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ANALYSIS OF EFFECT OF CONE AND PORES ON ACOUSTIC PERFORMANCE ANALYSIS OF REACTIVE MUFFLER

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Abstract: Internal combustion engine produced different types of gases when fuel burned to generate power .exhaust system is used to release this gases .mufflers are commonly used in Exhaust systems to minimize sound transmission caused by exhaust gases .Used destructive interference to reduce noise occurred because of high speed exiting gases of reactive muffler. The design of the muffler affects the emission, noise characteristics, and fuel efficiency of an engine .In this paper, a three-dimensional finite element analysis was carried out to predict the transmission loss of a conical chamber with a single inlet and perforated pipe muffler using COMSOL Multiphysics software.

***Index Terms* - Reactive muffler, Comsol Multiphysics, Transmission loss**

INTRODUCTION

Automobiles are major source of pollution producing harmful gases like CO, CO2,NO and Major source of noise pollution. Exhaust system is used to remove harmful substances and reduce noise. Mufflers are important part of automobile exhaust system specially used to reduce noise of exhaust system. Designing of muffler is a complex process required to study different parameters and how variations in this parameters affect the performance of exhaust system .This paper deals with practical approach to analyze the reactive muffler with various internal geometries for exhaust system.

LITERATURE REVIEW

Gyo woo lee, Man Young kim [1]studied pressure drop to improve the performance of the catalytic muffler by changing various design parameters such as porosity, inlet and outlet shape of the muffler with perforated cone.

Mohamed Jolgaf [2] performed a three-dimensional finite element simulation to predict the transmission loss of a reactive muffler. Performance of the muffler studied by adding additional geometrical features like a perforated pipe.

Shantanu V. Kanade[3] studied process to calculate transmission loss of single chamber perforated muffler. Algorithms used to optimize the various factors to Achieve maximum transmission loss.

Zeynep Parlar [4] designed and Analyzed mufflers using pressure acoustic models. introduced new and improvised designs of mufflers with minimum transmission loss.

Nagesh choughule, A.R.Shinde [5] introduced new type of muffler which has relatively lower backpressure in exhaust muffler. Muffler was designed and analyzed in new software, Ricardo wave.

M. Rahman [6] worked on designs of new mufflers for petrol engine . The performance characteristics and noise level of the muffler has been studied.

Jun Chen [7] describes physical numerical modeling of the flow field of the muffler. Used CFD approach to analyze mufflers. The distribution and influence of the flow field has been analyzed.

M L Munjal, Vikas Kumar [8] modified plug muffler to obtain better acoustic performance while optimizing back pressure.

Chen Liu [9] introduced CFD Approach to calculate Noise level of muffler .Analyzed Cross flow perforated tube and Straight flow perforated tube silencer using CFD Approach and optimized transmission loss of muffler.

Vikram A. Tandon,Sudarshan pangavahane [10] worked on effects after changing dimensions of perforated tube hole and change in porosity of internal tube is investigated using CFD analysis.

Chandrashekhar Bhat [11] studied prediction of transmission loss .Using Finite element analysis method three different types of mufflers under different conditionssuccessfully predicted transmission loss. It is observed that mufflers used same conditions to provide maximum attenuation.

Xiaong,Zuo[12] used transfer matrix method below cutoff frequency of Dual chamber reactive muffler using Helmotzs equation.

PROBLEM FORMULATION

Selecting Target frequency:-
Exhaust gasses mainly consist of CO_2, N_2, H_2O, O_2, and CO along with high-pressure sound wave. For preventing the exhaust gasses from being transmitted into the atmosphere catalytic converter is used. Also for attenuating high-pressure sound waves at the end of the exhaust system silencer is used. Noise from exhaust stroke is about 110 dB to 120 dB which crosses the noise limit 75 DB to 80 DB set by pollution control boards.
Noise from exhaust stroke is divided into two types
1. Pulsating noise
2. Flow noise
Pulsating noise is the noise produced from cylinder It is having low-frequency noise. The frequency generated from pulsating noise depends on number of cylinders, engine RPM and number of strokes of engine.
Flow noise is generated by turbulent exhaust gas flow eddying, impacting and oscillating within the exhaust system and as the exhaust flow exits the system.
i)Engine data for commercial passenger vehicles like Maruti Suzuki Vitara Brezza
Compression ratio: 10:1
Displacement: 1462 cc
Engine type: K15B ISG Petrol Engine
Number of cylinder: 4
Bore Stroke: 73 *72 mm
Maximum power: 103.26bhp@6000rpm
Maximum torque: 138nm@4400rpm
Therefore target frequency is calculated as,
F = engine speed in Rpm * N/120 For 4-stroke engine
= (6000*4)/120
= 200 Hz
The harmonics of the target frequency can be given as, 200, 400, 600, 800…..Hz. but the first frequency i.e. 200 Hz is the most dominant frequency to generate noise from exhaust system therefore this frequency is the target frequency which is to be controlled.

DESIGN OF REACTIVE MUFFLER

Exhaust gas propagating through small pipes, produces some resonance in such frequency range which causes audible noise. So, properly designed muffler is required to reduce exhaust noise. Generally, 75 DB to 80 dB noise limit is set by pollution control boards which vary country-wise depending on the type of the vehicle. There are three types of mufflers used mainly reactive, absorptive and hybrid mufflers. Reactive muffler is characterized by controlling lower frequencies i.e. below 1000Hz. Therefore controlling target frequency 200 HZ.
Considering, the inlet diameter of the muffler as 50mm. The expansion chamber diameter is obtained by using area ratio.
Area ratio or Expansion ratio (m):
It is the ratio of area of the expansion chamber to the area of the inlet or outlet tube. It is mathematically given as,
$m=D^2/d^2$
Muffler design is a very crucial step because with increase in expansion ratio attenuation of noise also increases. Due to objective constraints the value of expansion ratio [21] should be between 9 to 16
Hence, consider area or expansion ratio m=16
Therefore, $m= D^2/d^2$
$D^2= 50^2*16 = 40000$
D = 200 mm.
This geometry of muffler with inlet tube and outlet tube diameter 50 mm and expansion chamber diameter 200 mm is modeled in Creo parametric and further analysis is carried out in COMSOL multiphysics.

DESCRIPTION OF MODELS

Model 1: Simple Expansion Chamber
A simple expansion chamber consists of a hollow cylindrical chamber with an inlet and outlet tube.
Length of Inlet and Outlet Pipe: 100mm
Diameter of Inlet and Outlet Pipe: 50mm
Length of Expansion Chamber: 600mm
Diameter of Expansion Chamber: 200mm.

Fig.1 model 1) Simple Expansion Chamber

Model 2: Perforated tube muffler

Perforated tube muffler consists of perforated hollow pipe of length 600 mm connecting inlet pipe to outlet pipe with 12% porosity.

Length of Inlet and Outlet Pipe: 100mm

Diameter of Inlet and Outlet Pipe: 50mm

Length of Expansion Chamber: 600mm

Diameter of Expansion Chamber: 200mm

Diameter of holes: 4 mm.

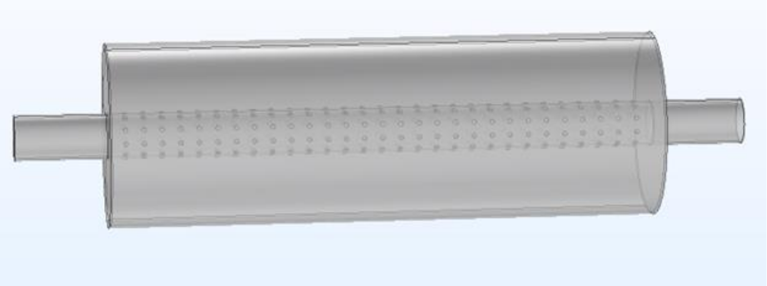

Fig.2 model 2) perforated tube muffler

Model 3: One Plug Perforated tube muffler: One plug perforated muffler consists of a 10mm long plug at a distance of 295 mm from the left side of the chamber. 295mm long perforated tube with porosity of 12% is on both the sides of plug.

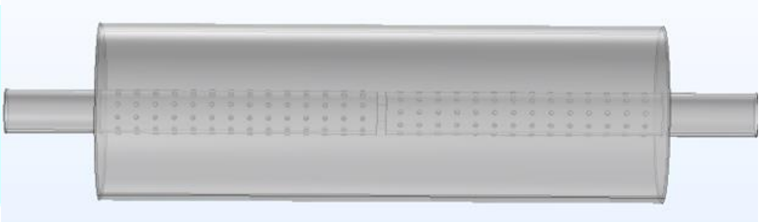

Fig.3 Model 3) One plug perforated tube muffler

Model 4: Combined cone and perforated tube muffler:

In this muffler Cone geometry is combined with perforated tube. Length of cone is 200mm. Length of perforated tube is 400mm with porosity of 12%.

Fig.4 model 4) Combined cone and perforated tube muffler

Model 5: One Plug Perforated tube muffler combined with cone: In this muffler length of cone is 200mm. Length of plug is 10mm. Perforated tube of length of 195mm with porosity of 12% is on both the sides of the plug.

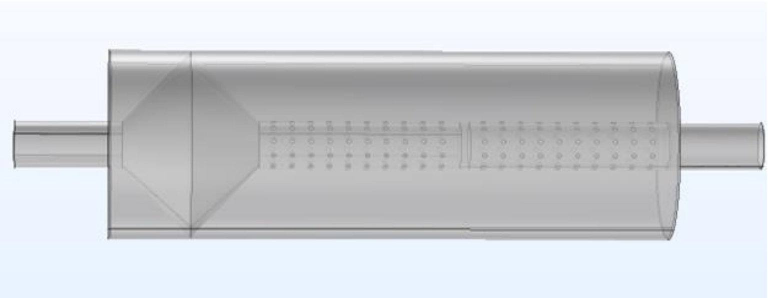

Fig.5 model 5) One plug perforated tube muffler combined with cone

Model 6: Extended tube muffler-1

In this model the inlet and outlet tube are extended 100mm inside the expansion chamber.

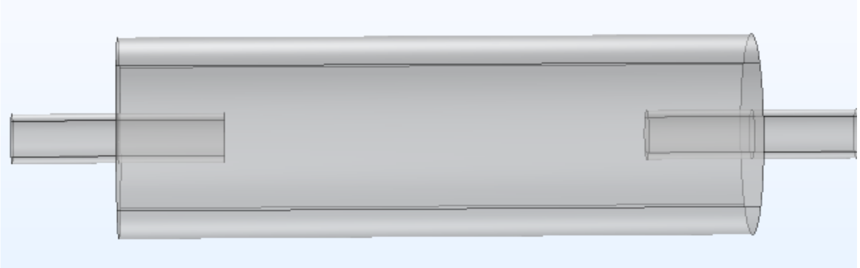

Fig.6 model 6) Extended tube muffler -1

Model 7: Extended tube muffler-2: In this model the inlet and outlet pipes are extended 150mm inside the expansion chamber.

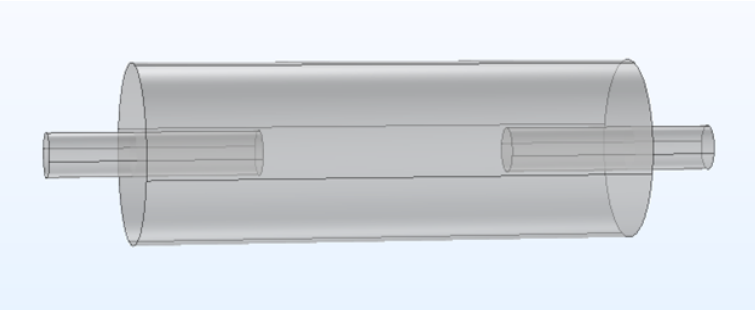

Fig.7 model 7) Extended tube muffler -2

Model 8: Extended tube muffler combined with perforated tube

This muffler is created by introducing a perforated tube of length 300mm with porosity 12% in model 7.

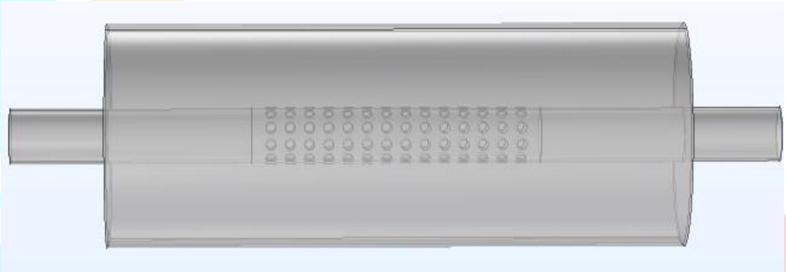

Fig.8 Model 8) Extended tube muffler Combined with perforated tube

Model 9: Extended tube muffler combined with cone-1

In this muffler cone of length 150mm is introduced in Model 7.

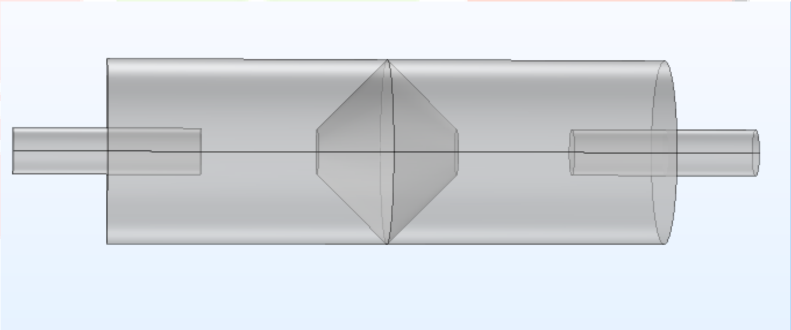

Fig.9 Model 9) Extended tube muffler Combined with cone -1

Model 10: Extended tube muffler combined with cone-2

In this muffler cone of length 200mm is introduced in Model 7.

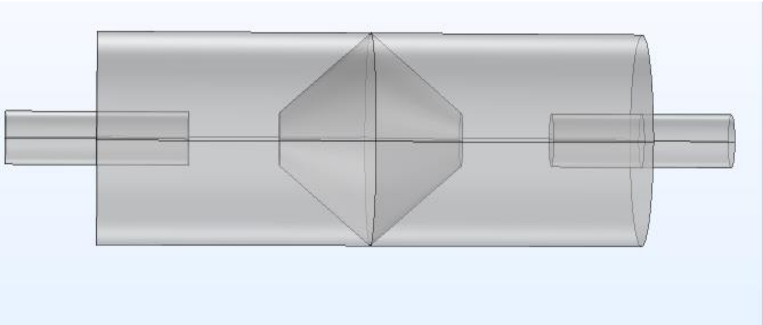

Fig.10 Model 10) Extended tube muffler Combined with cone -2

FINITE ELEMENT ANALYSIS

All the models which are mentioned above are created using Creo Parametric 7.0.0.0. After that Finite Element Analysis (FEA) is done using Comsol Multiphysics 5.6. The models created in Creo are brought in the Comsol using 'import' function. Then 'Pressure acoustic frequency domain' study is selected in comsol. Using 'add material' option Air medium is used in muffler. 'Plane wave radiation' physics is applied to both inlet and outlet. Meshing is done with an element size as fine.

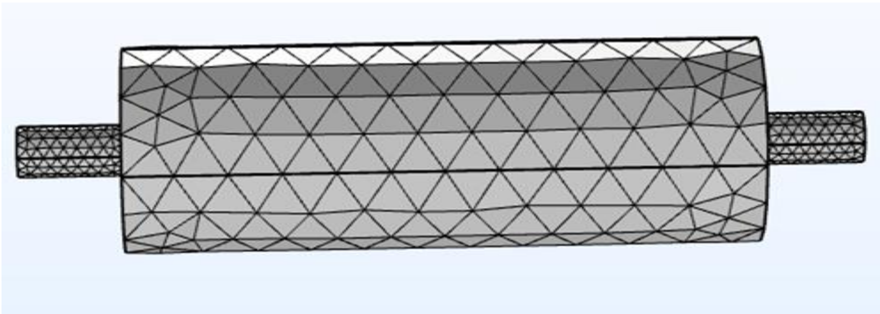

Fig.11 Meshing of simple expansion chamber

Frequency range specified is 1 to 1000Hz with step frequency of 10Hz. After the computation of the study result of 'Sound pressure level' is obtained.

Fig.12 shows Sound pressure level of simple expansion chamber. The incident pressure is assumed to be 1Pa. Steps involved in FEA of all models are identical, only the internal geometry is changed.

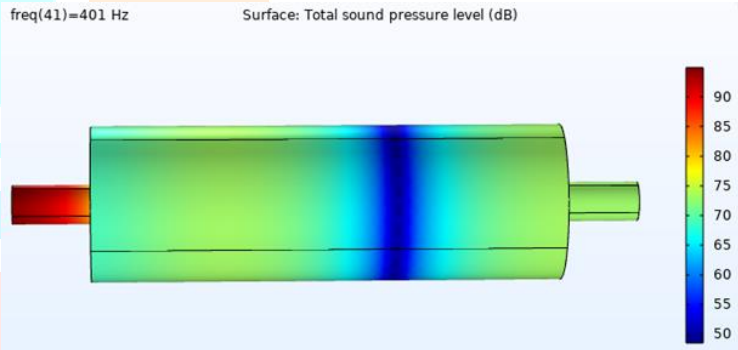

Fig.12 Sound pressure level of simple expansion chamber

RESULT AND DISCUSSION

The analysis is performed between the frequency range of 1Hz to 1000Hz.

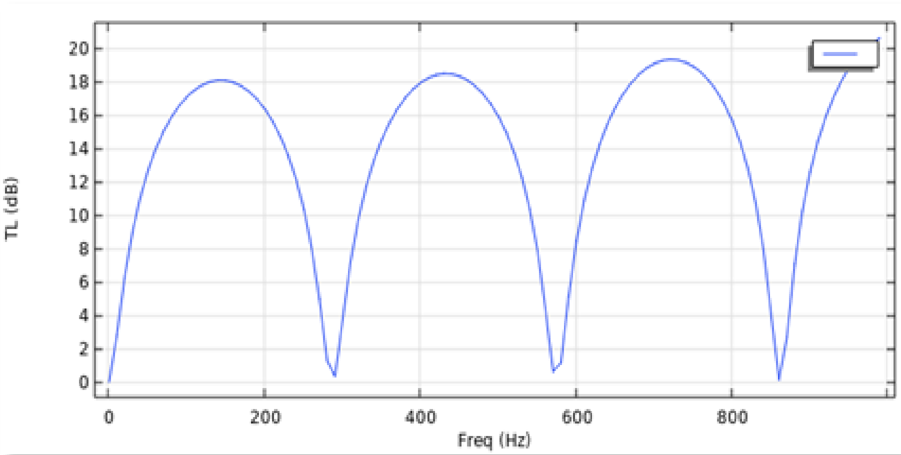

Fig.13 Transmission loss Vs Frequency graph of model 1)Simple Expansion Chamber

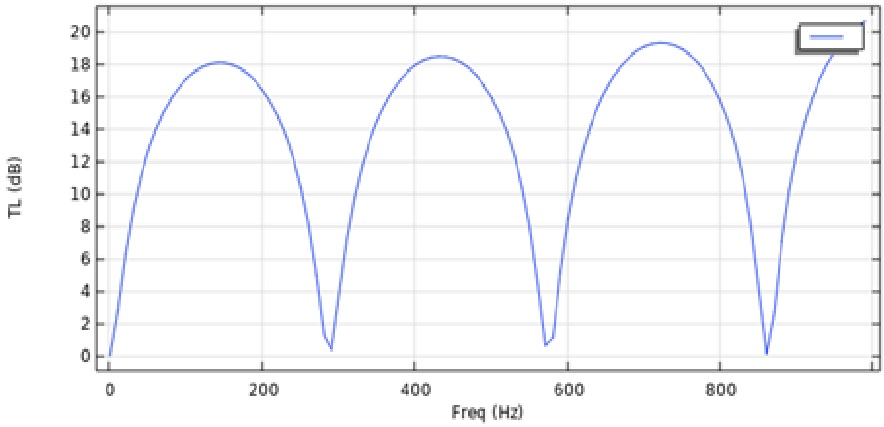

Fig.14 Transmission loss Vs Frequency graph of model 2) Perforated tube muffler

From the above fig.13 and fig.14, it is found that transmission loss curve of simple expansion chamber and perforated tube muffler is almost identical between 1Hz to 1000Hz.

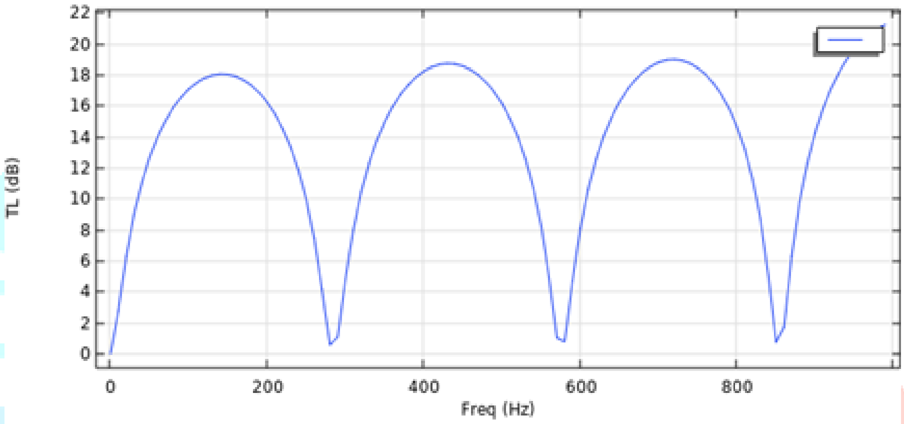

Fig.15 Transmission loss Vs Frequency graph of model 3) One Plug Perforated tube muffler

Fig.15 shows transmission loss curve for one plug perforated tube muffler. It is found that introduction of a plug in perforated tube muffler does not make significant changes in transmission loss curve for the frequency range of 1Hz to 1000Hz.

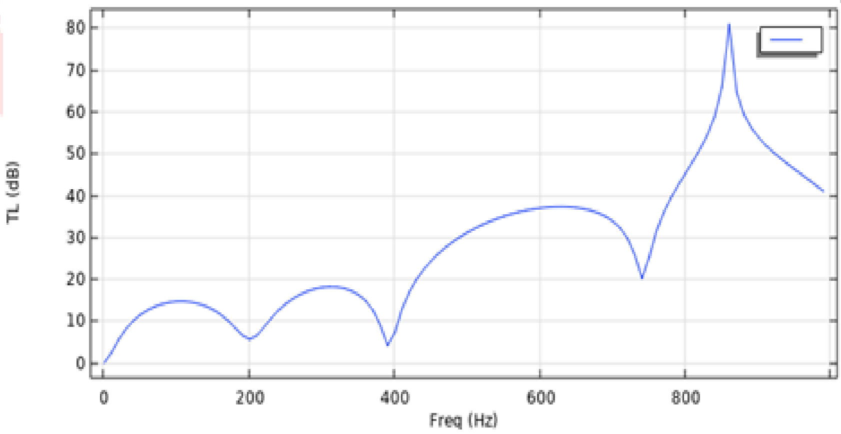

Fig.16 Transmission loss Vs Frequency graph of model 4) Combined cone and perforated tube muffler

With the help of fig.16, it is observed that model 4 shows low transmission loss at frequencies 200Hz and 400Hz while it shows high transmission loss values at 600Hz and 800Hz

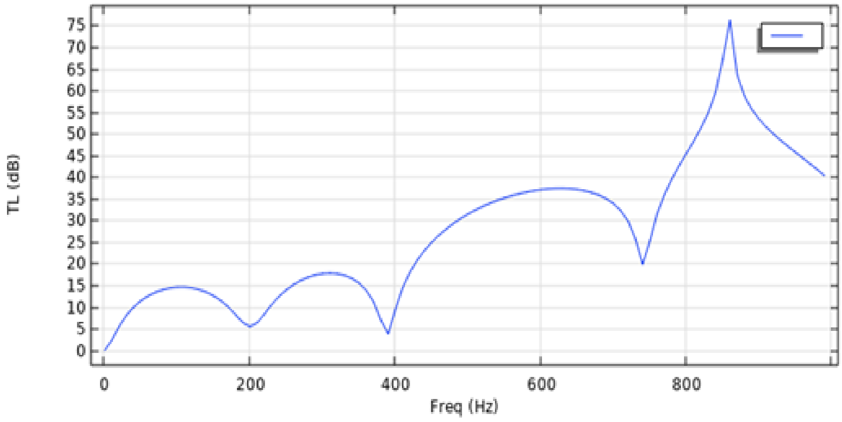

Fig.17 Transmission loss Vs Frequency graph of model 5) One Plug Perforated tube muffler combined with cone

Fig.17 also shows that for frequencies below 1000Hz, the introduction of a plug does not change the transmission loss curve significantly.

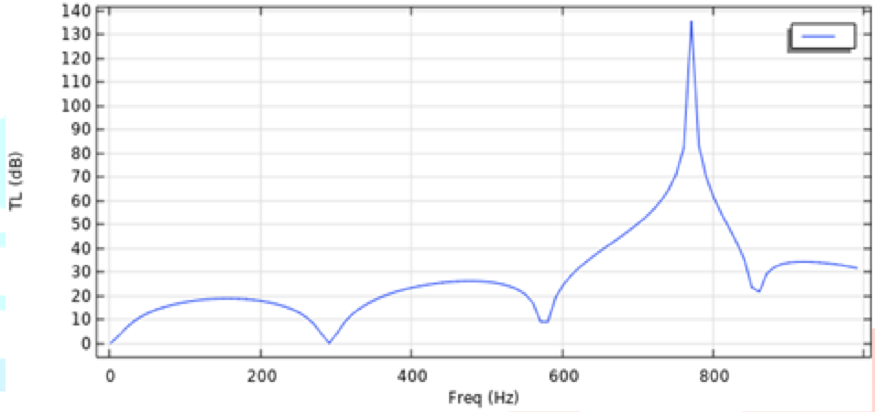

Fig.18 Transmission loss Vs Frequency graph of model 6) Extended tube muffler-1

From fig.18, it is observed that model 6 shows high values of transmission loss in the range 1Hz to 1000Hz.

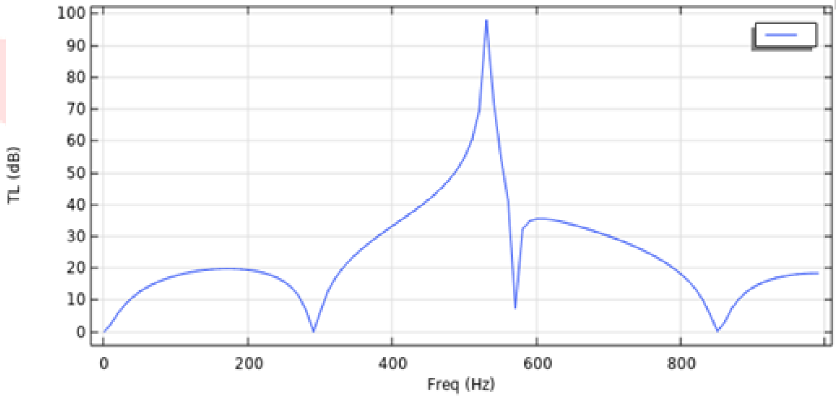

Fig.19 Transmission loss Vs Frequency graph of model 7) Extended tube muffler-2

From fig.19 it can be seen that with the increase in the length of inlet and outlet pipe inside the expansion chamber the value transmission loss also increases

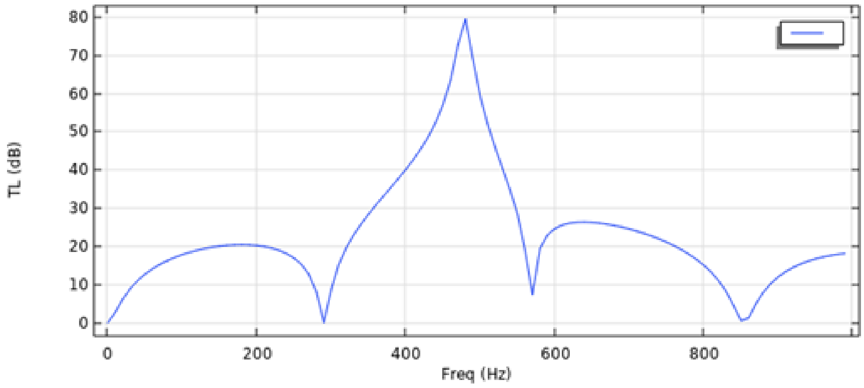

Fig.20 Transmission loss Vs Frequency graph of model 8)Extended tube muffler combined with perforated tube

Fig.20 shows transmission loss of model 8 which is formed when a perforated tube is introduced in model 7. It is observed that addition of a perforated tube increases the transmission loss.

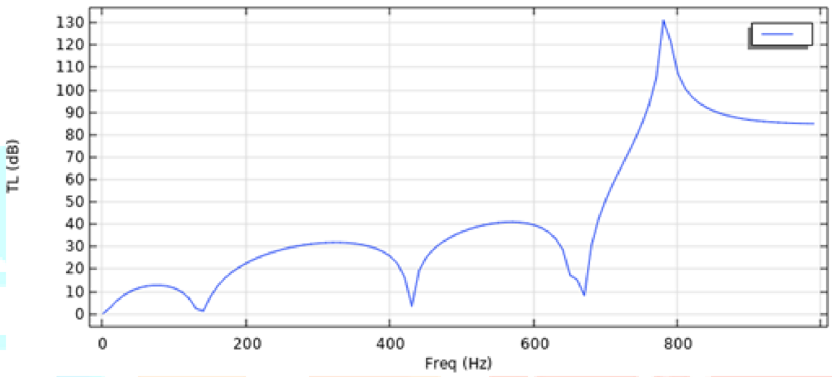

Fig.21 Transmission loss Vs Frequency graph of model 9) Extended tube muffler combined with cone-1

Fig.21 shows transmission loss of model 9, it is observed that replacement of a perforated tube with cone geometry gives good values of transmission loss at 200Hz, 400Hz and 600Hz. It gives very high transmission loss at 800Hz.

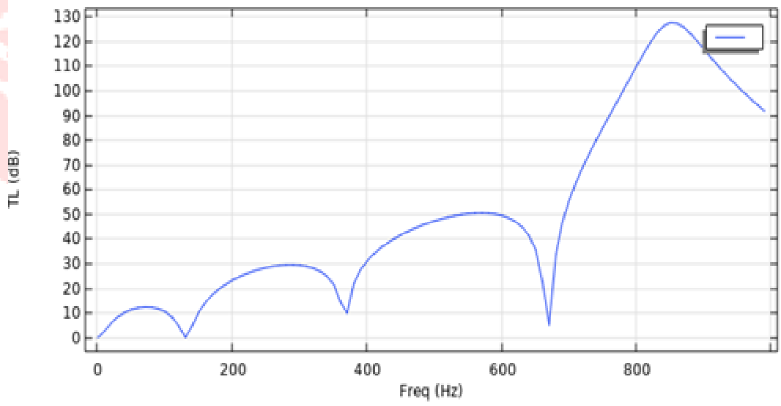

Fig.22 Transmission loss Vs Frequency graph of model 10 Extended tube muffler combined with cone-2

From fig.22, it can be seen that with increase in length of the cone transmission loss values also increases.

Table 1: Comparison of transmission loss (dB) of all models

	200HZ	400HZ	600HZ	800HZ
Model 1	16.42	17.90	8.40	15.43
Model 2	16.46	18.00	8.48	15.70
Model 3	16.25	18.25	8.09	14.68
Model 4	5.68	7.30	37.04	45.42
Model 5	5.58	9.53	37.21	45.55
Model 6	17.80	23.43	24.46	61.07
Model 7	19.45	33.39	35.54	18.04
Model 8	20.23	40.15	24.67	15.05
Model 9	22.75	25.68	39.67	107.40
Model 10	23.31	31.18	49.44	110.20

CONCLUSION

Reactive silencers with different internal geometries are designed using creo parametric and analyzed using comsol multiphysics successfully. By comparing all the models mentioned in this study, it is observed that use of cone geometry gives high values of transmission loss. Thus from this study, it can be concluded that cone geometry with perforated tube is not suitable for low frequencies (i.e. 200Hz and 400Hz) while the cone geometry with extended inlet and outlet pipe gives high values of transmission loss for all the values of frequencies between 1Hz to 1000Hz.Thus cone geometry with extended inlet and outlet pipe is better suitable as compared to all the other models studied in this research for the frequency range of 1Hz to 1000Hz. Thus model 10 is best as compared to all the other models studied in this research. The model 10 as compared to simple expansion chamber gives 29% increase in transmission loss at frequency 200 Hz, 42% increase in transmission loss at frequency 400 Hz, 83% increase in transmission loss at frequency 600 Hz while it gives 86% increase in transmission loss at frequency 800 Hz.

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