DESIGN AND ANALYSIS OF AUTOMOTIVE MUFFLER

[1]Dr.Y. NAGINI, [2]M. MAHESH, [3]G. CHOODAMANI CHANDANA, [4]G. ARUN KUMAR, [5]K.SAI KRISHNA

[1](Assistant Professor), [2,3,4,5](Students)Mechanical Engineering Department, Chaitanya Bharathi Institute of Technology (A),Hyderabad,ynagini_mech@cbit.ac.in, maheshmaloth847@gmail.com, kathrojusaikrishna1@gmail.com,

ABSTRACT

Mufflers are most important part of engine system and commonly used in exhaust system to minimize sound transmissions caused by exhaust gases. Design of mufflers is a complex function that affects noise characteristics, emissions, and fuel efficiency of engine. Therefore, muffler design becomes important for noise reduction. Traditionally, muffler design has been an iterative process by trail and error. But these days the design and analysis are done by using CAD and ANSYS software. The essential function of a muffler is to facilitate the exhaust gases from the exhaust manifold while reducing the noise produced and backpressure by the engine. The exhaust gas must reach the atmospheric pressure, due to the perforations and inclination of exhaust muffler. There is a considerable amount of backpressure which restricts the free flow of the exhaust gases. It is necessary to reduce the backpressure as it enhances the fuel economy of the engine. The major concern for a designer is to ensure that the backpressure is to keep minimum. The geometry of muffler was modelled using CATIA V5 version. The dimensions for construction of geometry were selected from the standard design. The model was imported to ANSYS WORK BENCH FLUENT for further numerical simulations.

1.INTRODUCTION

Muffler is a device used to decrease the noise produced by the vehicles. it can also be termed as a silencer or Resonator. The high-pressure sound waves are absorbed by the components of muffler and converts it

into heat energy, hence designing of the muffler for uniform heat distribution is of major thing to do. Also exhaust gases leaves from the engine to the surrounding via exhaust muffler are at very high speed and temperature.

1.1.1 Exhaust system of automobile:

The exhaust system in automobiles collects the exhaust gases from the cylinders and removes harmful substances to reduce noise and air pollution produced by the exhaust gases. To ensure the exhaust system functions properly, the components are developed accordingly and coordinate with the specific vehicle and engine. The parts of exhaust system:

- Exhaust manifold
- Catalytic convertor
- Resonator
- Muffler
- Tailpipe

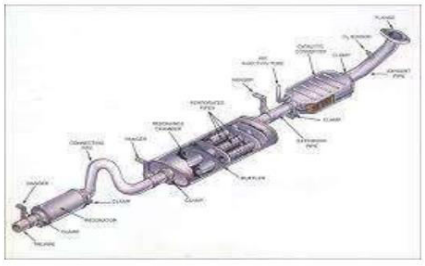

Fig1.1: Exhaust system of automobile

1.1.2 EXHAUST MAINFOLD:

The first part in the exhaust system is exhaust manifold and which collects the emissions from multiple cylinders in to the single pipe. It burns the incompletely burnt gases at high temperature and inspects the amount of oxygen entering the system. The manifold is made up of cast iron or stainless steel which absorbs the high temperature and pressure and maintain the whole exhaust system.

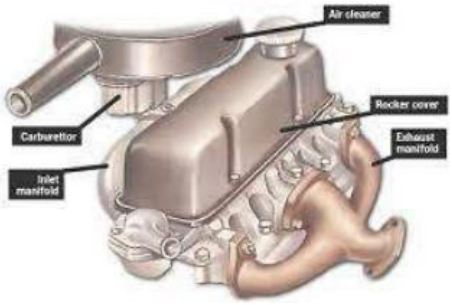

Fig 1.2: Exhaust manifold

1.1.3 CATALYTIC CONVERTER:

Catalytic converter takes the harmful gases that car produces in to its chamber known as catalyst before releasing them in to air. It is located on the underside of the vehicle, with two pipes coming out. These two pipes including catalyst are used to turn these

emissions safe before expelling in to air. The catalytic convertor is generally made of platinum, rhodium, or palladium. There are two types of catalytic convertors: two way and three ways.

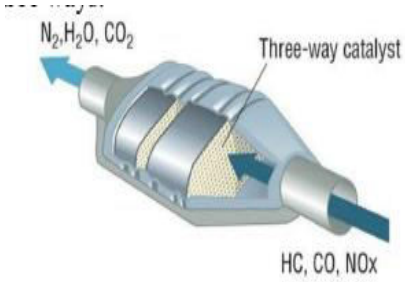

Fig 1.3: Sectional view of catalytic convertor

1.1.4 RESONATOR:

The resonator is an echo chamber which is used to cancel out sound produced by the vehicle up to certain frequency. The resonators are mainly used to change the vehicles engine noise before reaching the muffler

Fig 1.4: Sectional view of Resonator

1.1.5 MUFFLER:

The muffler is located at the bottom of the vehicle, they are made of steel and coated with aluminum to protect it from heat and other reactions. They are designed in a way that the noise which is reduced and gives us a pleasant sound while the vehicle is moving. When the exhaust valve opens, a large burst of the emissions is released in to the exhaust system and they produce the sound waves. Sound is the pressure formed by vibrations.so, when the valve is opened, a very high-pressured gas enters and collides with low pressure molecules thus creates a pressure waves and travel through exhaust system. The pressure wave is cancelled in muffler where another pressure wave of opposite wavelength is introduced.

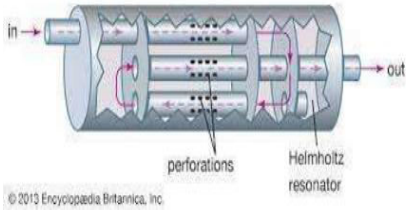

Fig 1.5: Sectional view of muffler

1.1.6 TAILPIPE:

The end of the exhaust pipe is known as tailpipe, the only visible part in an exhaust system where it vents to open air with straight or angled cut. The emissions are released through tailpipe after going through all parts in exhaust system. It is also used to give aesthetic looks to the automobile. Some vehicles may have more than one tailpipe.

They produce final reduction in exhaust pressure.

Fig 1.6: Tailpipe connected with muffler

1.2: MUFFLERS:

The muffler reduces the noise produced by the engine and controls the backpressure which improves the performance of the engine. Backpressure is caused by the engine's valves moving, colliding, and cancelling each other out. The muffler should be maintained well in order to prevent from unnecessary stress and damages to the engine and exhaust system. There are two types of mufflers which uses 1. Perforated pipe 2. Baffle pipe

1.2.1: PERFORATED PIPE:

The perforated pipe is located inside the muffler, they help to reduce or increase the sound produced in the engine. Including the sound suppression, the vehicle performance is also maintained by these perforated tubes. If the backpressure is high in chamber, then the vehicle does not produce any sound, generally very quiet. If the backpressure is less, the vehicle produces less sound than usual. In mufflers that use perforated the sound absorption is different than traditional chamber. The muffler forces the exhaust straight through a perforated pipe that contains metal, fiberglass, or some other kind of soundabsorbing material. This type of muffler is designed to reduce back pressure, which occurs when exhaust travels back up the pipes toward the engine, and consequently makes more noise

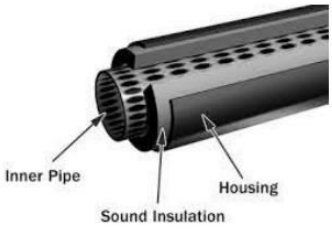

Fig 1.7: Sectional view of perforated muffler

1.2.2: BAFFLE PIPE:

Baffle is a porous tube inside a muffler. The effect of baffle on backpressure is only light but had a huge effect on the loudness. The short baffles with small porous can maintain normal backpressure which provides more volume. On the other hand, the baffle with large pores will minimize the volume without disturbing the high-performance

outflow. As sound waves move through this type of muffler, they bounce off the baffles and expend their energy inside the muffler, losing force and volume. If the baffle is wrapped with fiberglass, then the volume is decreased than the original. Now a days the mufflers are removable, so it all depends on the people to either have a quiet day or loud.

Fig 1.8: The baffle pipe

1.2.3: WORKING OF EXHAUST SYSTEM:

After the exhaust gases are collected, they go through the catalytic converter through piping's. Stock piping's are made in such a way that they can cut the cost of the car so they have unnecessary tapers that After the 4th cycle of a combustion engine, exhaust gases are produced. The exhaust manifold is connected to the engine and is made in such a way that it has pipes going in all cylinder. It has only one output. The manifold collects all the exhaust gases from different chambers at the same time and push them through a single pipe. The opening and closing of the exhaust manifold are controlled by a poppet valve. Oxygen sensors are used to check the amount of oxygen in the exhaust gas. Too much oxygen means the car is not using enough fuel and less oxygen means too much fuel is being used. This data is transferred to the TCU and it changes the fuel delivery accordingly.

1.2.4: WORKING OF MUFFLER: The muffler contains tubes, channels, and holes which direct gases and reduce exhaust pressure. It quiets the engine by reducing the sound pressure emitted. The muffler is designed not to just dampen sound, but to combine sound waves and make them cancel out one another. The muffler is also responsible for releasing the toxic gases, which can harm if released into the cabin of vehicle. Some mufflers are designed to be silent while others are specifically designed to create a growling sound. The muffler also improves the overall performance of the vehicle. The engine can generate more power faster if it is able to get rid of all the exhaust gases it produces quickly. Therefore, these mufflers are used.

2.LITERATURE SURVEY

1. GHAZALY and MOAAZ (2014) (1)

demonstrated two categories viz. transmission loss and insertion loss for a suitable design of the mufflers. They also emphasize various reviews dealing with muffler acoustics. They also observed that the exhaust backpressure is one of the crucial parameters that is always scrutinized by the automotive manufacturers to ensure superior performance by the engine.

2. YASUDA (2015) (2)

carried out investigation with a interconnection, a muffler with an interconnecting hole on the tail piece was proposed to improve its acoustic performance in the present research. Acoustic performance of the proposed muffler was studied experimentally and theoretically in frequency and time domain. It was found that the interconnecting hole enabled the proposed muffler to have a noise of low frequency and middle frequency at the same time. The frequency equation of this structure was derived using the acoustic electronic analogy. It is useful for estimating the attenuation performance at the stages of pre-design or tuning. The influence of structure parameters of the proposed muffler on the acoustic performance was studied.

3. MILIND S SWAMI (2015) (3)

carried out thermal analysis in the existing muffler of C.I. Engine the various influencing factors of muffler such as thermal concentration. Thermal concentration, thermal stress and properties of material have been analyzed by the software and the input values are analyzed from the experimental setup. Based on the results of analysis, thermal modification is to be done in the design in order to improve the life and performance.

4. VAIBHAV D. PRAJAPATI, ANKIT J. DESAI (2016) (4)

discuss about the diver's design is done on top of an existing Maruti Suzuki Wagon R silencer and modeled in software. From the simulation, it is concluded that Design 1 is much better in terms of pressure loss, so with higher pressure loss the noise level decreases. Design 6 is a combination of muffler and resonator also known as dual silencer which also has higher pressure loss than the existing design. So, for more sound attenuation, we might prefer Design 1 and Design 6. But merit score and poor score go hand in hand. Increasing pressure loss will increase backpressure, which is not good for the engine.

5. SHI and MAK (2017) (5)

A detailed examination of the acoustic attenuation of a periodic array of microperforated tube mufflers. Mufflers having sub millimeter perforations; provided considerable sound attenuation for duct noise without using absorbing materials. These mufflers were located periodically in a duct and resulted in modulation effects on transmission loss. It has been observed that by selecting an appropriate periodic distance; the periodic structure can influence the sound attenuation performance. VISHAL

3.MATERIALS & METHODOLOGY

3.1 MATERIAL SELECTION:

The muffler should withstand the temperature and pressure produced from the emission gases, so accordingly the material which is used for muffler should adapt to the conditions. 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. 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. 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. 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. Aluminized vs. stainless: The 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. 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, performance and sound. 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.

3.2 EXPERIMENTAL TESTING AND DESIGN FINALIZATION

The experimental determination of backpressure on engine and for different concepts is to be verified. The prototypes of all concepts that are made at the above step are tested for the transmission loss to verify the target value.

3.3 BOUNDARY CONDITIONS

Boundary conditions have a great impact on the result of analysis and a simple mistake in Boundary conditions makes the difference between a model with 30% of error and 3% of error. So, we must give correct boundary conditions to get accurate results.

- To fix the value of a displacement or a load on a specific area of the model
- To impart or not stiffness to the model
- To replace parts of the assembly
- To stabilize the solver in nonlinear analysis
- To suppress or create singularities near your model’s boundary

In this paper mass flow rate are the inlet boundary conditions and atmospheric pressures are outlet boundary conditions.

BOUNDARY	CONDITIONS
Mass flow rate at inlet	17.995kg/hr
Inlet temperature	633k
Pressure outlet	Atmospheric pressure

Table 3.1: Boundary conditions

3.4 REFERRED PARAMETERS

Case study - LCV Petrol Engine Vehicle (Hyundai i20)

Engine Data:

• Bore(D)=71 mm

• Stroke(L)=78.8 mm

• No. Cylinder(n)=4

• Engine Power(P)=118.36 bhp at 6000 RPM

SINGLE OUTLET/DOUBLE OUTLET EXHAUST MUFFLER	DIMENSIONS (MM)
Shell length	500
Shell diameter	186.9
Inlet pipe diameter	62.3
Outlet pipe diameter	62.3
Inlet pipe length	85
Outlet pipe length	85

Table 3.2: Input parameters of petrol engine vehicle

3.5 PROCEDURE

Taking boundary conditions, design 4 cad models of the muffler by taking referred parameters Now do the analysis using Ansys software and find out which design gives the best noise reduction, Less backpressure and good performance

4.EXPECTED RESULTS

4.1 Design-1 (model without perforation with single inlet and single outlet).

• Pressure Contour: From the figure 4.1, it can be observed that the pressure is decreasing from inlet to Outlet. Inlet pressure is 3755 Pa and Outlet pressure is 3736 Pa.

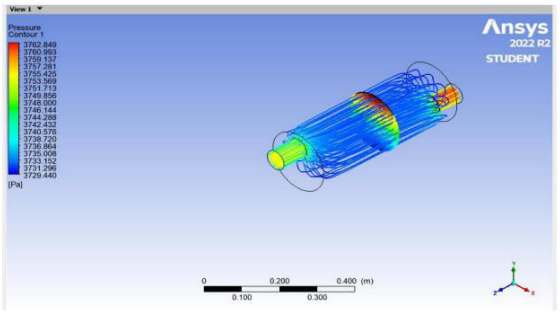

Fig- 4.1: Pressure contour of model 1

Velocity Contour: From the figure 4.2, it can be observed that the Velocity is increasing from inlet to Outlet. Inlet Velocity is 12.3 m/s and Outlet Velocity is 20.96m/s.

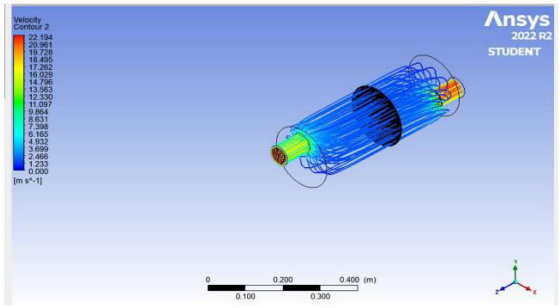

Fig-4.2: Velocity Contour of Model 1

4.2 Design-2 (3D CAD Model with Perforation with single inlet and single outlet).

• Pressure Contour: From the figure 4.3, it can be observed that the pressure is decreasing from inlet to Outlet. Inlet pressure is 468 Pa and Outlet pressure is 444 Pa.

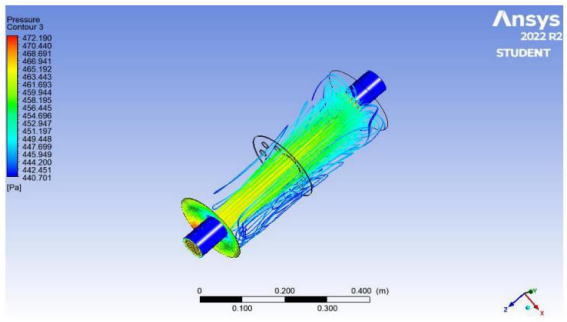

Fig-4.3: Pressure Contour of Model 2

Velocity Contour: From the figure 4.4, it can be observed that the Velocity is increasing from inlet to Outlet. Inlet Velocity is 20.187m/s and Outlet Velocity is 25.96m/s.

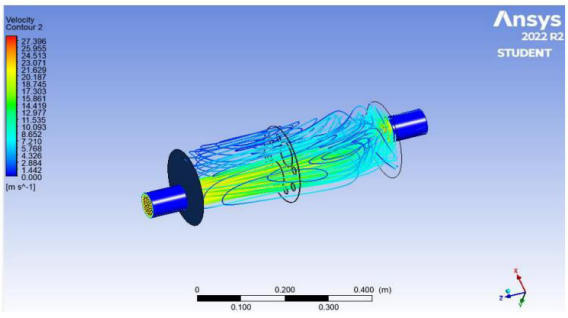

Fig-4.4: Velocity Contour of Model 2

4.3 Design-3 (3D CAD Model with Perforation with single inlet and double outlet).

• Pressure Contour: From the figure 4.5, it can be observed that the pressure is decreasing from inlet to Outlet. Inlet pressure is 778 Pa and Outlet pressure is 269 Pa.

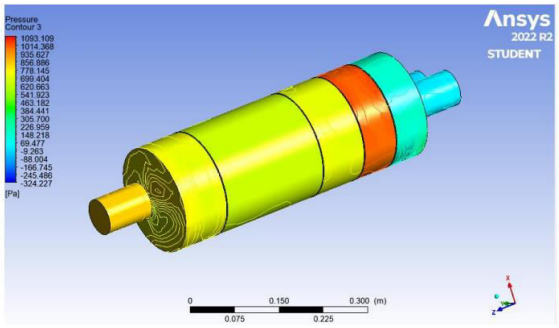

Fig-4.5: Pressure Contour of Model 3

Velocity Contour: From the figure 4.6, it can be observed that the Velocity is increasing from inlet to Outlet. Inlet Velocity is 23.2m/s and Outlet Velocity is 29.8m/s

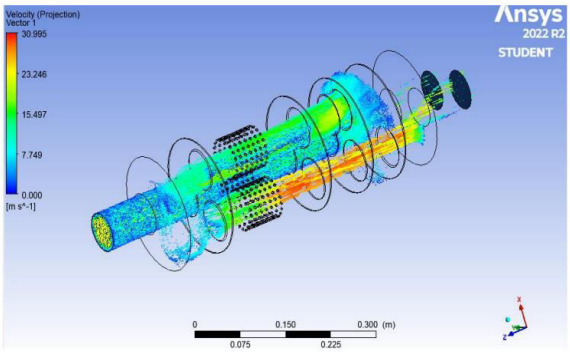

Fig-4.6: Velocity Contour of Model 3

• Pressure contour and Velocity contours have been obtained for the three mufflers models using CFD analysis.

• Acoustic Power levels, Transmission losses are also determined for each of the three models.

• Based on the given acoustic power level and transmission loss we need to consider that a lower acoustic power level and higher transmission losses indicates a lower noise level and the amount of sound energy transmitted through the exhaust system which is desirable.

• For model 1 muffler it has high Acoustic Power level of 139.6 dB and it has less transmission loss of 0.044 it is not preferable for noise reduction.

• Comparing of model 2 with model 1 it is quite better for noise reduction.

• Therefore, based on these factors the third muffler design with transmission loss of 9.224 and an acoustic power level of 109.1dB is the best choice as it strikes a good balance between reducing sound energy transmission and producing a lower overall noise level.

5.CONCLUSIONS

In this work Three Different models of a muffler have been designed for the engine output of an LCV diesel engine (i20) by using Solid-works and the flow has been simulated using ANSYS FLUENT. The flow characteristics obtained through the simulation were promising.

On Comparing the results of the three models, we observed that the third model was more effective in reducing the exhaust back pressure drop of 0.709Kpa. than the remaining two models because of its internal baffle arrangement.

• Maximum velocity in model 1 for velocity inlet boundary condition is 12.3m/s.

• Maximum velocity in model 2 for velocity inlet boundary condition is 20.187m/s.

• Maximum velocity in model 3 for velocity inlet boundary condition is 23.2m/s

• Model 1 with a pressure drop of 0.019kpa, has the lowest pressure drop and the highest acoustic power level of 139.6dB. It also has a transmission loss of 0.4044, indicating that it may not provide significant attenuation of noise at certain frequencies. • Model 2 with a pressure drop of 0.024kpa, has slightly higher pressure drop than model 1 but also provides significantly better acoustic attenuation with a transmission loss of 0.457

and a lower acoustic power level of 119. 2dB. This design is suitable for applications where noise reduction is a critical requirement, but some flow restrictions are acceptable.

• Model 3 with a pressure drop of 0.709kpa, has the highest pressure drop and the highest transmission loss of 9.224, indicating that it provides excellent acoustic attenuation. However, it also has the lowest acoustic power level of 109.1 dB, indicating this design is suitable for application where both noise reduction and flow restriction are critical requirement

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