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# A Brief Review on Advance Acoustic Control System Process of Automotive Muffler

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***Abstract:*** *Man's desire for pollution free atmosphere needs control of air pollution and noise pollution. The principal sources of noise in automotive engines are intake noise, radiator noise, combustion noise, exhaust noise, etc. Out of these, exhaust noise is predominant and it is to be controlled. Noise pollution affects human beings physiologically and psychologically. Prediction of un-muffled and muffled noise from internal combustion engines requires knowledge of the acoustic attenuation performance of the muffling system along with the engine noise source characteristics. So the muffler is a part of the exhaust system on an automobile that plays a vital role. The objective of this study is reviewing the literature and deciding the muffler design which one reduces a large amount of noise level and back pressure of the engine. In this paper, reactive, conventional, resistant muffler are discussed. By changing the design parameter of the muffler the noise level will be reduced.*

***Keywords:*** *Noise control ,Muffler ,FEA ,CFD ,Acoustic ,Convective flow effects, Review.*

## I. Introduction

The sole purpose of an automotive muffler is to reduce engine noise emission. If you have ever heard a car running without a muffler you will have an appreciation for the significant difference in noise level a muffler can make. If vehicles did not have a muffler there would be an unbearable amount of engine exhaust noise in our environment. Noise is defined as unwanted sound. Sound is a pressure wave formed from pulses of alternating high and low pressure air. In an automotive engine, pressure waves are generated when the exhaust valve repeatedly opens and lets high-pressure gas into the exhaust system. These pressure pulses are the sound we hear. As the engine rpm increases so do the pressure fluctuations and therefore the sound emitted is of a higher frequency. All noise emitted by an automobile does not come from the exhaust system. Other contributors to vehicle noise emission include intake noise, mechanical noise and vibration induced noise from the engine body and transmission. The automotive muffler has to be able to allow the passage of exhaust gasses whilst restricting the transmission of sound.

## II. Basic Requirement Of Muffler Design

**1. Genaral Requirements**

- ✓ Quiet
- ✓ Simple maintenance
- ✓ Performance Compact design Light weight

**2. Specific Requirment**

i. Reduce the sound emissions Replaceable
ii. Doesn't increase backpressure
iii. Easy mounting Within the budget Easy manufacturing

## III. Design Procedures Of Muffler

There are numerous variations of the two main types of muffler designs commonly used, namely absorptive and reactive. Generally automotive mufflers will have both reactive and absorptive properties. The reactive or reflective mufflers use the phenomenon of destructive interference to reduce noise. This means that they are designed so that the sound waves produced by an engine partially cancel themselves out in the muffler. For complete destructive interference to occur a reflected pressure wave of equal amplitude and 180 degrees out of phase needs to collide with the transmitted pressure wave. Reflections occur where there is a change in geometry or an area discontinuity. A reactive muffler, as shown in Figure 1, generally consists of a series of resonating and expansion chambers that are designed to reduce the sound pressure level at certain frequencies.

The inlet and outlet tubes are generally offset and have perforations that allow sound pulses to scatter out in numerous directions inside a chamber resulting in destructive interference. Reactive mufflers are used widely in car exhaust systems where the exhaust gas flow and hence noise emission varies with time. They have the ability to reduce noise at various frequencies due to the numerous chambers and changes in geometry that the exhaust gasses are forced to pass through. The down side to reactive mufflers is that larger backpressures are created, however for passenger cars where noise emission and passenger comfort are highly valued reactive mufflers are ideal and can be seen on most passenger vehicles on our roads today.

An absorptive or dissipative muffler, as shown in Figure 2, uses absorption to reduce sound energy. Sound waves are reduced as their energy is converted into heat in the absorptive material. A typical absorptive muffler consists of a straight, circular and perforated pipe that is encased in a larger steel housing. Between the perforated pipe and the casing is a layer of sound absorptive material that absorbs some of the pressure pulses. Absorptive mufflers create less backpressure then reactive mufflers, however they do not reduce noise as well.

Generally reactive mufflers use resonating chambers that target specific frequencies to control noise whereas an absorptive silencer reduces noise considerably over the entire spectrum and more so at higher frequencies.

It is good practice to design a muffler to work best in the frequency range where the engine has the highest sound energy. In practice the sound spectrum of an engine exhaust is continually changing, as it is dependent on the engine speed that is continually varying when the car is being driven.

It is impossible to design a muffler that achieves complete destructive interference, however some will always occur.

Noise spectrum variation makes muffler design quite difficult and testing is the only sure way to determine whether the muffler performs well at all engine speeds. However, as a general rule of thumb, exhaust noise is generally limited to the fundamental frequency and the first few harmonics, which can be calculated, therefore these frequencies should be used as a starting point for preliminary muffler design. A practical way of determining the frequency range to be controlled is to measure the unmuffled engine noise.

This measured spectrum can then be used to identify the frequencies, at which the higher noise levels occur. The high noise level frequencies should be treated with appropriate noise control to achieve an overall noise reduction.

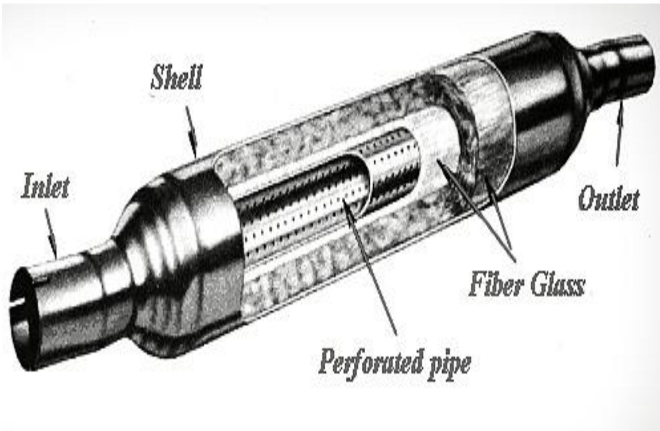


**Figure 1 Straight Through Muffler**

There is always more than one way to design a muffler for a specific application, however if the designed muffler is practical and achieves the required noise reduction and meets all functional requirements then the designer has succeeded.

**Selection parameters**

a. Number of chambers
b. Number of inlets and outlet pipes
c. Diameter of Inlet and outlet pipe
d. Holes on the pipe
e. Size of muffler

## IV. Different Types Of Muffler

**1. Reactive 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 reflective effect of the silencer chambers and piping (typically referred to as resonators) essentially prevents some sound wave elements from being transmitted past the silencer. 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. Absorptive muffler**

This type of muffler design uses only absorption of the sound wave to reduce the noise level without messing with the exhaust gas pressure. Ti is known as glass pack muffler and it reduces backpressure but producing higher noise. The sound produced by this type of muffler is much higher compared to the other type of mufflers.

**3. Combination muffler/silencer**

Some silencers combine both reactive and absorptive elements to extend the noise attenuation performance over a broader noise spectrum. Combination silencers are also widely used to reduce engine exhaust noise

**4. Heat recovery muffler/silencer**

Typical applications of heat recovery silencers for internal combustion engines include hot water heating, steam generation, heat transfer fluid heating

**5. Active silencer**

Active silencing or sound cancellation systems, employs detectors used in sensing the noise in an exhaust pipe and a loudspeaker that is used to reintroduce an inverted signal have been developed to reduce low frequency noise.

## V. Muffler selection

- Determine the exhaust flow and acceptable exhaust system backpressure of engine.
- A free-flowing air intake and exhaust system in vehicle.
- Muffler must be built t ough to handle high pressure exhaust gasses, absorb impact from road debris, and resist corrosion.
- Number of inlets, single or dual system.
- Diameter of pipe , Inlet and outlet.
- Size of the muffler.
- Material used, stainless steel muffler offers superior corrosion resistance, durability, and life span than the aluminized steel muffler.

## VI. Research Reviews

In 2005, A.K.M. Mohumudd in presents experimental study of noise and back pressure for silencer design characteristics. The main objective of this study was to find the relationship between the back pressure and the noise level. He concludes that the relationship between the noise and the back pressure is inversely proportional [1].

In 2010, Chndreshkumar Bhat et al. have study on design and analysis of expansion chamber mufflers. In that study, they used model analysis followed by acoustic analysis using finite element analysis technique for three different configurations of mufflers under different fixing conditions. He was found that three chamber muffler provides higher attenuation of sound pressure compare to one and two chamber mufflers. And fixing the muffler at the centre enhances sound pressure attenuation. He concludes that the transmission loss is minimum at resonance. The transmission loss increases with the increase in number of chambers and loss is uniform [2].

In 2010, Wang Jie et al. have study on the model analysis of an automobile exhaust muffler based on PRO/E and ANSYS in order to improve design efficiency. The solid model is created by PRO/E and model analysis is created out by ANSYS to study the vibration of the muffler, so as to distinguish working frequency from natural frequency and avoid resonating. Data exchange between PRO/E and ANSYS using IGES (Elementary graphics exchange specification) format for data exchange specification. Muffler natural frequencies modal shapes have been calculated by the FEM analysis software named ANSYS. So the muffler vibration can be intuitive analyzed. The natural frequencies and mode shape are considered during the design of the muffler, so avoid the resonance occurred in exhaust system [3].

In 2010, Mehmet Avcu et al. introduce diesel engine exhaust system design with help of the three-dimensional model of the system has been constructed by using “ANSYS Workbench”, the mathematical models via Finite Element Method (FEM) have been done via “ANSYS ICEM CFD” and, the Computational Fluid Dynamics (CFD) analyses covering back pressure and thermal analyses have been performed by using "ANSYS CFX 12" program. He Conclude, The dimensions and internal structure of the dry and wet-type silencers which are the main components of the exhaust system and the physical properties of the insulation material have been determined based on acoustic, back pressure and thermal analyses and, the layout of the diesel engine in the engine room. From the results of the back pressure analyses, it is seen that the total back pressure in the whole exhaust system is within the limits of the given diesel engine criteria and, the board outlet temperature of the exhaust system is substantially low[4].

In 2011, Ying Li Shao et al. have a study on a Exhaust Muffler Using a Mixture of Counter phase Counteract and Split-gas Rushing. In order to solve the problems of traditional exhaust silencers with poor characteristics of noise reduction in low-frequency range and high exhaust resistance, a new theory of exhaust silencer of diesel engine based on counter-phase counteract and split-gas rushing has been proposed. In single-cylinder diesel engine CG25 as the experimental engine. He measured the exhaust noise and its spectra. By comparing the results of the new types of mufflers to those without a muffler and those with the original muffler of the engine.He conducted on this noise experiment that the CG25 single cylinder diesel engine shows new muffler‟s good insertion loss characteristic in the wide range of engine speed comparable to the original passive muffler especially in the range of 500Hz. The original muffler can only reduce the high- frequency noise components, it cannot reduce, even strengthen the noise of frequency below 500 Hz, proved conventional muffler with poor capacity of lowering the low-frequency noise again. The new exhaust mufflers were obviously effective in controlling the low-frequency exhaust noise, which proved correctness of the new theory not only proved that the new mufflers have very good performance for low-frequency noise reduction, but also proved that using split-gas rushing can lower the air flow speed thus lowering the air regeneration noise.fig 2 shows the new design of muffler [5].

In 2011, Shi Wu et al. have study on Structural Design and Testing Study of Truck Muffler. He introduces the performance evaluation method of automobile's exhaust muffler and it's the size parameter to the noise elimination effect influence. It presents a two chambers impedance compound exhaust muffler designment's method based on a boundary element method, which focuses on the truck's diesel engine. Test shows that the truck exhaust muffler has a good effect with insertion loss of 22.7dB, and by the boundary element method, calculates transmission loss under the static condition. By the experiment he conclude that By laying cotton blankets absorbing sound on the inner surface of the truck muffler, not only can we solve the exhaust noise of the mid and high frequency band, and isolate the exhaust heat out of the radiation. By blocking imports of gas to prevent gas through, the muffler avoids the high frequency noise transmission to meet the technical requirements [6].

In 2011, Jun Chan investigates CFD Numerical Simulation of Exhaust Muffler based on the physical numerical modelling of the flow field of the muffler in this paper, the author simulated the field by numerical method with Fluent and analyzed the effect which the internal flow field has on the performance of the muffler. The author simulated the field by numerical method with Fluent and analyzed the effect which the internal flow field has on the performance of the muffler[7].

In 2012, M RAJASHKUMAR REEDDY explain design and optimization of exhaust muffler in automobiles by study of Muffler dimensions are measured through the Benchmarking, to create CAD models. The CAD models are created in CATIA V5 R19, later these CAD models of muffler are exported to HYPER MESH for pre-processing work. Free analysis is carried out on this muffler by FEA Method using NASTRAN Software. In order to determine the resonance frequencies, were then compiled to determine which peaks were the most significant for the system. From the data, side baffles were selected as weak parts of the muffler. In order to minimize the effects of these resonance frequencies, the suggested design improvement is to add thickness and also add damping to the system [8].

In 2012, Hua Huange et al. have study Multi-objectives Optimization on Exhaust Muffler Based on DoE. He builds comprehensive evaluation system and DoE development flows are built. RBF mathematical models of evaluated objectives are established to look for Pareto optimal solutions. he define design parameters(diameter of inlet and outlet pipe, position of Clapboard 1 and Clapboard 2, open hole rate of Clapboard 1 and Clapboard 2, length of inlet pipe in the second cavity, and length of middle pipe in the third cavity). Define optimized objectives, Building comprehensive evaluation system for Muffler, he use 2k factor analysis is the first step of DoE optimization, Build mathematical model. This paper builds muffler DoE development flow, and does multi-objectives research. Based on DoE way, it builds RBF mathematical model of each objective, and gets 300 Pareto optimal solutions (based on equable change of weight of optimized objectives) from RBF model by using NSEA+ arithmetic[9].

In 2013, Ehsan Sabah M. AL-Ameen et al. do Experimental Test for Noise Attenuation in Gasoline Engine with Different Types of Mufflers. Compares between three different types of an exhaust muffler for noise attenuation of single cylinder four stroke air-cooled gasoline engine. A set of conclusions achieved about the effect of the mufflers chamber's expansion ratio, chambers length, and wall thickness. Sound attenuation of 12.5, 15 and 16 dB A is achieved with, Multi-chamber Reactive Muffler, Concentric-tube

Resonator Muffler and Combined Reactive and Dissipative Muffler[10].

In 2013, Takashi Yasuda Studies on an automobile muffler with the acoustic characteristic of low-pass filter and Helmholtz resonator. Based on the typical structure, a muffler with an interconnecting hole on the tail pipe was proposed to improve its acoustic performance. Acoustic performances of the proposed muffler were studied experimentally and theoretically in frequency and time domain. Results showed that the specimen muffler had attenuation performances of low-pass filter and Helmholtz resonator when an interconnecting hole was designed on the tailpipe [11].

## VII. Conclusion

Different types of muffler and designing methods with analysis techniques are studied. After studying this methods and procedures for designing a muffler affects of back pressure based to constrain to setup of this work, we conclude that combination type of muffler is more efficient than reactive and absorptive mufflers. New theory for designing muffler by counter-phase counteracts split- gas and fluids rushing and methods of designing Active silencer are also preferable for new research work.

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