ISSN: 2366-1313

EXPLORING THE CREATION OF A SOLITARY EXPANSION CHAMBER FOR A DIESEL ENGINE AND EVALUATING ITS DESIGN

#1V.Venkatarami Reddy, Assistant Professor,
#2P. Bhaskar Rao, Assistant Professor,
#3K. Polaiah, Assistant Professor,
Department of Mechanical Engineering,
SAI SPURTHI INSTITUTE OF TECHNOLOGY, SATHUPALLY, KHAMMAM.

ABSTRACT : An Exhaust noise is a significant contributor to the noise pollution caused by combustion engines. Due to strict rules, it is critical to reduce the amount of noise released by exhaust systems. Mufflers reduce the noise produced by the exhaust system to a bearable decibel level. The goal of this research is to design a reactive muffler for a single-cylinder diesel engine that achieves the greatest feasible transmission loss. A muffler's effectiveness and productivity are determined by its level of transmission loss. Design and proportions influence a muffler's performance. The transmission loss at the muffler outlet is governed by the muffler's specifications, which include length, expansion ratio, and number of resonating chambers. An effort is made to improve the efficiency and acoustic performance of a muffler by optimizing its length and expansion ratio to the greatest extent permitted by the specified production restrictions. An analytical approach is utilized to calculate transmission loss, which is then mathematically modeled for a certain ideal length and expansion ratio. Finally, the two models are compared. The mathematical model is based on the Transfer Matrix Method. The Finite Element Method is used to evaluate acoustic performance. Both models are certified based on the desired muffler's calculated transmission loss. This methodology will aid in determining the relationship between muffler attenuation and variations in length and expansion ratio for a certain firing frequency and its harmonics.

keywords: Muffler, Transmission Loss, Expansion Ratio Variation, Length Variation, Single Expansion Chamber

1.INTRODUCTION

The advancement of technology in the contemporary day has made sustainable development necessary. The installation of severe regulations has mandated the employment of eco-friendly technologies, forcing the sector to look for more environmentally responsible solutions. Extensive research is being performed to develop quieter machinery in response to the serious problem of noise pollution in the mechanical sector. Acoustics is the scientific study of the characteristics of noise, vibration, and harshness (NVH) in order to mitigate and reduce disruptions generated by machinery and equipment.

Acoustics is a multidisciplinary field that studies mechanical waves such as sound, vibration, ultrasound, and infrasound in gases, liquids, and solids. This technology finds applications in practically every facet of modern living, particularly in audio and noise management. It focuses on the creation, propagation, and reception of vibrations and mechanical waves. A silencer or muffler is used to minimize exhaust noise from an internal combustion engine. Despite earlier substantial study into mufflers, there is currently a significant demand to reduce noise levels. As a result, doing study on muffler characteristics is critical for determining the best silencer. This study carefully studies a single expansion chamber used in a diesel engine to acquire a better understanding of muffler performance and design modifications based on various factors.

2.LITERATURE SURVEY

The US Military NACA report provides a comprehensive review of 77 different muffler designs and their applications. There are recommended diagrams and strategies for increasing the muffler's performance. The paper provides several key insights, including the use of the infinite tail theory to calculate transmission loss in a muffler, the computation of attenuation loss solely based on frequency, and a detailed analysis of the performance curves of a single expansion chamber, taking into account variations in length and size parameters. It permits study into muffler efficiency and design optimization to obtain the maximum amount of noise reduction.

The ISMSIT 2017 study presents a mathematical model for computing transmission loss, which is subsequently used to evaluate mufflers with various cross-sectional forms. The noise transmission loss is calculated using the four-pole transfer matrix approach.

Young and Crocker propose using the finite element approach to generate transmission loss curves. This analytical method yields a precise response for optimizing muffler design and may be applied to a variety of basic expansion chamber designs. The study examines the use of CAE (Computer-Aided Engineering) to assess the dynamic behavior of a vehicle exhaust muffler. This includes investigating the muffler's stresses, strains, and deformations. The work also includes establishing a muffler model to improve the analysis and testing process. An experimental test rig is used to analyze and test the exhaust muffler. CFD and heat transfer models for mufflers are generally accepted and constantly being developed.

This research analyzes the experimental approaches used to measure the four-pole parameters of passive and active vibration isolators. The rig's configuration, important contextual information, and other facilities are all researched.

Current research focuses on a variety of topics, including the construction of accurate boundary conditions, the examination of various muffler designs to determine their feasibility, the impact of elements such as back pressure, and the use of modeling software like MATLAB.

3.RESEARCH GAP

After reviewing the earlier publications, it is clear that they did not analyze mufflers manufactured particularly to optimize transmission loss and cross section diameter. This optimization is accomplished by considering both the expansion ratio and the length of the muffler. There is also no similarity between a mathematical and analytical model. This formed the basis for the current project's ongoing study.

4.THEORY

Single Expansion Chamber

The single expansion chamber is a passive muffler connected to an exhaust pipe and has a resonating chamber running parallel to it. Flat walls are intentionally excluded from this design because to their tendency to shake.

A single cylinder expansion chamber operates on the fundamental principle that gas expands when it enters the chamber through the input port due to a sudden change in cross-sectional area. This causes both pressure and velocity to drop. The attenuation capacity depends on the chamber's length and expansion ratio.

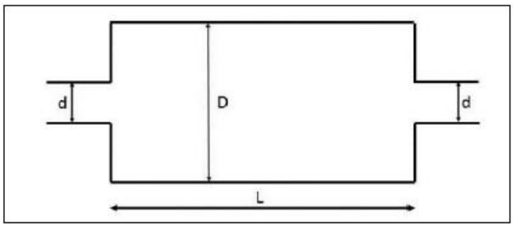


Fig 1 – Single Expansion Chamber Layout

Muffler Terms

a) Attenuation

Acoustical difference between two sites in a sound system.

ISSN: 2366-1313

b) Sound Transmission Loss

A logarithmic ratio is used to compare the sound power transmitted through a partition on one side to the sound power incident on the opposite side.

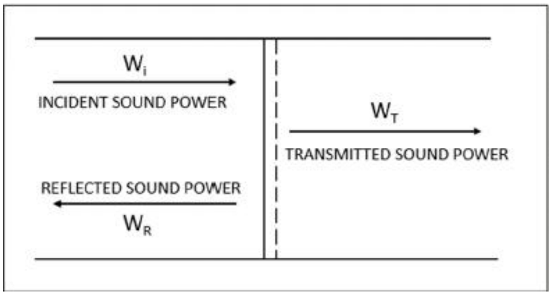


Fig 2 - Propagation of Sound over a Barrier

$$TL = 10 \log (W_T/W_I) = 10\log (1/W_R)$$

$$TL = 10 \log10 (1 + (1/4)(m - 1/m)^2 \sin (KL)^2)$$

c) Expansion Ratio

The expansion ratio of a silencer or muffler is the ratio of the cross-sectional area of the chamber to the cross-sectional area of the input pipe.

$$A1 = \pi d2/4 \text{ and } A2 = \pi D2/4$$

$$\text{Expansion ratio } m = A2/A1$$

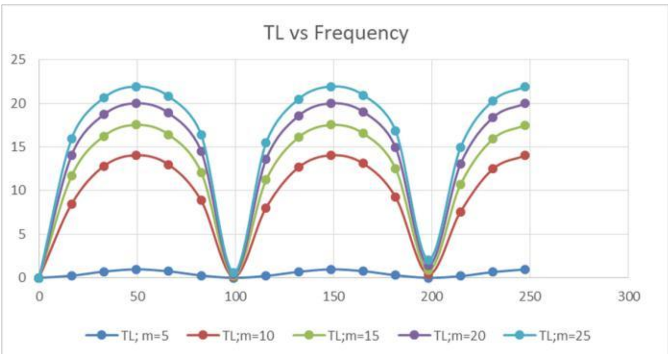
5.METHODOLOGY

Following method was followed to design and develop the muffler :

- The firing frequency and harmonics are determined using the engine's revolutions per minute (rpm).
- As a result, the length determines the firing frequency.
- For this precise length, a collection of values representing the expansion ratio is determined.
- The feasible lengths for this particular set of expansion ratios have been calculated.
- The Transmission Loss is calculated for various lengths and expansion ratios.
- To achieve the highest transmission loss, the length and expansion ratio parameters are modified simultaneously.
- Ansys Acoustics assisted with the study of the muffler.

6.DESIGN AND MODELING

Estimates of engine transmission loss are presented for various expansion ratios and lengths.



ISSN: 2366-1313

Chart 1 – TL vs Frequency (L is constant)

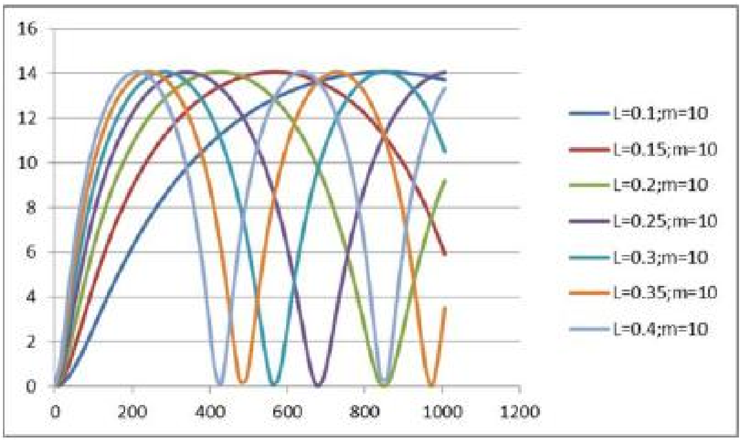


Chart 2 – TL vs Frequency (m = 5)wrh

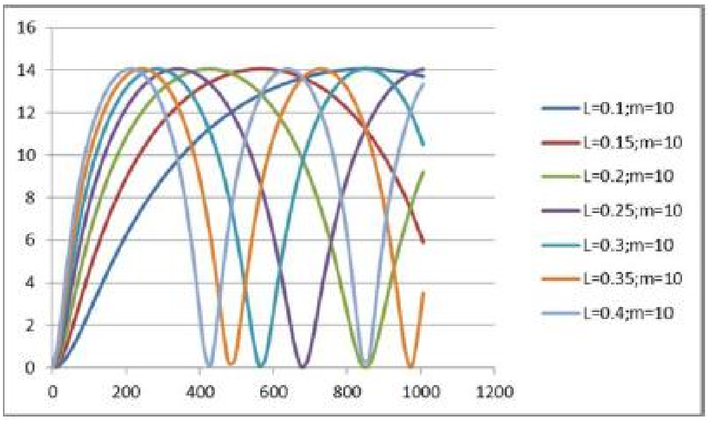


Chart 3 – TL vs Frequency (m = 10)

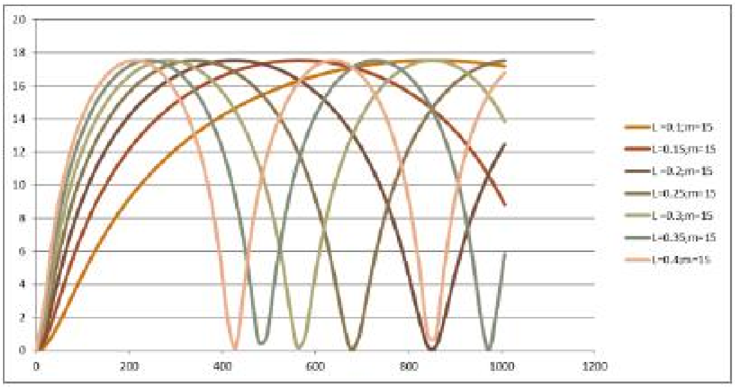


Chart 4 – TL vs Frequency (m = 15)

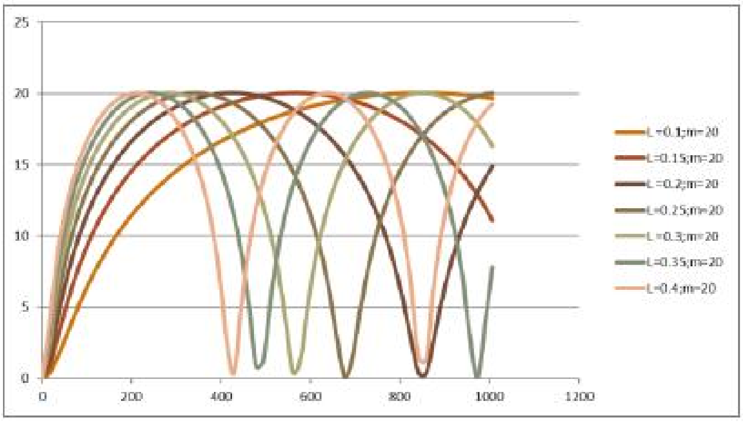


Chart 5 – TL vs Frequency (m = 20)

ISSN: 2366-1313

Creating Transmission Loss curves by adjusting the lengths in accordance with frequencies.

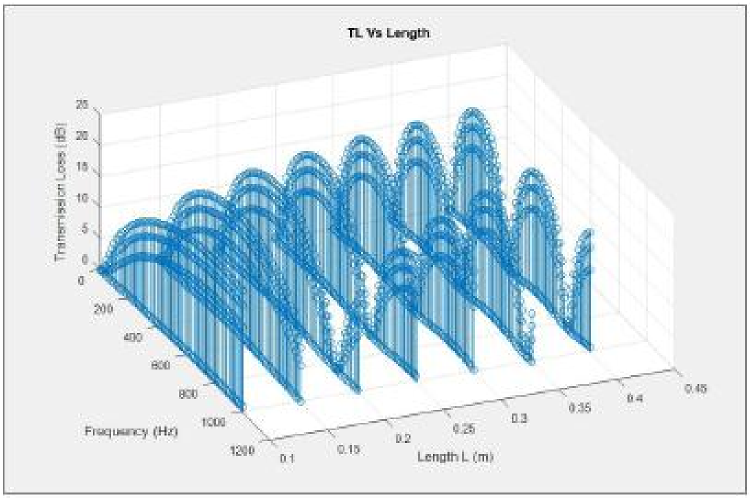


Chart 6 – TL vs Frequency vs Length

Plotting the Transmission Loss curves and altering all expansion ratios with respect to frequencies:

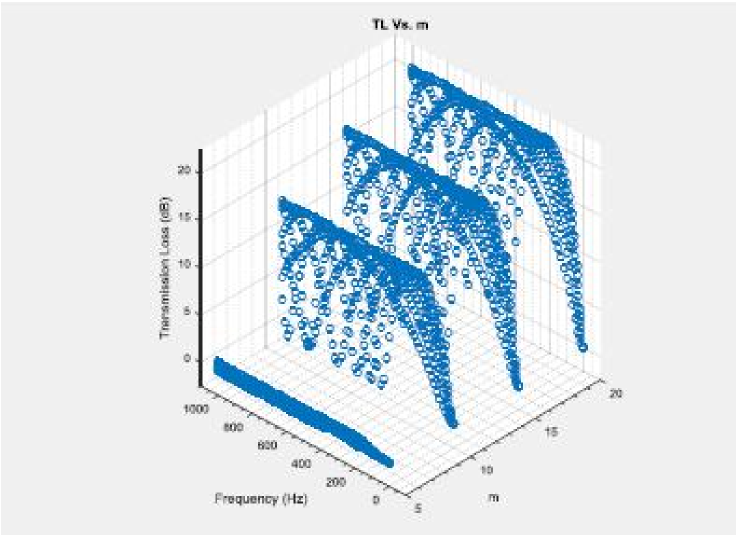
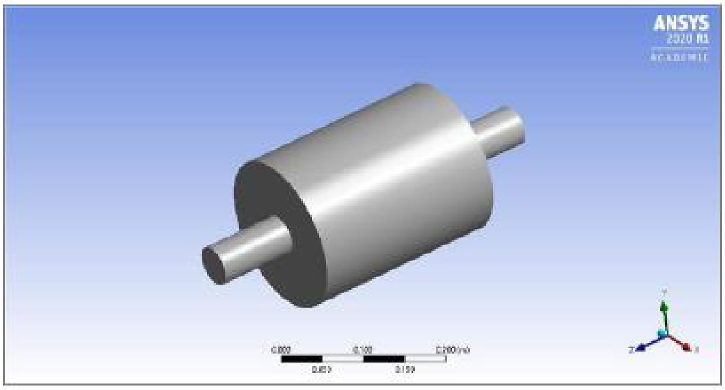


Chart 7 – TL vs Frequency vs Expansion ratio

The muffler dimensions for the specified engine are determined by taking into account the production limits and the graphs given above. The values for m and L are calculated to be 15 and 0.25m, respectively. This technique achieves a maximum transmission loss of 20 decibels. Materials with an absorbent lining, like as rockwool, can be utilized to improve transmission loss. The specified measurements are used to generate a model of the individual expansion chamber, which appears as follows:



ISSN: 2366-1313

Fig 3 - Model of the Single Cylinder Expansion Chamber

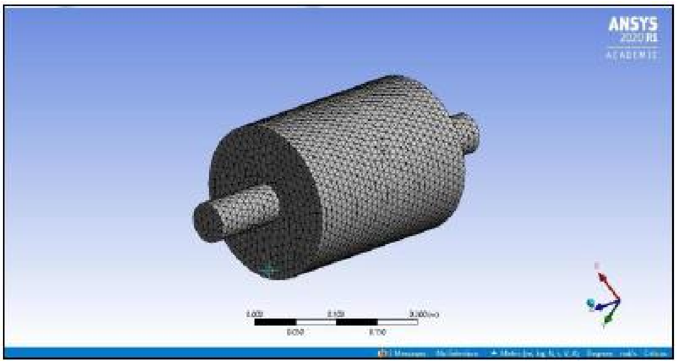


Fig 4 – Meshed Model

The muffler dimensions for the specified engine are m = 15 and L = 0.25 m. The method achieves a maximum transmission loss of 20 decibels. Materials with an absorbent lining, like as rockwool, can be utilized to improve transmission loss. The specified measurements are used to generate a model of the solitary expansion chamber, which looks like the following:

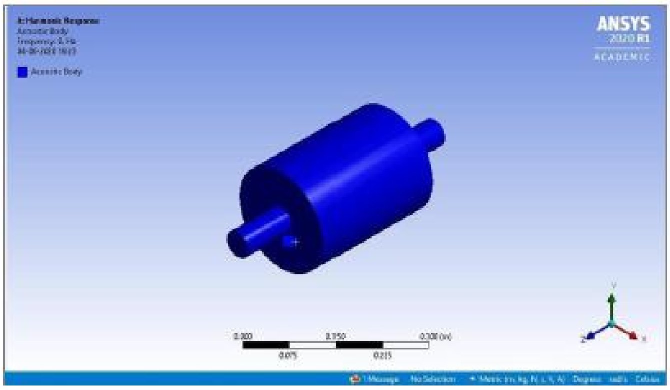


Fig 5 – Acoustic Body

The acoustic simulation produced a transmission loss of 21.456 decibels. As a result, the validity of analytical and mathematical discoveries is confirmed.

7.RESULTS AND DISCUSSION

From the graphs, we come to know the following :

- Charts 1 and 7 show that the transmission loss acquired increases according to the expansion ratio.
- Charts 2, 3, 4, 5, and 6 show that transmission loss increases as length increases.
- Attenuation at the peak happens at the firing frequency (50 Hz in this case) and its harmonics.
- There is no transmission loss at the acoustic body's resonance or harmonics.

8.CONCLUSION

The results show that the length of the muffler and the expansion ratio affect the transmission loss of an expansion chamber in a single-cylinder engine.

- As the muffler length rises, so does the transmission loss.
- The transmission loss increases in proportion to the growth ratio.

The maximum attenuation loss for the given problem statement is 20 decibels. The results are mathematically and analytically verified.

ISSN: 2366-1313

9.ACKNOWLEDGEMENT

I am grateful to my mentor, Prof. Sagar C. Atre, for his extraordinary knowledge, and to Dr. Vishwanath Karad of MIT World Peace University for his assistance with this project.

REFERENCES

1. Dox D. Davis Jr, George M. Stokes, Dewey Moore and George L. Stevens Jr, "Theoretical and Experimental Investigation of Mufflers with Comments on Engine-Exhaust Muffler Design", NACA Report 1192.
2. Mostafa Ranjbar, Hakan Arslan, Burak Dalkilic, Emin Calik, Mehmet Cem Arslan, "On Muffler Design for Transmitted Noise Reduction", Nov 2017.
3. Cheng-I James Young, Malcolm J. Crocker, "Prediction of transmission loss in mufflers by the finite-element method",
4. J. Acoustical Society America, Vol. 57.
5. J. D. Dickens, "Methods to measure the Four - Pole Parameters of Vibration Isolators", Acoustics Australia, Vol. 28 (2000).
6. S.R. Meshram, Devarashi, R. Nazirkar, A. Namdas, S. Navagire, "Design & Optimization of Exhaust Muffler & Design Validation", 10th IRF International Conference, Pune, India, 01st June-2014.
7. P. Srinivas, Venkata Ramesh Mamilla, G. Lakshmi Narayana Rao, Sowdager Moin Ahmed, "Design and Analysis of an Automobile Exhaust Muffler", Industrial and Systems Engineering Vol. 1, July 2017.
8. M. L. Munjal, Noise and Vibration Control, World Scientific Publishing Co. Pte. Ltd, 2013.
9. Nitinkumar Anekar, Kalpana Girase, Shrikant Nimbalkar, Santosh Sandanshiv, "Vibration and Noise in Reactive Muffler: A Study", Advances in Mechanical Engineering Techniques (AMET-2015), March12-13, 2015.
10. Anant W. Wankhade and Dr. A. P. Bhattu, "Optimization and Experimental Validation of Elliptical Reactive Muffler with Central Inlet Central Outlet", International Journal of Engineering Research & Technology (IJERT), Vol. 4 Issue 05, May-2015.
11. Prasad V. Shinde, P. M. Gavali, R. A. Barawade, Y. B. Mohite, P. B. Shinde, "A Review on Muffler Design for Exhaust Noise Attenuation", International Journal of Engineering and Technology (IJET)