DESIGN OPTIMIZATION OF HYBRID MUFFLER AND ACOUSTIC TRANSMISSION LOSS PREDICTION

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Abstract - *The present work involved the optimization of the mufflers design by designing a hybrid muffler. The objective of the current work is to design a hybrid muffler which is very good in performance and works well in the wide spectrum of frequency. For this purpose, we are going to perform acoustic analysis which can show how the sound pressure is changing when it is passing through the muffler and what the difference in between inlet sound pressure is and outlet sound pressure. .CAD files of the mufflers were established for developing FEA models in ANSYS. When we do acoustic analysis, we actually carry out transmission loss analysis. Two production mufflers were selected for this study. Both mufflers have complex partitions and one of them was filled with absorbent material. FEA models were validated by experimental measurements using a two-source method. After the models were verified, sensitivity studies of design parameters were performed to optimize the transmission loss (TL) of both mufflers. The sensitivity study includes the perforated hole variations, partition variations and absorbent material insertion.*

Key Words: Muffler, Transmission loss, hybrid muffler, ANSYS, Sound Pressure.

1. INTRODUCTION

Mufflers are installed within the exhaust system of most internal combustion engines, although the muffler is not designed to serve any primary exhaust function. The muffler is engineered as an acoustic sound proofing device designed to reduce the loudness of the sound pressure created by the engine by way of acoustic quieting. Mufflers are a fundamental part of engine exhaust system and are used to minimize sound transmissions caused by exhaust gases. Design of mufflers is a complex function that affects noise characteristics, emission and fuel efficiency of engine. Mufflers presently used in the automotive industry are either reactive muffler or a dissipative muffler which work at a certain target frequency spectrum. For example, the reactive muffler are good at a low frequency ranges whereas the dissipative mufflers work at high frequencies of 1500-2000Hz

2 TYPE OF MUFFLER

2.2Reactive Muffler:

In this type of muffler Inlet and outlet tube are extended in chambers. Reactive mufflers generally consist of several pipe segments that interconnect with a number of larger chambers. The noise reduction mechanism of reactive silencer is that the area discontinuity provides an impedance mismatch for the sound wave travelling along the pipe. This impedance mismatch results in a reflection of part of the sound wave back toward the source or back and forth among the chambers. The reactive silencers are more effective at lower frequencies than at high frequencies, and are most widely used to attenuate the exhaust noise of internal combustion engines.

2.3 Absorptive muffler

The absorptive muffler is the classic dissipative design, deriving its noise control properties from the basic fact that noise energy is effectively “absorbed” by various types of fibrous packing materials. That is, as the sound waves pass through the spaces between the tightly packed, small diameter fibers of the absorptive material, the Resulting viscous friction dissipates the sound energy as small amounts of heat.

3. CHARACTERISTICS OF MUFFLER

3.1 Insertion loss (IL)

Insertion loss (IL) is change in sound pressure level at tail pipe outlet with and without insertion of a muffler.

3.2Transmission loss, TL

Transmission Loss is defined as the ratio between the sound power incidents to the transmitted sound power with reflection free termination at outlet.

3.3Noise reduction (NR) Noise Reduction is difference in sound pressure level between one point upstream of the muffler and one point downstream.

4. LITERATURE SURVEY

This study presents an efficient process to optimize the transmission loss of a vehicle muffler by using both experimental and analytical methods. Two production mufflers were selected for this study. Both mufflers have complex partitions and one of them was filled with absorbent fiberglass. After the models were verified, sensitivity studies of design parameters were performed to optimize the transmission loss (TL) of both mufflers. It was observed that adding absorbent material to the right cavity of a muffler could cause significant improvement in TL performance as indicated in both mufflers.[1]. A quasi-one-dimensional approach is presented to analyze three-pass mufflers with perforated elements using numerical decoupling. The approach is further developed to include mufflers with ducts extended into the end cavities. Theoretical predictions are compared with experiments for three different muffler configurations, one fabricated and two commercially available mufflers, and shown to agree reasonably well. The effect of porosity, length of the end cavities, andexpansion chamber diameter are studied. Also, the effect of ducts extending into the end cavities are investigated.[2]

5. METHODOLOGY

The following steps are involved in the experimental work.

1. Data collection and Literature collection.

2. Muffler transmission loss using FEM will be validated with analytical and experimental results for Simple Muffler.

3. Geometric modelling of three pass perforated reflective muffler in ansys workbench.

4. Parametric Study is done to evaluate performance of muffler for different designpoints.

5. Geometric modelling of single pass absorptive muffler in ansys workbench.

6. Parametric Study is done to evaluate performance of single pass absorptive muffler for different design points.

7. Comparing Results at each stages and evaluating the best performance of muffler.

8. Geometric modelling of hybrid muffler and evaluate the performance of hybrid muffler.

The main objective of this study:

The objective of the current work is to design a hybrid muffler which is very good in performance and works well in the wide spectrum of frequency. For this purpose, we are going to perform acoustic analysis which can show how the sound pressure is changing when it is passing through the muffler and what the difference in between inlet sound pressure is and outlet sound pressure. When we do acoustic analysis, we actually carry out transmission loss analysis. This can be achieved by doing a transmission loss analysis which will be perfectly explained in the coming sections.

5.1 PARAMETRIC STUDY

- **Three Pass Muffler**

(i) Parametric Optimization one

Outlet Chamber Length (Lc)

Considered three Cases of outlet chamber length

1) Outlet chamber length (Lc) = 0.13 m

2) Outlet chamber length (Lc) = 0.15 m

3) Outlet chamber length (Lc) = 0.102 m

(ii) Parametric Optimization two

Porosity changes with change in the perforation hole diameter (dh).

Considered three cases,

1) hole diameter(dh)=0.0017 m, porosity ϕ=0.02

2) hole diameter(dh)=0.0023 m, porosity ϕ=0.045

3) hole diameter(dh)=0.0027 m, porosity ϕ=0.06

- **Dissipative Mufflers**

Parametric study is done for different fibrous material.

Different fibrous

Materials selected for parametric optimization were,

1) Glass fiber

2) Polyurethane Foam

3) Metal Foam

4) Rock Wool

6 MODELLING

6.1 Three Pass Muffler

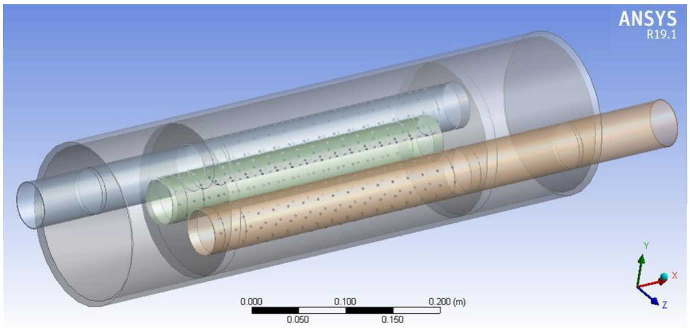

Fig -1: Geometry of Three Pass Muffler

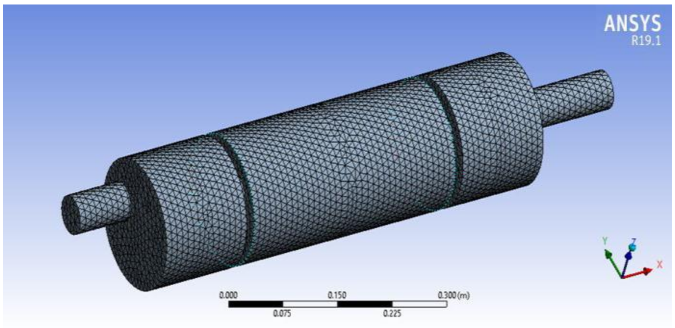

Fig-2: Meshing the Model

6.2 Dissipative Mufflers

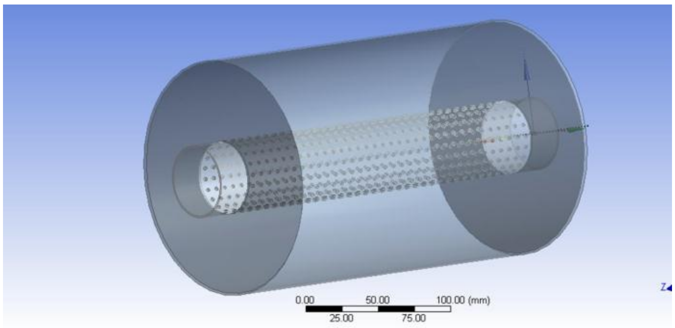

Fig-3: Dissipative Mufflers

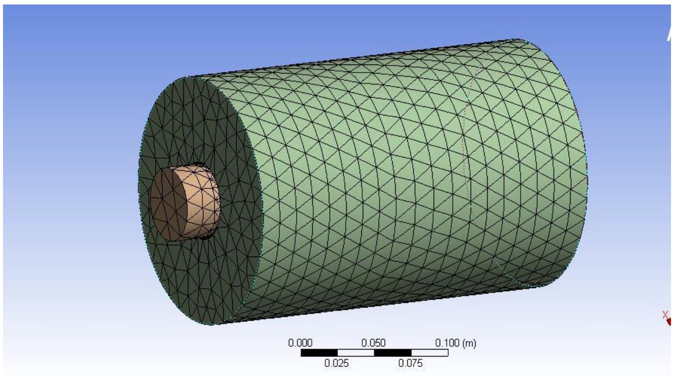

Fig-4: Meshing the Dissipative Mufflers

6.3 Hybrid muffler

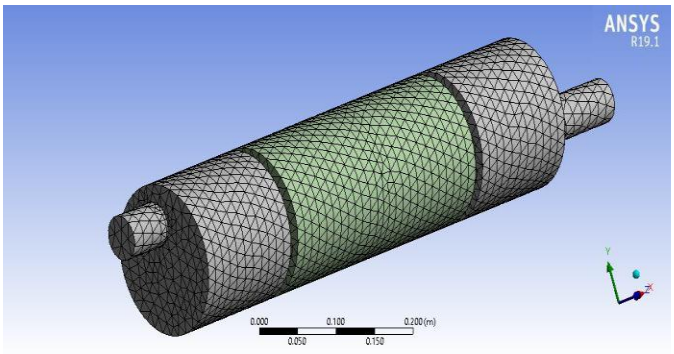

Fig -5: Meshing the hybrid muffler

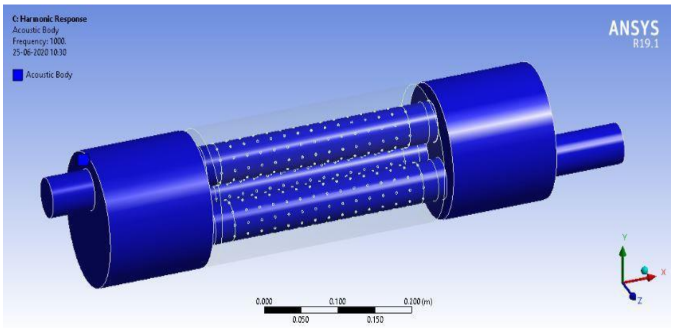

Fig -6: Hybrid Muffler Acoustic Body One

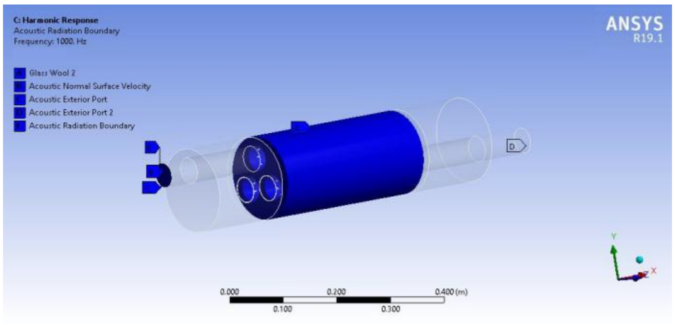

Fig-7: Hybrid Muffler Acoustic Body Two

7. RESULTS AND DISCUSSION

The solution for the acoustics analysis is done at a frequency interval. Parametric study is done for different fibrous material, parametric study is done for different Outlet Chamber Length in three pass muffler, parametric study is done for Porosity change by change the perforation hole diameter in three pass muffler and acoustic analysis. Geometric modelling of hybrid muffler and evaluate the performance of hybrid muffler is done. From the Optimization Study we can concluded that we can achieve maximum transmission loss when using Glass fiber as absorptive material. Three pass muffler shows maximum Transmission loss when the outlet chamber length is equal to inlet chamber length and porosity of 0.045.

7.1 Parametric Optimization One

1. Outlet Chamber Length (Lc),0.13 m

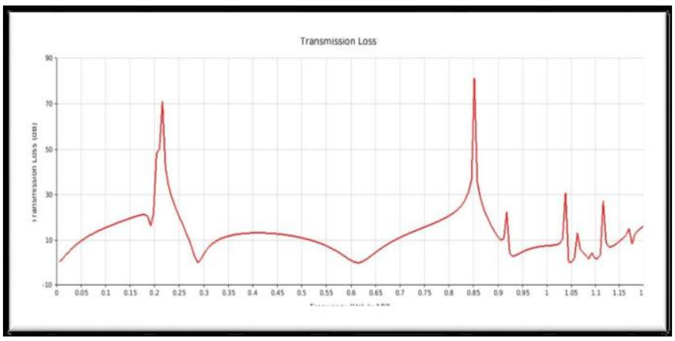

Chart -1: Outlet Chamber Length (Lc),0.13 m

Maximum Transmission Loss (TL) = 86.3638 dB @ 850Hz

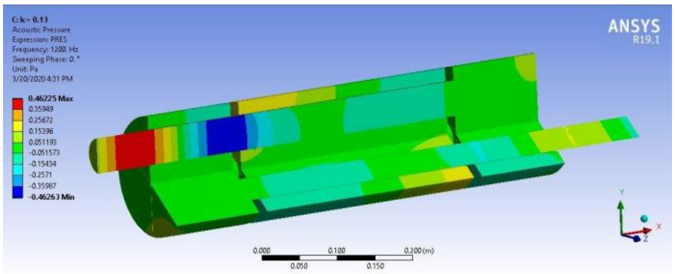

Fig.8 Sound Pressure Plot of 0.13m

The minimum acoustic pressure is -0.46263 Pa and its maximum acoustic pressure is0.46225 Pa.

2. Outlet Chamber Length (Lc), 0.15 m

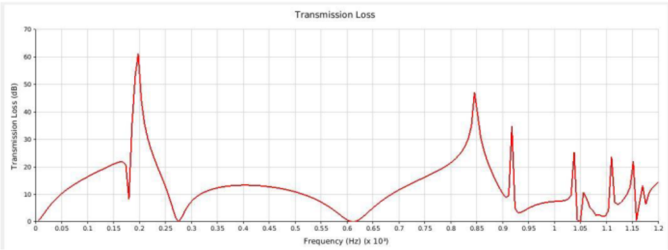

Chart -2: Outlet Chamber Length 0.15m

Maximum Transmission Loss (TL) = 61.3092 dB @ 180 Hz

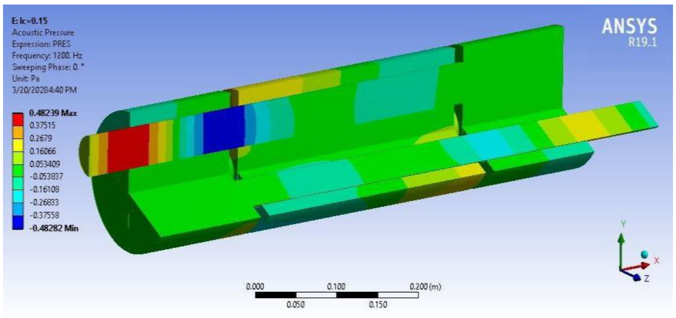

Fig -9: Sound Pressure Plot

The minimum acoustic pressure is -0.48282 Pa and its maximum acoustic pressure is 0.48239 Pa.

3. Outlet Chamber Length (Lc), 0.102 m

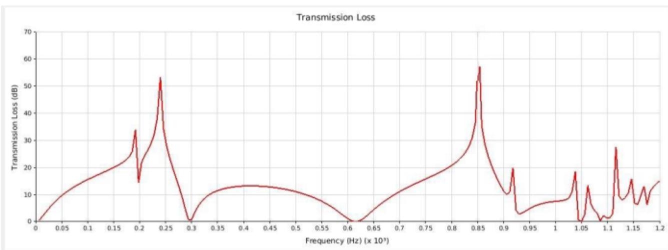

Chart -3: Outlet Chamber Length (Lc), 0.102 m

Maximum Transmission Loss(TL) = 56.2147 dB @ 850 Hz

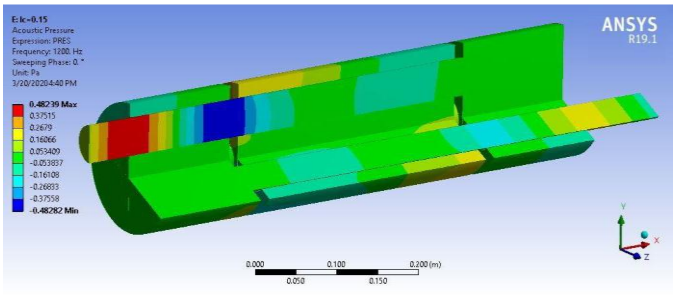

Fig -10: Sound Pressure Plot

7.2 Parametric Optimization Two

Porosity/ Open area ratio in the central pipe region

Porosity changes with change in the perforation hole diameter (dh)

1. Hole diameter (dh) = 0.0017 m, porosity ϕ = 0.02

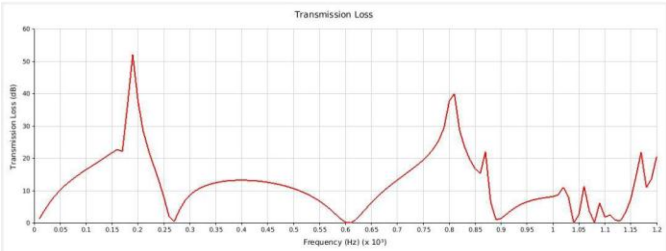

Chart -4: Graph of perforation hole diameter, dh 0.0017 m

Maximum Transmission Loss(TL) = 52.1754 [dB] @ 180 Hz

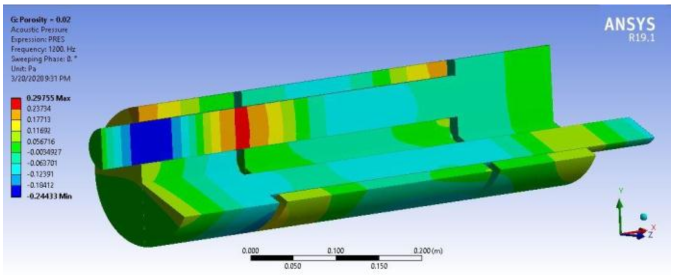

Fig -11: Sound Pressure Plot

The minimum acoustic pressure is -0.24433 Pa and its maximum acousticpressure is .29755 Pa.

2. Hole diameter (dh)=0.0023 m, porosity ϕ=0.045

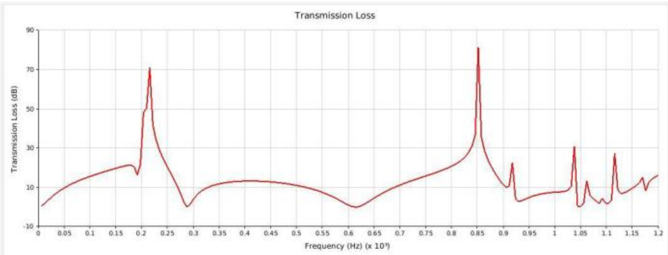

Chart -5: Graph of Perforation Hole Diameter, Dh = 0.0023m

Maximum Transmission Loss(TL) = 86.3638 dB @ 850Hz

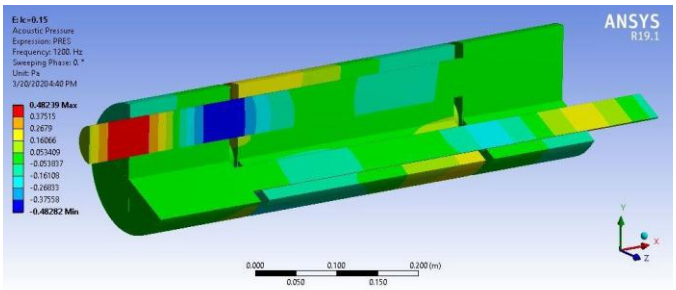

Fig -12: Sound Pressure Plot

The minimum acoustic pressure is -0.48282 Pa and its maximum acoustic pressure is0.48239 Pa.

3. Hole diameter (dh) = 0.0027 m, porosity ϕ = 0.06

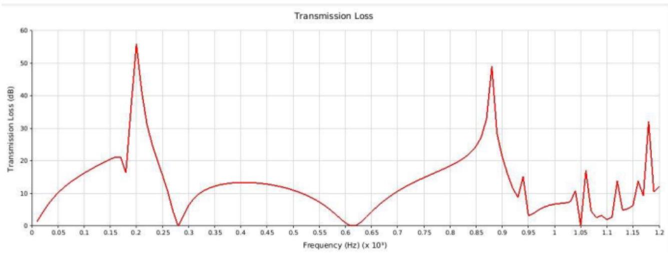

Chart -6: Graph of Perforation Hole Diameter, dh =0.0027

Maximum Transmission Loss(TL) = 55.9097 [dB]@ 200 Hz

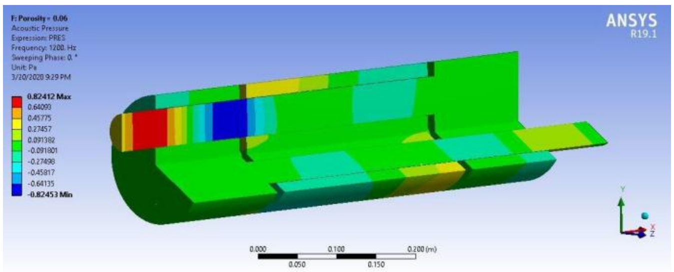

Fig -13: Sound Pressure Plot

The minimum acoustic pressure is -0.82453 Pa and its maximum acoustic pressure is 0.82412 Pa.

7.3 Fibrous Material Optimization

1. Glass Fiber

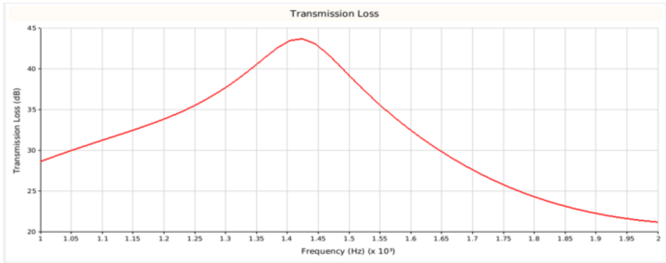

Chart -7: Graph of Glass Fiber

Maximum Transmission loss = 43.732 [dB] @ 1420 Hz

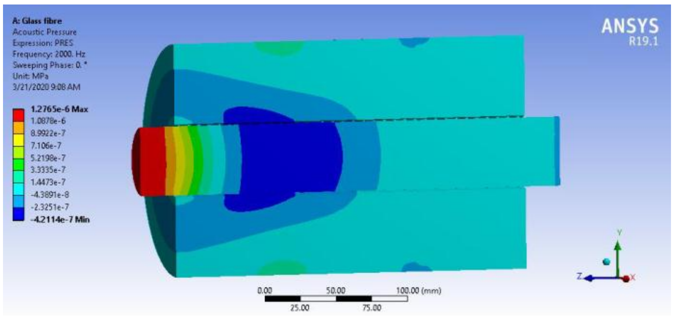

Fig -14: Sound Pressure Plot

The minimum acoustic pressure is -4.2114e-7 Pa and its maximum acoustic pressure is 1.2765e-6 Pa.

2. Polyurethane Foam

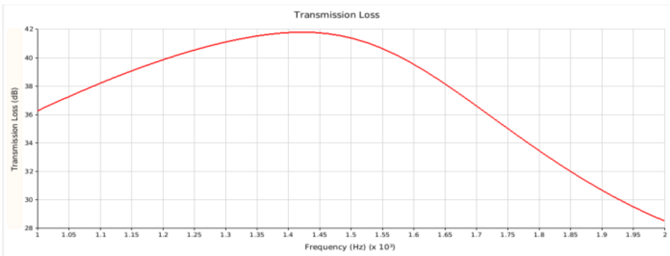

Chart -8: Graph Of Polyurethane Foam

Maximum Transmission loss = 41.7943 [dB]@ 1435 Hz

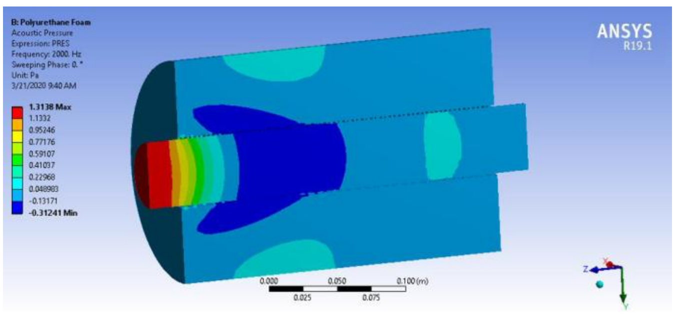

Fig -15: Sound Pressure Plot

The minimum acoustic pressure is -0.31241 Pa and its maximum acoustic pressure is 1.3138 Pa.

3. Metal Foam

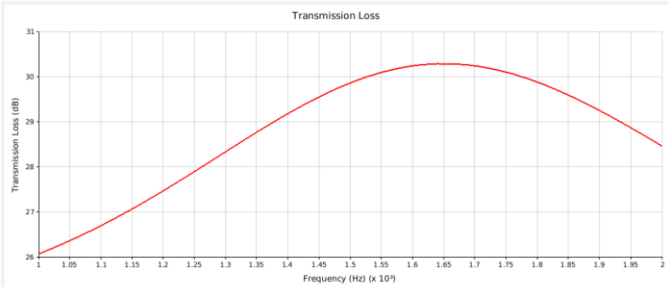

Chart -9: Graph of Metal Foam

Maximum Transmission loss = 30.2956 [dB]@ 1650 Hz

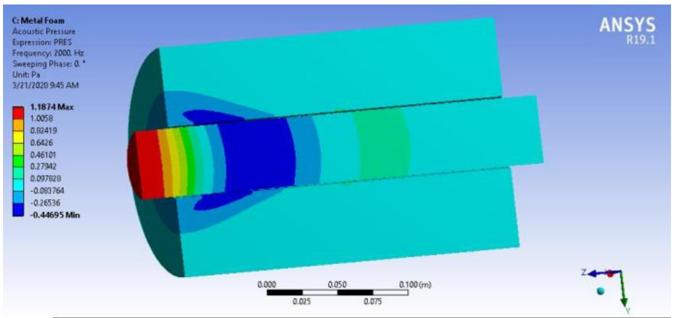

Fig -16: Sound Pressure Plot

The minimum acoustic pressure is -0.44695 Pa and its maximum acoustic pressure is1.1874 Pa.

4. Rock Wool

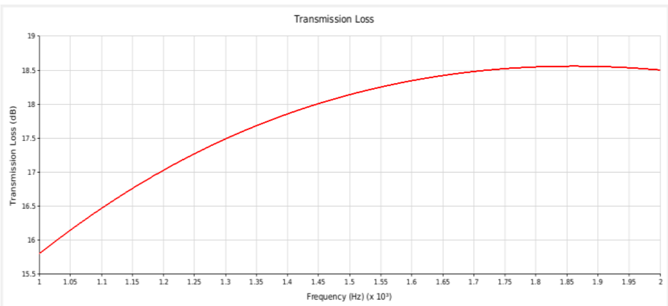

Chart -10: Graph of Rock Wool

Maximum Transmission loss = 18.5604 [dB] @ 1870 Hz

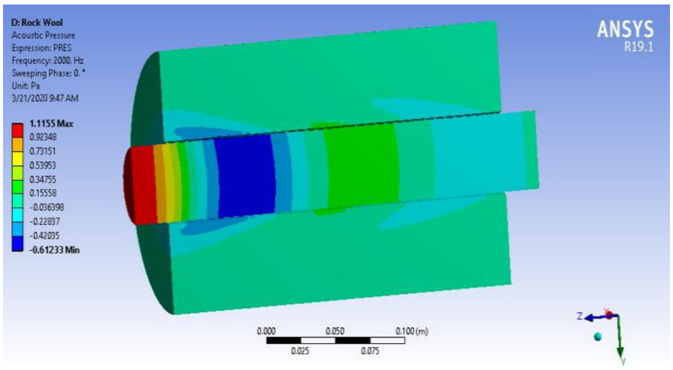

Fig -17: Sound Pressure Plot

The minimum acoustic pressure is -0.61233 Pa and its maximum acoustic pressure is 1.1155 Pa.

8 STAGE CONCLUSION

From the Optimization Study we can concluded that we can achieve maximum transmission loss when using Glass fiber as absorptive material. Three pass muffler shows maximum Transmission loss when the outlet chamber length is equal to inlet chamber length and porosity of 0.045.

9 HYBRID MUFFLER

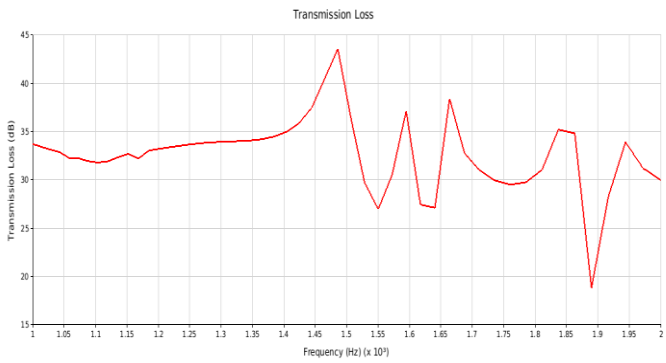

Chart -11: Graph of Hybrid muffler

Maximum Transmission loss = 43.59 [dB]@ 1485 Hz and

Average Transmission Loss(TL) = 32.6161 db

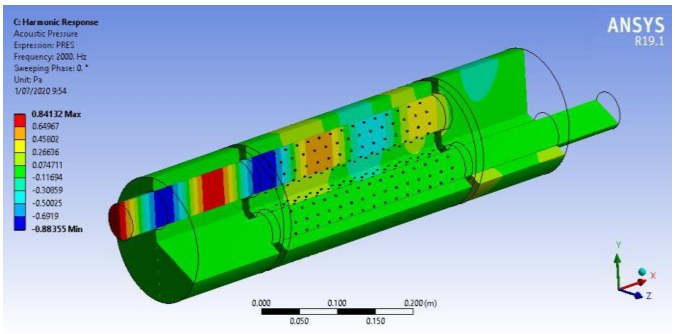

Fig -18: Sound Pressure Plot

The minimum acoustic pressure is -0.88355 Pa and its maximum acoustic pressure is 0.84132 Pa.

10. CONCLUSION

In this present work there can be numerous conclusion can be taken which can improve the study for future work in this area of research. From the Optimization Study we can concluded that we can achieve maximum transmission loss when using Glass fiber as absorptive material. Three pass muffler shows maximum Transmission loss when the outlet chamber length is equal to inlet chamber length and porosity of 0.045.An increase in TL was observed. This was due to combination of reactive, dissipative muffler and resonant behavior of muffler. Maximum Transmission Loss (TL), 43.5901 dB at 1484.9943Hz and Average Transmission Loss(TL) , 32.6161 dB. This work will significantly give hybrid muffler design a new way of analysis using ANSYS.

11. FUTURE SCOPE

In this study we have considered only the shape, size and transmission loss factor in designing the muffler. In future studies we can conduct analysis on other factors such as,

1. Durability.

2. Back pressure in engine caused due to muffler shape by conducting a CFD analysis.

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