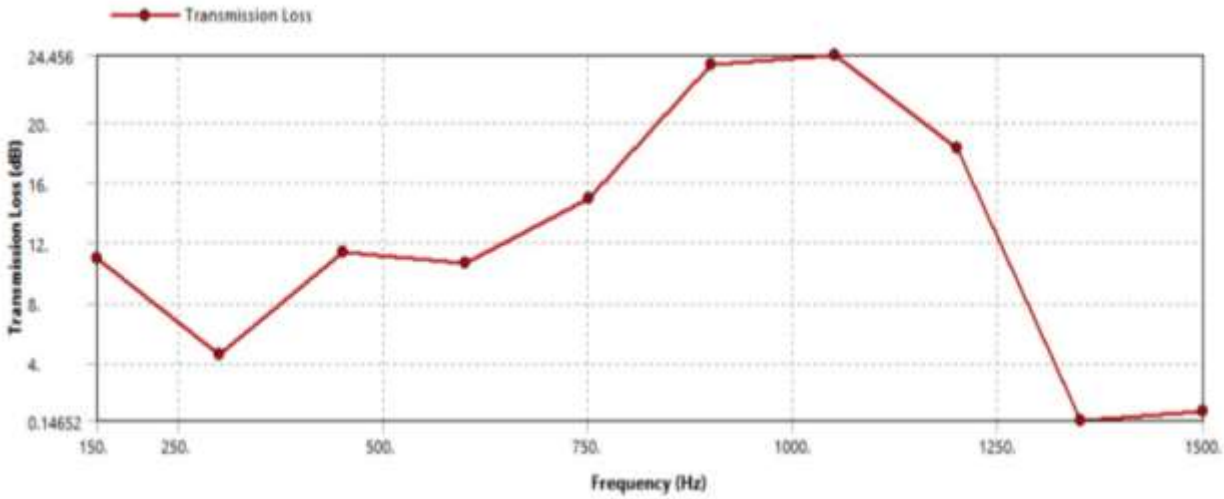
- Baffle near to the inlet port has 9 holes (8 holes has dia. 20mm and 1 in the middle has dia. 30mm)
- Baffle near the exit port has total 7 holes (six holes has dia. 15mm and 1 hole has dia. 30mm)
- Inlet and outlet diameter of port is same as 50mm.



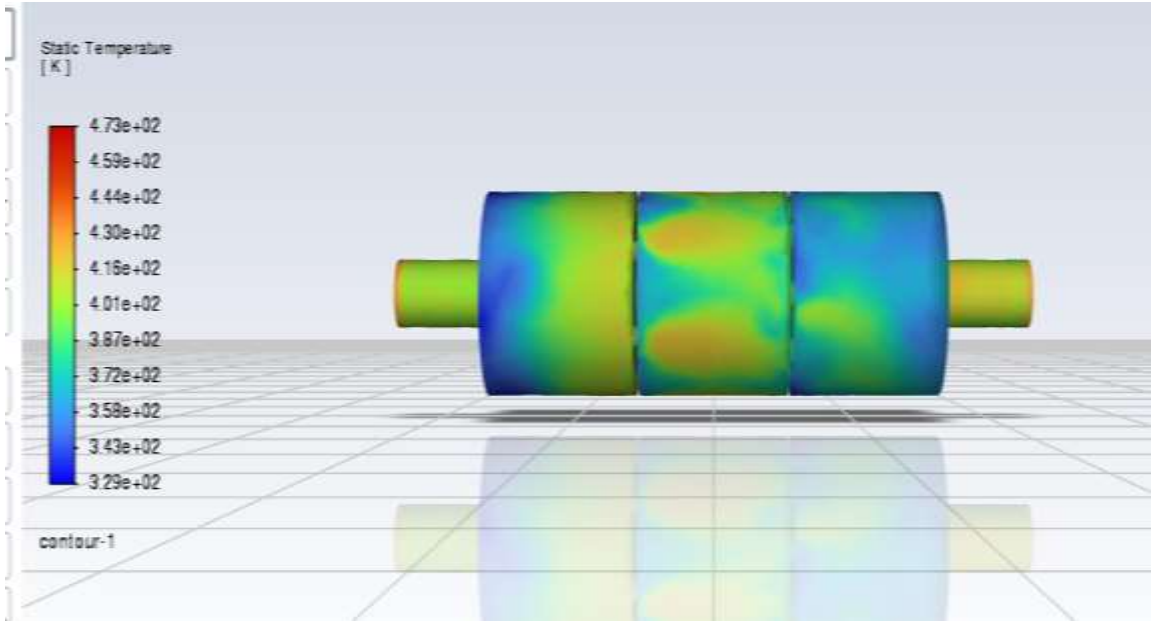
Results

Adithyaa Priyansh

- **Transmission Loss (TL)** varies significantly across the frequency range **150 Hz to 1500 Hz**
- The silencer performs well (TL > 20 dB) across most of the **800–1100 Hz**
- Maximum TL (~24.4 dB) Achieved near **1050 Hz**, showing **excellent noise attenuation** at high frequencies



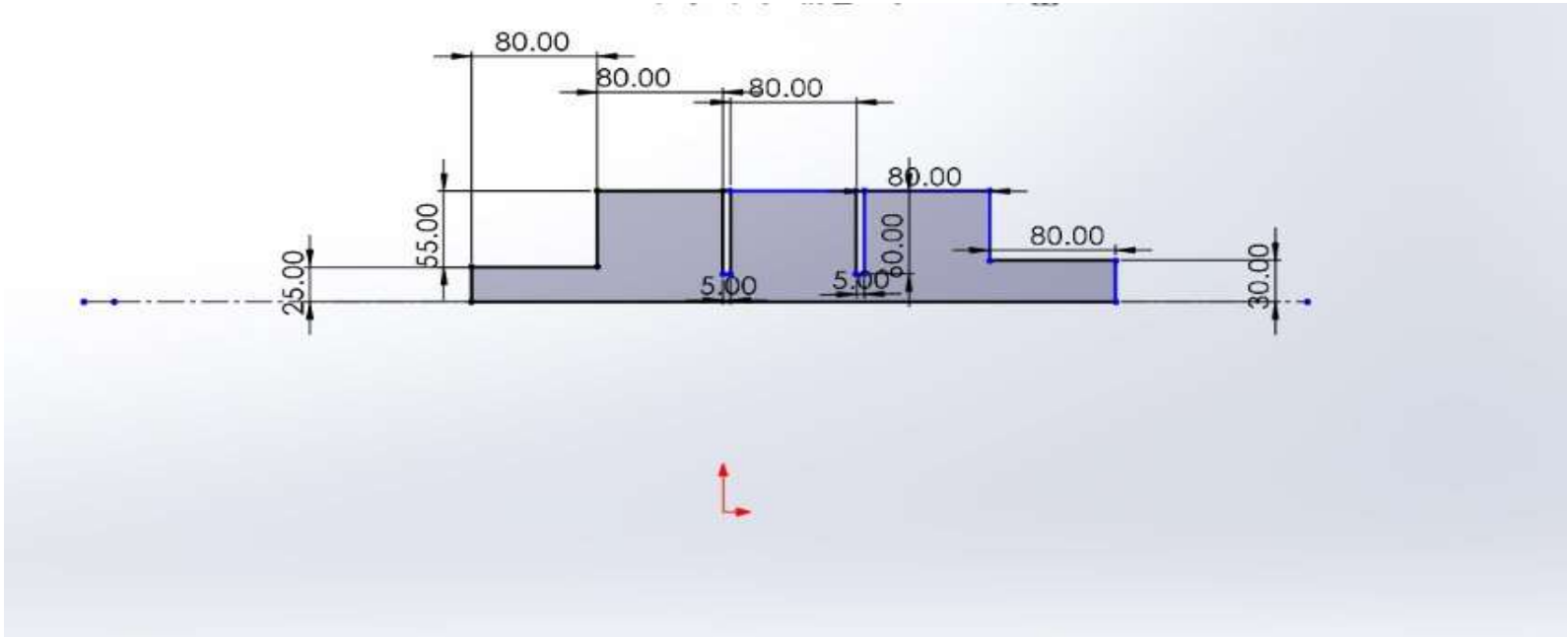
THERMAL ANALYSIS



Design Variation – 2

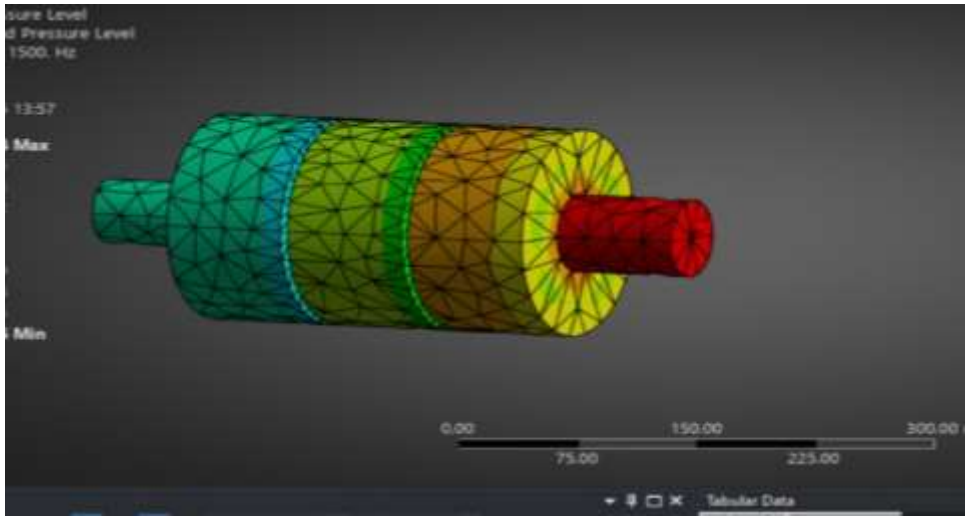
Changes made in the model:

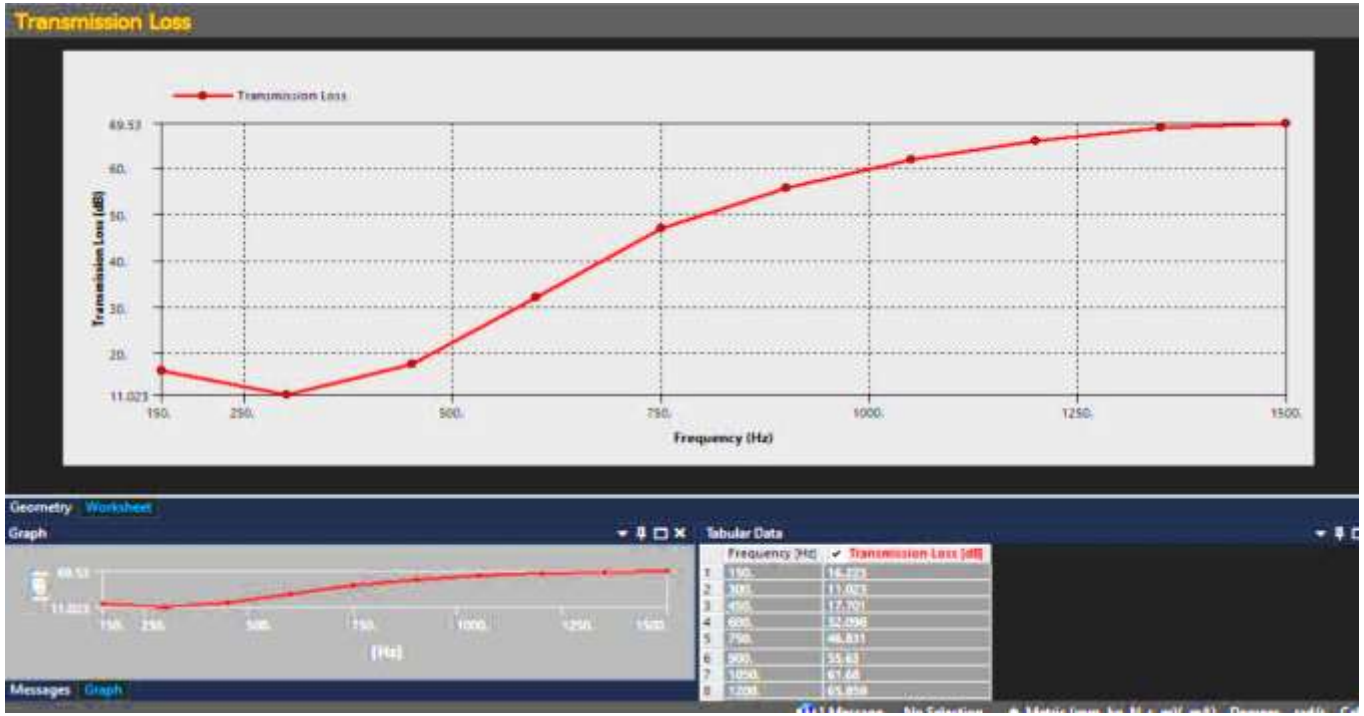
- The baffle hole radius near to the inlet port has been changed to 30 mm
- The baffle hole radius near to the outlet port has been changed to 25 mm
- Baffle thickness is changed to 5 mm
- Length of the muffler 410 mm
- Radius of the baffle 55 mm



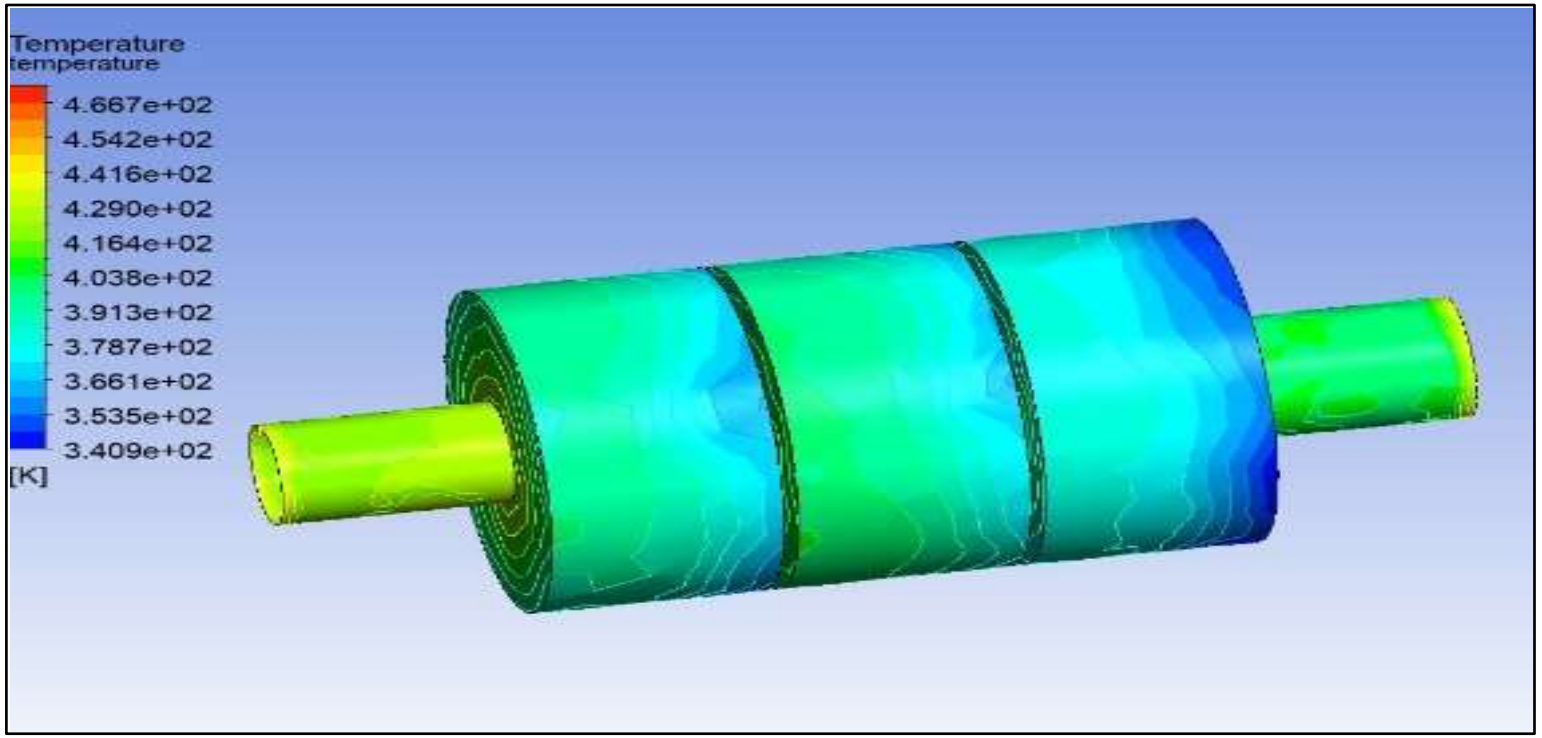
ACOUSTICS ANALYSIS

- Transmission Loss (TL) varies across the frequency range between 150 - 1500 HZ
- The silencer performs well across 600 – 1200 HZ of band frequency
- The maximum TL 69.53 achieved near 1250 HZ shows commendable noise
- attenuation at higher frequencies.





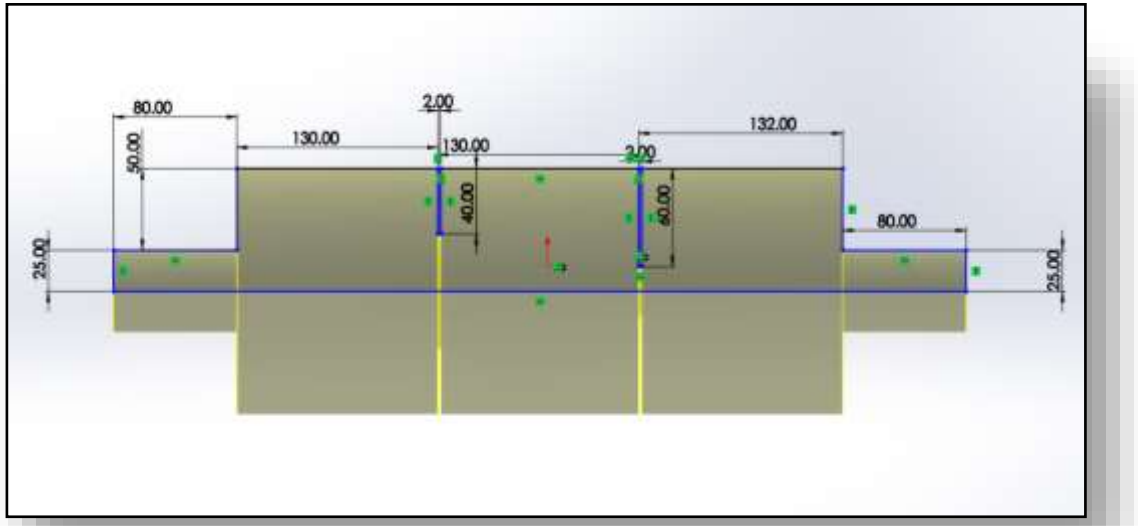
- **THERMAL ANALYSIS**



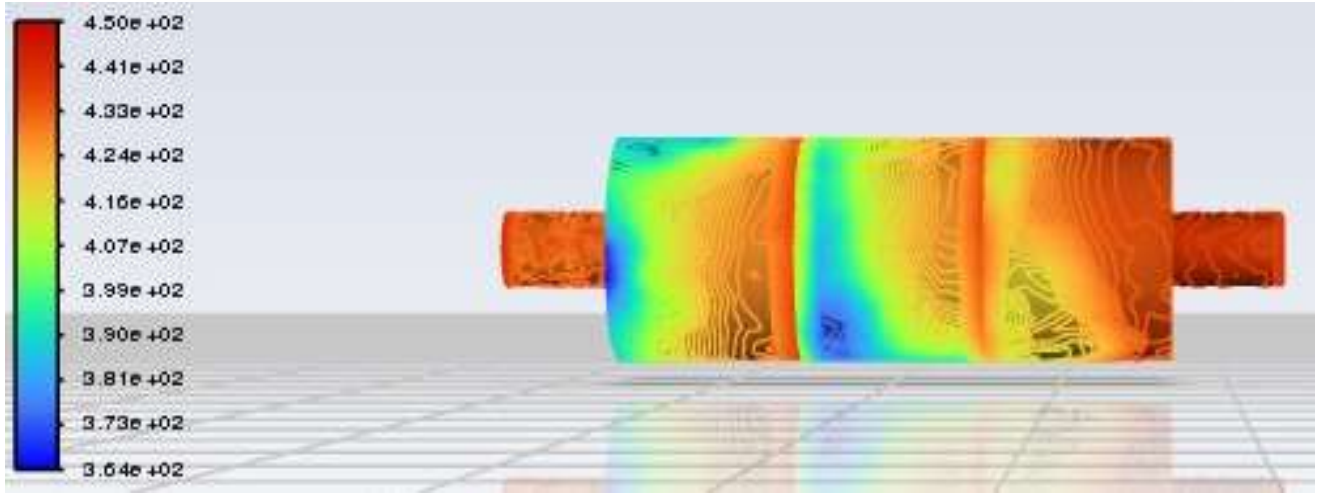
Design Variation –3

Changes made in the model:

- Diameters of the holes in the two baffles has been swapped
- The baffle hole diameter near to the inlet port has been changed from 60mm to 40mm
- The baffle hole diameter near to the outlet port has been changed from 40 mm to 60 mm

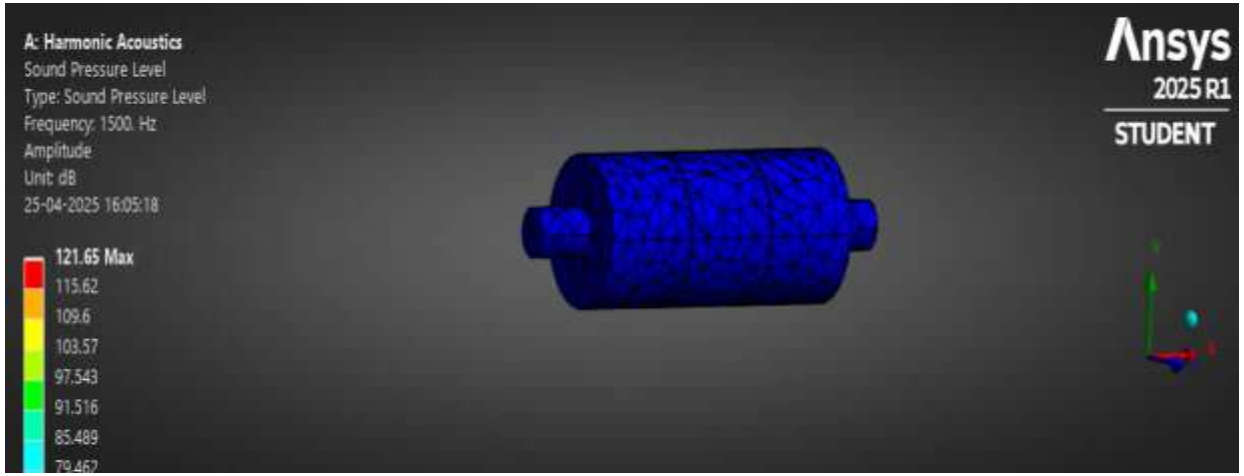


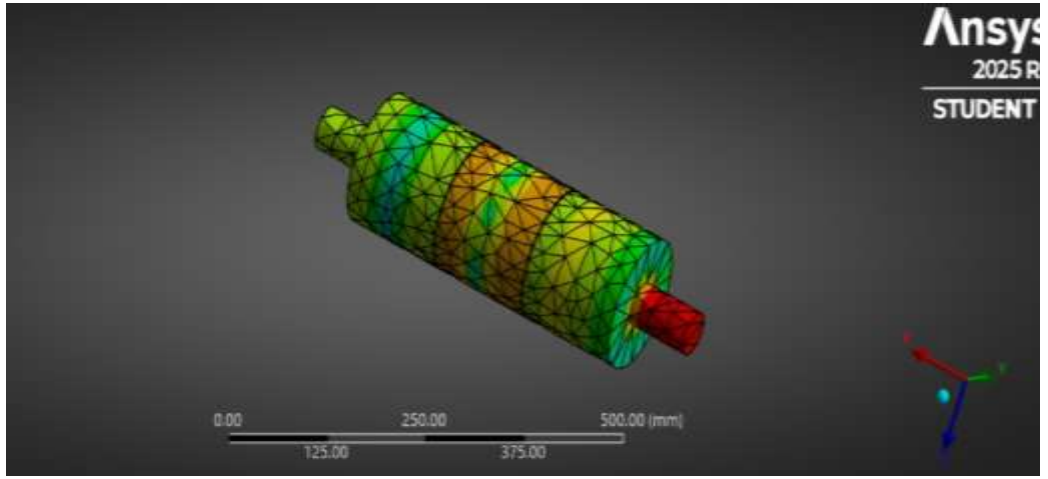
THERMAL ANALYSIS



ACOUSTICS ANALYSIS

- **Transmission Loss (TL)** varies across the frequency range between **150 Hz to 1500 Hz.**
- The silencer performs well (TL>30dB) across **500-1250 Hz** band frequency.
- The maximum TL achieved is **48.412 Hz** achieved near **900 Hz** which shows appropriate noise attenuation at high frequencies.

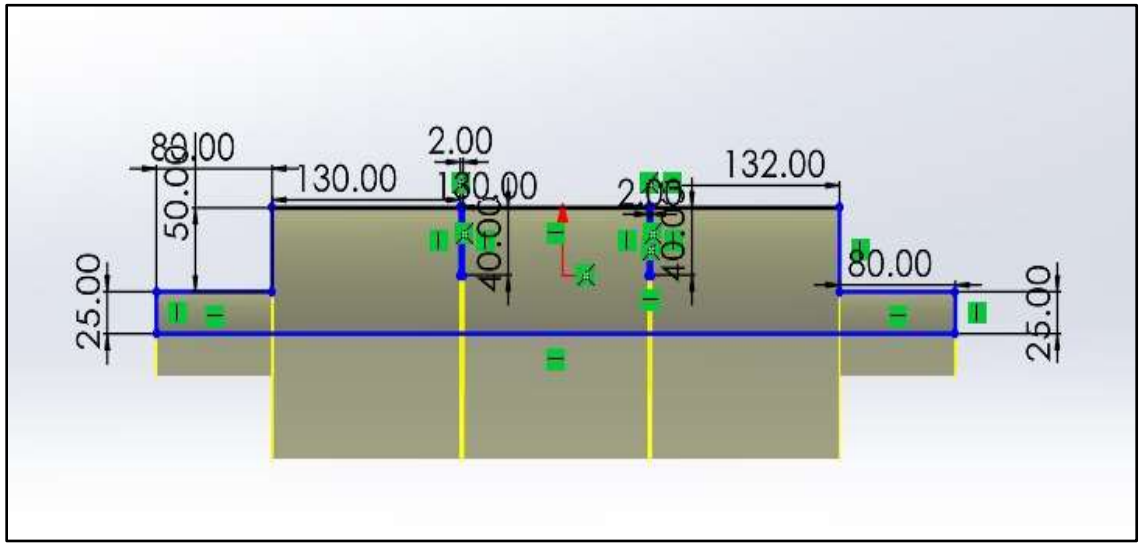




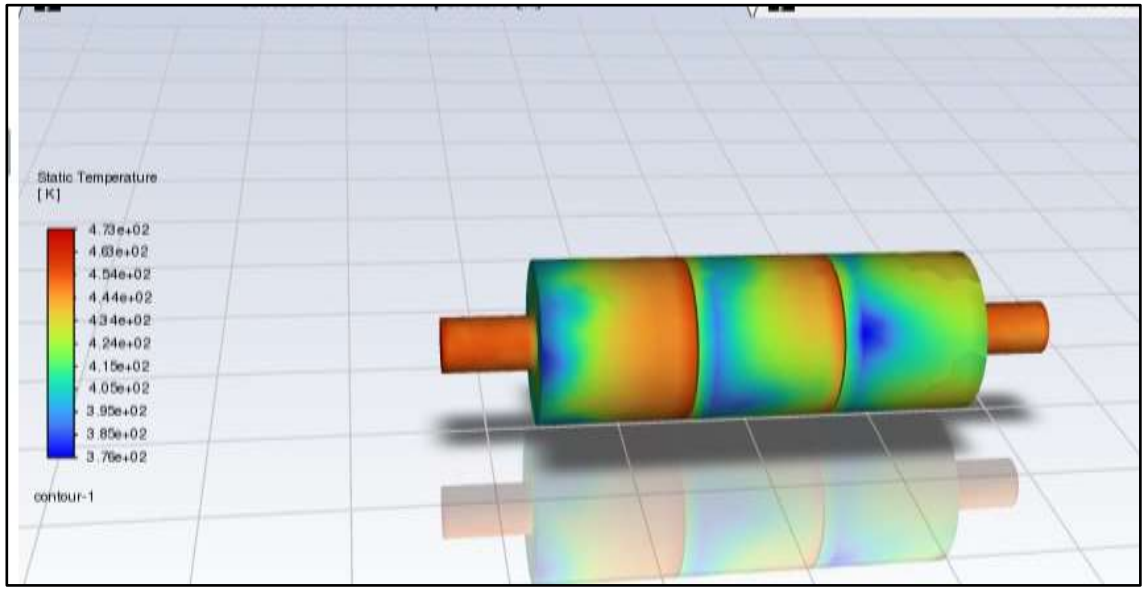
Design Variation –4

Changes made in the model:

- Diameters of the holes in the two baffles has kept constant.
- The baffle hole diameter near to the inlet port has been changed from 60mm to 40mm.
- The baffle hole diameter near to the outlet port has kept constant as 40mm.

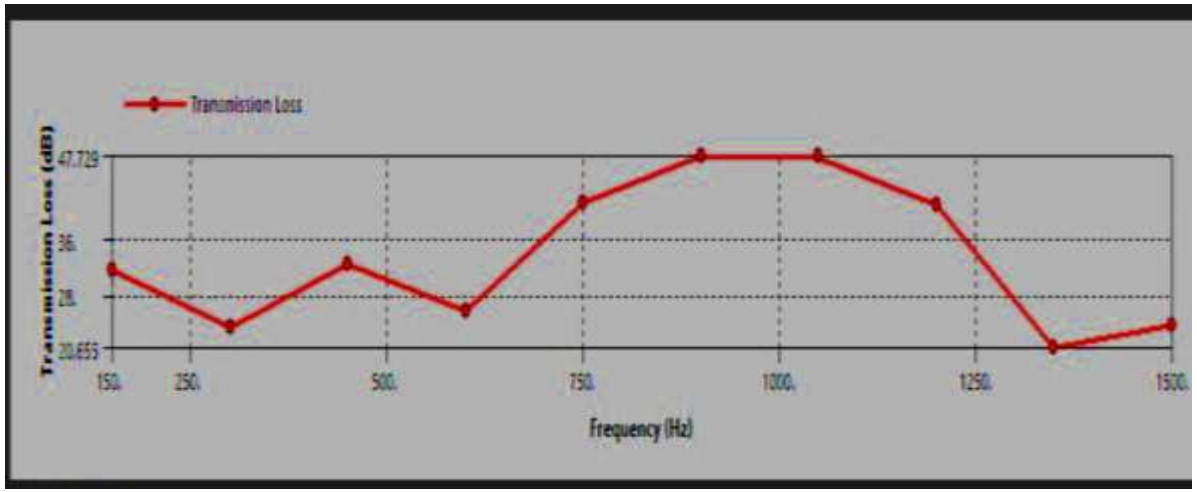


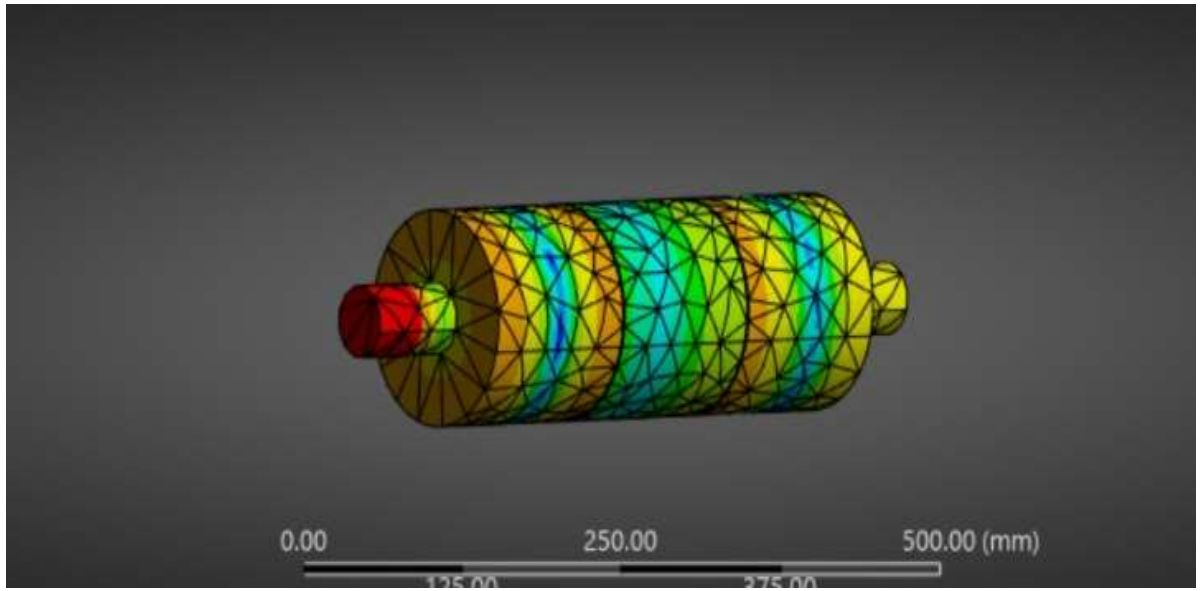
THERMAL ANALYSIS



Results:

- Transmission Loss (TL) varies across the frequency range between 150Hz to 1500Hz.
- The silencer performs well (TL>30dB) across the bands 900Hz to 1050Hz.
- The maximum TL (~47.729dB) achieved near 900Hz, demonstrating excellent noise attenuation at higher frequencies.





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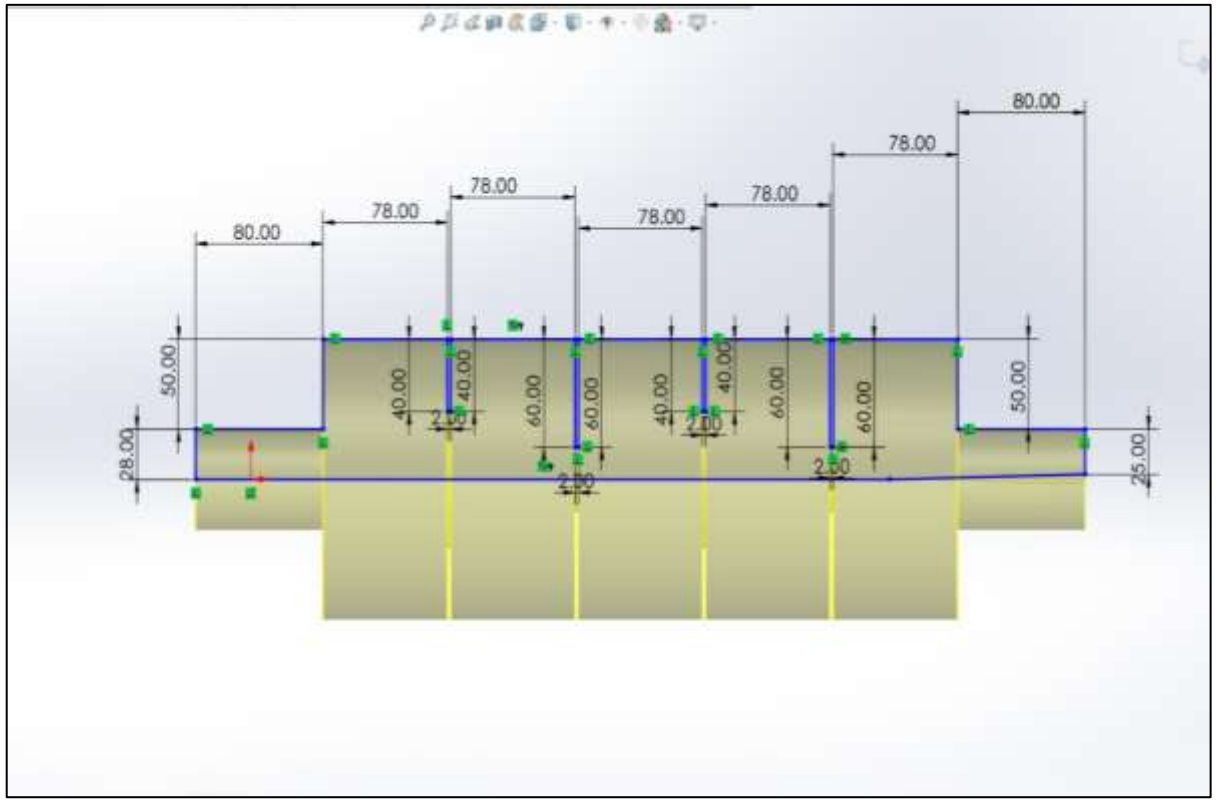
Design Variation –5

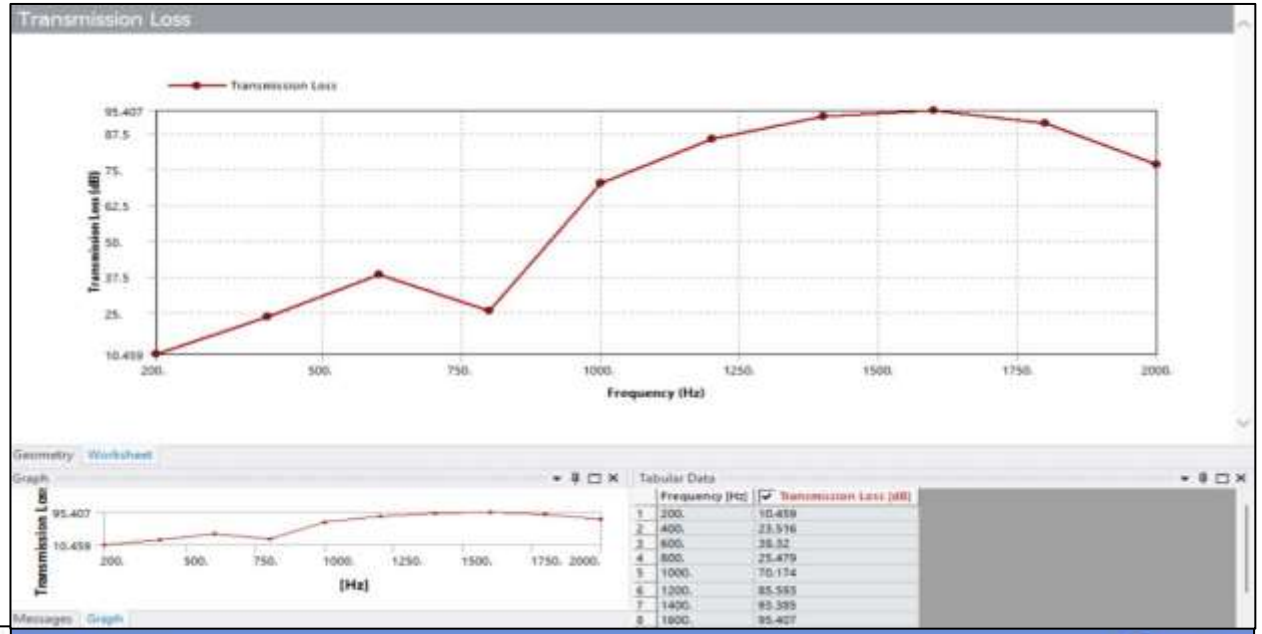
Changes made in the model:

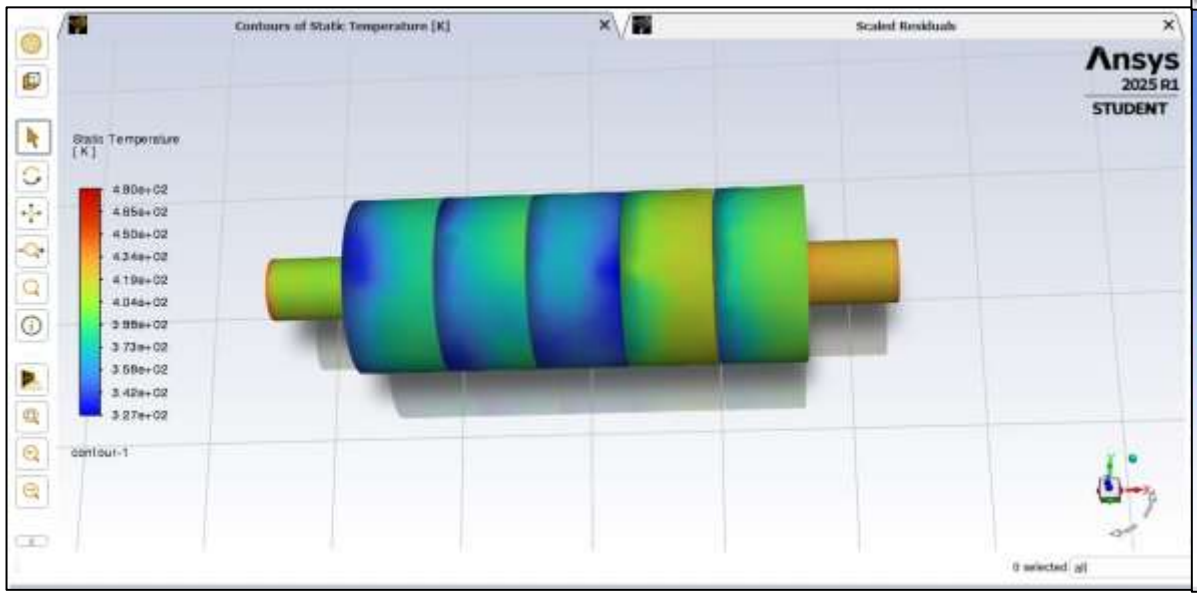
- Multiple Baffles are kept along the silencer length.
- The baffles of different hole diameters are kept alternatively to analyze the change in the pressure and temperature levels.
- First Baffle hole diameter near the inlet port is kept 40mm, second of 60mm then again 40mm and the last one is of 60mm.
- Radius of inlet port is also kept bigger from the outlet port i.e. 28mm.
- The distance between the consecutive baffles is kept constant while analyzing.

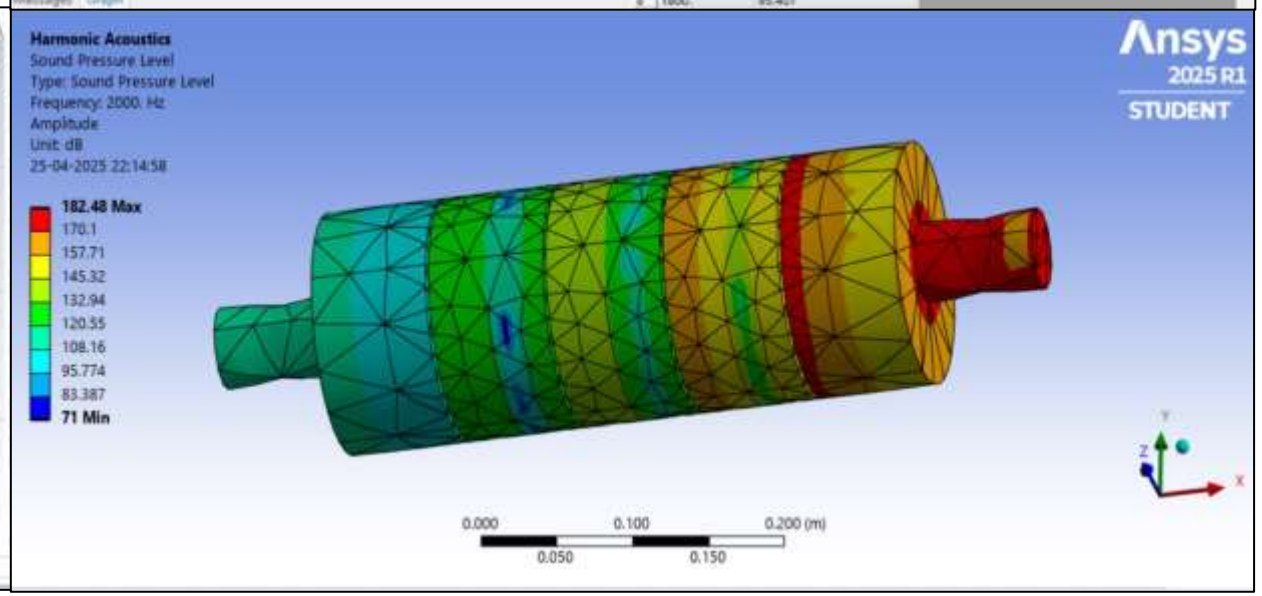


Results:

- Transmission Loss (TL) varies across the frequency range between **200Hz** to **2000Hz.**
- The maximum TL (**~95.407dB**) achieved near 1500 Hz, demonstrating excellent noise attenuation at higher frequencies.
- Maximum Temperature coming out to be 480K.







THERMAL ANALYSIS

ACOUSTICS ANALYSIS

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"Thank You"