International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Impact Factor (2020): 6.733

Acoustic Analysis of Single Expansion Chamber Reactive Muffler - A Critical Review

Mahesh Kulkarni[1], Sahil Jadhav[2]

[1]Assistant Professor, School of Mechanical Engineering, Dr. Vishwanath Karad MIT World Peace University, Pune, India

[2]PG Student, School of Mechanical Engineering, Dr. Vishwanath Karad MIT World Peace University, Pune, India

Abstract: ***Internal combustion engines, in particular, contribute significantly to societal noise pollution. Mufflers are typically used at the end of an exhaust system to reduce noise. The muffler's components' design and use determine how well it lowers noise. As a result, it is critical to design mufflers that reduce noise to the greatest extent possible. In this study, the Transmission Loss (TL) of a single expanding chamber reactive muffler will be measured utilizing a variety of approaches. The Acoustic Examination of the Silencer is carried out using three methods: theoretical analysis, finite element approach using COMSOL Multi - Physics, and experimental analysis using the two - load method.***

Keywords: Transmission Loss, Single Expansion Chamber Muffler, Numerical Method, Experimental Method

1. Introduction

The noise that internal combustion engines make has been an ongoing environmental concern since their development in the late 19th century. Notably, structural noise and other noise sources combined only produce about 10 times as much pressure as exhaust noise. As a result, attenuating exhaust noise is the main obstacle to lowering engine noise. Mufflers, also referred to as silencers, are acoustic filters that are inserted in the exhaust system of internal combustion engines to minimize the noise they produce. They are frequently utilized in many different applications, such as air conditioning units, compressors, and engines. By using either absorptive or reactive principles, mufflers reduce the noise produced by the exhaust system and serve as soundproofing devices. Absorptive mufflers reduce noise transmission by absorbing acoustic energy when sound waves pass through them. Reactive mufflers, on the other hand, operate according to the impedance mismatch principle. An illustration of a reactive muffler is shown in Figure 1. The acoustic performance of exhaust mufflers is typically assessed using variables like insertion loss (IL) and transmission loss (TL). Transmission loss assesses the muffler's sound radiation properties particularly.

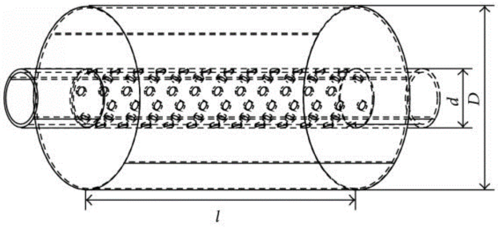

Figure 1: Single Chamber Reactive Muffler

Types of Mufflers

1) Absorptive Muffler - A type of muffler called an absorptive muffler dampens noise by absorbing sound energy as it passes through it. It is made up of substances or constructions intended to scatter sound waves and transform their energy into heat. This conversion mechanism aids in lowering the sound's volume and intensity. The sound - absorbing material, also known as the absorbent or acoustic packing, is the main part of an absorptive muffler. Fiberglass, mineral wool, or perforated tubes packed with sound - absorbing materials are frequently used in its construction. These substances effectively trap sound waves and transform them into heat energy thanks to their high porosity and surface area. HVAC systems, industrial machinery, and vehicle exhaust systems all frequently employ absorbent mufflers. They can be made to fulfill certain noise reduction requirements and are effective at lowering noise across a wide frequency range. It's crucial to remember that absorptive mufflers could contribute some extra backpressure to the exhaust system, which could somewhat impair engine performance.

2) Reactive Muffler - An example of a muffler that uses the impedance mismatch theory to reduce noise is a reactive muffler. Reactive mufflers work by reflecting and canceling sound waves through careful design and tuning, in contrast to absorptive mufflers that absorb sound energy. Based on the idea that there is an impedance mismatch between the incoming sound waves and the internal design of the muffler, the reactive muffler functions. Variations in cross - sectional area, expansions, contractions, and variations in the flow route are all experienced by sound waves when they enter the muffler. These changes result in pressure differences and interference patterns that can either cancel out or weaken certain frequencies. Reactive mufflers are commonly used in automotive exhaust systems, motorcycles, and other internal combustion engines. They can provide effective noise reduction while minimizing any adverse effects on engine performance compared to absorptive mufflers. However, it is important to properly tune and design reactive mufflers to ensure optimal noise reduction and minimal backpressure in the exhaust system.

3) Combination Muffler: As the name implies, a combination muffler is a type of muffler that includes both reactive and absorptive features to reduce noise. To maximize the muffler's performance, it makes use of a hybrid design that combines the advantages of both absorptive and reactive principles. Typically, chambers, baffles, and sound - absorbing materials make up a combined muffler. These parts are positioned carefully to make the most of the absorption and reflection qualities in order to efficiently reduce exhaust noise. Combination mufflers are frequently employed in a wide range of applications, such as automobile exhaust systems, motorcycles, generators, and industrial machinery, when a complete and efficient noise reduction solution is needed. They offer a versatile approach to noise control by combining the advantages of both absorptive and reactive muffler designs.

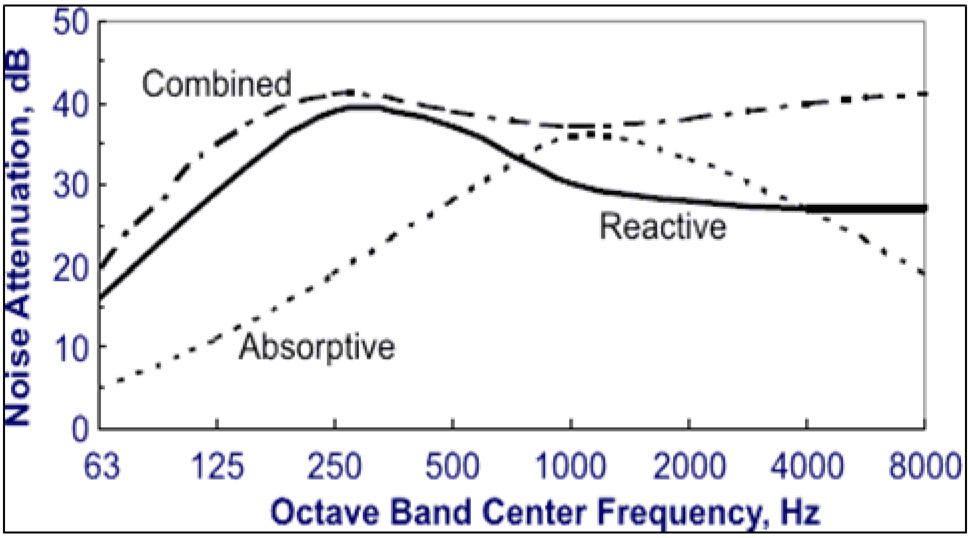

Figure 2: Muffler comparison for noise attenuation

Reactive, absorptive, and combination mufflers' noise attenuation is compared in Figure 2 for each type. The findings show that reactive mufflers excel at lowering higher frequency noise, whereas absorptive mufflers are particularly good at attenuating lower frequency noise. The combination mufflers offer a complete solution by effectively reducing noise throughout a wide frequency range. They integrate both reactive and absorptive features.

2. Literature Review

In the paper **"Acoustic analysis and modeling of Reactive muffler to reduce noise of the System"**, Dr. Mahesh V. Kulkarni and Akshay Vijay Shinde The acoustic analysis of a reactive muffler with various placements of baffle plates in the chamber is studied in this research. The modelling of the reactive muffler involves three different configurations of baffle plate placements. Four parameters are kept constant during the modelling process: temperature at 298 K, absolute pressure at 1 atm, speed of sound at 343 m/s, and density at 1.5 kg/m³. Numerical analysis is conducted using the software COMSOL Multiphysics, where three different types of muffler models are created. The first model is an extended inlet - outlet muffler with a single baffle plate, the second model is a reactive muffler with double baffle plates, and the third model is a reactive muffler with three baffle plates of different circumferential diameters. All three models have a chamber diameter of 60 mm and a chamber length of 560 mm. The figures in the paper illustrate the geometry of the muffler, meshing geometry, acoustic sound pressure in dB at 801 Hz, and transmission plot. The paper also discusses the experimental analysis, where two impedance tubes are connected and an FFT analyzer collects pressure data from microphones, which is then recorded in a data storage system. The two - load method theory is explained, and a setup figure is provided. The formula for transmission loss is given, and the procedure for the experimental analysis is described. The paper concludes that the third model, with three baffle plates equally placed in the muffler chamber, achieves the maximum transmission loss, up to 27 dB with an average transmission loss of up to 16 dB. The first model, with a single baffle plate and extended inlet - outlet, achieves a transmission loss of up to 58 dB. The second model, with two baffle plates placed at different locations in the chamber, achieves a transmission loss of up to 27 dB. The results suggest that the placement of baffle plates significantly affects the transmission loss performance of the muffler [1] [2].

In this article "**Design and analysis of core chamber of muffler", Rameshwar Cambow.** The study focuses on geometrical optimization in terms of transmission loss for a simple expansion chamber muffler. The research begins by selecting a range for the diameter of the chamber (D) to diameter of the inlet tube (d) based on a literature survey. Simulations are then conducted using Ansys software within this selected range to determine the maximum transmission loss. It is found that the maximum transmission loss occurs when the ratio of D to d is equal to 4.38. Next, simulations are performed for the length of the chamber (L) to diameter of the chamber (D) ratio within the range of 1.2 to 1.6. The results indicate that a stable maximum transmission loss value is obtained for an L/D ratio of 1.6. However, the transmission loss values for an L/D ratio of 1.3 are found to be comparable to those of the 1.6 ratio. Due to size restrictions, the 1.3 L/D ratio is considered for further analysis. The maximum transmission loss achieved for this ratio is found to be 22.055 dB. Based on these findings, an optimized muffler can be designed and manufactured using the proposed L/D ratio and the specified geometric dimensions. [3]

In the article, **"Investigation on Effect of Extended Inlet and Outlet tubes on Single Expansion Chamber Muffler**

for Noise Reduction" Mahesh V Kulkarni, Dr. Ravindra B. Ingle. The paper describes the acoustic analysis of a single expansion chamber reactive muffler with extended inlet and outlet. The objective of this analysis is to maximize the sound transmission loss. The muffler considered in the study has a length of 400mm and a diameter of 110mm. The inlet and outlet chambers have a diameter of 44mm and a length of 80mm. The modeling and meshing of the muffler are performed using COMSOL Multiphysics, a software tool for numerical simulations. The paper then presents the formulas for the uniform tube and extended tube configurations, which are used to develop a MATLAB code. The MATLAB code is employed for theoretical analysis, and the stagnation pressure loss coefficients are calculated. Next, the numerical analysis of the muffler is conducted using COMSOL Multiphysics, and simulations for three different muffler configurations are presented. The transmission loss is evaluated analytically and numerically for four cases: the single expansion chamber, chamber with extended inlet, chamber with extended outlet, and chamber with extended inlet and outlet. The paper demonstrates that the average transmission loss obtained from the theoretical and numerical analyses is nearly identical. This indicates that the transmission loss trends depicted in the graphs are in good agreement with each other. Based on the results, the conclusion is drawn that mufflers with extended inlet and outlet achieve the lowest transmission loss. [4] [5] [6] [7]

In the paper "**Prediction of Transmission Loss ona Simple Expansion Chamber Muffler**" **by Ujjal Kalita, Dr. Manpreet Singh.** The research focuses on optimizing the design of a single expansion chamber muffler by considering the length and diameter of the chamber as key parameters. The design process involves utilizing CAD software to create the muffler design, followed by conducting acoustic analysis using ANSYS software's simulation method. To evaluate the acoustic performance of the muffler design, the findings of the analysis are compared to the work of two other authors, Milad et al. and Lee et al. The study aims to establish a correlation between the optimized muffler design and the previous works. The main parameters considered in the study are the length of the chamber, the diameter of the chamber, and the inlet/outlet diameter of the chamber. Initially, the acoustic performance parameters of Milad et al. 's work are examined using simulation methods. The relationship between the length of the chamber (L) and the diameter of the chamber (D), represented by the L/D ratio, is varied from 1.2 to 1.6 for analysis. Meanwhile, the relationship between the chamber diameter and the inlet tube diameter remains constant. The obtained results are then compared to the findings of Lee et al. for a simple expansion chamber. Based on the collected data and the comparison of the results, an optimized design for the single expansion chamber muffler is proposed. [8]

In the article, "**Design and Analysis of Reactive Muffler for Enhancement in Transmission Loss"** Tushar Sonkule, Suyash Dhadve, Akshay Shahane, Yash Malpani, and Mahesh Kulkarni conducted a study on different methodologies for evaluating the transmission loss of a single expansion chamber reactive muffler. The study involved both theoretical analysis and numerical simulations using COMSOL Multiphysics. In the theoretical analysis, the researchers determined the muffler's transmission loss based on fixed dimensions of the expansion chamber (length: 540mm, diameter: 120mm) and the inlet/outlet pipes (diameter: 44mm). COMSOL Multiphysics was then used to perform a numerical analysis of the single expansion chamber. The muffler was automatically meshed with tetrahedral elements, and the Helmholtz equation was employed to calculate the sound pressure (P), allowing for the determination of the acoustic pressure distribution and transmission loss curve. The comparison between the transmission loss obtained from the theoretical analysis and the numerical analysis showed good agreement, indicating the accuracy of both methods. In the experimental analysis, the researchers validated the acoustic performance of the single expansion chamber muffler using the method of two loads. To calculate the transmission loss in the experimental analysis, the method of two loads utilized four pole equations derived from four microphone positions. Two different loads were employed to ensure stable results. Finally, the results obtained from the experimental analysis and the numerical analysis were compared, and a good agreement was observed. The maximum transmission loss indicated the minimum noise radiated at the specified frequency. However, there was a small difference between the experimental and numerical outcomes, which could be attributed to factors such as sound leakage from the impedance tube, issues with FFT white noise production, and inconsistencies in the impedance tube's surface finish. [9]

In this article**, "Validation of set up for experimental analysis of reactive muffler for the determination of transmission loss"** Mahesh V Kulkarniand Ravindra B Ingle mentioned that to overcome the problem of noise vibration, a muffler is used. The article focuses on the precise prediction of sound radiation characteristics of reactive mufflers, which play a critical role in automotive exhaust system design. The evaluation of acoustic analysis in this study is done using the transmission loss (TL) method. Transmission loss refers to the difference between the power incident on a muffler and the power transmitted downstream into an anechoic termination. To predict the acoustic performance of a reactive muffler, an experimental setup is created using the two - load method. This setup is then validated by measuring the transmission loss of a known reactive muffler model using the finite element method (FEM). The three - dimensional finite element method is employed in this study to calculate the transmission loss of the muffler, assuming a Mach number of zero. COMSOL Multiphysics is used for the finite element analysis, without considering fluid - structure interaction. The transmission loss obtained from the experimental analysis is compared to the results obtained from the finite element method for the muffler model. The comparison demonstrates that the experimental analysis setup developed in this study is reliable for determining the transmission loss of an exhaust muffler within the low to mid - frequency ranges. [10] [11]

In this article, **"Acoustics analysis of single expansion chamber reactive muffler with single baffle for maximum transmission loss", Mahesh Kulkarni.** The use of generators is becoming increasingly prevalent across various sectors. However, there are limitations regarding transmission loss associated with their operation. To ensure compliance with specified transmission loss requirements, the use of mufflers or soundproofing measures becomes necessary. This research article focuses on the acoustic analysis of a single expansion chamber muffler with the aim of achieving maximum transmission loss. The study investigates the use of baffles and explores the effect of varying baffle positions from the inlet and outlet. The results obtained from different cases are compared to determine the optimal combination. The article presents a comparison between theoretical and numerical analysis methods, demonstrating their similarity and thereby simplifying the muffler analysis process. When baffles are employed, the transmission loss increases as the hole diameter of the baffle decreases. However, it is important to note that this also leads to an increase in back pressure, which imposes a limitation on the smallest diameter, restricting it to be equal to the inlet diameter. Furthermore, the positioning of the baffle plays a role in transmission loss. The study finds that the transmission loss is greater when the baffle is positioned closer to the inlet and outlet locations. [12] [13]

In the article **"Design Development and Analysis of a Single Expansion Chamber for a Diesel Engine", Chinmayeev Askhedkar, Sagar C. Atre** In the study, a reactive muffler is specifically designed for a single cylinder diesel engine to achieve maximum transmission loss. The transmission loss plays a crucial role in determining the performance and efficiency of a muffler. The performance of the muffler is influenced by its shape and dimensions, including the length, expansion ratio, and number of resonating chambers. The aim of the research is to enhance the acoustic performance and efficiency of the muffler by optimizing its length and expansion ratio, while considering the constraints of the manufacturing process. The transmission loss for the chosen optimal length and expansion ratio is mathematically modeled using the Transfer Matrix Method, and it is also computed analytically. Both models are compared to assess their accuracy and consistency. The mathematical model is based on the Transfer Matrix Method, while the acoustic performance analysis is conducted using the Finite Element Method. The obtained transmission loss values for the designed muffler are used to verify and validate both models. This methodology enables the establishment of a relationship between the attenuation across the muffler and variations in length and expansion ratio for a given firing frequency and its harmonics. The results of the study indicate that the transmission loss in a single cylinder expansion chamber is dependent on the length and expansion ratio of the muffler. It is observed that the transmission loss increases with an increase in the muffler length and expansion ratio. For the specific problem addressed in the study, the maximum attenuation loss achieved is 20 dB. The results obtained from both the analytical and mathematical models are verified and validated through comparison. [14] [15]

The paper **"Acoustic analysis of extended inlet and outlet tube parameters in single expansion chamber reactive muffler for increment in transmission loss"**, by Dr Mahesh Kulkarni, Tushar Sonkule, Suyash Dhadve, Akshay Shahane, Yash Malpani explains the effective use of extended inlet and outlet to maximize the transmission loss. Noise pollution is a significant issue associated with internal combustion engines. To address this problem, a detailed study is conducted using three approaches: theoretical analysis, finite element method using COMSOL Multi - Physics, and experimental validation using the method of two loads. A noise level of 80 dB or higher is considered harmful to human health. The transmission loss of a muffler is analyzed theoretically, and it is calculated using parameters such as expression ratio (m), wave number (k), velocity of sound (c), length of the expansion chamber (l), and transmission loss (TL). The evaluation of transmission loss for a single expansion chamber reactive muffler is based on the following design conditions:

a) The length of the expansion chamber is kept constant.
b) The diameter of the expansion chamber remains constant.
c) The inlet and outlet pipe diameters connected to the expansion chamber are constant.
d) The length of the inlet pipe connected to the expansion chamber remains constant.
e) The length of the outlet pipe connected to the expansion chamber remains constant.

The frequency range analyzed and programmed using MATLAB is 1 - 1600 Hz. Numerical analysis of the muffler is performed using COMSOL, and the sound pressure is determined using the Helmholtz equation. A comparison between theoretical and numerical analysis of transmission loss shows good agreement. In the experimental analysis using the two loads method, the setup includes a noise generation system, noise propagation system, and measurement system. This method utilizes a transfer matrix and four pole equations for four microphone positions to calculate the transmission loss. The experimental procedure is conducted under both no - load and loaded conditions. Comparing numerical and experimental analysis, it is observed that the maximum transmission loss indicates minimum noise radiation at a specific frequency. The results also indicate that the addition of extended inlet and outlet mufflers increases the transmission loss. [16] [17] [18]

In the paper **"Optimization and Experimental Validation of Elliptical Reactive Muffler with Central Inlet Central Outlet", Anant W. Wankhade and Dr. A. P. Bhattu** The research aims to propose a practical and effective silencing device for noise reduction, focusing on the analysis of sound levels at the tailpipe. Acoustic analysis is used as one of the methods to assess the performance of the muffler. The optimization process involves utilizing Finite Element Analysis (FEA) to enhance the acoustic analysis of the muffler. The muffler is initially modeled using 'PRO E Wildfire5.0, ' and the acoustic analysis is carried out using 'COMSOL MULTIPHYSICS. ' The study investigates the impact of two factors: the extrusion of the inlet and outlet pipes inside the chamber and the positioning of an additional inlet tube (divided inlet) within the chamber. The objective is to achieve the lowest sound pressure level (SPL) or the highest transmission loss (TL) through the optimization of these factors. However, the effect of SPL on the muffler walls and the consideration of muffler material are not taken into account in this analysis. The optimized muffler model, an elliptical muffler, is then manufactured and subjected to experimental analysis to validate its performance. A comparison between the Finite Element Method (FEM) analysis and experimental results demonstrates good agreement between the two. Subsequently, an analysis of an elliptical chamber muffler with extended inlet and outlet is conducted, revealing that the extension of the inlet and outlet significantly affects the transmission loss (TL). The study also investigates the impact of inserting an extra divided inlet tube into the muffler with extended inlet and outlet. It is found that the presence of the extra tube increases TL in the initial frequency range (1 - 400Hz) compared to the muffler without the tube. Furthermore, the average TL is shown to increase in the 1 - 1500Hz frequency range. Using FEM analysis with COMSOL MULTIPHYSICS, an elliptical chamber muffler with extended inlet, extended outlet, and an extra tube (divided inlet) is analyzed. Taguchi analysis is employed to identify the optimal model with high transmission loss compared to the others. This optimal model is then created and tested to determine the average transmission loss. The experimental results indicate an average transmission loss of 43.89 dB, while the FEM analysis predicts a value of 49.43 dB. The comparison of these values suggests a similar nature between the experimental and FEM analyses. [19] [20] [21]

3. Conclusion

The research paper focuses on the analysis of a single expansion chamber reactive muffler using two different methodologies: Theoretical analysis and Numerical analysis.

In the Theoretical analysis, a MATLAB program is developed based on empirical relations to calculate the Transmission Loss. The program takes into account the internal geometry of the muffler, including factors such as extended inlet and outlet, as well as baffles. Theoretical analysis helps in understanding the influence of these internal geometrical changes on the transmission loss, particularly within specific frequency ranges.

On the other hand, Numerical analysis is conducted using COMSOL Multiphysics software. The muffler is modeled, meshed, and analyzed using this software. The analysis is performed in the frequency domain, allowing for a detailed examination of the muffler's acoustic performance.

The results indicate that the modifications in the internal geometry, such as extended inlet and outlet, and the presence of baffles, have a significant impact on increasing the transmission loss, particularly within specific frequency ranges. This suggests that careful optimization of the muffler's internal geometry can lead to improved acoustic performance.

To validate the results obtained from the numerical analysis, experimental analysis is conducted using the two load method. This experimental approach helps in verifying the accuracy and reliability of the numerical analysis results, thereby providing a comprehensive evaluation of the muffler's performance.

Overall, the research paper highlights the importance of both theoretical and numerical analysis in understanding and optimizing the acoustic performance of a single expansion chamber reactive muffler. The experimental validation further enhances the credibility of the numerical analysis results.

References

[1] A. V. Shinde, M. V Kulkarni, Acoustic analysis and modelling of Reactive muffler to reduce noise of the System, Int. J. Sci. Eng. Res.12 (2021) 535–539. https: //doi. org/10.17577/ijertv5is050386.

[2] T. Sonkule, S. Dhadve, A. Shahane, Y. Malpani, M. Kulkarni, ACOUSTIC ANALYSIS OF EXTENDED INLET & OUTLET TUBE PARAMETERS IN SINGLE EXPANSION CHAMBER REACTIVE MUFFLER FOR INCREMENT IN TRANSMISSION LOSS, Int. Res. J. Eng. Technol.08 (2021) 870–876. www.irjet. net.

[3] R. Cambow, Design and Analysis of Core Chamber of Muffler, Int. J. Res. Anal. Rev. (2019). www.ijrar. org.

[4] M. V Kulkarni, R. B. Ingle, Investigation on Effect of Extended Inlet and Outlet Tubes on Single Expansion Chamber muffler for Noise Reduction, Am. Int. J. Res. Sci.18 (2017) 10–15. http: //www.iasir. net.

[5] M. Kulkarni, EVALUATION OF EXTENDED INLET & OUTLET TUBE PARAMETERS IN SINGLE EXPANSION CHAMBER REACTIVE, YMER.22 (2023) 1134–1142.

[6] M. Kulkarni, R. Ingle, Effect of variations in Extended Inlet lengths for constant Extended Outlet lengths on Transmission Loss of Double Expansion Chamber Reactive Muffler, J. Seybold Rep.15 (2020) 2318–2324.

[7] M. Kulkarni, R. Ingle, Effect of Extended Inlet and Outlet Lengths on Transmission Loss of Double Expansion Chamber Reactive Muffler, Int. J. Veh. Struct. Syst.14 (2022) 135–137. https: //doi. org/10.4273/IJVSS.14.2.01.

[8] U. Kalita, PREDICTION OF TRANSMISSION LOSS ON A SIMPLE EXPANSION CHAMBER MUFFLER, J. Emerg. Technol. Innov. Res.5 (2018) 1022–1031.

[9] T. Sonkule, S. Dhadve, A. Shahane, Y. Malpani, M. Kulkarni, DESIGN AND ANALYSIS OF REACTIVE MUFFLER FOR ENHANCEMENT IN TRANSMISSION LOSS, IJRAR21B1974 Int. J. Res. Anal. Rev.8 (2021) 870–876. www.ijrar. org.

[10] M. V. Kulkarni, R. B. Ingle, Validation of set up for experimental analysis of reactive muffler for the determination of transmission loss: Part 1, Noise Vib. Worldw.49 (2018) 237–240. https: //doi. org/10.1177/0957456518781857.

[11] M. V. Kulkarni, R. B. Ingle, Attenuation analysis and acoustic pressure levels for double expansion chamber reactive muffler: Part 2, Noise Vib. Worldw.49 (2018) 241–245. https: //doi. org/10.1177/0957456518781859.

[12] A. Patil, C. Kulkarni, O. Bhujbal, S. Shete, M. Kulkarni, Acoustics analysis of single expansion chamber reactive muffler with single baffle for maximum transmission loss, Int. J. Adv. Eng. Manag.03 (2021) 833–839. https: //doi. org/10.35629/5252 - 0307833839.

[13] P. Shirode, A. Lokhande, A. Shete, D. Mohite, M. Kulkarni, Effect of Baffle Placement on Transmission Loss of Single Expansion Chamber Reactive Muffler, Int. J. Res. Anal. Rev.9 (2022) 24–34.

[14] C. Askhedkar, S. C. Atre, Design Development and Analysis of a Single Expansion Chamber for a Diesel Engine, (2020) 1076–1080.

[15] P. Shirode, A. Lokhande, A. Shete, D. Mohite, M. Kulkarni, Review Of Acoustic Analysis Of Single Expansion Chamber Reactive Muffler, Int. J. Res. Anal. Rev.9 (2022) 635–640.

[16] T. Sonkule, S. Dhadve, A. Shahane, Y. Malpani, M. Kulkarni, ACOUSTIC ANALYSIS OF EXTENDED INLET & OUTLET TUBE PARAMETERS IN SINGLE EXPANSION CHAMBER REACTIVE MUFFLER FOR INCREMENT IN TRANSMISSION LOSS, Int. Res. J. Eng. Technol.08 (2021) 2589–2595. www.irjet. net.

[17] S. Salunkhe, S. Dayne, M. Kulkarni, Review paper on Analysis of Reactive Muffler for enhancement in Transmission Loss, Res. J. Sci. Eng. Technol.12 (2022) 34–39.

[18] S. Salunkhe, M. Kulkarni, Optimization of Extended Inlet length and Extended Inlet diameter of Single Expansion Chamber Reactive Muffler with Extended Inlet and Extended Outlet for maximum Transmission Loss in specific frequency range, YMER.22 (2023) 708–721.

[19] Anant W. Wankhade, Dr. A. P. Bhattu, Optimization and Experimental Validation of Elliptical Reactive Muffler with Central Inlet Central Outlet, Int. J. Eng. Res. V4 (2015) 1321–1328. https: //doi. org/10.17577/ijertv4is051209.

[20] M. V Kulkarni, D. BIngle, Finite Element Analysis of Double Expansion Chamber Reactive Muffler with Side Outlet., Int. J. Res. Anal. Rev.5 (2018) 758–764. http: //ijrar. com/.

[21] R. I. Mahesh Kulkarni, Acoustic Analysis And Optimization Of Double Expansion Chamber Reactive Muffler using Taguchi Method, J. Seybold Rep.15 (2020) 1844–1855.