Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

Design and Analysis of Automotive Muffler

Vaibhav D. Prajapati
PG Student,
Department of Automobile Engineering
Cgpit, Uka Tarsadia University
Bardoli, Gujarat , India

Ankit J. Desai
Asst. Professor,
Department of Mechanical/Automobile Engineering
Cgpit, Uka Tarsadia University
Bardoli, Gujarat , India

***Abstract*—Noise pollution is a very crucial problem for today's life, so to reduce noise level sound proofing is necessary. Muffler is a very important part of the vehicle exhaust system to reduce the noise produced by engine combustible products when passing through the exhaust system. To achieve maximum noise reduction with the minimum pressure drop is very difficult. A conventional muffler of Maruti-Suzuki WagonR is taken as reference and depending upon parameters new muffler is designed and modelled in software and analysis will be done numerical codes. Analysis ease the design parameters to be change, so that an appropriate design can be generate and maximum amount of noise reduction and pressure drop takes place with minimum back pressure. Comparison of conventional muffler and proposed designed muffler is based on amount of noise reduction, pressure drop and muffler life. In experimental setup pressure drop calculated by the water manometer tube and sound intensity measured by Sound Level Meter (SLM) device.**

Keywords—Pressure Drop; Back Pressure; Noise Reduction; Water Tube Manometer; Sound Level Meter(SLM)

I. INTRODUCTION

Noise from automobile is one of component noise pollution to the environment [1]. Muffler is a device to reduce the noise created inside the exhaust of an internal combustion engine [2]. Pressure drop also takes place inside the muffler. Muffler is situated in exhaust system after catalytic converter and also it is last component attached in exhaust system.

The sole purpose of an automotive muffler is to reduce engine noise emission. A car running without a muffler 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 unbearable amount of exhaust noise in our environment [3].

Sound is a pressure wave formed from pulses of alternating high and low pressure air. In an automotive engine, pressure waves generated when the exhaust valve repeatedly opens and lets high pressure gas into the exhaust system. These pressure pulses are the sound. As the engine rpm increases so do the pressure fluctuations and therefore the sound emitted is of a higher frequency. Noise is defined as an unwanted sound. The automotive muffler is able to allow the passage of exhaust gases while restricting the transmission of sound [3].

Back-pressure is defined as the difference between the ambient pressure and is due to a drop in stagnation pressure across various perforated elements and the sudden area discontinuities. Increase in back pressure leads to decrease in thermodynamic efficiency as well as the net power available [3]. Back pressure is directly related with the engine performance. Increase in back pressure reduces engine net power and reduction in back pressure improves engine efficiency.

Muffler is mainly divided in two types [1]:

1. Reactive muffler
2. Absorptive muffler

Other than these two type one more is exists, which is the combination of reactive and absorptive type muffler. The combined reactive and absorptive type muffler is commonly used now-a-days also known as hybrid muffler [4].

1.1 Reactive muffler

The reactive or reflective mufflers use the phenomenon of destructive interference to reduce noise. This means they are designed so that the sound wave 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 [3].

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 and have perforations that allow sound pulses to scatter out in numerous directions inside a chamber resulting in destructive interference [3].

Reactive mufflers are widely used in car exhaust system 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 chamber and changes in geometry that the exhaust gasses are forced to pass through.

Disadvantages : The downside to reactive muffler 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 the most passenger vehicles on our roads today[3].

1.2. Absorptive muffler

An absorptive or dissipative muffler, as shown in figure, 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 [3].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

Rock wool

Rock wool insulation's unique fire redundant properties combined with longer sound absorption, thermal insulation, dimensional stability and water resistance.[6]

Very much durable in insulation and bio-solubility in the body. Rockwool not contain any toxic, mutagenic or carcinogenic to reproduction or ozone-depleting substance. This material can be recycled. Melting point above 1000 ºC. non-combustible, and anti-vibrating property.

Light weight rock wool products with slightly flexible edges allows knitting together at the joints and fitting closely without leaving gaps and voids. Long term dimensional stability means that they stay in place, and keep their shape and maintain the same performance even after 50 years of period. Rock wool products can provide a very high level of sound absorption in walls roofs and under flooring. It can reduce the sound intensity maximum up to 50 dB depending upon the construction and geometry.[5]

II. LITERATURE REVIEW

Takashi Yasuda et.al,[1] in this paper based on the typical structure, a muffler with an interconnecting hole on the tail pipe was proposed to improve its acoustic performance in the present research. Acoustic performances of the proposed muffler were studied experimentally and theoretically in frequency and time domain. It was found that the interconnecting hole enabled the proposed muffler to have a noise attenuation performance of Helmholtz Resonator. So the proposed muffler can attenuate the 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.

Anant W. Wankhade et al.,[2] The objective of the paper is to propose a simple in construction, effective silencing device, which can achieve good results in minimizing the noise. The acoustic analysis is one of the methods which help to analyses the sound level at the tail pipe. This optimization revises acoustic analysis of muffler using Finite Element Analysis. The muffler is modelled in 'PRO E Wildfire 5.0 and 'COMSOL MULTIPHYSICS' is used for acoustic analysis. Effect of extrusion of inlet and outlet pipe inside the chamber and also the position of the extra inlet tube (i.e. divided inlet) to the chamber and then optimized this parameter to get the minimum sound pressure level (SPL) or maximum transmission loss (TL). The effect of SPL on the walls of the muffler is not considered. The material of the muffler is also not considered. This optimized model of elliptical muffler is manufacture and then validate with the experimental analysis.

Potente, Daniel, [3] this paper discuss about general principles of muffler design and explains the main advantages of various styles of mufflers. When designing a muffler for any application there are several functional requirements that should be considered, which include both acoustic and non-acoustic design issues as detailed in this paper. A graph of transmission loss vs. frequency for straight pipe absorptive silencer is shown in figure. By using a absorptive material double transmission loss can achieve

A. Selamet et al,[4] The acoustic attenuation of a single-pass, perforated concentric silencer filled with continuous strand fibre is investigated first theoretically and experimentally. The study is then extended to a specific type of hybrid silencer that consists of two single-pass perforated filling chambers combined with a Helmholtz resonator.

III. MATERIALS AND METHODS

3.1 Problem Formulation

The exhaust system is defined as the hardware necessary to vent the exhaust system from the vehicle beginning at the exhaust plane defined by the engine manufacturer and necessary to isolate the exhaust thermally from vehicle structures. The virtual design of the exhaust muffler, as minimum, include an accurate estimate of space required for the exhaust, back-pressure to the engine, system weight, gas species distributions, gas temperature distributions. Maruti-Suzuki WagonR muffler is being taken as reference muffler to compare with the proposed design of muffler with same engine exhaust parameters for better result. The existing design of muffler is shown in figure.

Figure 3- 1 Existing muffler of Maruti-Suzuki WagonR

This is a reactive type of muffler. So the reduction of sound takes place inside the muffler by sound wave cancellation. The resonant chamber is designed such that the same amount of frequency generated against the sound waves coming from the exhaust of engine so cancels each other effect. The inside view of muffler is shown in figure.

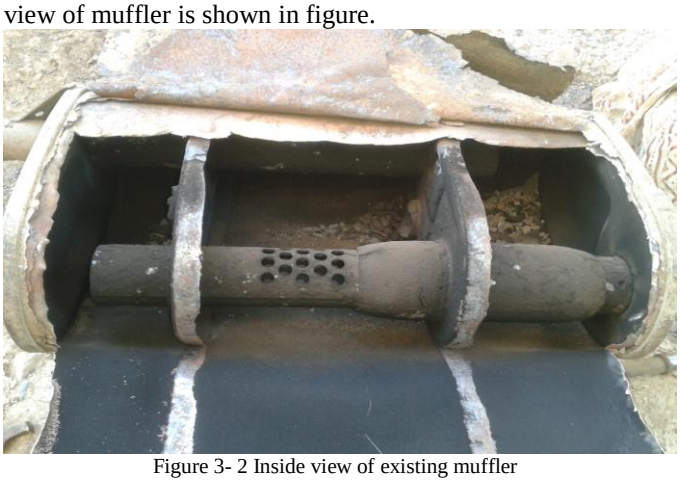

Figure 3- 2 Inside view of existing muffler

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

It is designed in main three resonant chambers, inlet chamber; middle chamber; outlet chamber. The exhaust gas from engine outlet enters inside the muffler from inlet pipe (at right in fig.) through the catalytic converter in a way. The gas strikes on muffler wall and reflected. Some of that reflects exactly opposite to direction of inlet flow gas and other gas moving in reverberation chamber and passes through baffle hole enters into the middle chamber. Here, gas from perforation and from inlet chamber comes together and enters into the outlet chamber from there it evacuated to the atmosphere by means of the outlet pipe.

Maruti-Suzuki WagonR engine data:

Bore diameter (D) = 69 mm,
Stroke Length (L) = 72 mm,
No. of Cylinders (n) = 3,
Engine Power (P) = 67.04 bhp @ 6200 rpm
Swept Volume = 0.998 litre

Maruti-Suzuki WagonR Muffler data:

Length (l) = 350 mm,
Width (w) = 235 mm,
Height (h) = 135 mm,
Inlet pipe diameter (OD) = 40 mm,
Inlet pipe diameter (ID) = 38 mm,
Outlet pipe diameter (OD) = 35 mm,
Outlet pipe diameter (ID) = 33 mm,
No. of perforated holes = 45
Perforated holes Diameter (d) = 8 mm

Velocity calculation

From the engine specification we can calculate volume flow rate and from that we can calculate velocity of exhaust gas at the outlet of engine.

For 1 litre four stroke WagonR engine,
Volume Flow Rate(VFR),

$$Q = \{\text{engine capacity(cc)} / 2\} * N \text{ (rpm)}$$

Where,

Q = Volume Flow Rate (cubic meter / sec)
N = Engine speed (RPS)

Now,

$$Q = AV$$

Where,

A = Cross sectional area,
V = velocity, m/s

Existing Design

From the existing muffler data a model is designed in Creo Parametric (student version) and simulated in ANSYS. A hidden line view of existing muffler is as shown in figure.

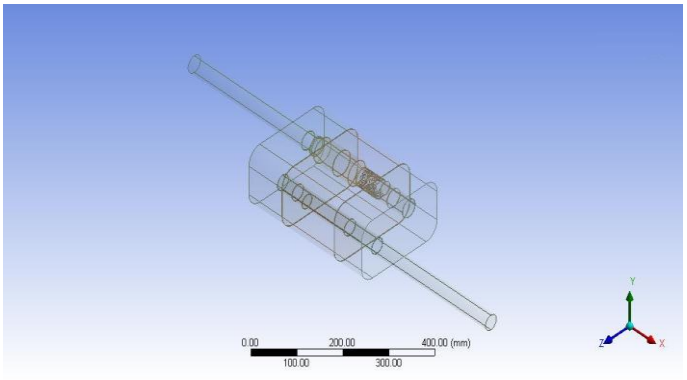

Figure 3- 3 Three dimensional view of existing muffler

Design 1

The design of muffler is, with same volume as the existing muffler. But the internal structure of the muffler so that the exhaust gas from engine get divided into two pipes which makes easy to flow. Perforation provided to the pipe in the middle chamber for high frequency waves to come out. This design is also of two types. The tail pipe diameter is changed for the investigation. Internal view of the design is as shown in figure.

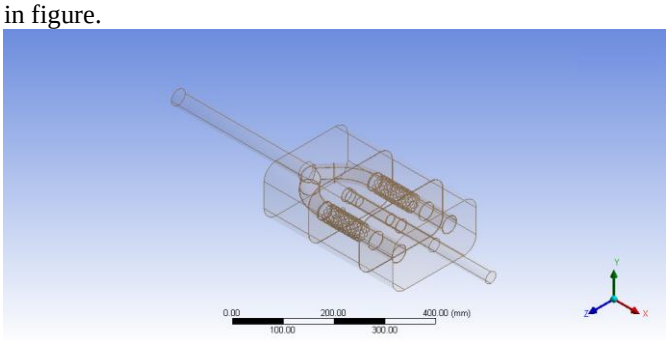

Figure 3- 4 Three dimensional view of Design 1

Design 2

This muffler is designed so that easy evacuation of the flow gases. The flow is divided by the arrangement like plate then from both side gas comes opposite in direction so that cancel each other effect at some level. The internal view is as shown in figure

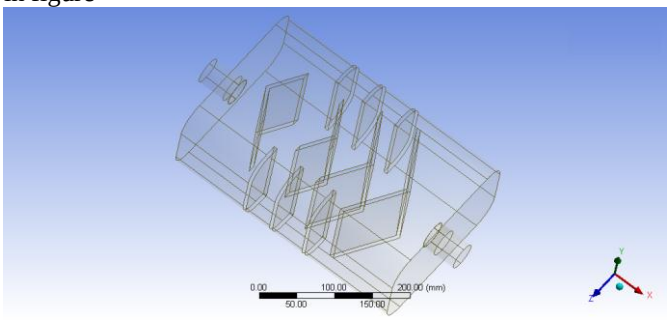

Figure 3- 5Three dimensional view of Design 2

Design 3

This is a simple perforated muffler of elliptical shape. Only two pipes, one is inlet and other is outlet. The inlet pipe inside the muffler chamber is of convergent-divergent type with the perforation provided on its surface. This muffler is designed aiming that with the simple construction of the muffler how much the pressure drop takes place. The internal view is as shown in figure

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

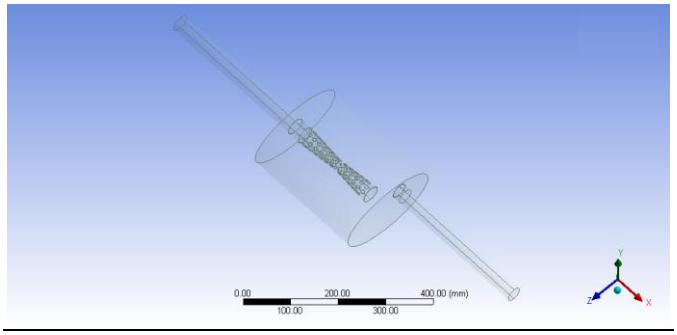

Figure 3- 6 Three dimensional view of Design 3

Design 4

In this elliptical design three resonant chamber is provided. Inside the body three pipes for better evacuation of gas. There is also perforation on the middle pipe so that some waves can come out from it and cancel the other same frequency waves. The middle chamber also be filled by the sound proofing material to convert it into the hybrid muffler. The inside view of muffler is as shown in figure 3-7.

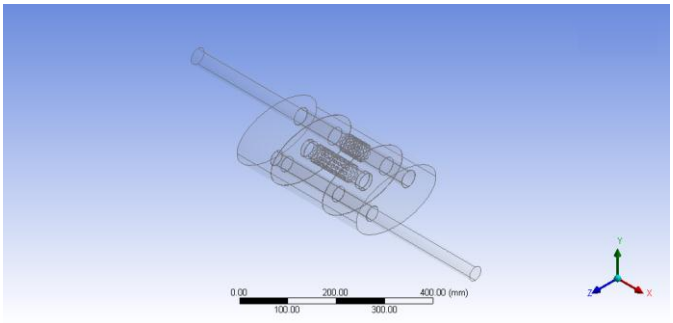

Figure 3- 7 Three dimensional view of Design 4

Design 5

This is resonator, a part of exhaust assembly after the muffler to reduce more sound. The purpose of resonator is further sound reduction. It is simple in construction so that ease for gas passes through it. The design as shown in figure

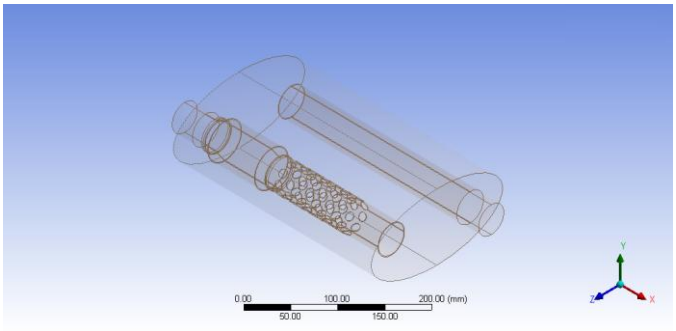

Figure 3- 8 Three dimensional view of Design 5

Design 6

In this design shown in figure 4-14, mufflers and resonator attached with a pipe to see the effect of the pressure reduction and reduction in the sound.

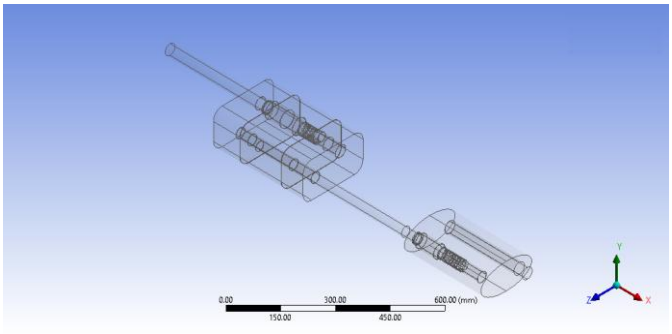

Figure 3- 9 Three dimensional view of Design 6

boundary condition

The engine has maximum power 64.07 bhp at 6200 rpm. So, we calculated velocity at 6000 rpm is 39.7899 m/s. other inlet and outlet boundary condition for the analysis is shown in table

Table 3-1 boundary condition

Inlet Condition	
Inlet velocity	39.7899 m/s
Inlet temperature	773 K
Density(constant at temperature)	1.225 kg/
Outlet Condition	
Opening at outlet	0.05 Pa
Outlet temperature	300 K
Energy	On

For this boundary condition analysis has been done in Computation Fluid Dynamics tool CFX of ANSYS (student version). Each muffler is analysed under same boundary condition as mentioned above.

IV RESULTS

For different design of mufflers analysis is done in CFX tool of ANSYS and for validity the simulation results experiments results also computed. For the simulation boundary condition for the various muffler is velocity of 39.7899 m/s for maximum power of engine at 6200 rpm.

4.1 Simulation Results

Existing Design

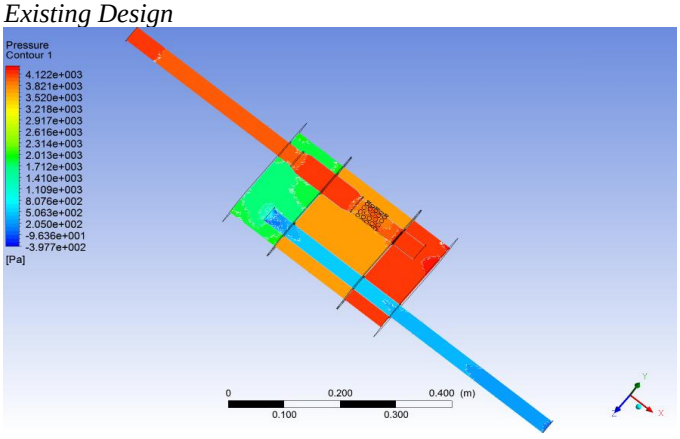

Figure 4- 1 Pressure contour of existing design

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

From the pressure contour figure we can find that maximum pressure is in inlet chamber of the muffler and gradually decrease in the other chamber.

Design 1

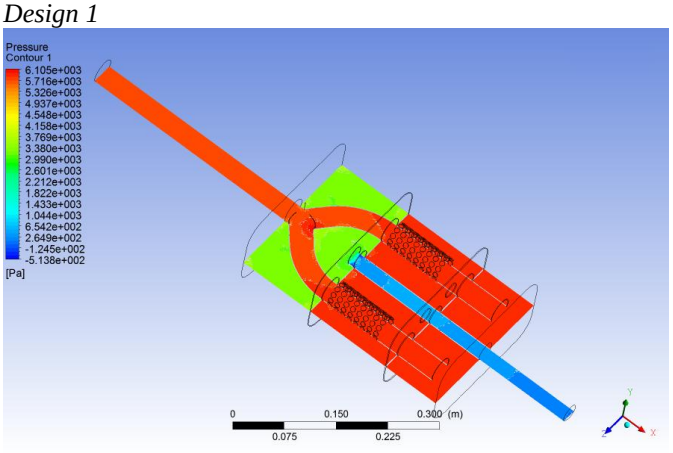

Figure 4- 2 Pressure contour of design 1

In above figure, design 1 for 30 mm outlet pipe diameter shows the better pressure loss than the existing design. The value of pressure loss is 6105 Pa. due to more pressure loss velocity at outlet in this design is much higher.

Design 2

As the design 2 muffler is simple in construction with only arrangement of plates at different angle to guide the way for exhaust gases are poor in pressure loss. Because the flow is passed through the plates easily due to less obstacles. So this design is not good at pressure loss as compared to the existing design.

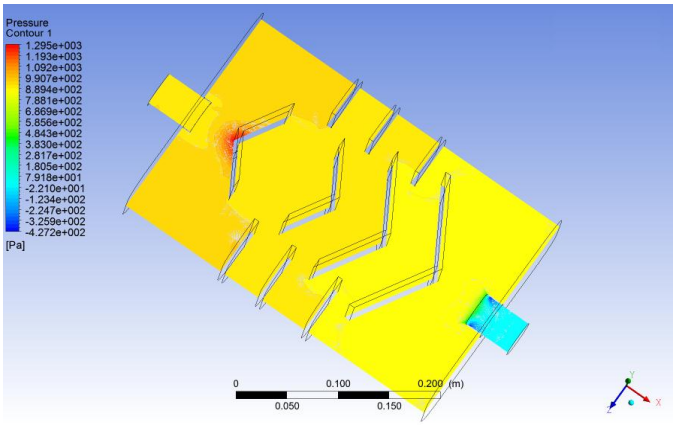

Figure 4- 3 Pressure contour of design 2

Design 3

Muffler design is so simple that having only one inlet and one outlet pipe having different axis. The inlet pipe perforated and convergent divergent type so the flow gas passes through it easily. So as design 2 this also having a lesser pressure drop.

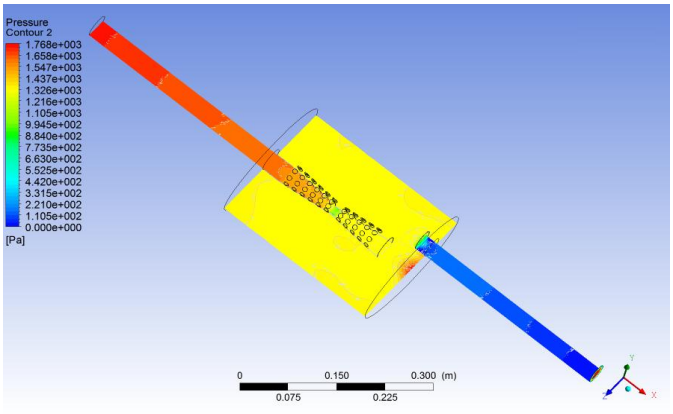

Figure 4- 4 Pressure contour of design 3

Design 4

The maximum pressure is at inlet chamber and when it moves to other chamber through a pipe it having a good pressure loss and with that path for flow gas is easy than existing design. Value of pressure loss is around 2050 Pa.

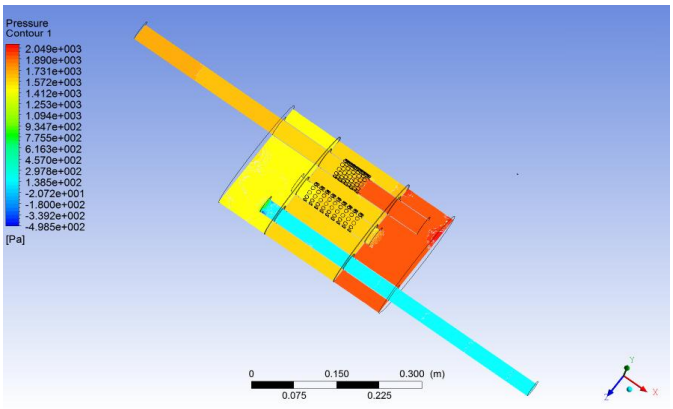

Figure 4- 5 Pressure contour of design 4

Design 5

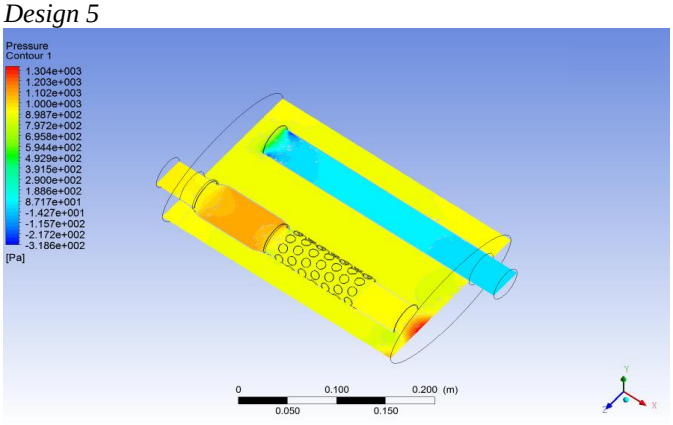

Figure 4- 6 Pressure contour of Design 5

As resonator is only a series member after the muffler for better sound proofing and due to simple in construction it having a lower pressure loss value.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 05, May-2016

Design 6

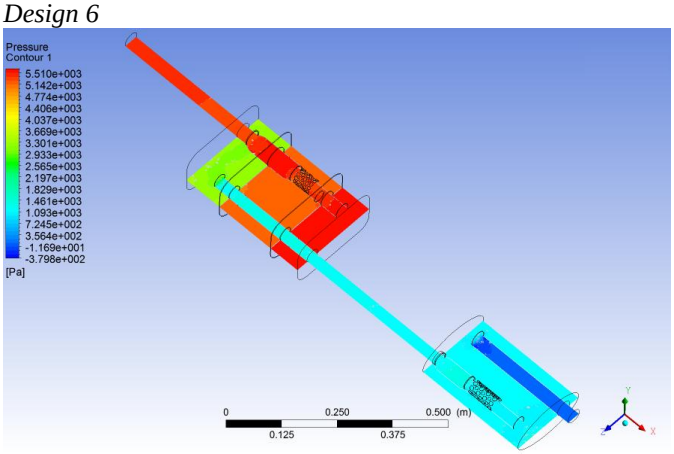

Figure 4- 7 Pressure contour of Design 6

From figure 4-7, a resonator is attached with muffler in a series after it. It is clear from the figure that excess pressure loss occurs due to resonator. But simultaneously it increases the back pressure value. So little modification require in that

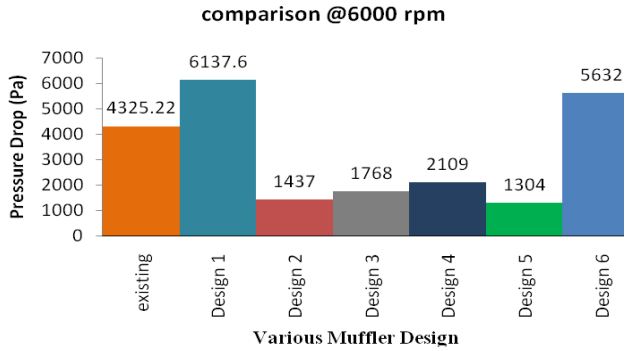

Figure 4- 8 Comparison of existing and various proposed design

From the results of all mufflers graph is generated for 6000 rpm as shown in figure 4-8. It shows that design 1 having maximum pressure loss (6137.6 Pa) because of smaller tail pipe diameter which gives more noise reduction than others. After that twin muffler having a pressure loss of 5632 because of resonator attached at muffler tail pipe which further increase in the pressure loss hence reduce the noise. But more the pressure loss tends to more back pressure which affect the performance of the engine. Other design than these having a lesser pressure drop because they are providing easy way for the gases to passes through. But they having lower noise reduction quality.

V CONCLUSION

Various design are created in comparison to the existing muffler of Maruti-Suzuki WagonR car and simulated in software. From the simulation it is concluded that design 1 is far better in pressure loss so with higher pressure loss there is more noise reduction. Design 6 which is the combination of muffler and resonator also called as twin muffler also having higher pressure loss than existing design. So for more sound attenuation we can prefer design 1 and design 6. But merit and demerit are always together increase in pressure loss will increase back pressure which is not good for engine.

ACKNOWLEDGMENT

I take opportunity to express my immense gratitude to my guide. I am greatful to them for their prolonged interest in my work and excellent guidance. They have been a constant source of inspiration to me. By their uncompromising demand for quality and their instance for meeting the deadlines I could do such a work. I very much thankful to my family for their motivation and support and those person who have directly or indirectly helped me in making this work.

REFERENCES

[1] Yasuda T., Wu C., Nakagawa N., Nagamura K., "Studies on an Automobile Muffler With The Acoustic Characteristics of Low-pass Filter and Helmholtz resonator", Applied Acoustics, 74: (2013) 49-57

[2] Wankhade A. W., Bhattu A. P., "Optimization and Experimental Validation of Elliptical Reactive Muffler with Central Inlet Central Outlet", International Journal of Engineering Research & Technology, ISSN: 2278-0181, Vol. 4 Issue 05, May-2015

[3] Potente, Daniel, "General Design Principles For an Automotive Muffler", ACOUSTICS 2005, 9-11 November 2005, Busselton, Australia

[4] Selamet A., Lee I.J., Huff N.T., "Acoustic Attenuation of Hybrid Silencers", Journal of Sound and Vibration 262; (2003): 509-527

[5] Yasuda T, Wu C., Nakagawa N., Nagamura K Bazhenov D.V., Bazhenova L.A. et al., "Noise Silencer in the Form of Helmholtz Resonator at the Outlet of an Air Duct of Finite Length", Acoustical Physics, Vol. 46; No. 3; 2000: pp. 256-260

[6] http://www.rockwool.in/why+rockwool-c7-/performance+and+properties