Design and Analysis of Automobile Exhaust Assembly

Submitted in the partial fulfillment of the requirements of the degree of

BACHELOR OF TECHNOLOGY
(Mechanical)

by

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CERTIFICATE

This is to certify that the Research work titled DESIGN AND ANALYSIS OF AUTOMOBILE EXHUAST ASSEMBLY that is being submitted by SHUBHAM YADAV, SAHARSH SRIVASTAVA, CHHAVI SHARMA AND ANSHUL KAUSHAL is a partial fulfillment of the requirements for the award of degree of **Bachelor of technology**, is a record of bonafide work done under my guidance. The contents of this project work, in full or in parts, have neither been taken from any other source nor have been submitted to any other institute or university for award of any degree or diploma.

……………………………………

Mr. K.S Srikanth

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Approval Sheet

This Project report entitled **DESIGN AND ANALYSIS OF AUTOMOBILE EXHUAST ASSEMBLY** by **SHUBHAM YADAV, SAHARSH SRIVASTAVA, CHHAVI SHARMA AND ANSHUL KAUSHAL** is approved for the degree of Bachelor of Technology in Mechanical Engineering.

Examiners

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Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ACKNOWLEDGEMENT

The contributions of many different people, in their different ways, have made this possible. We would like to extend my gratitude to the following.

We are grateful to our Supervisor **Mr. K.S Srikanth** for providing us the proper guidance for this project.

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ABSTRACT

The main stress of this study is the Design and perform computer aided analysis of an automobile exhaust assembly comprising of an exhaust manifold and a muffler, by means of CAD modelling software. Existing engines require additional engine power and also must meet the stringent noise emission standards. The exhaust assembly in the automobile plays an important role in disposing of the automobile sound. To maintain the desired noise level and smooth travel, the muffler's mode needs to be analysed. The manifold design enacts an critical role in efficient combustion and reduces the harmful gases i.e C.O, NOx and etc from the engine. Here flow and modal analyses of the virtual model will be carried out to finalize the mode shapes, stresses and deformations of exhaust muffler using CAE analysis and comparison of the exhaust gas back pressures and its velocities at altered operating load condition of engine will be done.

Mufflers are fitted within the exhaust system of most I.C engines, while the muffler is not intended to serve any primary exhaust function. The muffler is planned as an aural Noise reduction device intended to decrease the noise level of the resonating pressure brought into being by the engine with the way of acoustic silencing.

An exhaust emission control device is also attached to the assembly called catalytic convertor. It reduces toxic gases and pollutants in exhaust gas from internal combustion engine into less toxic pollutants by catalysing a redox reaction.

An improved exhaust system uses the entire length of the system in which to perform the essential functions of muffling noise and converting unburned hydrocarbons. The improved exhaust system performs these functions with a relatively uniform minimum diameter along its length.

1. INTRODUCTION

1.1 Project Background

The exhaust system was created to eliminate exhaust fumes from the engine and to break up the sound waves of varied frequencies by its structure. An Exhaust is generally a piping joined to the engine to direct Exhaust gases away from a regulated combustion which takes place in an engine or stove. The complete structure consists of burned gases from the engine and one or several exhaust pipes. The automobile's exhaust system includes exhaust manifold, exhaust pipe, muffler and tail pipe. An exhaust emission control device is also attached to the assembly called catalytic convertor. It reduces toxic gases and pollutants in exhaust gas from internal combustion engine into less toxic pollutants by catalysing a redox reaction. It is also a vital & essential part of combustion & Exhaust discharge control. There should be no outflow upstream of the catalytic converter to work properly. IC engines are one of the major sources of noise pollution. Since the invention of the internal combustion engine in the second half of the nineteenth century, the noise it has generated has been a constant disturbance to the environment. The gases from the combustion chamber are collected in a mass to fill and transfer it to a single pipe and leave it in the atmosphere. The pressure required for engine design to tolerate or overlap the resistance of the connecting system to release the exhaust gases into the air is considered to be the engine pressure back. The engine pumps the gas by pressing it under high pressure to overcome the flow barriers of the exhaust system. So, the engine does the extra work of the machine to compress the exhaust gases when it reaches high pressure and then when it raises the engine's fuel consumption.

Mufflers are ordinarily found with exhaust systems. In particular, the noise of the suppression depending on the pressure is close to 10 times all other sounds (structural noise) combined. Therefore, the severity of the slashing engine noise is contained, especially in detecting the exhaust noise. The muffler has been developed as a sound proofing device designed to reduce the noise compression noise generated by the engine in the form of muted noise. The international law of 'high power, loud noise' applies to most of such programs. Many exhaust systems that use various designs and construction techniques are:

A. Vector Muffler

B. Spiral baffle Muffler

C. Aero Turbine Muffler

Muffler Design has been an issue of enormous attention for many years and hence a greater intellect has been gained. Most developments in the technique of acoustic filters and exhaust mufflers have come about in the last few decades. Hence reliable design and specifications of the muffler must give the finest noise reduction and present optimum backpressure for the engine. The strength of that fragment of the system is therefore essential. The aim of this is to optimize the acoustic level of IC Engine and to perform CFD and Modal analyses of the virtual model to conclude the structural shapes, stresses and distortions of muffler utilizing CAE analysis and correlation of the gas backpressure and its speeds at altered operating load conditions of IC Engine will likewise be done., bringing about less contamination being depleted to the environment and strive towards a Cleaner Environment. The Manifold of the engine have gone through analysis in this work. After analysis when the fallouts were examined from present day models, it was found that the modified gives low backpressure in comparison with other model which ensures the improvement in the efficiency of the engine.

2. LITERATURE REVIEW

2.1 Introduction

Although the works on this subject are more than 10 years old, presently the system includes a uniform diameter pipe extending from the engine exhaust manifold to an opening to the atmosphere. The pipe carries the exhaust gases from the engine to the atmosphere. In recent years, the exhaust system has also been required to eliminate unburned hydrocarbons and other harmful compounds from the exhaust gases. This function is performed by a catalytic converter **[1].** The learning of heat transfer in exhausts has lately involved the significance it deserves due to its essential part in the design of modern exhaust aftertreatment systems. Such findings are today vital for better intellect grasp of these systems and, thus, being able to influence under body heat transfer, momentary cold-start warmup of the catalytic converter, thermal ageing of the converter, or the regeneration performance of diesel particulate traps etc.

The research done in 2014 by Rumdeo Rathod and Akshay Tajane **[10]**, shows that the exhaust system is essentially linear downstream of the flexible joint. Highly simplified finite element models of the major components are made. These models include changeable suppleness in their assembly to the exhaust pipes, and a technique is produced for automatic updating of these parameters to gain better correlations with experimental results. The pact between the simulation results of the reorganized models & the experimental results is very decent, which limits the serviceability of these models.

Experimental research on heat transfer rates in exhaust ports was initially intended to support thermodynamic engine cycle models, particularly for engine turbocharger machining applications [2]. Those experimental results were exploited in computer models developed by Frank [3], which simulated manifold's heat transfer by applying scientific correlations to curved pipes. Meitner and Sorenson **[4]**, on the other hand, based on the experimental results of Sachdev **[5]**, presented a comprehensive model covering also heat transfer in takedown pipes. Both models emphasize, however, primarily on the temperature distinction throughout single engine operating cycles. Pattas et al. studied the thermal feedback behaviour of diesel exhausts are outfitted with a particulate filter **[7]**. Zhang et al. Developed a model computing the steady state temperature distribution in exhaust systems with single wall and with double wall, air gap insulated piping **[8]**. Recently, a dimensional transient model covering a numerous designs of exhaust system has been demonstrated [6], demonstrating a model that can simulate real-world heat transfer in gasoline car sand exhaust systems and CAE has been working extensively on research. **[6]**.

The investigational procurement of valuable data for the estimation of heat transfer rates and their application in the optimized design of various exhaust configurations forms the subject of the present paper.

In the very beginning **[9]**, when the consequences of early investigations of brown haze in Los Angeles were distributed, Houdry got to be distinctly worried about the part of car fumes in air contamination and established a unique organization, Oxy-Catalyst, to create exhaust systems for fuel motors - a thought relatively revolutionary for which he achieved a patent. In any case, until the to a great degree viable against thump specialist tetra-ethyl lead was dispensed with from most gas over natural concerns, it would "harm" the converter by shaping a covering on the impetus' surface, successfully crippling it. The fumes framework was later on further made by John J. Mooney and Carl D. Keith at the Engelhard Corporation making the essential creation debilitate framework in 1973. Starting in 1979, an ordered diminishment in NOx required the advancement and utilization of a three-path impetus for CO, HC and NOx reduction **[10].**

In last 10 years innovative research in the area of auto exhaust catalysis is being developed and CeO2has been found to play a major role in this area due to its unique redox properties. In this review, auto exhaust emission and its impact on earth's environment, global concern and recent advances in science and technology in automotive exhaust catalysis have been documented. A new preparative method of dispersing metal ions by solution combustion technique over CeO2and TiO2resulting mainly $Ce_{1-x}M_xO_{2-\delta}$, $Ti_{1-x}M_xO_{2-\delta}$and $Ce_{1-x-y}Ti_xM_yO_{2-\delta}$(M =Pd, Rh and Pt) catalysts, structure of these materials, their catalytic properties towards auto exhaust catalysis, structure–property relation and mechanism of catalytic reactions are accounted here. In these materials, metal ions are incorporated into substrate matrix to a certain limit in the solid solution form and we have established a new direction in heterogeneous catalysis by turning to the concept of dispersed metal ions as catalytically active sites from the conventionally nurtured idea of metal particles as active centres for catalysis **[1]**.

Material test suggest that material chosen (SUS 409 S.S.) is suitable for this system. Transmission loss test suggests that max. transmission loss through the system is 13.12 dB & is less. Leak test suggests that actual leakage rate is less than allowable leakage rate. According to weld test, the parameters which are tested are in specified range hence it can be stated that welds in the system have good quality **[10].**

As a result of a study conducted by P. Verboven **[11]**, a suitable measurement setup to perform a successful experimental modal analysis of an exhaust system has been found. The MDOF time domain (LSCE followed by LSFD) method was the best available method to estimate the modal parameters. Based on the obtained modal model, a sensitivity analysis was used to optimize the dynamical behaviour of the exhaust system. Point masses are easy to apply but result in an important increase of the overall mass of the exhaust system.

On the other hand, the application of stiffness modifications is hampered by the need of an accurate characterizing of these modifications. A running mode analysis of the exhaust system was also successfully obtained. The influences of the operating conditions were clearly indicated by the bad correlation between the modal and the running modes. It is very important to characterize these different influences to be able to convert the results of the modal analysis to the exhaust system under real operating conditions.

Numerous investigators [5, 6] have done their study in this field to reduce emissions produced by the engine. P.L.S. Muttiah and Hessamedin Naeimi [7, 8] analysed the manifold exhaust using CFD by changing the shape of the conical manifold with the help of a grid mesh, and therefore continued research on backspace. After analysing the results for both models, the revised version was found to offer less backpressure than the other base models, which confirmed an improvement in engine efficiency.

Hong Han-Chi and Siddaveer Sangamad [9, 10] scrutinised the exhaust gas flow from two different modified manifolds with the help of CFD. To evaluate the correct geometry for the low backpressure, they analysed two different exhaust vents, one with base geometry and the other with transformed geometry. In the modified model of the exhaust manifold, the outlet is in the centre of the exhaust manifold, where the base model of the exhaust manifold is on the edge of the first outlet. Two asymmetric exit expressions were analysed in this work. After comparing the results for the two models, the revised version was found to offer less backpressure than the other base models, which ensured better engine efficiency.

2.2 Reviews

An experimental evaluation of rates of heat transfer in exhaust ports was primarily intended to back thermodynamic engine cycle models, precisely for engine turbocharger machining applications [1].

Lately, the transient models covering numerous designs of exhaust have been bestowed [3, 4], showing a model which was able to simulate real world heat transfer in exhaust systems of gasoline car sand is extensively employed in CAE investigations [3].

Based on the present experimental study, use of metal oxides as catalyst in the catalytic converter for gasoline fuelled engine were investigated as shown in Table 1 and following conclusion were drawn:

Table 2 Experiment test result

As Per Bharat Stage 2 Complaint 4 Wheeler				
Test Gas	Unit	Prescribed Standard	Without Converter	With Converter
CO	% Vol.	0.5	0.3	3.77
HC	PPM	750	43	91
CO_2	% Vol.	NA	0.5	3.47
O_2	% Vol.	NA	19.82	11.44

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3. Problem Description

3.1 Problem Description

IC engines are one of the major sources of pollution. Since the invention of the internal combustion engine in the second half of the nineteenth century, the noise it has generated has been a constant disturbance to the environment. Gases released from the engine are collected from the exhaust manifold and released into the atmosphere. The engine exhaust back pressure is the pressure developed by the engine to withstand or withstand the exhaust gases out into the exhaust atmosphere. In order to overcome the flow barrier in the exhaust system, the engine sends gas by compressing it with a little more pressure. Therefore, the engine does extra mechanical work to compress the exhaust gases at high pressure, which increases the engine's fuel consumption. Hence it is clear that optimum efficiency of exhaust can be achieved by optimizing the design of the exhaust and by achieving optimal required back pressure.

The goal of this is to optimize the acoustic level of IC Engine and to perform CFD and Modal analyses of the virtual model to conclude the structural shapes, stresses and distortions of muffler utilizing CAE analysis and correlation of the gas backpressure and its speeds at altered operating load conditions of IC Engine will likewise be done., bringing about less contamination being depleted to the environment and strive towards a Cleaner Environment.

EXHAUST SYSTEM

A Piping/ Tube like arrangement usually used to exhale the reaction or combusted exhaust gases from a controlled combustion inside the Engine or Stove. The whole arrangement which contains one or multiple exhaust pipes transports Exhaust Gases from Engine to the atmosphere. Depending upon the arrangement and conditions the gases may flow through these components;

- Cylinder head
- Exhaust manifold.
- Turbocharger
- A catalytic converter to diminish emissions.
- Muffler or Silencer

The exhaust system begins with manifolds on the engine and ends with the tail pipe.

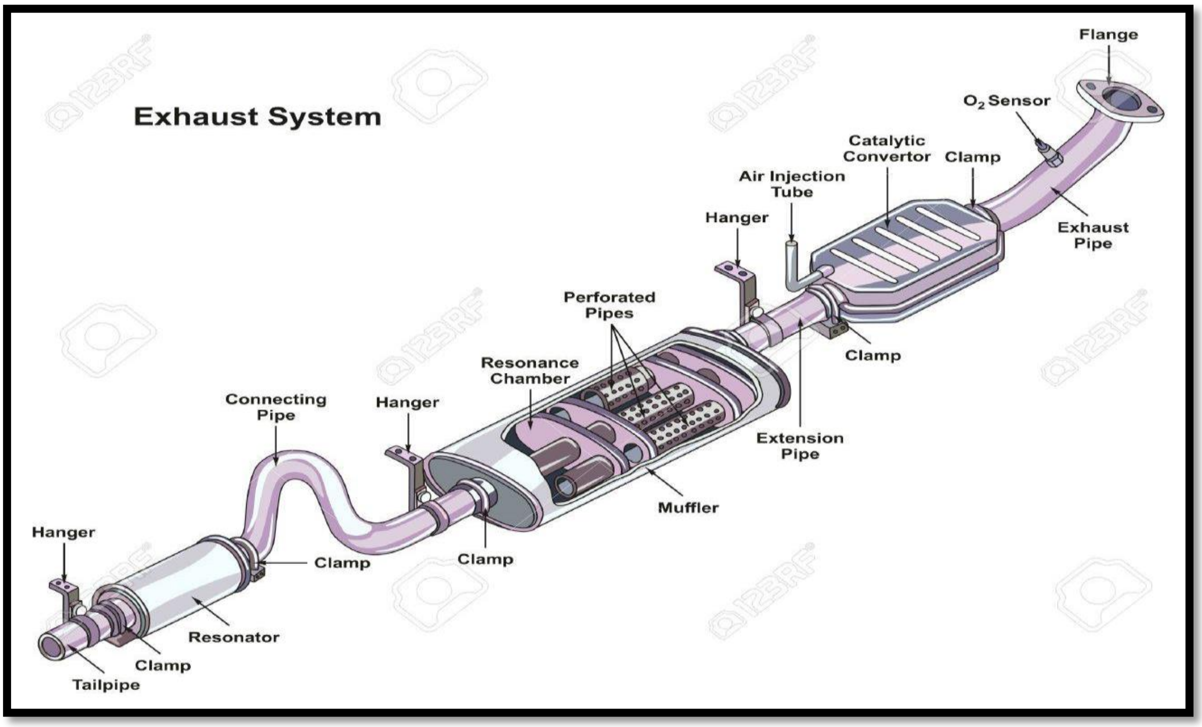


Figure 1: EXHAUST SYSTEM

Components of Exhaust System:

a. Exhaust Manifold.
b. Catalytic Converter.
c. Exhaust Pipes.
d. Muffler.
e. The Tail Pipe**.**

A. <u>EXHAUST MANIFOLD</u>: An Exhaust Manifold is the first part of the exhaust assembly, which is directly attached to the Engine. The Manifold burns any fuel that was inadequately burned by the engine and funnels it down into the main Exhaust system. Due to high temperatures, Excellent oxidation resistance, High-temperature strength, Thermal fatigue properties are required.

Figure 2: MANIFOLD

Figure 3: CATALYTIC CONVERTER

B. <u>CATALYTIC CONVERTER</u>: A Catalytic Converter is a mechanism that utilizes a catalyst to change over three pollutant mixes in Exhaust gases into innocuous mixes.

- **Hydrocarbons:** They are in the form of unburnt gasoline.
- **Carbon Monoxide:** Formed by the combustion of gasoline.
- **Nitrogen Oxides:** Created when the heat in the engine forces nitrogen in the air to combine with the oxygen.

The setup consists of Manifold followed by Converter and then followed by Muffler, where the Converter treats the gases in the middle.

C. MUFFLER: A Muffler or Silencer is a component used in IC engines to reduce the sound of it. The Main Muffler absorbs the noise of the Exhaust gas and is composed of an outer shell, inner pate, inner pipes, end plates and other components. It contains a deceptively simple set of tubes that are finely tuned to reflect the sound waves produced by an engine so that they cancel each other out.

There are numerous variations of the two main types of muffler designs commonly used namely:

- Absorptive Muffler
- Reactive Muffler

Generally Automotive Mufflers will have both absorptive and reactive properties.

D. EXHAUST PIPES: The Exhaust Pipes are placed for moving the combusted Exhaust gases from the motor and ventilation system towards the tailpipe. There are fundamentally two kinds of Exhaust Pipes:

- Regular Pipes: Regular Pipe is solid and typically available in straight lengths.
- Flexible Pipes: Flexible Exhaust pipe is flexible enough to bend with conditions.

E. TAIL PIPE: The Tail Pipe is the end of the final length of Exhaust pipe which ends with just a straight or angled cut where it vents to open air.

Working Process of Exhaust System

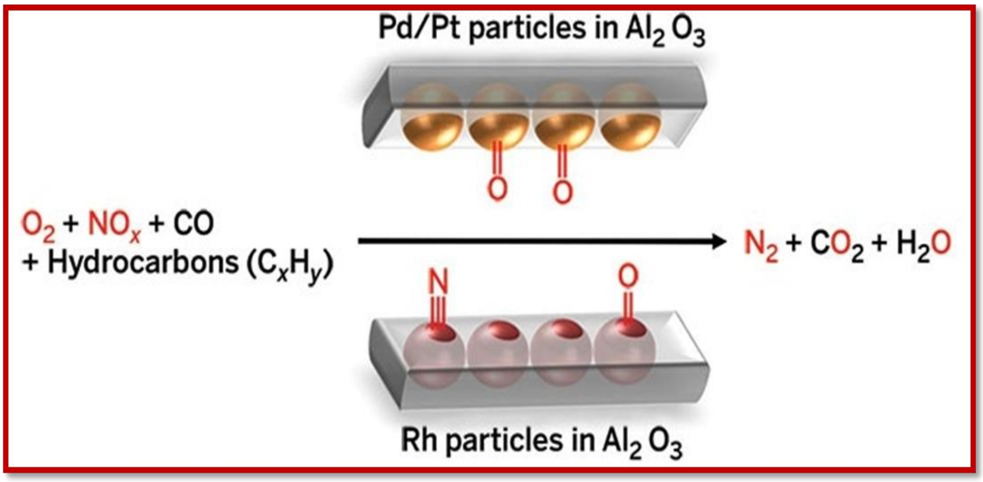
Exhaust Fumes are marshalled from the barrel head into the motor by a manifold. The exhaust manifold goes about as a channel, redirecting fumes gasses from all barrels of the motor then discharges them through a solitary opening, frequently alluded to as the front pipe. These exhaust fumes then move across a catalytic converter which ejects toxic components including C.O and hydrogen monoxide which are altered over into less harmful gasses. The gasses then go through a silencer or muffler. It's exclusive when you hear an auto with a harmed silencer that you understand what a colossal contrast it makes to diminishing clamour levels. The silencer holds a misleadingly elementary assembly of tubes that are excellently tuned to reflect the sound waves formed by the motor with the goal that they counteract each other. The silencer will consume after some time and when it in the end builds up a gap, regardless of how little, the sound waves are no longer constrained via tubes and escape outside – causing a ton of turmoil simultaneously. At last the exhaust Fumes exit by means of the tail pipe at the back which diverts gasses from the vehicle and the travellers inside.

<u>Working of Catalytic Converter</u>:

The reduction catalyst is the underlying period of the Catalytic Converter. It uses Platinum and Rhodium to help in reducing the NOx emanations.

•The oxidation catalyst is the subsequent stage. It lessens the unburned Hydrocarbons and Carbon Monoxide by oxidizing them over Platinum and Palladium impetus.

•In the last stage Hydrocarbons join with Oxygen to shape Water and Carbon Dioxide.



TYPES OF CATALYTIC CONVERTER: There are basically four types of catalytic converters:

- Two-Way Catalytic Converter: This type is also known as a two-way catalytic converter, because it can only operate with hydrocarbons (unburned fuel) and carbon monoxide (brought about by somewhat blazed fuel).
- Three-way Catalytic Converter: In this type of converter, a reduction reaction also occurs in addition to two oxidation reactions same as two-way converter.
- Monolithic Converters: These types of converters consist of ceramic material finished in a honeycomb arrangement to regulate exhaust gases flowing through it. The catalysts are sealed off by stainless steel.
- Dual Bed Converter: This is probably one of the most capable converters. The dual-bed is nothing, it is the arrangement of two-and three-way catalytic converters housed in a solitary part.

Preferably, the exhaust is designed with an agenda to accomplish the desired sound. Emphasis on this leads to the properties of reactive and absorbent types of mufflers. However, performance mufflers have mixed characteristics of both, as the main priority is not to attain the desired sound but to achieve some moderate sound.

Effects of Increased Back Pressure: Mounting backpressure of the engine increases fuel consumption, PM and CO emission rates and exhaust temperature. To put this into perspective, engine exhaust gases must be compressed at high pressure, requiring extra mechanical work and / or less energy than the exhaust turbine can achieve, which increases engine pressure and mechanical efficiency many times over.

DESIGN METHODOLOGY

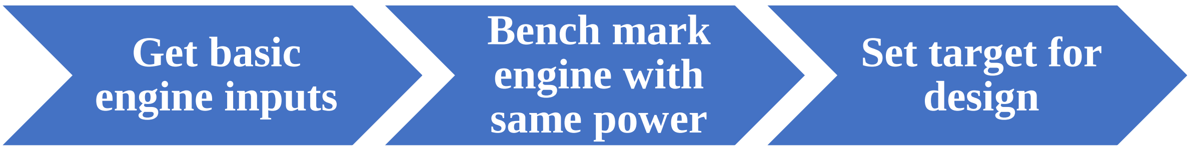
The suitably designed muffler for any specific function should assure the often – contradictory demands of at least five criteria simultaneously

- The acoustic parameter, which particulate the minimum noise reduction, necessitated from the suppressor as a purpose of frequency.
- The aerodynamic parameter, which specify the highest acceptable average pressure drop via the muffler at a given temperature and mass flow.
- The geometrical parameter, which stipulates the maximum allowable volume and restrictions on shape.
- The mechanical parameter, which particularize the materials with less maintenance.
- The economic parameter plays major role in commercial sector.

The Design methodology of a Exhaust for a specified engine involves 7 steps. Following are the broad steps followed to arrive at a good design of muffler making use of practical experimental data figure 1.

Step 1

Target settling and bench marking.

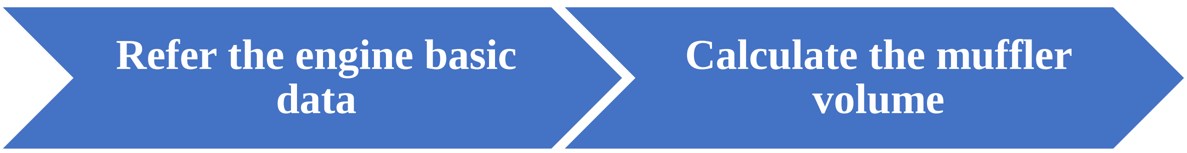


Step 2

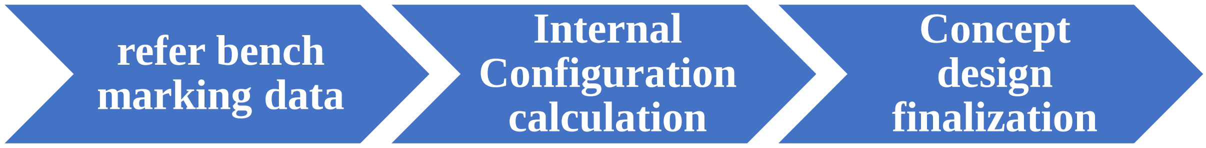
Calculating target frequencies.

Step 3

Muffler volume calculation.



Step 4
Internal configuration and concept design



Step 5
Virtual simulation

Step 6
Manufacturing

BENCHMARKING

The first step in any design and development activity is to set a target by doing benchmarking exercise of same kind of models. The same will be applicable for the silencer here, to set a target in terms of transmission loss of same engine power models of competitor benchmarking vehicles. Based on the provided engine input data and bench mark study target for back pressure and noise are range decided.

TARGET FREQUENCIES

After benchmarking exercise, one needs to calculate the target frequencies to give more concentration of higher transmission loss. For calculating the target frequencies engine max power rpm is required and calculation follows,
Theoretical Computation:

The exhaust tones are calculated using the following formulae:

CFR = Engine Speed in RPM/60 ……… For a two-stroke engine

= Engine Speed in RPM/120 ……... For a four-stroke engine

$$EFR = n \times (CFR)$$

DESIGN PROCESS AND CONSIDERATIONS

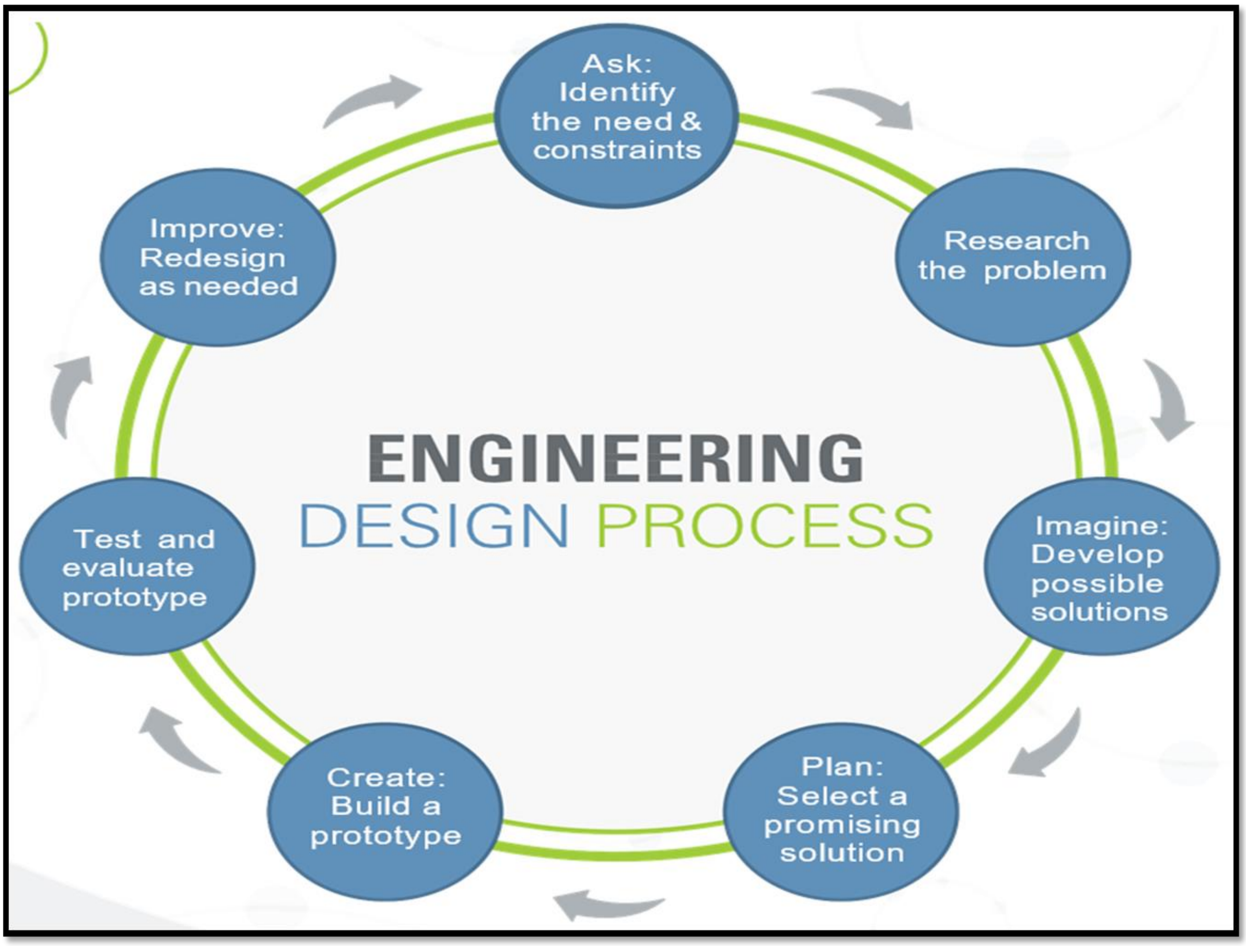


Figure 4: Source Google Images

Current engines entail greater engine power and must meet stringent pollution standards. To improve the performance of the exhaust system, several design features are required.

The chimney acts as an exhaust pipe in a stable structure. For internal combustion engines.

- It is important to have the exhaust system “tuned” (refer to tuned exhaust) for optimal efficiency.
- Also, this should meet the regulation norms maintained in each country.

Designing of Parts: There are a lot of software available in the market for spare parts design and analysis. Some of these are SOLIDWORKS, CATIA, ANSYS etc. From the above software, SOLIDWORKS chose the exhaust design in this work. Figure 1 below is the design assembly of the exhaust.

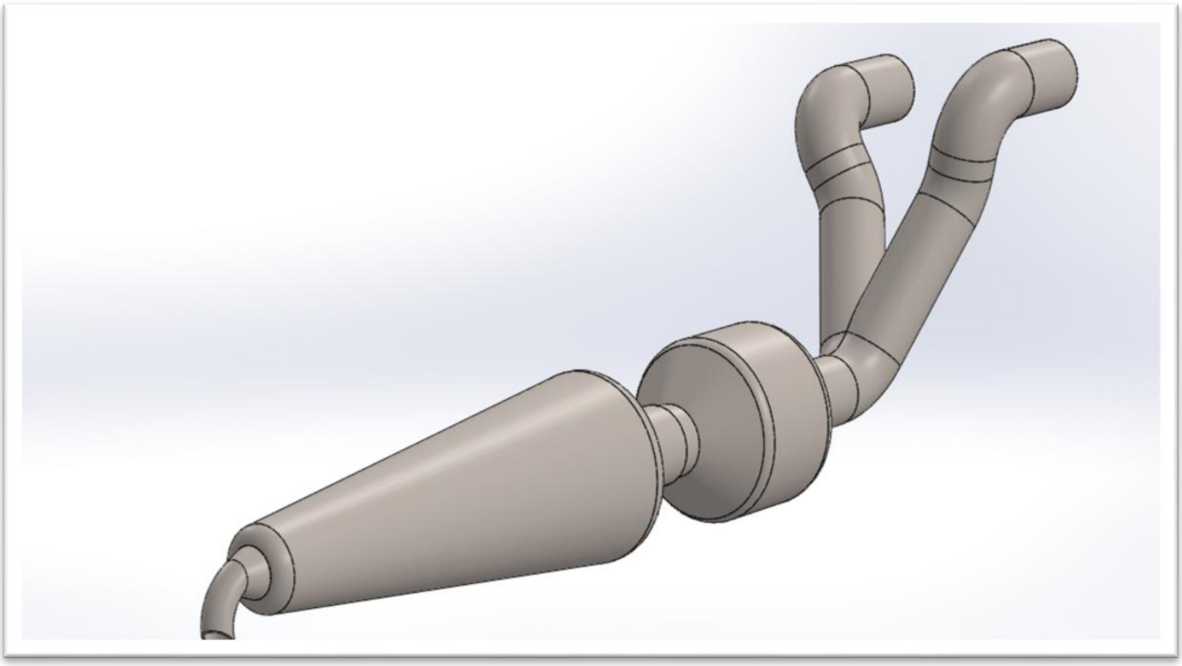


Figure 5: Full Assembly Design

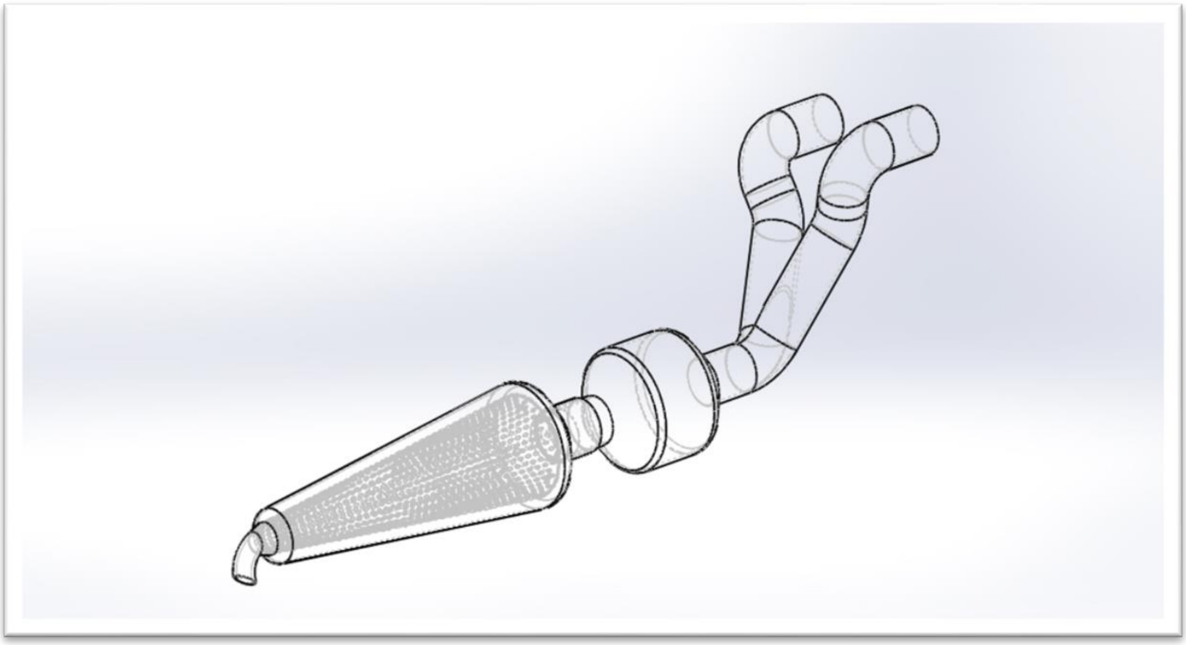


Figure 6: Exhaust Assembly Transparent View

MUFFLER VOLUME CALCULATION

Based on the experience and theory of acoustics for muffler design for various engines, the following equation works well.
Volume of the muffler (Vm):

$$(Vm) = Vf \times \left[\frac{\pi}{4}(d^2 \times l)\right] \times (No.of\ cylinders) \div 2$$

Now the designer needs to check packaging space that can be made available for the muffler.

INTERNAL CONFIGURATION AND CONCEPT DESIGN

Based on the benchmarking transmission loss and the target frequencies, designer draws few concepts of internal configuration that meets the packaging dimension within the volume mentioned above. Each concept and internal configuration are then formulated to the best possible configuration so as to achieve best acoustic performance and best (i.e. least) backpressure.

Perforations: Perforated pipe forms an important acoustic element of muffler, which is tuned in line with the problematic frequencies identified in step 2.

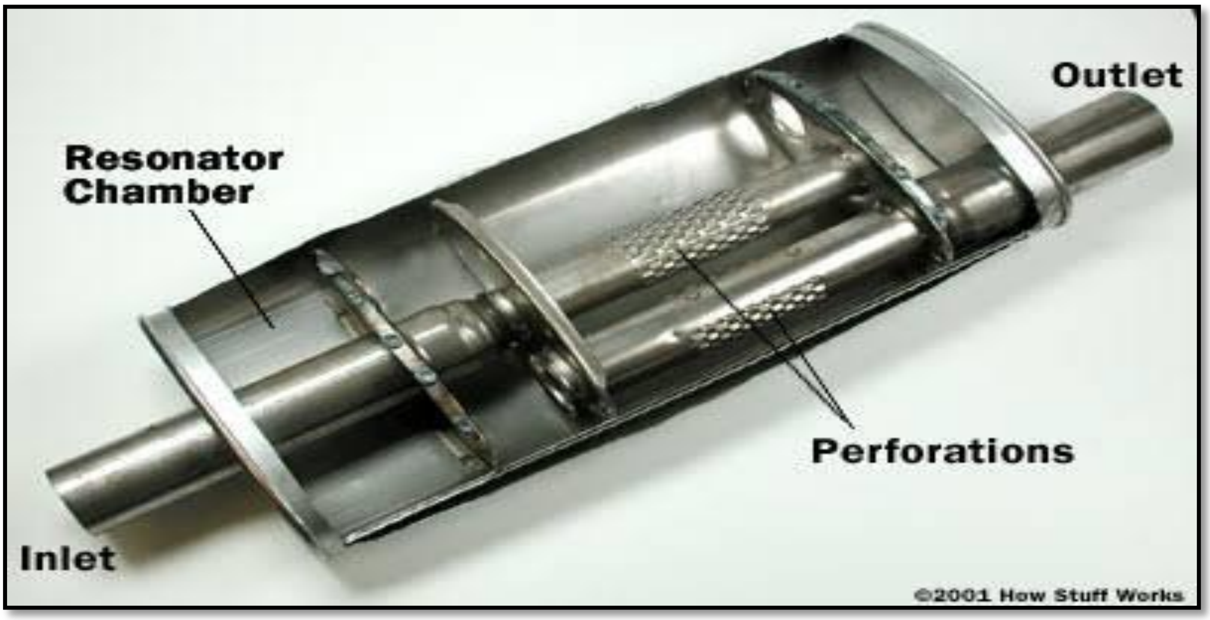


Figure 7: Source Google Images

The designer needs to keep in mind lesser the porosity more is the restriction and hence more will be the backpressure.
Open area ratio:

The open area ratio is given by,

AOP = Area of perforation / Area of the plain sheet.

Lesser the AOP better the transmission loss and better the acoustic performance.

At this stage, the diameter of the hole to be drilled, pitch, number of holes per row, number of rows for each pattern of holes is frozen and hence, the distance at which perforation starts and at which the perforation ends also gets frozen.

Thus, the design of the perforated tube for individual hole patterns is finalized. Based on this best concept mufflers are designed and carry forward for virtual simulations.

VIRTUAL SIMULATION

Based on above mentioned approach, different concepts will be arrived with optimum combinations of different elements inside volume of the silencer. Finalised concepts will be verified virtually using CAE simulation software's towards the achievement of transmission loss and back pressure.

CFD ANALYSIS

At the point when consistent air stream goes through the silencer, there will have consistent pressure drop which is identified with stream and geometry of air entries. Pressure drop in the Silencer assumes a significant job in the structure and advancement of silencers. Expectation of pressure drop will be exceptionally valuable for the plan and improvement of the silencer. To anticipate the pressure drop related with the consistent move through the muffler CFD has created in the course of the most recent two decades. Along these lines, stream expectation can be made solid.

TRANSMISSION LOSS ANALYSIS

Prediction of transmission loss virtually is an important analysis required for the development of muffler at an initial design stage. There are different software packages available in market for predicting the transmission loss. We have used virtual lab for Transmission loss measurements.

It is also to be noted the limitations of the CAE tools, as the co-relation at higher frequencies is difficult since the plane wave theory holds good only up to 3000Hz beyond which the wave is no more 2 dimensional but 3 dimensional for which the computations are far complex to match the practical results. Hence need of research to blend both strengths of CAE & Practical resulting in a Practical approach/methodology. After completion of simulation the best three concepts will (with less back pressure and higher transmission loss) be taken forward for the prototype manufacturing to check for the transmission loss and back pressure physically.

MANUFACTURING

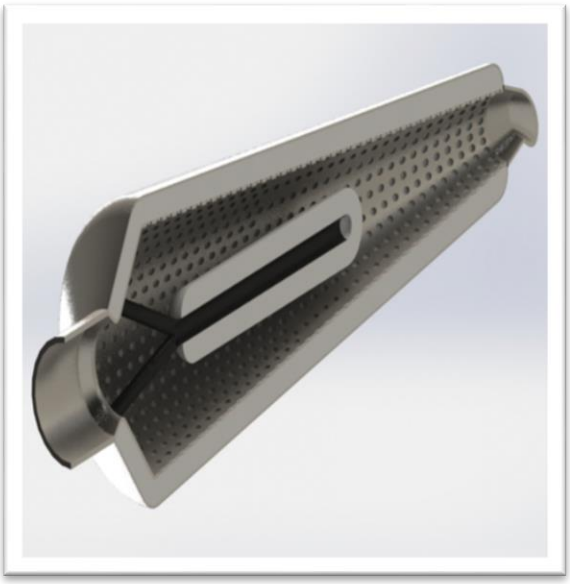
All the above stages combined with the packaging of the engine evolve the design of the prototype muffler and those; can be taken up for manufacturing.

Following are some of the important manufacturing considerations summarized based on experience:

- There should not be any leakage of gas from one chamber to another.
- Full welding is better than stitch welding.
- Acoustic performance of extruded tubes with perforations is better than the tubes that are made out of perforated and welded sheets.
- CEW or ERW tubes are the common materials used.
- Either of Crimping or full welding of jacket can be used.
- Either of flanged or flared tubes can be used as end connections of the muffler. However, with leakage point of view, flanged connections are better.

However, with leakage point of view, flanged connections are better. But at the same time, this adds to the weight and cost of the exhaust system. Bearing all above in mind, a physical prototype is made in such a way that there will not be any tooling investment for the prototype.

Original Design Pictures of Muffler and Manifold



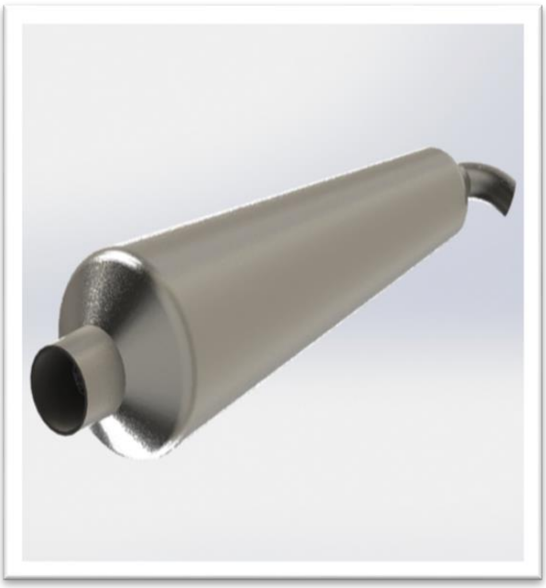


Figure 8: Sectional View of the Muffler

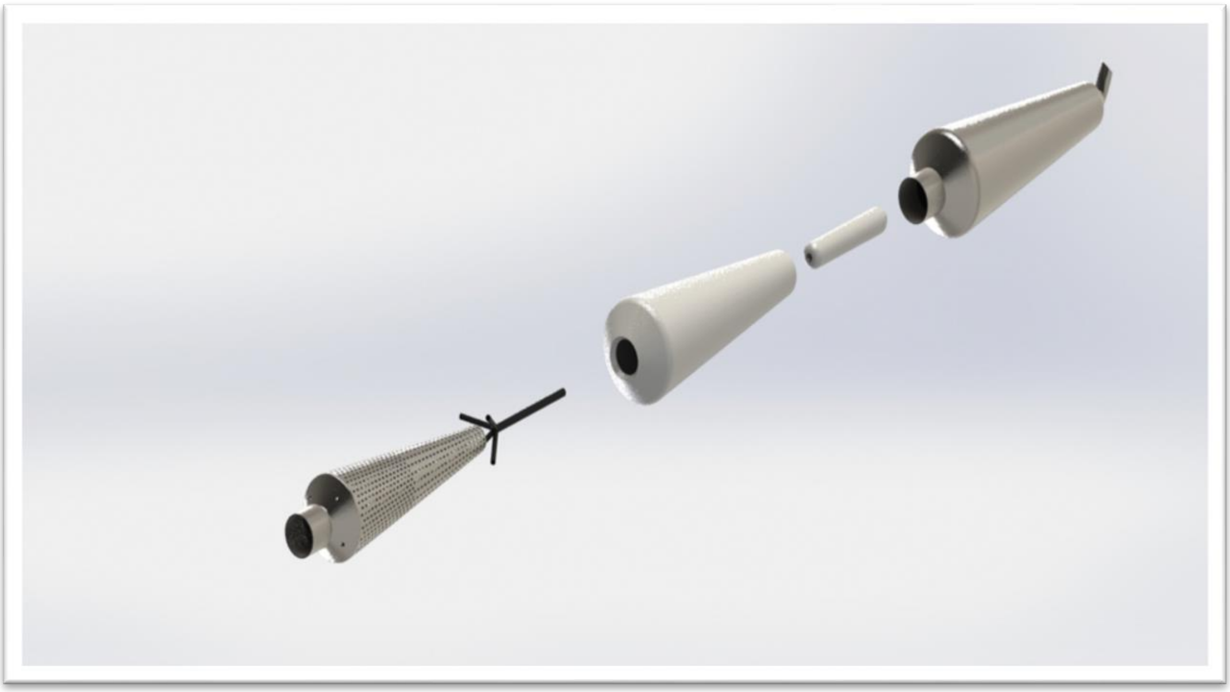


Figure 9: The Exploded View of the Muffler

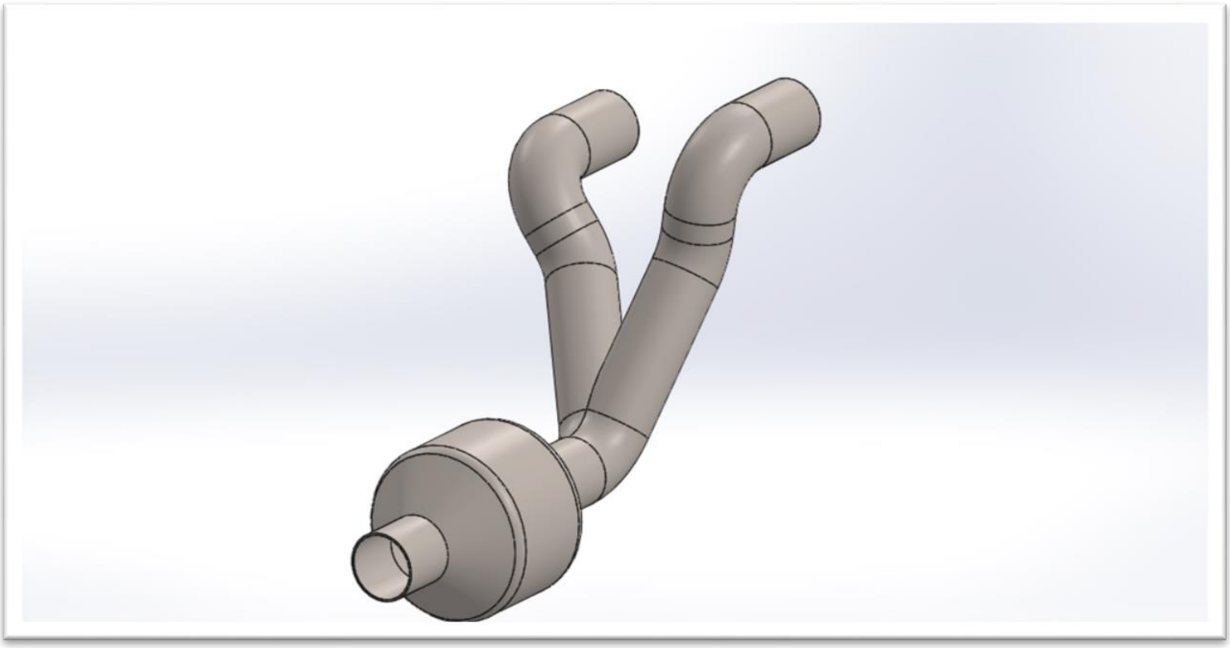


Figure 10: Design of the Manifold

Design inputs used in muffler design

- Extended inlet and outlet will be minimum 60 to 70 mm for better attenuation results.
- Inlet and outlet are introduced 180 deg reversal to increase the acoustic performance.
- From benchmark and theory 3 expansions chamber good for noise target.
- Hole perforations choose to match frequency that needs to be killed based on CFR and EFR calculations.
- la and lb is 15 to 20 mm as per theory of acoustic for good acoustic performance.
- Primary for choosing diameter of hole first four CFR and EFR should be used.

VIRTUAL SIMULATION OF THE DESIGN

All three concept of muffler designed as per above steps are tested for flow analysis using CFD simulation tool.

Assumption and boundary conditions:

- Take Flow as Steady.
- Consider Air to be Fluid.
- Turbulent Flow always.
- Mass Flow Rate for Inlet = $0.8x10^{-6}$
- Fluid Temperature for Inlet = 525°C.
- Outlet considered as pressure outlet opened to the environment

Observations:
Figure 1 and 2 show flow through the concept 0A, 0B and 0C muffler. The CFD result shows that the Concept 0A is good for back pressure as provide less back pressure compare to concept muffler 0B and 0C.

ANALYSIS

The average flow execution of the suppressor considered in the acoustic investigation has been evaluated. Transmission loss measured as per engine firing order calculated in above step 2. Assumption and boundary conditions.

- Sound termination is anechoic.
- Finalized the mode shapes, stresses and deformations in the muffler using CAE analysis.
- Linear step for analysis is 10 Hz in the frequency range of 10-2000 Hz.

- ♦ Perforate holes with zigzag pattern are modelled as parallel pattern of holes.
- ♦ Embossing on inlet and outlet end cover of muffler is neglected.

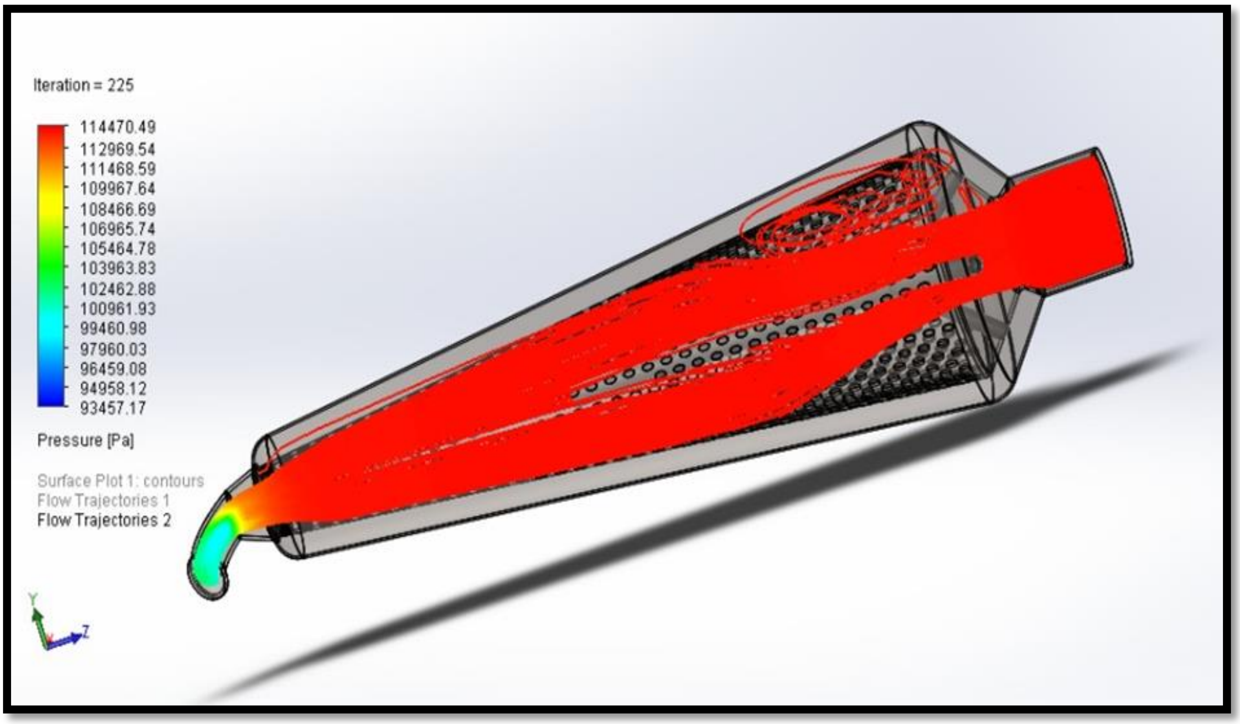


Figure 11: Complete Pressure Distribution of Exhaust Muffler

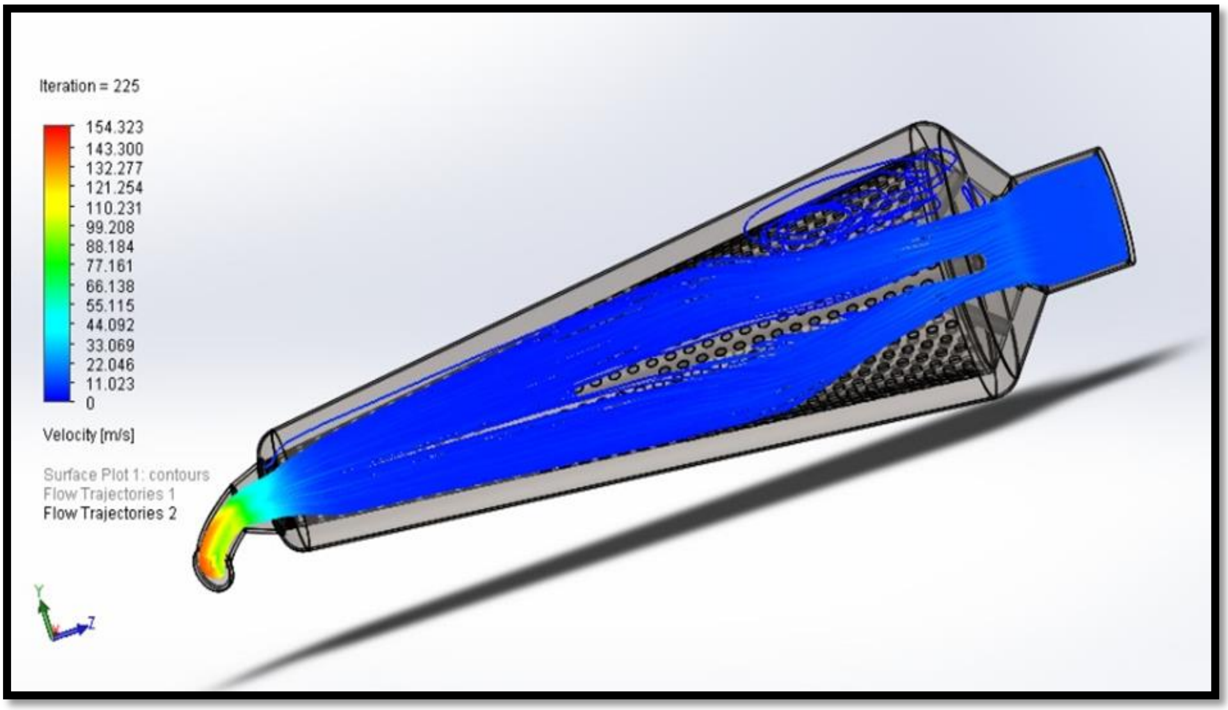


Figure 12: Detailed Velocity Distribution of Exhaust Muffler

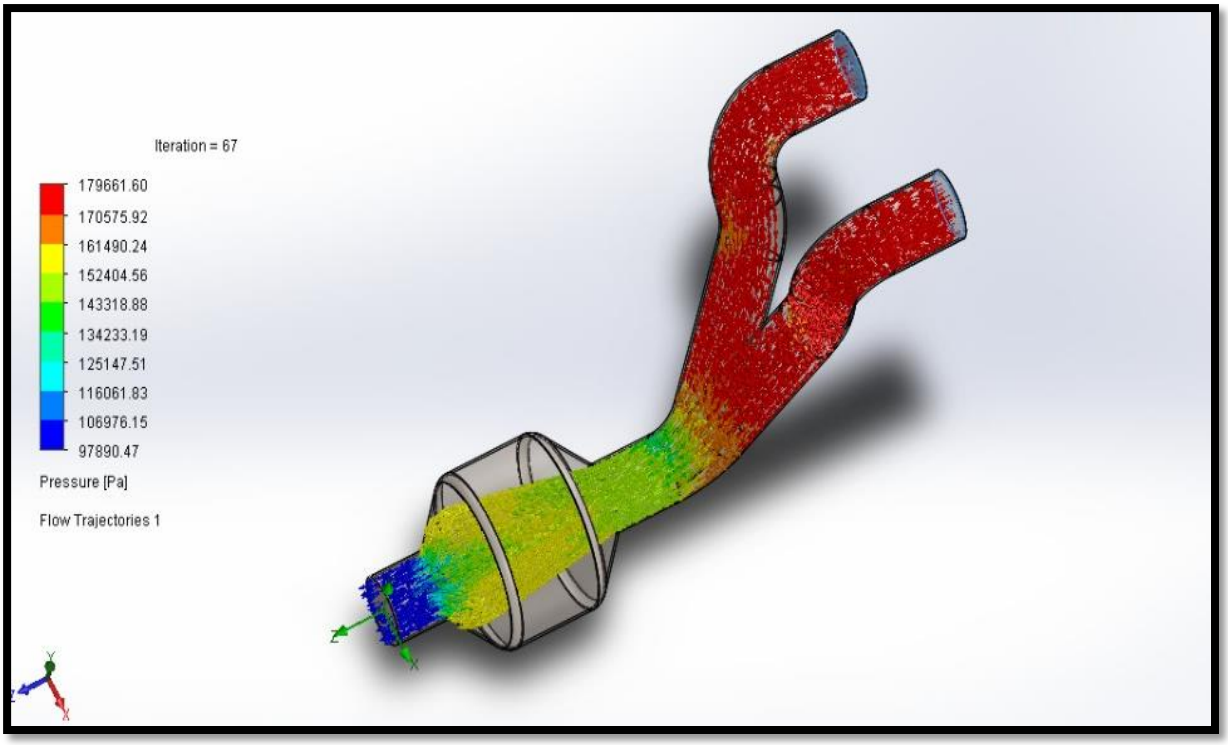


Figure 13: Detailed Pressure Distribution of Exhaust Manifold

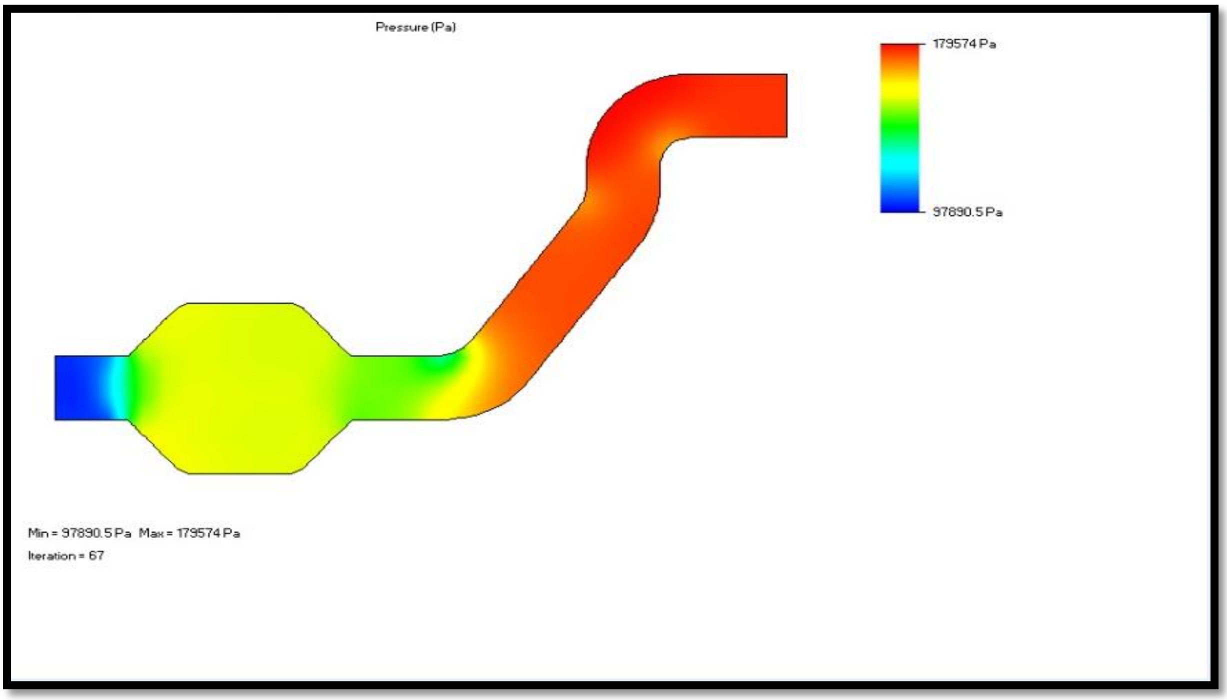


Figure 14: Exhaust Manifold Pressure Distribution

After completion of simulation we selected the best three concepts (with minimum back pressure and higher transmission loss) taken forward for the prototype manufacturing to experimental validations of the transmission loss and back pressure.

OUTCOMES AND DELIVERABLES

- The model of manifold is designed and results were analysed through CFD Post processing. In the model of exhaust manifold, it is examined that due to the divergent-convergent shape, the outlet velocity is higher. It is noticed that by designing the exhaust manifold by decreasing the straight length of the outlet the exhaust velocities are significantly raised. Figure _ gives the turbulence kinetic energy contour of the model.
- A brief background on evaluation of muffler concept design for the proto type and validation with new approach.
- A methodology has been developed for optimum design stages and less cost for muffler design by balancing various parameters.
- A practical tool to estimate the quality of muffler design, which used for concept selection and filter out the best concept proposal at initial phase of design.
- A practical approach for muffler design to optimization of product development time & cost by balancing conflicting requirements like Noise & Back pressure.
- Muffler is made by Solid Works.
- Modelling of muffler is done with proper dimensions.
- Analysis is performed to finalize the mode shapes and stresses and deformations in the muffler using CAE analysis

CONCLUSION

The exhaust assembly is designed and examined, where the flow and model analysis of the virtual model dictates the size, tension and deformation of the exhaust muffler using CAE analysis and considers the manifold design of the engine because it reduces turbulence, rear stress and exhaust speeds and volume Increasing the lattice efficiency and reducing the size of the muffler can reduce the dealer's manufacturing cost. Due to the reduction in the size of the muffler, space requirements will also decrease. This report highlights the importance of the Design Methodology-– a common methodology from the idea plan to proto assembling and approval of gas suppressor. This technique will help designers in understanding the significance of each progression of planning in detail from idea level to approval level. This methodology effectively reduces the quantity of emphasis, item improvement time and cost with a better plan.

Although the practical approach to making muffler design is more important than science, design verification is always necessary at the end of each stage.

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