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Investigation of Geometrical Parameter on Performance of Muffler: An Overview

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Abstract: *Internal combustion engines are typically equipped with an exhaust muffler to suppress the acoustic pulse generated by the combustion process. A high intensity pressure wave generated by combustion in the engine cylinder propagates along the exhaust pipe and radiates from the exhaust pipe termination. Exhaust mufflers are designed to reduce sound levels at certain frequencies. New regulations and standards for noise emission increasingly compel the automotive firms to make some improvements about decreasing the engine noise. On the other hand, developments on automobile technology and increasing competition between manufacturers necessitates having being reduced weight, having capability of higher sound absorption and lower back pressure mufflers. Lightness could be possible if the thickness is decreased or the volume is reduced. However, this causes high back pressure. Therefore, the optimum design requires. Recently finite element methods are used to obtain flow characteristics and back pressure values of mufflers. Having used of this method, effect of different parameters can be examined without prototyping and best suitable muffler can be determined in the design process. Furthermore time and money can be saved.*

1.Introduction: Main Components Of The Exhaust System

1.Exhaust manifolds
2.Catalytic converters
3.Mufflers
4.Resonator
5.Tail Pipe

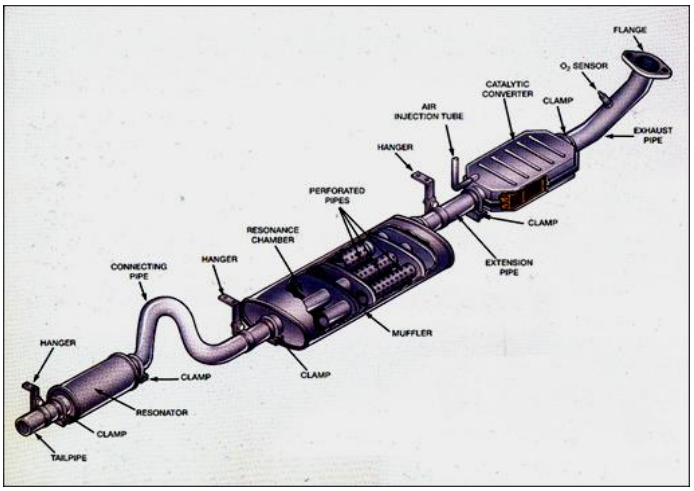

Fig 1 : Exhaust system in automobile

1.1. Muffler. : One of the components in the exhaust system of a vehicle is the muffler. Basically, the purpose of the muffler is to reduce the exhaust noise produced by the engine. The purpose of the muffler is to reduce the exhaust noise produced by the engine. Mufflers usually consist of:

- **The tubular metal jacket**
- **Perforated tubes**
- **The expansion chamber.**

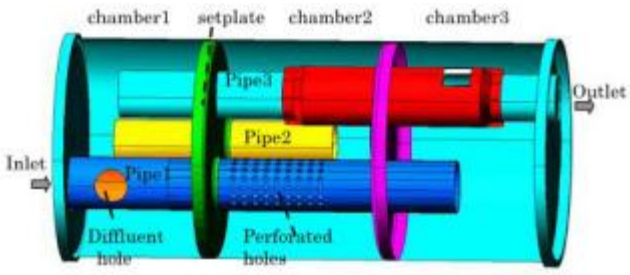

Fig 2 : Schematic diagram of muffler

The basic constructions of muffler usually consist of the tubular metal jacket, perforated tubes and the expansion chamber. The arrangement of these components will guide the exhaust gas to flow from the inlet pipe of the muffler to the outlet (tail pipe). Inside the muffler, the noise from the exhaust gas will be reduced by dissipation of the wave energy, reflection of the wave energy towards the engine or the combination of the two. Today's vehicles are equipped with two types of muffler, either the reflective muffler which consists of a number of tubular elements of different transverse dimensions joined together so as to cause, at every junction, impedance mismatch and hence reflection of substantial part of the incident acoustic energy back to the source or the dissipative muffler which consist of ducts lined on the inside with acoustically absorptive materials. Both mufflers are having different construction, geometry, and principles in their application. The performance of a muffler is described by the Insertion loss, Transmission loss and Back pressure.

Insertion loss is defined as the difference between acoustic powers radiated without any filter and that with filter.

Transmission loss is a measure of the difference between the sound power incident (in decibel) at the entry to the muffler to that transmitted by the muffler. Transmission loss is independent of the source and presumes (or required) an anechoic termination at the downstream end.

Back pressure is the extra static pressure exerted by the muffler on the engine through restrictions in the flow of exhaust gases. An exhaust muffler is an acoustic filter except that wave's are convicted downstream by the moving medium. Inside a muffler, it contains a deceptively simple set of tubes (not in all cases) with some holes in them. These tubes and chambers are actually designed to reflect the sound waves produced by the engine in such a way that they partially cancel themselves out. Most conventional mufflers are round or oval-shaped with an inlet and outlet pipe. Some mufflers contain partitions to help reduce engine noise. Generally an exhaust muffler should satisfy some basic requirements such as adequate insertion loss, low back pressure, ideal muffler sizing which couldaffect the cost and accommodation and the last one could be the durability to withstand rough conditions and extremely high temperatures. Hence some design considerations have to be taken in order to come up with an optimum muffler design. The parameters that govern the performance of the muffler are the muffler chamber design, restrictions of the flow of the exhaust gasses and the material of the muffler itself. The relationship between the noise and the back pressure is inversely proportional; lowering the noise level at the tip will result in high back pressure. However, thisrelationship is undesirable as the requirement is to have a quiet muffler with a small back pressure. The higher the back pressure created by the exhaust system, the less is the net power available on the crankshaft and hence the more is the specific fuel consumption.

Vehicle engines generate noise because of the pressure wave created during the (sudden) opening of the exhaust valves of the engine. The noise is unwanted. Because exhaust noise must meet legislation targets, customer expectations and cost reduction which call for design optimization of the exhaust systems in the design phase. One of the components in the exhaust system of a vehicle is the muffler.

The arrangement of these components will guide the exhaust gas to flow from the inlet pipe of the muffler to the outlet (tail pipe) inside the muffler; the sound/noise energy is absorbed by muffler linig, or reflected back to the engine before the gas flows out to the atmosphere. The noise cancellation will reduce the noise that radiated by the vehicle to the surrounding.

The noise from the exhaust system consists of three components :

1. Pulsation noise
2. Flow generated noise coming from the orifice of the muffler outlet
3. Shell noise coming from the shell of the muffler. Shell noise may be limited by using a stiffer or damped shell, while flow generated noise. Such as turbulence and vortex shedding may be limited by minimizing geometrical discontinuities (edges, sharp bends etc).

A reciprocating internal combustion engines are normal fitted with mufflers. The muffler fitted to an engine is intended to reduce the pressure pulses associated with the exhaust gas leaving the cylinders of the engine. Generally, mufflers fitted to such engines are essentially reactive devices as opposed to being dissipative devices. Practically reactive mufflers also have some dissipative function. An ideal muffler for reciprocating internal combustion engines functions as a low pass filter. The mean flow should be allowed to pass unimpeded through the muffler with the acoustic pressure fluctuation is minimized. If the steady flow is impeded the so-called' back pressure' will be higher and the engine will function less efficiently. It is desirable to be able to predict the pressure drop associated with the steady flow through the muffler. It is also desirable to be able to predict the acoustic performance of the muffler. Essentially this means determining as a function of frequency how harmonically varying pressure fluctuations at the inlet of the muffler are attenuated before they emerge at the outlet.

1.2 Different Types Of Muffler

1.2.1. 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.

1.2.2.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.

1.2.3. Combination muffler : 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

1.2.4. Heat recovery muffler: Typical applications of heat recovery silencers for internal combustion engines include hot water heating, steam generation, heat transfer fluid heating

1.2.5. 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.

1.3. Problem Statement: There is an increasing awareness of noise pollution on the part of the general public in urban areas, especially noise caused by automotive. A pollutant of concern to the mankind is the exhaust noise in the internal combustion engine. However this noise can be reduced sufficiently by means of a well designed muffler. The suitable design and development will help to reduce the noise level, but at the same time the performance of the engine should not be hampered by the back pressure caused by the Muffler. In particular, users of certain types of general automotive may be compelled to restrict operations and/or modify their automotive to comply with existing or forthcoming noise legislation that will specify upper limits on external noise levels. Analysis of this noise indicated that engine-exhaust noise was the primary cause of both unacceptably high cabin-noise levels and radiated far-field noise.

2. FACTORS AFFECTING ON PERFORMANCE OF MUFFLER

The Factors are as follows

2.1. Engine Noise. : An engine is a mechanical device that produces some form of output from a given input. An engine whose purpose is kinetic energy output from a fuel source is called a prime mover; alternatively, a motor is a device which produces kinetic energy from a preprocessed "fuel" (such as electricity, a flow of hydraulic fluid or compressed air). The various factors that contribute to the noise in engine are:

1 Combustion Noise.
2 Mechanical Noise: Some of the factors that cause mechanical noise are as follows: Engine clicking noise, Collapsed lifter noise. Valve lash noise, Damaged engine parts noise, Rapping or deep knocking engine noise
3 Piston Slap Noise.
4 Bearing Noise: Some of the factors that cause bearing noise are as follows: Dirt, Heat, Misalignment, Disassembly, Corrosion
5 Spark Knock (Detonation) Some of the factors that cause spark knock are as follows: EGR valve not working, Compression ratio too high, Engine overheating, Performance of fuel used.

2.2 Exhaust Noise.: The engine exhaust noise originates at the exhaust tailpipe openings and is transmitted through the cabin walls, firewall, and nose gear bay. This is the loudest and most objectionable noise heard.

3. BASIC REQUIREMENT OF MUFFLER DESIGN

3.1 General Requirements

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

3.2. Specific Requirement

- Reduce the sound emissions
- Replaceable
- Doesn't increase backpressure
- Easy mounting
- Within the budget
- Easy manufacturing

3.3 Functional Requirements Of A Muffler.:

There are numerous functional requirements that should be considered when designing a muffler for a specific application. Such functional requirements may include adequate insertion loss, backpressure, size, durability, desired sound, cost, shape and style. These functional requirements are detailed below focusing on an automotive muffler's functional requirements

Adequate Insertion Loss: The main functional of a muffler is to "muffle" or attenuate sound. An effective muffler will reduce the sound pressure of the noise source to the required level. In the case of an automotive muffler the noise in the exhaust system, generated by the engine, is to be reduced. A muffler performance or attenuating capability is generally defined in terms of insertion loss or transmission loss.

Backpressure: Backpressure represents the extra static pressure exerted by the muffler on the engine through the restriction in flow of exhaust gasses. Generally the better a muffler is at attenuating sound the more backpressure is generated. In a reactive muffler where good attenuation is achieved the exhaust gasses are forced to pass through numerous geometry changes and a fair amount of backpressure may be generated, which reduces the power output of the engine. Backpressure should be kept to a minimum to avoid power losses especially for performance vehicles where performance is paramount. Every time the exhaust gasses are forced to change direction additional backpressure is created. Therefore to limit backpressure geometric changes are to be kept to a minimum, a typical example of this is a "straight through" absorption silencer. Exhaust gasses are allowed to pass virtually unimpeded through the straight perforated pipe.

Size : The available space has a great influence on the size and therefore type of a muffler that may be used. A muffler may have its geometry designed for optimum attenuation however if it does not meet the space constraints, it is useless. Generally the larger a muffler is, the more it weights and the more it costs to manufacture. Effectively supporting a muffler is always a design issue and the larger a muffler is the more difficult it is to support. A muffler's mounting system not only needs to support the mufflers weight but it also needs to provide vibration isolation so that the vibration of the exhaust system is not transferred to the chassis and then to the passenger cabin. This vibration isolation is usually achieved with the use of hard rubber inserts and brackets that isolate or dampen vibration from the muffler to the chassis.

Durability: The life expectancy of a muffler is another important functional requirement especially when dealing with hot exhaust gasses and absorptive silencers that are found in performance vehicles. Overtime, hot exhaust gasses tend to clog the absorptive material with un burnt carbon particles or burn the absorptive material in the muffler. This causes the insertion loss to deteriorate. There are however, good products such as mineral wool, fiberglass, and sintered metal composites and white wool that resist such unwanted effects. Generally mufflers are made from corrosion resistive materials.

Aluminized vs. stainless are two types of steel commonly used to manufacture muffler. Stainless steel mufflers are considered more durable and can last up to 10 years. Aluminized mild steel mufflers are prone to corrosion, and therefore they typically last around 4 years. Mild steel or aluminized steel is generally used for temperature up to 500 0 c ,type 409 stainless steel up to 700 0 c and type 321 stainless steel for even higher temperatures. Reactive type mufflers with no absorption material are very durable and their performance doesn't diminish with time .

Desired sound: There has however been a growing trend in Australia in recent years for young drivers wanting to "hot up" their vehicles and this includes muffler modification. Muffler modification of a stock vehicle is generally done for two reasons being performance and sound. Vehicles leave the factory floor with mufflers generally designed for noise control not optimal performance. The standard reactive muffler is generally replaced with a straight through absorption silencer for aesthetics and to minimize backpressure and therefore improve vehicle performance.

Having exchanged the stock muffler for an absorptive type performance muffler generally means that exhaust noise is increased, leaving a noticeable deep rumble in the exhaust system. In most cases this sound is what the owner of the vehicle desires so that the public is aware of their presence. However mufflers should be designed so that exhaust noise emission is only barely audible within the passenger cabin and the appropriate government regulations are adhered to. Breakout noise from the muffler

shellmay be a problem and should be minimized together with flow-generated noise, especially when designing a muffler for a high insertion loss.

Cost: A major factor in any component is the cost to the consumer. Silencers not only have to be effective in performing their task they need to be affordable otherwise the product will fail in the marketplace. Aftermarket car exhaust mufflers vary in price from $90 to $700. The cost is dependent on the materials used in the construction of the muffler, design integrity, durability and labor costs.

Shape and Style: Automotive mufflers come in all different shapes, styles and sizes depending on the desired application. Generally automotive mufflers consist of an inlet and outlet tube separated by a larger chamber that is oval or round in geometry. The inside detail of this larger chamber may be one of numerous constructions. The end user of the muffler usually doesn't care what is inside this chamber so long as the muffler produces the desired sound and is aesthetically pleasing. It is therefore the task of the muffler designer to ensure that the muffler is functional as well as marketable.

4. DESIGN PARAMETERS OF MUFFLER

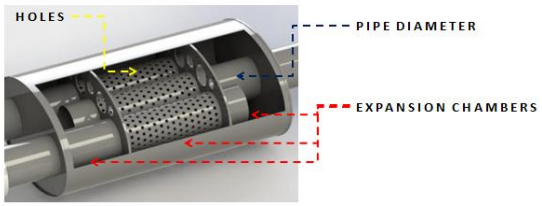

Fig 3 : Cut section and parameter of muffler

4.1Diameter of expansion chambers

As expansion chamber diameter increases, the Transmission Loss (TL) of the simple expansion chamber muffler increases

4.2 Expansion chamber length

As expansion chamber length increases keeping other muffler dimensions constant; there is no significant change in the muffler performance (TL).

4.3 Diameter of Inlet and outlet pipe

Transmission Loss of the reactive simple expansion chamber is inversely proportional to the inlet and outlet pipe diameter. As the inlet and outlet pipe diameter decreases the Transmission Loss increases and vice versa.

4.4 Holes on the pipe

The diameter of the hole is increased the backpressure decreases sharply.

5. SCOPE FOR FUTURE WORK.

The present work can be extended by working up on different configuration of simple expansion chamber muffler. Some of them are listed below.

- Expansion chamber with an extended inlet and outlet.
- Straight through absorption muffler.
- Side branch resonator.
- Helmholtz resonator.

Noise can be further attenuated by the addition of porous material inside the expansion chamber whilst maintaining the same muffler dimensions. Sound waves loose energy as they travel through a porous medium. The absorptive material (porous material) causes the fluctuating gas particles to convert acoustic energy to heat.

6. CONCLUSION

The objective of this paper to evaluate the acoustic performance of mufflers for vehicles.
If vehicles did not have a muffler there would be an unbearable amount of engine exhaust noise in our environment. Noise is defined us 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 doesn't 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.
A reactive muffler 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.

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 numerous chambers and changes in geometry that the exhaust gasses are forced to pass through.

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