

DESIGN AND ANALYSIS OF CONVENTIONAL EXHAUST MUFFLER FOR BETTER NOISE REDUCTION WITH FEA VALIDATION

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Abstract: This paper presents a different approach towards an automobile exhaust muffler. An effort has been made to understand importance of an exhaust muffler in automobiles and various types and working of them. Compression ignitions are the ones who required muffler essentially. Conventional design of mufflers are lacking in performance, noise reduction and maintenance comparing with advance designs. So selection procedure of modified muffler design is based on finite element analysis and experimental testing. This research has been done in an Automobile Industry which is facing this issue particularly in compression ignition internal combustion engine. An approach has been made to solve the root cause.

Keywords: Conventional muffler, noise reduction, compression ignition, delta plate

I INTRODUCTION

Noise pollution is one of the biggest problems the world is currently fighting with and major components of noise pollution are exhaust noise and industrial noise. Exhaust systems were developed to reduce the exhaust noise and to meet required decibel levels and quality of sound based on government emission and environmental protection norms. So, this point has attracted researchers to do developments in this area, majority of development in acoustic filters and mufflers have been occurred in last few years.

Exhaust mufflers are important and essential part of engine system and commonly being used in exhaust system to control exhaust noise coming out of internal combustion engine. Internal combustion engines required using exhaust muffler due to higher combustion pressure of gas; it generates very loud noise every cycle of engine which is not bearable if a device which controls the noise is not used. Design of exhaust muffler is not a simple task. Noise characteristics, emission, fuel efficiency, engine performance due to back pressure are major factors which affects design of muffler. Conventionally muffler design was totally based on trial and error method. Due to importance of product development cycle duration of a company many researches has been done and number of theories and science of muffler has undergone muffler design advancement and this leads to less number of iterations and less complexness in design.

In this paper a practical approach has been made to design, analysis and development of a conventional muffler, which will give advantages of using conventional design with modern science. Conventional design will give easiness, cost effectiveness and less maintenance requirement while modern acoustic science will give better performance characteristics, which will give shorten product development time.

The reason behind use of exhaust muffler is very simple. An internal combustion engine is having high compression rate and working cycle temperature is comparatively high. Every cycles exhaust gas produces with high pressure and temperature. When exhaust gas come outside of engine it produces very high noise which is not bearable. Muffler is essential exhaust system component of an automotive used to reduce and control engine noise to surrounding. There are two main methods to damping the noise, reflection or interference and absorption. In reflective mufflers the sound wave reflection principle is used to create a maximum amount of destructive interferences. Absorptive mufflers works on sound absorbing principle, this principle is used to reduce noise by use of sound absorbing materials fitted in it. Exhaust muffler performance is determined numerically by method of Transmission loss. In other words acoustic performance can be described by transmission loss, the more transmission loss the more noise cancelation. By having logarithmic value ratio of input power and output power transmission loss at different frequencies can be calculated. In this paper a single expansion chamber having single delta plate is designed and analyzed by finite element analysis method. Delta plate is provided to separate the sound waves and mix them again from opposite direction to make destructive interference. Day by day vehicle numbers are increasing and it leads to noise pollution which is very harmful to the nature. So a good design of exhaust muffler is very much needed in automobile vehicles.

An exhaust muffler should have following characteristics:

- General characteristics
 - Maintenance free – An exhaust muffler must be very simple in maintenance procedure.
 - Light weight, compact and simple in design – Muffler must have these characteristics which lead to its performance.
 - Performance – Muffler must have good performance otherwise it will lead to decrease vehicle performance.
- Specified characteristics
 - Noise reduction – The prime need of any muffler is noise reduction capability.
 - Replaceable and interchangeable – Muffler must have this quality. At the time of replacement it must be compatible to fit with exhaust manifold and mountings.
 - Mounting - Mounting of muffler must be clear at proper place and well finished.
 - Manufacturing and cost – Manufacturing time must not be very long because it directly affects company's profit and cost of muffler.

1.1 Types of muffler

A. Absorptive muffler

Absorptive mufflers do not interfere with exhaust gas pressure and only absorb sound waves to reduce noise level. Absorptive muffler is also called as glass pack muffler and it reduces backpressure. Main disadvantage of this muffler is comparing with other mufflers it generates higher noise. Absorptive muffler is shown in figure 1.

B. Reactive muffler

Reactive muffler is having extended inlet and extended outlet tubes in chamber. There are many pipe parts which are interconnected with many other chambers in this muffler. When sound waves enter into discontinuity area an impedance mismatch occurs and on this basis reactive muffler works. This impedance mismatch of sound waves then gets reflected towards the source or between the chambers, these results in reducing the sound of pressure wave's intensity. Reflective effect of silencer chamber and piping system (resonators) prevents sound waves to travel after the silencer. The reactive silencers are widely used to reduce the exhaust noise of internal combustion engine because they are effective at lower frequencies compared to higher frequencies. Reactive muffler is shown in figure 1.

C. Combination muffler

Some silencers collaborate with both reactive and absorptive elements in one muffler to utilize good qualities to extend the noise reduction performance over a broader noise spectrum. These silencers are also widely used to reduce engine exhaust noise. Combination muffler is shown in figure 1.

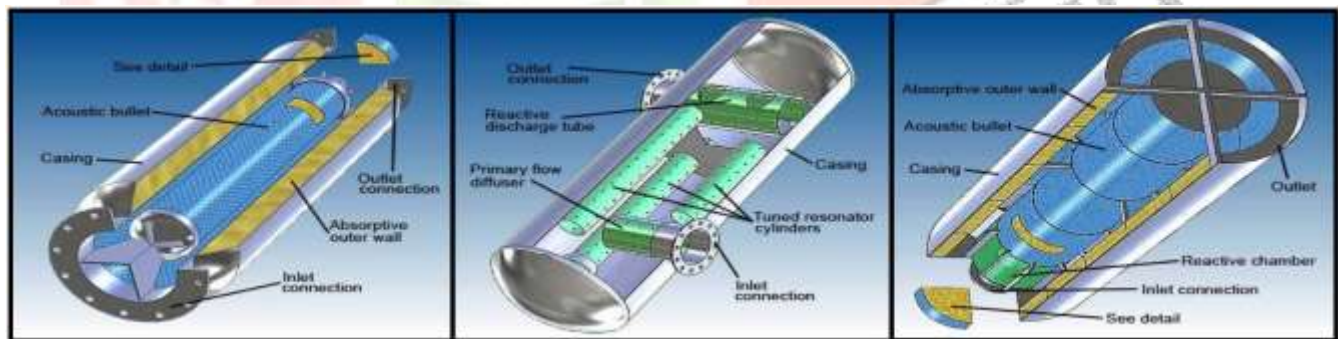


Figure 1- Different types of exhaust mufflers: Absorptive muffler, Reactive muffler, Combination muffler respectively ^[4]

1.2 Problems regarding faulty exhaust muffler

Regarding automobile vehicles preventive maintenance is always good for the vehicle life, most of the time it saves vehicle owners money. This same thing also applies to muffler. If routine maintenance done to the muffler it can save money and increase life of it. Sometimes it may happen that ignorance of small issue regarding muffler can lead to replacement of whole assembly. Though, some vehicle owners don't prefer preventive maintenance and that ends with the replacement of muffler. There are some key points by which vehicle owners can identify that there is an issue regarding muffler.

A. Unpleasant smells

Third one is bad smell coming out of exhaust is one of the most dangerous problems. If muffler is working properly then it will funnel exhaust fumes outside and away from vehicle. Those fumes can be stuck inside of the vehicle if there is a leak or other problem. Exhaust gas could be fatal over time so it is most dangerous problem. Whenever this issue found out vehicle must undergo servicing from mechanic. There are many systems and components which neither seen nor heard when they are working properly.

Unfortunately this leads to make them out of site and out of observation. So issues regarding muffler must resolved without any delay. It may cost more repairing bills. So always check for these three warning signs.

B. Loud exhaust noises

When a muffler is working properly it works quietly in the background. When something goes wrong it work loudly. So the most common sign is a sudden change in the volume of your muffler. If muffler creates loud noise then its sign that muffler should checked by mechanic.

C. Lower efficiency and mileage

Better fuel economy is one of the major benefit can be achieved from a well-tuned exhaust system. If more visits of petrol pump are needed then it shown your vehicle has some issue. In some vehicles there is dash board mounted system which tracks mileage. By this system also performance can be compared and if problem can be found before it becomes serious.

II PROBLEM STATEMENT

One of the most irritating and major issue facing by customer of the company is not properly working of exhaust muffler. Those vehicles which are having this problem are majority of compression ignition engine. Compression ignition engines are having larger compression ratio so that their exhaust gas is also having very high pressure and temperature. So exhaust muffler also must bear this much pressurized exhaust gas. But due to less maintenance done by vehicle owners, mounting and fittings are getting loosen.

One more issue is after sometime mufflers are getting small cracks but without maintenance these cracks are getting larger and larger and it leads to loud exhaust noise and then finally breaking of the muffler.

The problem with modern muffler is they are highly expensive but they are having good characteristics regarding noise reduction. Due to higher rates of modern automobile exhaust muffler customers do not want to install a new muffler and as a whole it creates too much noise pollution. So customers are in need to some solution to have economical rate mufflers. So here design modification of conventional muffler and its analysis is carried out to have both conventional and modern muffler's advantages.

Conventional mufflers are having similar size and shape with the muffler design of Flowmaster muffler manufacturer which is United States of America based company. In figure 2 a Flowmaster 40 series muffler's cross-sectional view is shown. From that design base of modified muffler can be taken and then analysis of that design can be carried out.

The prime change is to set delta plate at the center from the front of muffler the section plate to set at the front of center portion of muffler. The outer dimensions or boundary and inlet-outlet pipe diameter are not being changed. To make exhaust gas flow smooth and easy to improve the design the section plate is modified as shown in figure 2. The figure shows only base changes in the muffler. The delta plate and cut plate diameter of section plate.

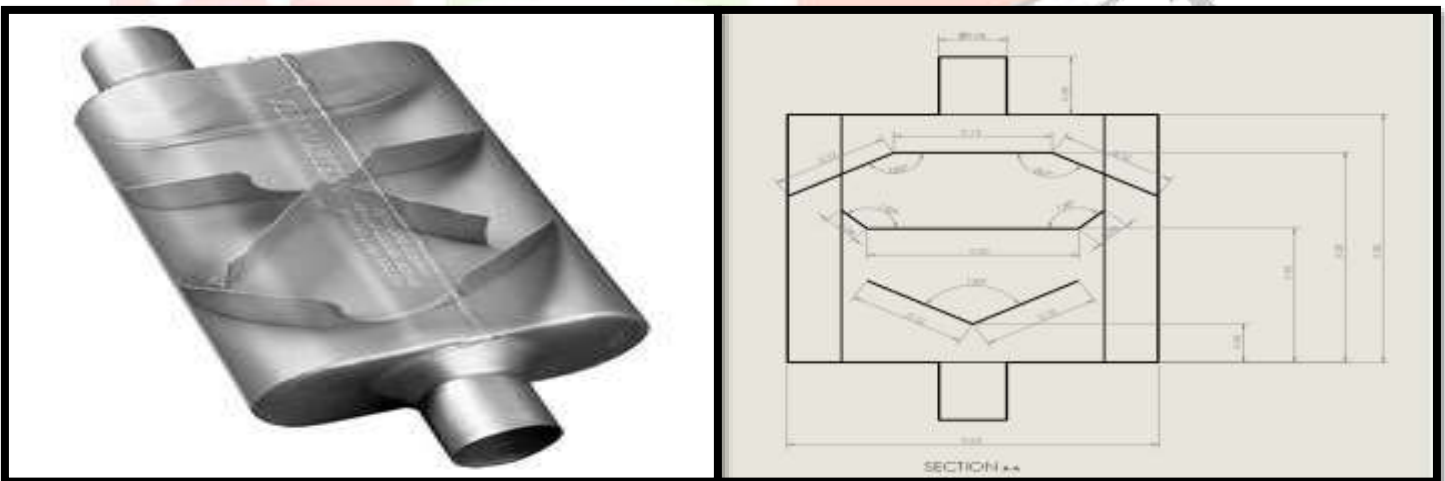


Figure 2- sectional cut view of 40 series Flowmaster design & design with basic modifications ^[11]

III METHODOLOGY

To study and investigate fluid flow behavior is having significance task for muffler which is having extended inlet-outlet muffler to drop pressure loss between the ends. To calculate back pressure in CFD software lots of efforts are required. One study CFD analysis on cross flow type and perforated type of muffler has been done by Mr. Saifee Ali Akbar A., Mr. Harshad Keshar and Mr. B.Venkateshan and discussed the effects of an inlet velocity flow rate and distribution of pressure inside the muffler chambers.

3.1 Change in dimension

In the modified muffler some parameters only being changed and effects on air flow is studied due to those changes. The parameters being changes are length, angle and cut plate diameter.

A. Change in delta plate angle

The plate length is constant in this study only delta plate angle is being changed. The plate length in our base modified design is 0.120 meter. From angles 80° to 170° range the analysis is taken. The different angles which are to be analyzed are 80°, 90°, 115°, 145°, 170°. thickness of delta plate is taken constant in this analysis i.e. 0.003912 meter.

Table 1- Different delta plate angles

Sr.no.	Angle(in degrees)	Length of plates(m)	Thickness of plate(m)
1	80°	0.120	0.003912
2	90°	0.120	0.003912
3	115°	0.120	0.003912
4	145°	0.120	0.003912
5	170°	0.120	0.003912

B. Change in diameter of curve plate

Further diameter of cut plate is changing and other parameters like length of plates, angles of plate and thickness are constant. Diameter range is 0.05050 to 0.08850 meter.

Table 2- Different values of diameter of cut plate

Sr.no	Change in diameter (m)	Length(m)	Both side plate (m)	Angle (in degrees)	Thickness of plate (m)
1	0.05050	0.150	0.120	145	0.003912
2	0.06050	0.150	0.120	145	0.003912
3	0.07050	0.150	0.120	145	0.003912
4	0.08850	0.150	0.120	145	0.003912

C. Boundary conditions

To study fluid flow behavior is very important task for muffler which is having extended inlet and outlet. To calculate transmission loss or pressure drop between two ends is essential thing to study because it indicates the performance of muffler. Following are the boundary conditions to study fluid flow behavior and transmission loss. One study has done by Mr. Saifee Ali Akbar A., Mr. Harshad Keshar and Mr. B.Venkateshan has done on this topic.

Table 3- Boundary Conditions

Sr.no.	Different variables	
1	Model	40 series type delta flow
2	Solver of	2 nd order implicit function
4	Fluid type	Air (in ideal state)
5	Pre-acting pressure	101318 Pa
Boundary conditions		
1	Velocity of air	15 m/s

2	Outer gauge pressure reading	0 Pa
3	Turbulent intensity of air	3%
4	Hydraulic diameter	Diameter of inlet-outlet
5	Density of air ρ	1.225 kg/m ³
6	Sound speed in air	340.0 m/s
7	Porosity σ	0.2827
8	Flow resistivity R	4896 rayl/m

IV RESULT AND DISCUSSION

4.1 Conventional design pressure and velocity distribution

Conventional design of muffler is good in air flow rate. In the following figure pressure at inlet is 101466.7592 Pa and outlet pressure is 101325 Pa. pressure drop between two ends is 141.7592 Pa. Following figure also shows velocity distribution, inlet velocity is 10.24 meter/second and outlet velocity is 13.33 meter/second.

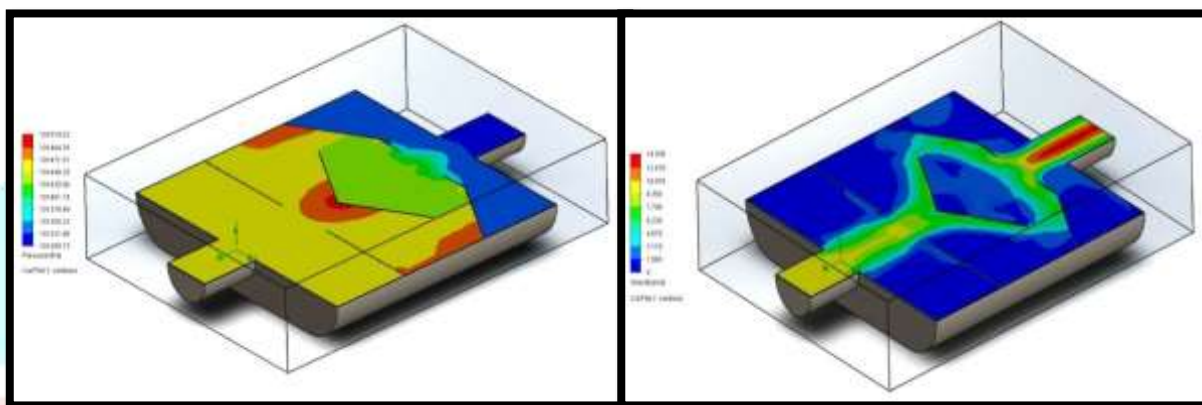


Figure 3 - Conventional muffler pressure and velocity distribution

4.2 Basic modified design pressure and velocity distribution

With basic modifications as discussed above rearrangement of delta plate angle and section plate the pressure and velocity distribution with same inputs and boundary conditions is as below.

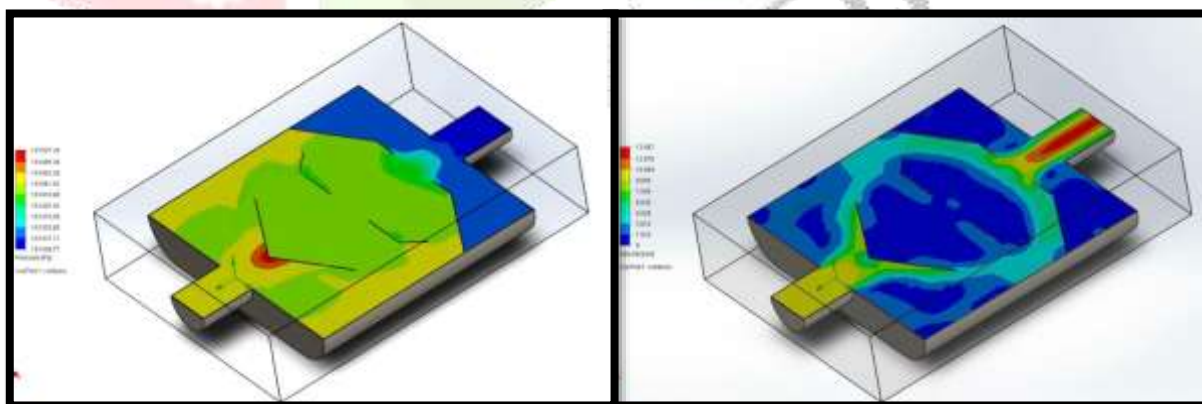


Figure 4 Pressure and Velocity distribution with basic modifications

4.3 Delta plate angle modification

By keeping all other parameters constant as discussed above, for different delta plate angles pressure and velocity distribution is carried out and from the chart angle of delta plate for least acoustic power is for the angle 145°. Following figure shows pressure and velocity distribution for input pressure 101435.7560 Pa and output pressure 101325 Pa, so drop is 110.7560 Pa. Inlet velocity 10.24 meter/second and output velocity 13.332 meter/second. This boundary is same for diameter modification also.

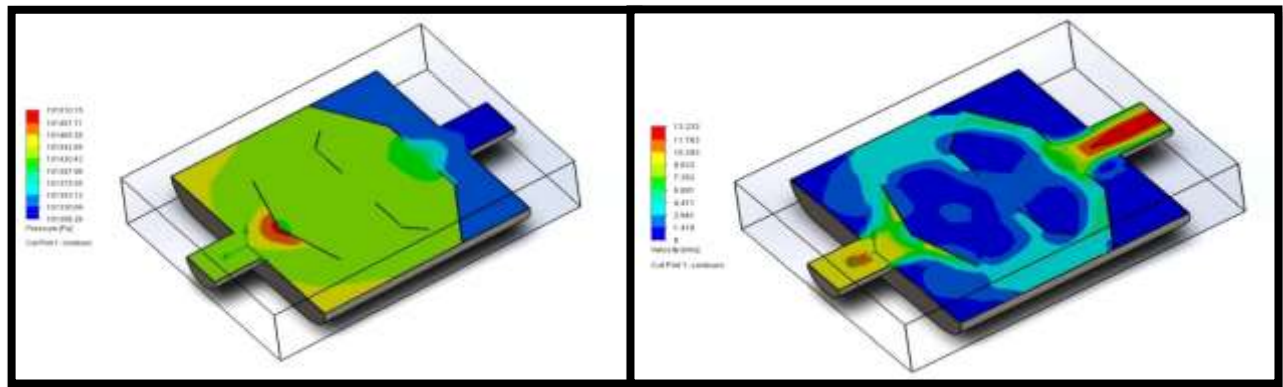
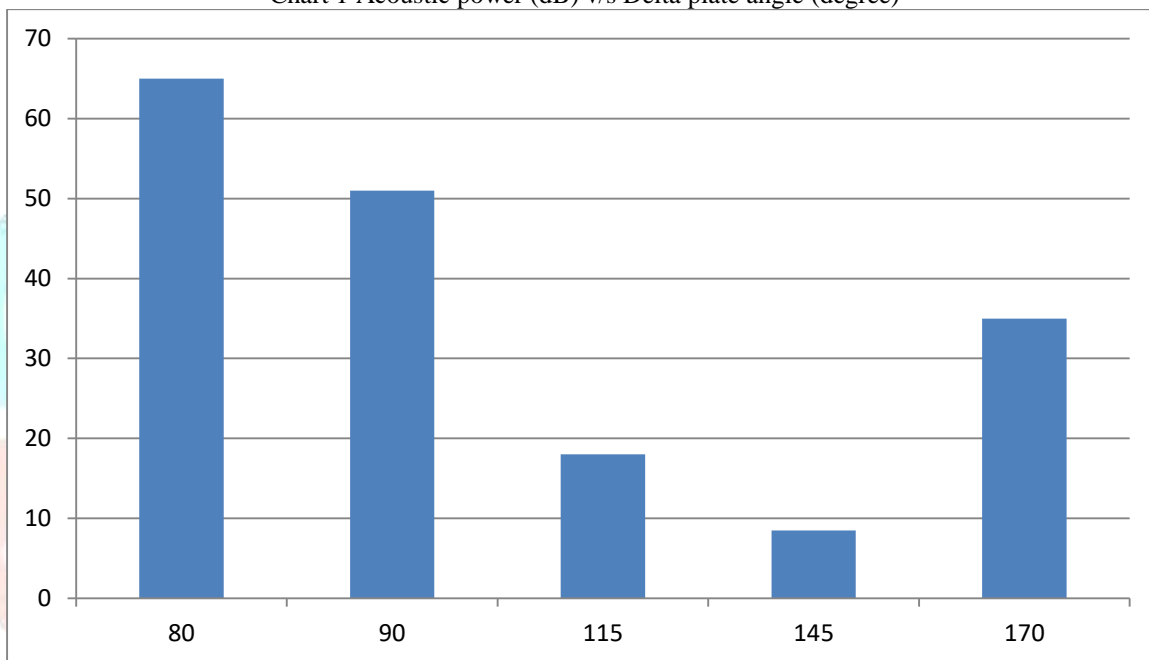


Figure 5 Pressure and velocity distribution at delta plate angle 145°

Chart 1 Acoustic power (dB) v/s Delta plate angle (degree)



4.4 Cut plate diameter modification

By keeping all the parameters constant other than cut plate diameter the result of pressure and velocity distribution is carried out and as per the chart showing the least acoustic power value is for the diameter value 0.08850 meter. The boundary conditions are same as delta plate modification analysis.

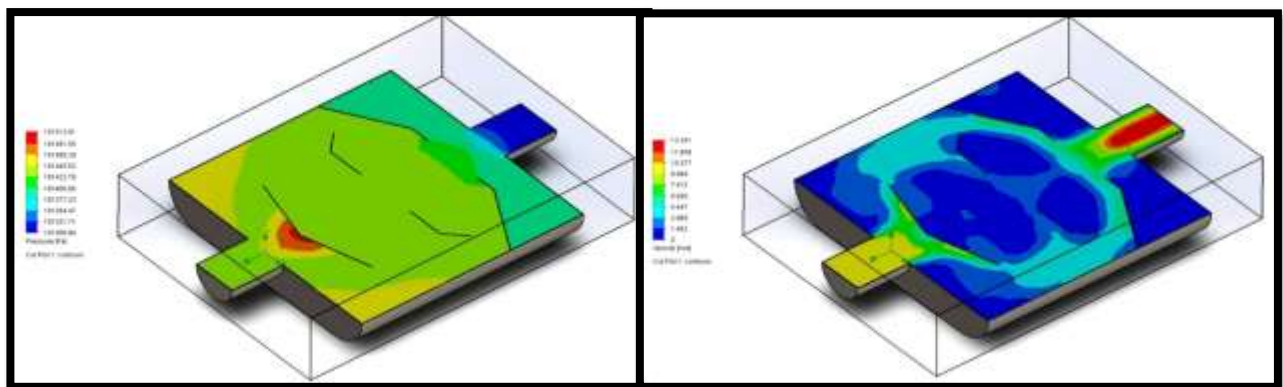
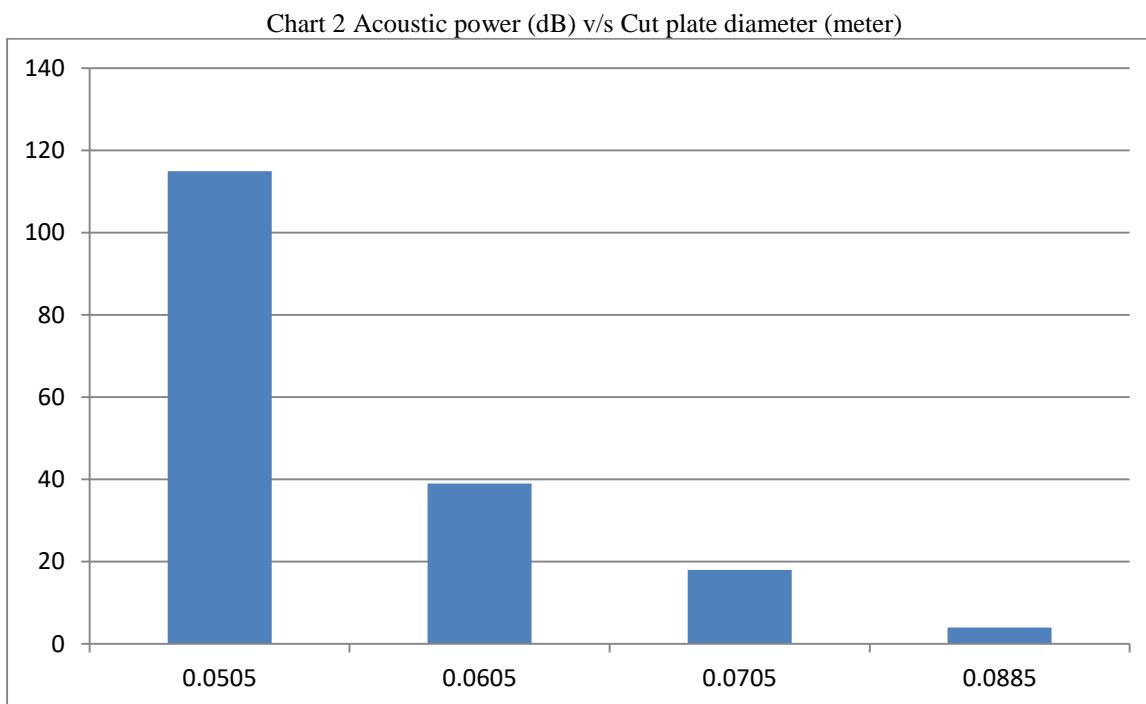


Figure 6 Pressure and velocity distribution for diameter 0.08850 meter



4.5 Pressure and velocity distribution of final design

For the delta plate angle 145° and diameter value 0.08850 meter the pressure and velocity distribution for the same boundary condition is as shown in the following figure.

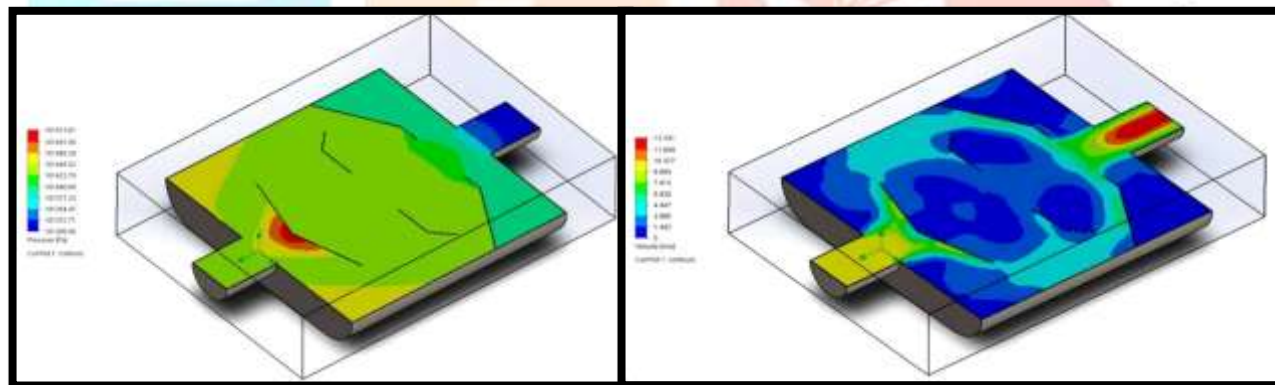


Figure 7 Final design pressure and velocity distribution

V CONCLUSION

From this paper conclusion can be derived as the modification in conventional design of exhaust muffler leads to reduce noise level coming out of engine without using modern expensive exhaust mufflers. Few more modification is needed to replace modern exhaust muffler. For the delta plate angle 145° this muffler design gives better performance. Noise level at this angle is around 8.95 dB comparing conventional muffler noise level which was around 40 dB. And for the cut plate diameter modifications the muffler shows better performance of diameter value 0.08850 meter. So this paper does have future scope to do research for better acoustic performance. This paper shows there are many possibilities to use conventional design exhaust muffler with some modifications.

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