MODELLING AND ANALYSIS OF DIESEL ENGINE MUFFLER USING CFD

A Project report submitted

in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

In

MECHANICAL ENGINEERING

BY

ROHIT YADAV	**(318126520045)**
PAKKI VENKATA NAGA LOHITH	**(318126520039)**
YASODA DAMMU	**(319126520L07)**
A.S.M BHARADWAJ	**(318126520004)**
K.B.JEEVAN KUMAR	**(318126520023)**

Under the esteemed guidance of

Dr. K. SATYANARAYANA M.Tech, Ph.D.

Assistant Professor

Department of Mechanical Engineering

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES

Autonomous status accorded by UGC and Andhra University

(Approved by AICTE, Permanently Affiliated to Andhra University, Accredited and reaccredited by NBA, accredited by NAAC- 'A' Grade)

Sangivalasa, Bheemunipatnam Mandal

Visakhapatnam (District) – 531162

(2018- 2022)

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGGY & SCIENCES

Autonomous statusaccorded by UGC and Andhra University (Approved by AICTE, Permanently Affiliated to Andhra University, Accredited and reaccredited by NBA, accredited by NAAC- 'A' Grade) Sangivalasa, Bheemunipatnam Mandal Visakhapatnam (District) – 531162

CERTIFICATE

This is to certify that the Project Report entitled **"MODELLING AND ANALYSIS OF DIESEL ENGINE MUFFLER USING CFD"** being submitted by **ROHIT YADAV (318126520045), P.V.N LOHITH (318126520039), YASODA DAMMU (319126520L07), A.S.M BHARADWAJ (318126520004), K.B JEEVAN KUMAR (318126520023)** in partial fulfilments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING.** It is the work of bonafide, carried out under the guidance and supervision of, **Dr. K. Satyanarayana M.Tech , Ph.D,** Assistant Professor, **DEPARTMENT OF MECHANICAL ENGINEERING** during the academic year of 2018- 2022.

Project Guide

(Dr. K. Satyanarayana M.Tech, Ph.D)
Assistant Professor
Mechanical Department
ANITS, Visakhapatnam.

Head of the Department

(Dr. B. Naga Raju)
Professor
Mechanical Department
ANITS, Visakhapatnam.

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES
Sangivalasa 531 162 VISAKHAPATNAM Dist A P

THIS PROJECT WORK IS APPROVED BY THE BOARD OF EXAMINERS

INTERNAL EXAMINER:

27.5.22

PROFESSOR & HEAD
Department of Mechanical Engineering
ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES
Sangivalasa-531 162 VISAKHAPATNAM Dist A.P.

EXTERNAL EXAMINER:

27/5/22

ACKNOWLEDGEMENTS

We express immensely our deep sense of gratitude to **Dr. K. Satyanarayana**, Assistant Professor, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences, Sangivalasa, Bheemunipatnam Mandal, Visakhapatnam district for his valuable guidance and encouragement at every stage of the work made it a successful fulfilment.

We were very thankful to **Prof. T.V. Hanumantha Rao**, Principal, Anil Neerukonda Institute ofTechnology& Sciences for their valuable suggestions.

We were very thankful to **Dr.B.Naga Raju**, Professor, and Head of the Department, Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences for his valuable guidance and encouragement at every stage of the work made it a successful fulfilment.

We express our sincere thanks to the members of non-teaching staff of Mechanical Engineering for their kind co-operation and support to carryon work.

Last but not the least, we like to convey our thanks to all who have contributed either directly or indirectly for the completion ofour work.

Rohit Yadav	(318126520045)
P.V.N Lohith	(318126520039)
Yasoda Dammu	(319126520L07)
A.S.M Bharadwaj	(318126520004)
K.B Jeevan Kumar	(318126520023)

ABSTRACT

Noise pollution is the major drawback of I.C engines. Automotive engineers and researchers have been working consistently on reducing automotive noise as well as pollution. Automobile engineering is one of the fields where in the advancements were witnessing a steep upward trend. On comparing with early design, the recent automobiles were highly efficient and were formed with sophisticated systems. However, the area which still demand improvisation in automobile design exists in the areas like fuel economy, efficiency and exhaust systems.

Exhaust systems focus majorly on reducing the emission of pollutants into atmosphere and also on controlling the sound that comes through exhaust. The devise used for reducing the sound is called as Muffler and the devise used for controlling the emissions is called catalytic convertor.

Mufflers make use of different techniques and components to reduce the noise. Usually the noise is reduced when the transmission loss increases inside the muffler. Components like perforated tubes, sound absorbing materials, pipe bends, sudden expansions and contractions of pipe etc.

In this work focus was laid on altering the design of a muffler to further reduce the noise and increasing the performance of the muffler. This is carried out by designing and using flow simulation through the muffler. Two muffler designs have been modelled and CFD gas flow simulation has been carried in both of them at various boundary conditions. Based upon the gas flow through them, on comparison we have selected the optimum model, for which the performance is best and sound reduction is maximum. The geometry of the model is prepared in CATIA V5 and analysis is carried out in ANSYS 2020 R2 using Computational Fluid Dynamics (CFD).

CONTENTS

PUBLICATION:

Modelling and Analysis of Diesel Engine Muffler using CFD Analysis, Journal of Information and Computational Science, UGC CARE Approved 'Group - II' Journal

ISSN: 1548-7741, Volume 12 Issue 5 – 2022

Page No: 181 – 190 DOI:10.12733.JICS 2022.V12I05.535569.58023

http://joics.org/VOL-12-ISSUE-5-2022/

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

INTRODUCTION

Automobile engineering is the one of the stream of mechanical engineering. It deals with the various types of automobiles, their mechanism of transmission systems and its applications. Automobiles are the different types of vehicles used for transportation of passengers, goods, etc. Basically all the types of vehicles works on the principle of internal combustion processes Different types of fuels are burnt inside the cylinder at higher temperature to get the transmission motion in the vehicles Therefore, every mechanical and automobile engineer should have the knowledge of automobile its mechanism and its various applications.

1.1 AUTOMOBILE

Automobile engineering is a branch of engineering which deals with everything about automobiles and practices to propel them.

Automobile is a vehicle driven by an internal combustion engine and it is used for transportation of passengers and goods on the ground. Automobile can also be defined as a vehicle which can move by itself.

Examples: Car, jeep, bus, truck, scooter, etc.

1.2 AUTOMOTIVE PARTS AND SYSTEMS CANBE ORGANIZED INTO TEN MAJOR CATEGORIES:

• Body and frame- support and enclose the vehicle

• Engine- provides dependable, efficient power for the vehicle.

• Computer systems- monitor and control various vehicle systems.

• Fuel system- provides a combustible air-fuel mixture to power the engine.

• Electrical system- generates and/or distributes the power needed to operate the vehicle's electrical and electronic components.

• Cooling and lubrication systems-prevent engine damage and wear by regulating engine operating temperature and reducing friction between internal engine parts.

• Exhaust and emission control systems-quiet engine noise and reduce toxic substances emitted by the vehicle.

• Drive train systems-transfer power from the engine to the drive wheels.

• Suspension, steering, and brake systems support and control the vehicle.

• Accessory and safety systems-increase occupant comfort, safety, security, and convenience.

1.2.1 Exhaust and Emission Control Systems

The exhaust system quiets the noise produced during engine operation and routes engine exhaust gases to the rear of the vehicle body. Trace the flow of exhaust gases from the engine exhaust manifold to the tailpipe Learn the names of the parts. Various emission control systems are used to reduce the amount of toxic (poisonous) substances produced by an engine. Some systems prevent fuel vapors from entering the atmosphere (air surrounding the earth). Other emission control systems remove unburned and partially burned fuel from the engine exhaust.

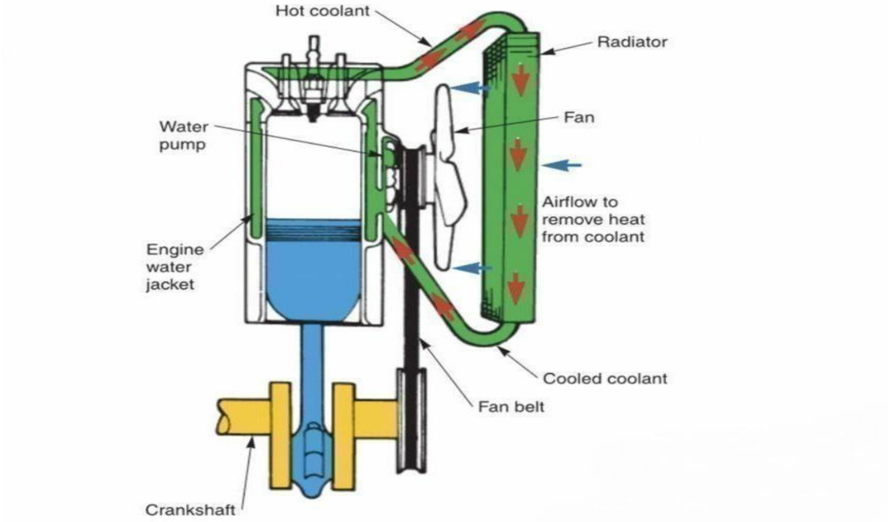


Figure 1.1 Exhausts and Emission Control System

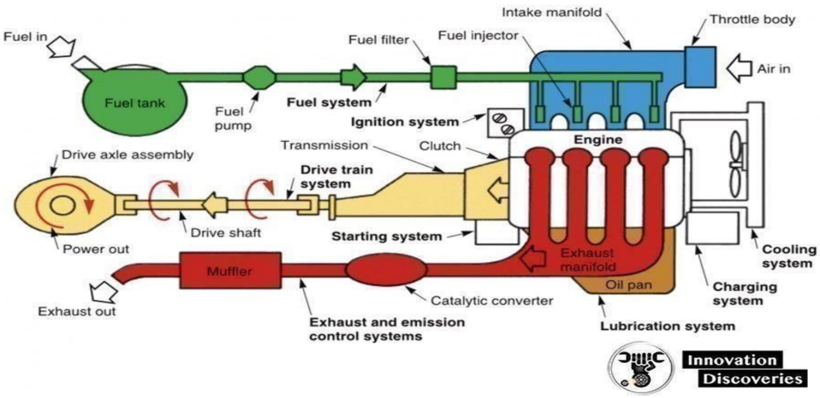


Figure 1.2 Automotive Systems

1.3 EFFECTS TO HEALTH OWING TO AUTOMOBILE EMISSIONS

The emissions from millions of vehicles add up. These emissions are by products from the engine combustion process and from the evaporation of fuel. Despite the ever-growing number of vehicles on the road, studies show that ten to thirty percent of vehicles cause the majority no vehicle-related air pollution.

1.3.1 Carbon Monoxide

Carbon monoxide is a colorless, odourless, poisonous gas emitted from the vehicle's exhaust as a result of incomplete combustion. It interferes with the blood's ability to carry oxygen to the Brain, heart, and other tissues. Un born or new-born children and people with heart disease are in greatest danger from this pollutant, but even healthy people can experience headaches, fatigue and reduced reflexes due to CO exposure.

1.3.2 Particulate Matter

Particulate matter includes microscopic particles and tiny droplets of liquid. Because of their small size, these particles are not stopped in the nose and upper lungs by the body's natural defences but go deep into the lungs, where they may become trapped and cause irritation Exposure to particulate matter can cause wheezing and similar symptoms in people with asthma or sensitive airways. Particulate matter can serve as a vector for toxic air pollutants.

1.3.3 Toxic Air Pollutants

Toxic air pollutants such as benzene and formaldehyde are substances from automobile emissions that are known to cause or are suspected of causing cancer, genetic mutation, Birth defects, or other serious illnesses in people even at relatively low levels. The chemicals can be inhaled directly or carried by small particles (dust or lint) into the lungs.

In India like many other developing countries noise is major continents of environmental pollution and now it has become a permanent part of urban and sub urban life. It is very harmful to human beings.

Noise is a major factor of environmental pollution Noise affects human body in a number ways ranging from Psychological to Physiological, e.g. auditory damage, speech interference. sleep interference, general annoyance, reduces the working efficiency, increases blood pressure & fatigue etc.

1.4 INTRODUCTION TO EXHAUST SYSTEMS

A typical exhaust system comprises of a combination of metallic pipes for carrying out the toxic emissions released by the combustion of gases, more often from auto engines. The efficient working of an exhaust is essentially needed for the safe and reliable running of vehicles. The latest exhaust systems are designed to clean the gases before throwing them out in the atmosphere. Modified systems facilitate a smoother flow of gases, and thus enhance the efficiency of engines.

If exhausted gases are not released appropriately, they could prove dangerous on entering the passenger section of the vehicles. Once released. the exhausted gases first reach the piping system of the exhaust. Since the engine generally comprises of more than one cylinder, various pipes are suitably installed to collect the gases from different cylinders to gather them together, before being fed to one single pipe, from where they are released into the atmosphere. The gases keep moving to the rear part of the vehicle, and they are continuously pushed ahead by the gases being continuously released by the engine.

Next, the gases enter the converter before reaching the exhaust system. The function of the convertor is to eliminate the harmful materials Contained in the gases. So, the gases that leave the converter are not as harmful as those entering it. Subsequent to that, the gases pass through a muffler, the main function of which is to significantly reduce the noise produced by the running engine. And at last, the exhaust leaves the system via a tailpipe. The present exhaust system of cars can be modified to slightly enhance the performance of the engine. This can be achieved by minimizing the friction and resistance offered by the system to enable the exhaust to travel faster and more easily. This enhances the efficiency of the engine. Friction can be reduced by making the interiors of the pipe smoother with the help of specially meant after sale parts.

1.5 MUFFLER

A muffler (silencer in many non US English speaking countries) is a device for decreasing the amount of noise emitted by the exhaust of an internal combustion engine.

1.5.1 Description

Mufflers are installed within the exhaust system of most internal combustion engines, although the muffler is not designed to serve any primary exhaust function. The muffler is engineered as an acoustic soundproofing device designed to reduce the loudness of the sound pressure created by the engine by way of acoustic quieting. The majority of the sound pressure produced by the engine is emanated out of the vehicle using the same piping used by the silent exhaust gases absorbed by a series of passages and chambers lined with roving Fiberglass insulation and/or resonating chambers harmonically tuned to cause destructive interference wherein opposite sound waves cancel each other out An unavoidable side effect of muffler use is an increase of back pressure which decreases engine efficiency. This is because the engine exhaust must share the same complex exit pathway built inside the muffler as the sound pressure that the muffler is designed .

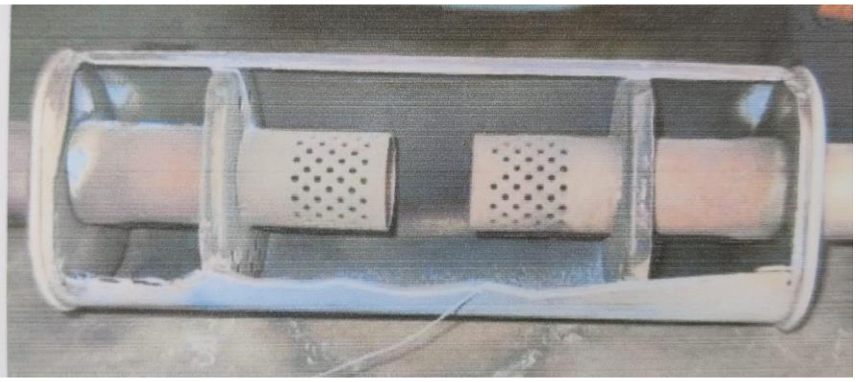


Figure 1.3 Sectional view of Muffler

When the flow of exhaust gases from the engine to the atmosphere is obstructed to any degree, back pressure arises and the engine's efficiency, and therefore power, is reduced Performance-oriented mufflers and exhaust systems thus strive to minimize back pressure by Employing numerous technologies and methods to attenuate the sound. For the majority of such systems, however, the general rule of more power, more noise applies.

Several such exhaust systems that utilize various designs and construction methods: Vector muffler: for larger diesel trucks, uses many concentric cones, or for performance automotive applications, using angled baffles to cause exhaust impulses to cancel each other out.

Spiral baffle muffler for regular cars, uses a spiral shaped baffle system.

1.5.2 Muffler Construction

The first muffler was patented in 1897 by Marshall and Milton Reeves. The muffler is the main component of the exhaust system for silencing acoustic exhaust noises. There are many different designs of mufflers available today. Some being chambered, glass pack, straight through glass packs and combinations of those. It is designed to reduce loudness acoustic sound pressures created by the combustion process. Fiberglass is the most commonly used material inside of traditional mufflers. Other materials could include rock minerals, wool, fiber mat, or simple metal chambers to aid in absorption and reduce unwanted exhaust sounds.

A muffler must be able to withstand the running conditions of a vehicle. This includes the engine sound frequencies, hazardous driving conditions (off- roading), and most of the muffler must withstand rust and corrosion.

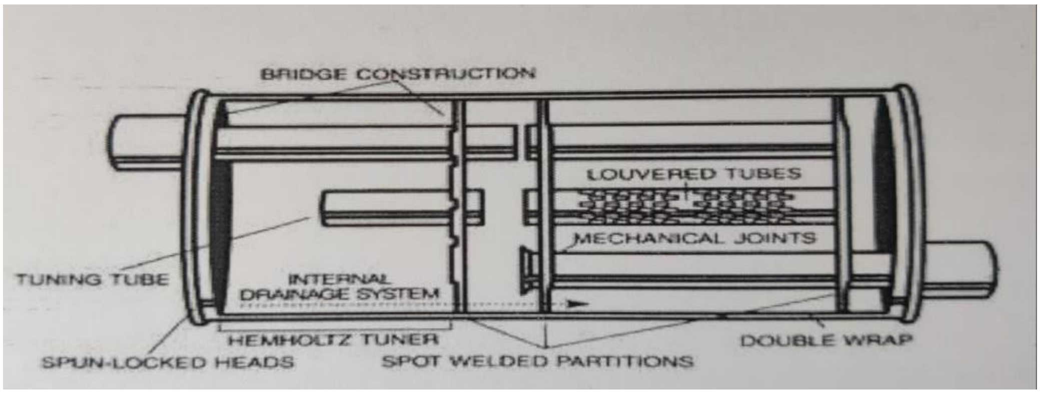


Figure 1.4 Sectional view of the muffler

The spun-locked heads and shell lock seam also ensure a gas-tight fit between the head and shell. As exhaust gases pass through the catalytic converter, one of the chemical reactions by products is water. The muffler has a series of pin holes in the bottom to allow this water to escape. If these holes become plugged up, and water cannot escape or be evaporated quickly enough, the muffler will start to rust from the inside out. Do not drink this water, as it's not entirely pure. Generally, long distance highway and city driving will keep the mufflers hot enough to evaporate any water that is collected. Short distance driving and low speed stop-and-go driving can cause a build up of excessive water within the system. It is nothing to fear, or to get worried about however. Louvered Tubes - These tubes provide better gas flow to maintain a more uniform internal temperature. By avoiding cool spots within the muffler, most acid condensation can be prevented.

Internal Drainage System - A complete internal drainage system prevents most water from collecting within the muffler. The exits can be seen on the bottom of the Muffler or near the outlet tube.

Spot Welded Partitions - Spot welding is used to attach the partitions to the muffler shell. The idea behind this is to keep strength, but also allow small amounts of space for exhaust water to be able to escape through in order to drain out.

Joined Internal Tubes To ensure longer life, internal tubes are mechanically joined to the partition to allow free-floating expansion and contraction during temperature changes. This unique design eliminates the breaking of spot welds and subsequent part distortion or loose part noise problems.

1.5.3 Possible Muffler Designs

There are numerous types of automotive mufflers currently in the market place and described below are the key features and benefits of various muffler designs that may be found on a vehicle. The following types of mufflers have been widely tested and the general observations from such tests are described.

Automotive mufflers usually have a circular or elliptical cross section. A circular shaped crosssection is best suited in a vehicle as it delays the onset of higher order modes.

Most formulas that are used to predict the transmission loss of a muffler assume plane wave propagation. The properties of the following designs are only valid up to the cut off frequency, where higher order modes occur. Generally for all mufflers maximum transmission loss occurs at odd multiples of a quarter wavelength.

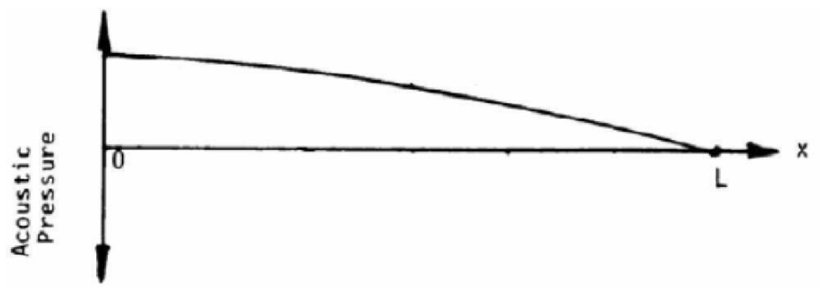


Figure 1.5 Quarter Wave length

The most basic type of silencing element that may be used for intake and exhaust mufflers is the expansion chamber. It consists of an inlet tube, an expansion chamber and an outlet tube as shown in Figure 1.8. The inlet and outlet tubes may be coaxial known as a concentric expansion chamber or offset known as an off set expansion chamber.

The sudden expansion and contraction in this type of muffler causes sound waves to reflect back and interfere with each other.

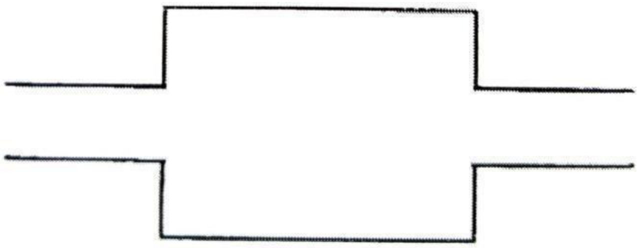


Figure 1.6 Simple Expansion Chamber

Expansion chambers are efficient in attenuating low frequency sound, which makes them ideal for automotive applications. They do not attenuate high frequency sound so well as it 'beams' straight through the muffler.

Expansion chamber mufflers have been widely studied and results show that the larger the expansion ratio the greater the transmission loss. The length of the chamber should be at least 1.5times the diameter.

The greater the protrusion into the muffler the greater the transmission loss however the inlet and outlet tubes should maintain a separation space of at least 1.5 times the diameter of the chamber to ensure the decay of evanescent modes.

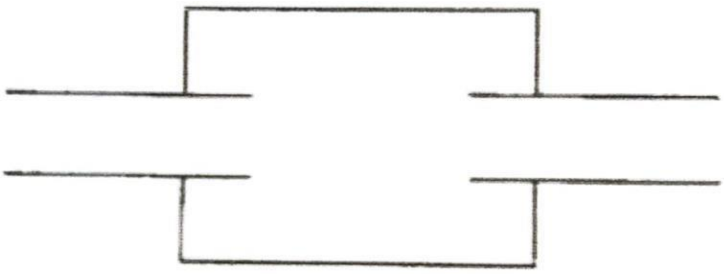


Figure 1.7 Expansion chamber with an extended inlet and outlet

Noise can be further attenuated by the addition of porous material inside the expansion chamber whilst maintaining the same muffler dimensions Sound waves loose energy as they travel through a porous medium. The absorptive material (porous material) causes the fluctuating gas particles to convert acoustic energy to heat. The main benefit of a straight through absorptive silencer, as shown in Figure 1.8, is that insignificant backpressure is generated therefore improving vehicle performance. The perforated tube is used to guide the exhaust flow and avoids the creation of turbulence as is found in an expansion chamber.

Figure 1.8 Straight Through Absorption Muffler

The material used to guide the exhaust flow, yet allow sound waves to escape, is usually perforated steel with an open area of approximately 20%.

An absorptive silencer produces a more consistent transmission loss (TL) curve as shown in Figure 1.9. The expansion chamber TL curve is typically domed in shaped and as can be seen the absorptive material not only irons out these humps but also increases transmission loss dramatically especially for the higher frequencies.

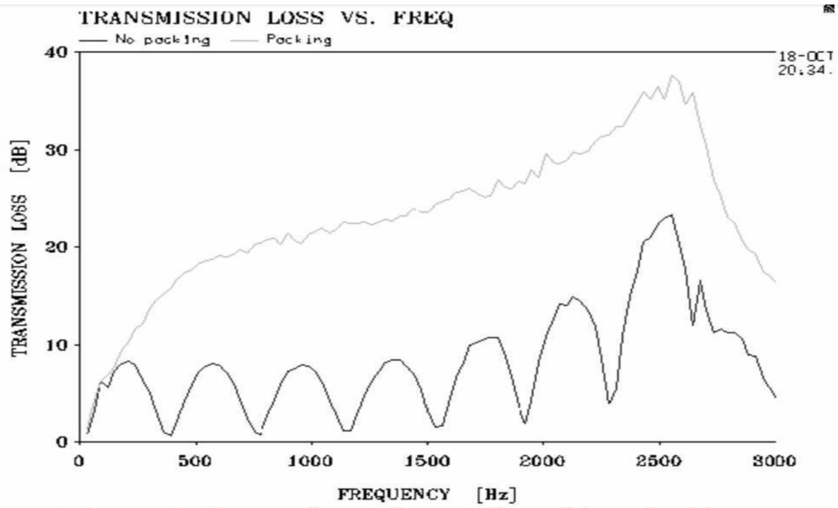


Figure 1.9 Comparison of a muffler with and without absorptive material

Aside branch resonator as seen in Figure 1.10 is a muffling device used to control pure tones of a constant frequency. It generally takes the form of a short length of pipe whose length is approximately a quarter of the wavelength of the sound frequency to be controlled.

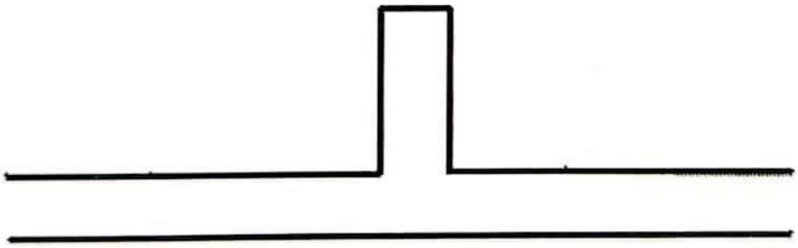


Figure 1.10 Side Branch resonator

A Helmholtz resonator as seen in figure 1.11 is similar to a side branch resonator the only

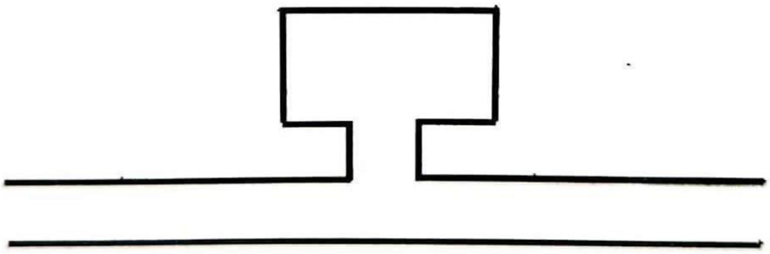


Figure 1.11 Helmholtz Resonator

difference being that there is a backing volume joined to the connecting orifice.

If it is found that the unruffled exhaust noise spectrum has noticeable peaks at resonating chamber (concentric resonator) muffler or a side branch resonator may be used, to target these specific resonant frequencies. The resonating chamber style of muffler is extremely efficient in providing noise control for a specific frequency band; however the attenuation band is very narrow. This characteristic is not very useful in automotive exhaust system where attenuation is needed over all frequencies. A side branch resonator may be however used in addition to a muffler to treat a particular problem frequency.

If a broader and improved attenuation spectrum is required multiple resonators should be used. Each chamber is designed to reduce a specific frequency being an odd multiple of a quarter wave lengths apart. Attenuation is increased as the number of chambers increase although the addition of a third chamber only provides a small increase in attenuation. If a tube connects the chambers, the longer the tube the greater the attenuation achieved. This type of muffler is useful when space is limited and low frequency performance is required.

The volume and shape of the resonating chamber govern its performance capabilities. Generally as the volume of the resonating chamber increases the resonant frequency reduces.

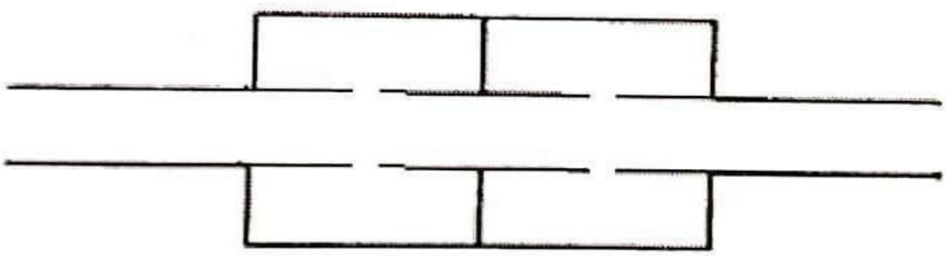


Figure 1.12 Resonating Chamber Muffler

1.6 FUNCTIONAL REQUIREMENTS OF A ENGINE EXHAUST MUFFLER

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

1.6.1 Adequate Insertion Loss

The main function of a muffler is to "muffle" or attenuate sound. An effective muffler will reduce the sound pressure of the noise source to the required level. In the case of an automotive muffler the noise in the exhaust system, generated by the engine, is to be reduced.

A mufflers performance or attenuating capability is generally defined in terms of insertion loss or transmission loss. Insertion loss is defined as the difference between the acoustic powers radiated without and with a muffler fitted. The transmission loss is defined as the difference (in decibels) between the sound power incidents at the entry to the muffler to that transmitted by the muffler.

As a general principle when designing an automotive muffler, a reactive muffler with many area discontinuities will achieve a greater attenuation than one with fewer area discontinuities. The addition of sound absorptive material will always increase the attenuation capacity of a muffler, but should be located in an appropriate place.

1.6.2 Backpressure

Backpressure represents the extra static pressure exerted by the muffler on the engine through the restriction in flow of exhaust gasses.

Generally the better a muffler is at attenuating sound the more backpressure is generated. In a reactive muffler where good attenuation is achieved the exhaust gasses are forced to pass through numerous geometry changes and a fair amount of backpressure may be generated, which reduces the power output of the engine. Backpressure should be kept to a minimum to avoid power losses especially for performance vehicles where performance is paramount.

Every time the exhaust gasses are forced to change direction additional backpressure is created. Therefore to limit backpressure geometric changes are to be kept to a minimum, a typical example of this is a "straight through" absorption silencer. Exhaust gasses are allowed to pass virtually unimpeded through the straight perforated pipe.

1.6.3 Size

The available space has a great influence on the size and therefore type of muffler that may be used. A muffler may have its geometry designed for optimum attenuation however if it does not meet the space constraints, it is useless.

Generally the larger a muffler is, the more it weighs and the more it costs to manufacture. For a performance vehicle every gram saved is crucial to its performance/acceleration, especially when dealing with light open wheeled race vehicles. Therefore a small light weight muffler is desirable.

1.6.4 Durability

The life expectancy of a muffler is another important functional requirement especially when dealing with hot exhaust gasses and absorptive silencers that are found in performance vehicles.

Overtime, hot exhaust gasses tend to clog the absorptive material with unburnt carbon particles or burn the absorptive material in the muffler. This causes the insertion loss to deteriorate. There are however, good products such as mineral wool, fiberglass, sintered metal composites and white wool that resist such unwanted effects.

Reactive type mufflers with no absorptive material are very durable and their performance does not diminish with time.

Generally mufflers are made from corrosion resistive materials such as stainless steel or aluminum. Mild steel or aluminized steel is generally used for temperatures up to 500°C, type 409 stainless steel up to 700 "C and type 321 stainless steel for even higher temperatures Automotive exhaust gas temperatures are usually around 750 °C.

1.6.5 Desired Sound

Generally a muffler is used to reduce the sound of a combustion engine to a desired level that provides comfort for the driver and passengers of the vehicle as well as minimizing sound pollution to the environment. Muffler designs generally aim to reduce any annoying characteristics of the untreated exhaust noise such as low frequency rumble.

Breakout noise from the muffler shell may be a problem and should be minimized together with flow-generated noise, especially when designing a muffler for a high insertion loss.

1.6.6 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.

1.6.7 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 oval or round geometry. The inside detail of this larger chamber may be one of numerous constructions. The end user of the muffler usually does not care what is inside this chamber so long as the muffler produces the desired sound and is aesthetically pleasing. It is therefore the task of the muffler designer to ensure that the muffler is functional as well as marketable.

1.6.8 Noise Control

Noise control or noise mitigation is a set of strategies to reduce noise pollution or to reduce the impact of that noise, whether outdoors or indoors.

Many of these techniques rely upon materials science applications of constructing sound baffles or using sound absorbing liners for interior spaces. Industrial noise control is really a subset of interior architectural control of noise, with emphasis upon specific methods of sound isolation from industrial machinery.

1.6.9 Basic Technologies

Sound insulation: prevent the transmission of noise by the introduction of a mass barrier. Common materials have high density properties such as thick glass, metal etc.

Sound absorption: a porous material which acts as a "noise sponge by converting the sound energy into heat within the material. Common sound absorption materials include decoupled lead based tiles. "Noise cancelling" devices are also available. These devices use a microphone to intercept incoming sounds. Then they send out "anti-noise" signals to cancel the noise. Noise cancelling headphones or smartphone apps are among the cheaper noise. cancelling options. Hearing aid type devices are also available, but are much more expensive.

Acoustic block is a high performance soundproofing and noise deadening solution, now available in India where strict laws have been put in place to reduce noise pollution.

1.7 TYPES OFMUFFLERS

1.7.1 Baffle Type Muffler

It consists of a number of baffles spot welded inside the cylindrical body. the purpose of these baffles is to close the direct passage of the exhaust gases, thus the gases travel a longer path in the muffler.

The flow pipe of this type of muffle having number of baffles which restricts the exhaust gases to directly pass through the system. Instead, there are many secondary passages are made in the flow pipe so that exhaust gas will pass through this secondary passage and thus, the gas has to travel a longer path in the system. The long travel path definitely reduces the pressure and temperature of the gas but due to restriction in flow, because of baffles, the back pressure is generated in the system which may further lead to degrade the engine efficiency and performance.

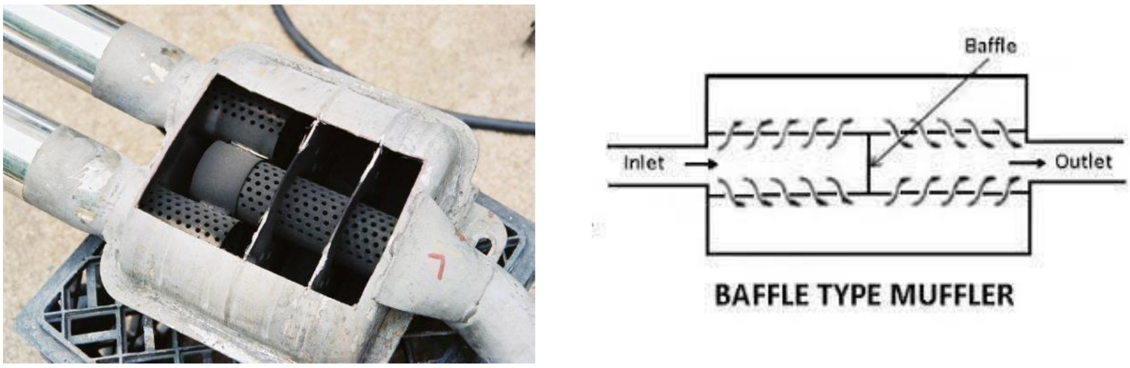


Figure 1.13 Baffle type Muffler

1.7.2 Wave Cancellation Type Muffler

In this type of muffler, as the exhaust gas enters into it, the gas is divided into two equal streams. Both streams of gas move along the long path and then return back to a single point where the streams get merged and start moving towards the outlet as a single stream. The length of the passage that contains the separated stream are designed in such a way that at the merging point the crest of one wave (stream) merged with the trough of another wave (stream).Thus, both waves cancel the amplitude of each other and theoretically reduces the noise to the zero level. But, practically the zero noise is impossible in the system because the noise produced by an engine is at different frequency while running at different speeds. However, the wave cancellation type muffler reduces the noise significantly up to the acceptable level.

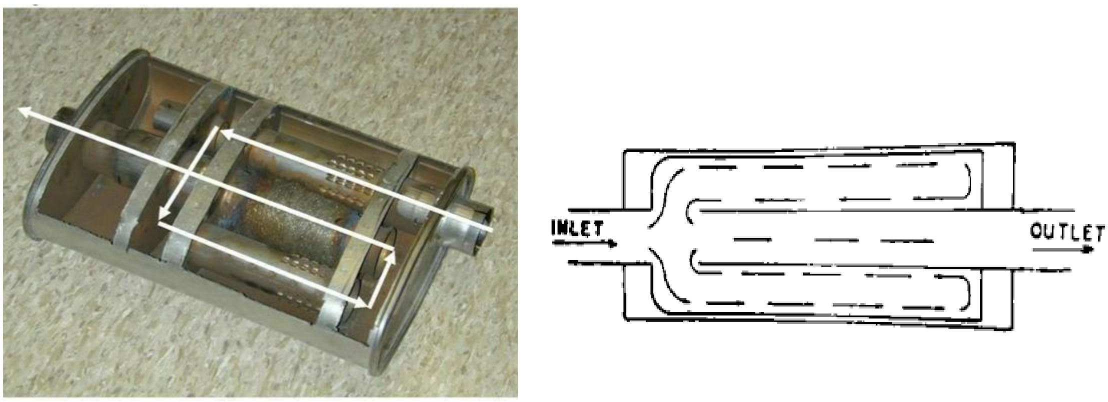


Figure 1.14 Wave Cancellation Type Muffler

1.7.3 Resonance Type Muffler

This type of muffler consists of a series of Helmholtz resonator. The flow pipe passes through this resonator. The flow pipes are having access ports through which the gas flows into the resonator. The resonator generates the destructive frequencies which when superimposed over the noise wave of the exhaust gas, the resonance occurs. Thus, the frequency of noise wave gets diminished up to very low extent, and hence significant elimination of the noise takes place. This kind of resonator is very helpful at engines which is not having ample space to fit other type of muffler.

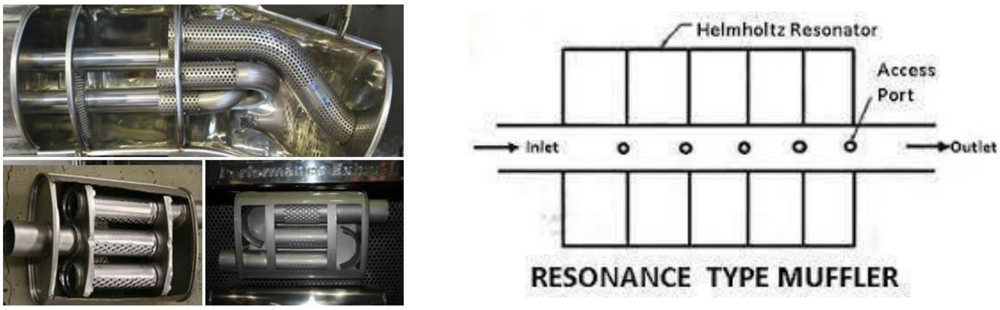


Figure 1.15 Resonance type Muffler

1.7.4 Absorber Type Muffler

This is the most common type of muffler used in now days. This muffler consists of a perforated tube (a tube having ‘n’ number of small fine holes) and around this tube the sound or noise absorbing material such as steel wool, fiber glass etc. are wrapped. As the exhaust gas passes through this perforated tube, the noise absorbing material provides the cushioning effect to the high pressure fluctuation of the exhaust gas. Due to this phenomenon, the pressure intensity of the exhaust gas decreases and thus level of exhaust noise gets reduced up to acceptable range. Generally, the flow pipes are straight through, but, sometimes the helical coiled pipes are also used to increase the passage length.

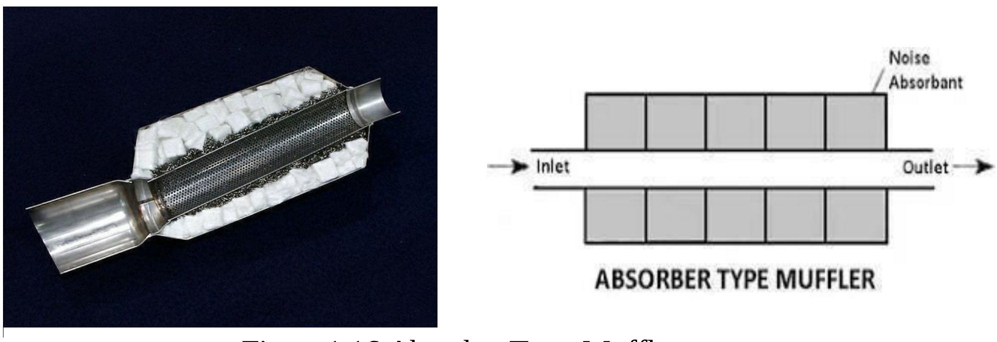


Figure 1.16 Absorber Type Muffler

1.7.5 Combined Type Muffler

This kind of muffler consist the combination of absorber type muffler and resonance type muffle. The design of combined type muffler made in such a way that the exhaust gas first pass through the absorber type area, which contains the similar setup as described in preceding segment (4th type of muffler). At the end of the flow tube, instead of perforation, an access port is created and over this port the Helmholtz resonator is fixed.

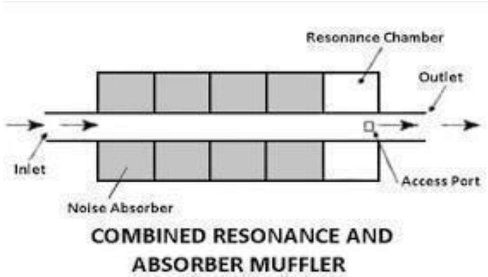


Figure 1.17 Combined Type Muffler

1.8 NOISE STANDARD IN INDIA

The central pollution control board constituted committee on noise pollution control. The committee recommended noise standards for ambient air and for automobiles according to various zones are as follows

Table 1.1 Noise Standards In INDIA

Area	Day time noise limit (dB)	Night time noise limit (dB)
Industrial area	75	70
Commercial area	65	55
Residential area	55	45
Silence zone	50	40

The Noise Limits for vehicles were notified by Environment (Protection) Amendment Rules, 2000. Noise limits for vehicles applicable at manufacturing stage applicable from 1st April, 2005 are as given in the table below:

Table 1.2 Noise Limits for Vehicles

Categories	**Noise limit in dB**
Motor cycle and scooter	75 to 80
Three Wheelers	77 to 80
Passenger cars	78 to 80
Transport Vehicles	77 to 80

1.9 WORKING OFMUFFLER

Mufflers are used mainly to dissipate the loud sounds created by the engine's pistons and valves. Every time your exhaust valve opens, a large burst of the burnt gases used during your engine's combustion is released into the exhaust system. This release of gases creates very powerful sound waves. To understand how a muffler dissipates the sound waves created by your engine, one must understand how sound is produced. Sound is a pressure wave formed by vibrations. These vibrations are pulses of alternating high and low air pressure.

So, every time your exhaust valve opens, a very high-pressured gas enters into the exhaust system. These high-pressure gases will collide with low-pressure molecules, create pressure waves (sound), and travel through the exhaust system. Sound can actually be cancelled out. If you can introduce a pressure wave that is the exact opposite of the initial sound wave, meaning their wavelengths, or high- and low-pressure points, are opposite, they cancel each other out, and there is no sound. Another way to describe what happens is when one sound wave is at its maximum pressure, the other sound wave is at its minimum pressure; so, they cancel each other out. This is called destructive interference and is what occurs inside your muffler. A muffler design is very simple yet very precise. Inside a muffler there are tubes with perforations that direct the sound waves through the inside of the muffler and out the end. Sound waves will enter through a central tube, hit the back wall, pass through a hole and enter the center chamber. Then the sound wave will travel through another hole and enter the resonator chamber, which is back towards the front of the muffler where the sound waves first entered. Now, some of the sound wave will reflect off the center chamber's wall, while the rest will pass through the hole and into the resonator chamber. The resonator chamber has a very specific length in order to produce sound waves that will cancel out other waves. The resonator chamber's length is designed so that when the sound wave hits the back wall of the resonator chamber and travels back through the hole in which it came, it will meet with the next sound wave exactly when it hits off the center chamber's wall. So, the high-pressure sound wave that travelled through the resonator will join with the low-pressure sound wave that was reflected off the center chamber's wall and cancel each other out. Every aspect of the muffler is designed to aid in cancelling out noise. Even the walls of a muffler are specifically designed; they are actually able to absorb some of the pressure waves. Now, back to the tubes with perforations, these perforations allow thousands of tiny pressure waves to escape into the center chamber, bounce off the walls and cancel each other out. Basically, a muffler is specifically designed to control how sound waves bounce off its walls so they cancel each other out.

CHAPTER 2

LITERATURE REVIEW

LITERATURE REVIEW

Amit Kumar Gupta, Dr.Ashesh Tiwari et al ., [1]

Mufflers are device which are installed within the exhaust system. It is basically used for noise reduction. Reactive muffler plays an important role as noise control element for reduction of automotive exhaust noise, fan noise, and other noise sources involving the flow of gases. Mufflers are typically arranged along the exhaust pipe as the part of the exhaust system of an internal combustion engine to reduce its noise. The expansion chambers with various cross section like Circular, Elliptical, Square & Rectangular are commonly use for noise attenuation. The degree of attenuation can also be improved with design optimization of inlet pipes, outlet pipes & baffle plates. The present paper aims to concentrate to study the acoustic performance of reactive mufflers with various cross sections by one-dimensional wave approach. Here the result shows to identify the transmission loss characteristics by taking different cross sections of simple expansion chambers by taking consideration of constant volume of expansion chamber.

Ayush Lal et al., [2]

considered CFD Analysis of Flow through Muffler to Select Optimum Muffler Model for CI Engine Mufflers increase the pressure of the exhaust gases (back pressure) thereby reducing the sound levels of the same. Therefore importance is given to muffler designing and a particular design is selected for which the sound reduction is maximum. for this exhaust gas CFD simulation is carried in software's such as ANSYS FLUENT. Two muffler designs have been modelled and CFD gas flow simulation has been carried in both of them. Based upon the gas flow through them, on comparison we have selected the optimum model.

Demonstrates that model is more efficient for noise reduction and other design offers more reduction in gas pressure and hence reduces noise levels.

Balraj.D.Kawade, Niranjan D. Khaire et al., [3]

discussed on Design alternatives for automobile silencer. The exhaust gases coming out from engine are at very high speed and temperature. Silencer has to reduce noise, vibrations. While doing so it is subjected to thermal, vibration and fatigue failures which cause cracks. So it is necessary to analyse the Vibrations which would further help to pursue future projects to minimize cracks, improving life and efficiency of silencer. For silencer vibration analysis we can use FEM simulation methodology described as a better solution over conventional trial and error method for predicting the errors in modal analysis. Natural frequencies can be determined and the mode shapes can be reviewed in the light of its performance contributing to any increased like hood of undesired trends.

Prof. Bharat S. Patel, Mr. Kuldeep, D. Patel et al.,[4]

The purpose of this paper is to present Air pollution generated from mobile sources is a problem of general interest. Vehicle population is projected to grow close to 1300 million by the year 2030. Due to incomplete combustion in the engine, there are a number of incomplete combustion products CO, HC, NOx, particulate matters etc. This review paper discusses automotive exhaust emissions and its impact, automotive exhaust emission control by platinum (noble) group metal based catalyst in catalytic converter, history of catalytic convertor, types of catalytic convertor, limitation of catalytic convertor and also achievements of catalytic convertor.

Jayashri P. Chaudhari and Amol B. Kakade et al.,[5]

considering different noise parameters produced by the engine. Here different design parameters with ammonia pulsator have been considered to improve the efficiency & emission control of the absorptive muffler. Considering different noise parameters produced by the engine. Here different design parameters with ammonia pulsator have been considered to improve the efficiency & emission control of the absorptive muffler. His Aim is to design, develop and analysis of mathematical modelling and derivation of dimensional parameters of absorptive muffler with ammonia pulsator using UG NX-8.0 and ANSYS workbench. The formulated muffler traditional design problem will be solved by new design and optimization.

M. Rajasekhar Reddy, Dr K. Madhava Reddy. et al., [6]

The present work aims at improve the frequency of NSD (Nash Shell Damper) muffler by controlling the noise level of a diesel engine by developing an exhaust muffler for the same, since exhaust noise is the single largest contributor to the overall noise from the engine.

The TATA INDICA TURBOMAX TDI BSIV four-cylinder diesel engine car was considered for test purposes. In this study Muffler dimensions are measured through the Benchmarking, to create CAD models. The CAD models are created in CATIA V5 R19, later these CAD models of muffler are exported to HYPER MESH for pre-processing work. Free analysis is carried out on this muffler by FEA Method using NASTRAN Software.

M. L. Munjal et al., [7]

explained Recent Advances in Muffler Acoustic, Challenges for muffler design has been constraints on size, back pressure, and, of course, the cost. Designing for sufficient insertion loss at the engine firing frequency and the first few harmonics has been the biggest challenge. Breakthroughs have been achieved in the prediction and control of breakout noise from the elliptical and circular muffler shell as well as the end plates of typical mufflers. Diesel particulate filters and inlet air cleaners have also been modelled acoustically.

Rahul D. Nazirkar, et al., [8]

improved the design efficiency of muffler, resonating of the exhaust muffler should be avoided by its natural frequency. The solid modelling of exhaust muffler is created by CATIA-V5 and modal analysis is carried out by ANSYS to study the vibration and natural frequency of muffler. So as to differentiate between the working frequency from natural frequency and avoid resonating. By fixing the muffler at first and double expansion chamber we can increase the frequency and avoid the resonance. Transmission loss of the muffler can be increased by adding protrusion pipe at inlet and outlet. It can be seen that the finite element modal analysis has certain significance in the study of vibration characteristics ofthe muffler.

S.Balamurugan et al., [9]

designed a muffler for four stroke diesel engine ln this research baffle arrangement are used to resist the flow of the exhaust from the engine. An exhaust pipe must be carefully designed to carry toxic and/or noxious gases away from the users of the machine Indoor generators and furnaces can quickly fill an enclosed space with carbon monoxide or other poisonous exhaust gases if they are not properly vented to the outdoors. Also, the gases from most types of machine are very hot, the pipe must be heat resistant and it must not pass through or near anything that can burn or damaged by the heat by using this kind of muffler we can eliminate the enormous amount of toxic exhaust that are all released from an engine which leads the way towards the eco-friendly vehicle production. It reduces the usage of fuel about 0.5%, also reduces the back pressure of the exhaust flow, and thus increases the range of continuous exhaust flow than a normal conventional engine.

Mr. Sanchit Babarao Dhotre & Prof. S.L. Shinde et al., [10]

describes various exhaust noises, vibration and their contribution. Frequency, vibration and noise technique is studied through energy flow. Hence, it is necessary to study the behaviour of muffler by analyzing the vibration modes and vibration response. They conclude that the natural frequency of existing model is much lower and this model of muffler silencer are unable to sustain the resonance which are formed due to noise and also jerk comes from road and this causes vibration in silencer which is un comfort to ride. But by making modification in muffler silencer the natural frequency at different modes is greater than existing and this frequency is capable to reduce vibration and it provide comfort ride and efficient ride.

Sandeep G Thorat et al., [11]

analysed with respect to both acoustics and back pressure. As per the various studies reactive mufflers with extended inlet and outlet pipes into muffler, which is not present in current design can significantly reduce the noise level. Helmholtz resonator can also be introduced to cancel the noise of dominating frequencies. Also a sound absorbing material like glass fibers and steel wool can be incorporated for better results. The new muffler design would be a 3 chamber muffler with extended perforated tube. Further it would have a resonator to damp the most dominating frequencies. The total length of the silencer may be reduced to make it more cost effective.

Shital Shah, Saisankaranarayana K ,Kalyankumar S.Hatti et al.,[12]

Exhaust noise from engines is one of component noise pollution to the environment. Exhaust systems are developed to attenuate noise meeting required db (a) levels and sound quality, emissions based on environment norms. Most of the advances in theory of acoustic filters and exhaust mufflers have been developed in last two decades. This paper deals with a practical approach to design, develop and test muffler particularly reactive muffler for exhaust system, which will give advantages over the conventional method with shorten product development cycle time and validation. This paper also emphasis on how modern CAE tools could be leveraged for optimising the overall system design balancing conflicting requirements like Noise & Back pressure.

Suyog S. Mane ,Prof . S.Y. Bhosale, Prof. H.N. Desh Pande et al.,[13]

The present study describes the analysis of back pressure of the muffler by using CFD simulation. The CFD analysis is done to avoid the tedious experimentation. The flow simulation is carried out using k-ε turbulent model as it is most suitable for turbulent flows having less converging time. Total four cases were analyzed including the base model muffler. Thus three modifications were done in muffler geometry. The modification with reduced baffle spacing produced least back pressure with reduction in back pressure by 9.60%.

Sweta Baruah, Sushovan Chatterjee et al.,[14]

In this work, an elliptical chamber muffler model of a MAHINDRA C.I. engine is studied based on CFD analysis of the exhaust gas flow through the muffler chamber. Two designs for the aforementioned muffler are analyzed one of which consists of perforated inlet, outlet and central pipes which, if implemented in actual practice could bring about better and improved sound attenuation. Transmission loss is calculated for both the muffler models based on pressure distribution obtained from CFD analysis results. Comparative study of the two muffler models, one without the presence of any perforation and the other after incorporation of perforation, is carried out in ANSYS FLUENT 14.5.

UjjalKalita et al., [15]

concentrated on Different sound absorption materials that are currently used for noise reduction Different components are present in the muffler for transmission loss like perforated tubes, absorption materials etc. by which noise is reduced. The production of metal foams, ceramic foams, and aerogels can contribute to greenhouse gas emissions, their practical use in transportation will help in reducing other emissions and help in reducing fuel consumption. Since these materials possess high structural strength and reduced structural weight simultaneously, their use in the aerospace and automotive industries has the potential to reduce fuel consumption and save energy.

CHAPTER 3

MODELLING AND ANALYSIS OF DIESEL ENGINE MUFFLER

MODELLING AND ANALYSIS OF DIESEL ENGINE MUFFLER

3.1 INTRODUCTION TO CATIA:

CATIA (Computer-Aided Three-dimensional Interactive Application) software is a complete multi- platform solution for computer-aided design, manufacturing, engineering, 3D and PLM. Marketed by manufacturer Dassault Systems, the software is ideal for creating solids, surfaces, assemblies, drawings, fabrication and analysis.

CATIA currently stands at version level 6, better known as CATIA V6.

The first release of CATIA was back in 1977 by Dassault Systems, who still maintain and develop the software. It was initially developed for use in designing the Dassault Mirage fighter jet.

Nowadays, the most widely used version is CATIA V5, with CATIA V4 still being used in some industries, mostly in conjunction with V5. Between versions, CATIA has varied significantly in terms of usage and appearance. Each Version brings significant additional functionality. Between V4 and V5, the fundamentals to the design process were developed and between V5 and V6 the handling of data changed. Within each version, Dassault Systems also offer updates in the form of releases. New releases are typically released annually and also bring additional functionality within the Version as well as bug fixes.

CATIA V5:

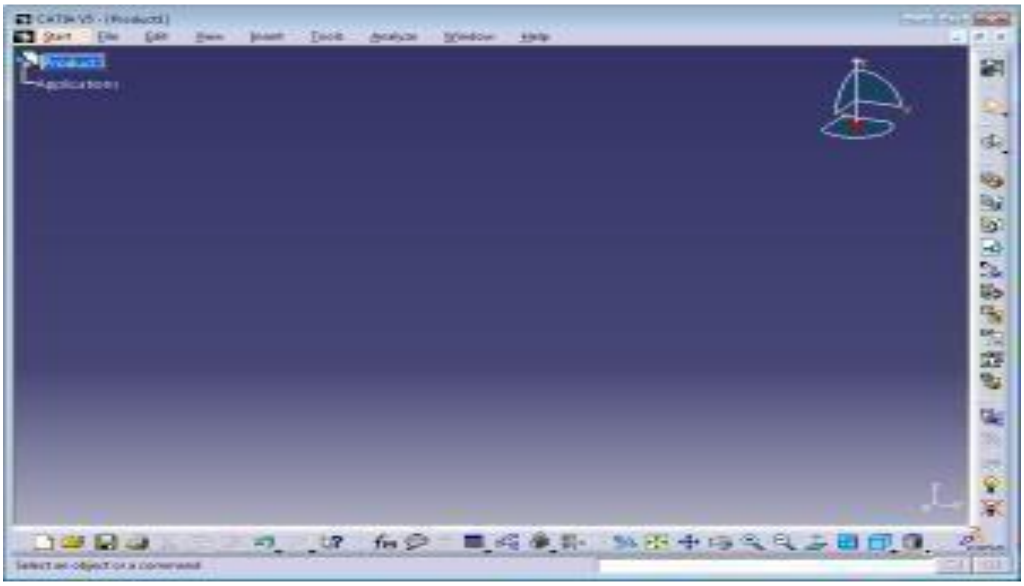


Fig 3.1 CATIA version 5 module

3.2 WHAT DOES CATIA DO?

CATIA provides the capability to visualize designs in 3D. When it was introduced, this concept was innovative. Since Dassault Systems did not have an expertise in marketing, they had revenue sharing tie-up with IBM which proved extremely fruitful to both the companies to market CATIA. In the early stages, CATIA was extensively used in the design of the Mirage aircrafts; however the potential of the software soon made it a popular choice in the automotive sector as well. As CATIA was accepted by more and more manufacturing companies, Dassault changed the product classification from CAD / CAM software to Project Lifecycle Management. The company also expanded the scope of the software.

CATIA can be used at different stages of the design - ideate, draw, test and iterate. The software comes with different workbenches ("modules") that allow CATIA to be used across varied industries – from parts design, surface design and assembly to sheet metal design. CATIA can also be used for CNC.

3.3 FUNCTIONALITIES OF CATIA:

CATIA has capabilities in multiple domains.

The majority of users do not require all functionalities available in CATIA, which has significant cost impacts on the user or organization. Licenses are therefore broken down to include required functionality and are pre-defined. Depending on the license, additional workbenches become available and/or additional tools within workbenches become available. Workbenches in CATIA work a bit like different software held within CATIA. They allow the user to perform different tasks, from:

1. Part Modelling

Part Design workbench

The Part Design workbench enables users to design precise 3D mechanical parts. From assembly sketching to detailed design, the Part Design application accommodates the vast majority of design requirements.

2. Assembly Modelling

Assembly Design workbench

The Assembly Design workbench enables users to design cooperate with Part Design and Generative Drafting apps on scalable design projects. Various visual tools allow for 3D navigation through large assemblies

3. Surface Modelling

Generative Surface Design workbench

The Generative Surface Design workbench enables users to create wireframe construction elements and enrich existing mechanical part design with wireframe and surface features.

4. Finite Element Analysis

Generative Structural Analysis

The Generative Structural Analysis enables users to perform first order mechanical analysis for 3D systems.

This workbench includes:

A) Generative Part Structural Analysis (GPS) for obtaining mechanical behaviour information.
B) ELFINI Structural Analysis (EST) for mechanical analysis developments.
C) Generative Assembly Structural Analysis (GAS) for analysis of the mechanical behaviour of a whole assembly.
D) Generative Dynamic Analysis (GDY) for working in a dynamic response context.

5. Sheet metal Part Design

Generative Sheet metal Design

Generative Sheet metal Design enables users to perform associative feature-based modelling, making it possible to design sheet metal parts in concurrent engineering between the unfolded or folded part representation.

6. Rendering

RealTime Rendering workbench

The Real Time Rendering workbench enables users to define material specifications that will be shared across the whole product development process, while mapping materials onto parts and products to produce realistic renderings.

7. Engineering Drawing creation

Generative Drafting work bench

The Generative Drafting workbench enables users to generate drawings from 3D parts and assembly definitions.

3.4 CATIA TOOLS:

Sketcher Work Bench ToolBars

The Sketcher workbench is a set of tools that helps you create and constrain 2D geometries. Features (pads, pockets, shafts, etc...) may then be created solids or modifications to solids using these 2D profiles. You can access the Sketcher workbench in various ways. Two simple ways are by using the top pull down menu (Start – Mechanical Design – Sketcher), or by selecting the Sketcher icon. When you enter the sketcher, CATIA requires that you choose a plane to sketch on. You can choose this plane either before or after you select the Sketcher icon. To exit the sketcher, select the Exit Workbench icon.

The Sketcher workbench contains the following standard workbench specific toolbars.

- Sketch tools toolbar: The commands in this toolbar allow you to work in different modes which make sketching easier.

- Profile toolbar: The commands located in this toolbar allow you to create simple geometries (rectangle, circle, line, etc...) and more complex geometries (profile, spline, etc...)

- Operation toolbar: Once a profile has been created, it can be modified using commands such as trim, mirror, chamfer, and other commands located in the operation toolbar

- Constraint toolbar: Profiles may be constrained with dimensional (distances, angles, etc...) or geometrical (tangent, parallel, etc...) constraints using the commands located in the Constraint toolbar.

- User Selection Filter toolbar: Allows you to activate different selection filters

- Visualization toolbar: Allows you to, among other things to cut the part by the sketch plane and choose lighting effects and other factors that influence how the part is visualized

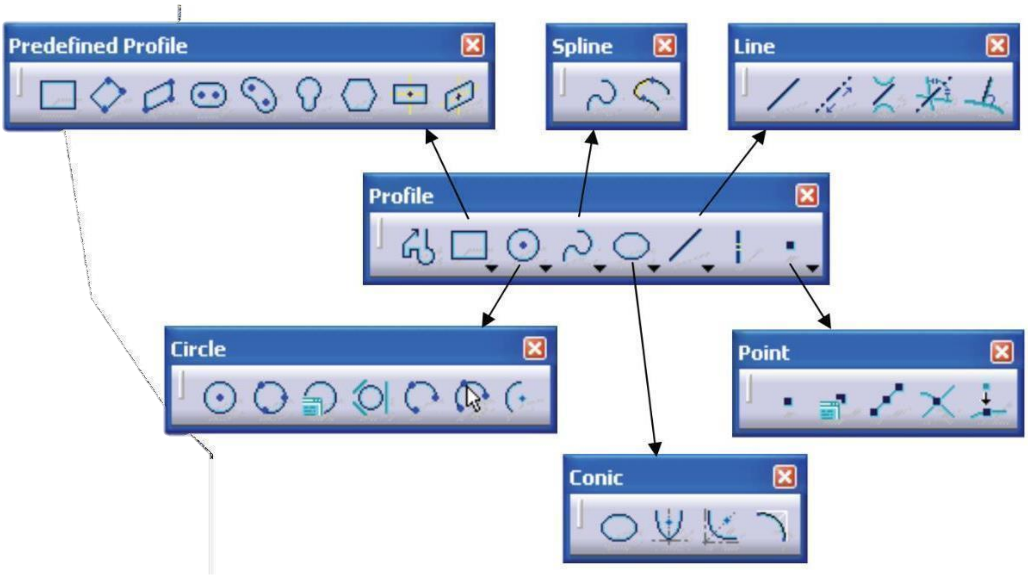
3.5 THE SKETCH TOOLS TOOLBAR:

The Sketch tools toolbar contains icons that activate and deactivate different work modes. These work modes assist you in drawing 2D profiles. Reading from left to right, the toolbar contains the following work modes; (Each work mode is active if the icon is orange and inactive if it is blue.)

- Grid: This command turns the sketcher grid on and off.
- Snap to Point: If active, your cursor will snap to the intersections of the grid lines.
- Construction / Standard Elements: You can draw two different types of elements in CATIA a standard element and a construction element. A standard element (solid line type) will be created when the icon is inactive (blue). It will be used to create a feature in the Part Design workbench. A construction element (dashed line type) will be created when the icon is active (orange). They are used to help construct your sketch, but will not be used to create features.
- Geometric Constraints: When active, geometric constraints will automatically be applied such as tangencies, coincidences, parallelisms, etc...
- Dimensional Constraints: When active, dimensional constraints will automatically be applied when corners (fillets) or chamfers are created, or when quantities are entered in the value field. The value field is a place where dimensions such as line length and angle are manually entered.

3.5.1 PROFILE TOOLBAR:

The Profile toolbar contains 2D geometry commands. These geometries range from the very simple (point, rectangle, etc...) to the very complex (splines, conics, etc...). The Profile toolbar contains many sub-toolbars. Most of these sub toolbars contain different options for creating the same geometry. For example, you can create a simple line, a line defined by two tangent points, or a line that is perpendicular to a surface. Reading from left to right, the Profile toolbar contain the following commands.



1. Profile: This command allows you to create a continuous set of lines and arcs connected together.
2. Rectangle / Predefined Profile toolbar: The default top command is rectangle. Stacked underneath are several different commands used to create predefined geometries.
3. Circle / Circle toolbar: The default top command is circle. Stacked underneath are several different options for creating circles and arcs.
4. Spline / Spline toolbar: The default top command is spline which is a curved line created by connecting a series of points.
5. Ellipse / Conic toolbar: The default top command is ellipse. Stacked underneath are commands to create different conic shapes such as a hyperbola.
6. Line / Line toolbar: The default top command is line. Stacked underneath are several different options for creating lines.

7. Axis: An axis is used in conjunction with commands like mirror and shaft (revolve). It defines symmetry. It is a construction element so it does not become a physical part of your feature.
8. Point / Point toolbar: The default top command is point. Stacked underneath are several different options for creating points.

3.5.2 PREDEFINED PROFILE TOOLBAR:

Predefined profiles are frequently used geometries. CATIA makes these profiles available for easy creation which speeds up drawing time. Reading from left to right, the Predefined Profile toolbar contains the following commands.

- Rectangle: The rectangle is defined by two corner points. The sides of the rectangle are always horizontal and vertical.
- Oriented Rectangle: The oriented rectangle is defined by three corner points. This allows you to create a rectangle whose sides are at an angle to the horizontal.
- Parallelogram: The parallelogram is defined by three corner points.
- Elongated Hole: The elongated hole or slot is defined by two points and a radius.
- Cylindrical Elongated Hole: The cylindrical elongated hole is defined by a cylindrical radius, two point and a hole radius.
- Keyhole Profile: The keyhole profile is defined by two center points and two radii.
- Hexagon: The hexagon is defined by a center point and the radius of an inscribed circle.
- Centered Rectangle: The cantered rectangle is defined by a center point and a corner point.
- Centered Parallelogram: The cantered parallelogram is defined by a center point(defined by two intersecting lines) and a corner point.

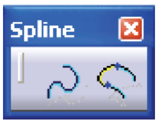
3.5.3 CIRCLE TOOLBAR:

The Circle toolbar contains several different ways of creating circles and arcs. Reading from left to right, the Circle toolbar contains the following commands.

- Circle: A circle is defined by a center point and a radius.
- Three Point Circle: The three-point circle command allows you to create a circle using three circumferential points.
- Circle Using Coordinates: The circle using coordinates command allows you to create a circle by entering the coordinates for the center point and radius in a Circle Definition window.
- Tri-Tangent Circle: The tri-tangent circle command allows you to create a circle whose circumference is tangent to three chosen lines.
- Three Point Arc: The three-point arc command allows you to create an arc defined by three circumferential points.
- Three Point Arc Starting with Limits: The three-point arc starting with limits allows you to create an arc using a start, end, and midpoint.
- Arc: The arc command allows you to create an arc defined by a center point, and a circumferential start and end point.

3.5.4 SPLINE TOOLBAR:

Reading from left to right, the Spline toolbar contains the following commands.



- Spline: A spline is a curved profile defined by three or more points. The tangency and curvature radius at each point may be specified.
- Connect: The connect command connects two points or profiles with a spline.

3.5.5 CONIC TOOLBAR:

- Reading from left to right, the Conic toolbar contains the following commands.
- Ellipse: The ellipse is defined by center point and a major and minor axis points.
- Parabola by Focus: The parabola is defined by a focus, apex and a start and end point.
- Hyperbola by Focus: The hyperbola is defined by a focus, center point, apex and a start and end point.
- Conic: There are several different methods that can be used to create conic curves. These methods give you a lot of flexibility when creating above three types of curves.

3.5.6 LINE TOOLBAR:

The Line toolbar contains several different ways of creating lines. Reading from left to right, the Line toolbar contains the following commands.

- Line: A line is defined by two points.
- Infinite Line: Creates infinite lines that are horizontal, vertical or defined by two points.
- Bi-Tangent Line: Creates a line whose endpoints are tangent to two other elements.
- Bisecting Line: Creates an infinite line that bisects the angle created by two other lines.
- Line Normal to Curve: This command allows you to create a line that starts anywhere and ends normal or perpendicular to another element.

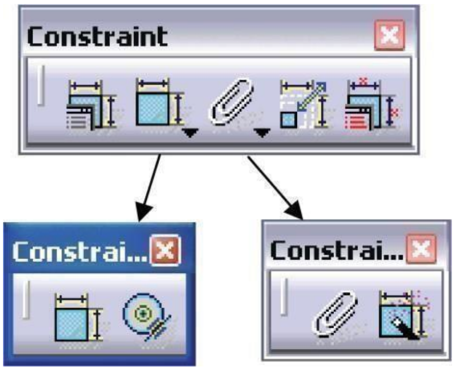
3.5.7 POINT TOOLBAR:

The Point toolbar contains several different ways of creating points. Reading from left to right, the Point toolbar contains the following commands.

- Point by Clicking: Creates a point by clicking the left mouse button.
- Point by using Coordinates: Creates a point at a specified coordinate point.
- Equidistant Points: Creates equidistant points along a predefined path curve.
- Intersection Point: Creates a point at the intersection of two different elements.
- Projection Point: Projects a point of one element onto another.

3.5.8 CONSTRAINT TOOLBAR:

Constraints can either be dimensional or geometrical. Dimensional constraints are used to constrain the length of an element, the radius or diameter of an arc or circle, and the distance or angle between elements. Geometrical constraints are used to constrain the orientation of one element relative to another. For example, two elements may be constrained to be perpendicular to each other. Other common geometrical constraints include parallel, tangent, coincident, concentric, etc... Reading from left to right:



- Constraints Defined in Dialogued Box: Creates geometrical and dimensional constraints between two elements.
- Constraint: Creates dimensional constraints.
- Contact Constraint: Creates a contact constraint between two elements.
- Fix Together: The fix together command groups individual entities together.

- Auto Constraint: Automatically creates dimensional constraints.
- Animate Constraint: Animates a dimensional constraint between to limits.
- Edit Multi-Constraint: This command allows you to edit all your sketch constraints in a single window

3.6 ANSYS:

ANSYS is a general purpose finite element modelling package for numerically solving a wide variety of mechanical problems. These problems include: static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro magnetic problems.

In general, a finite element solution may be broken into the following three stages. This is a general guideline that can be used for setting up any finite element analysis.

1. Pre processing: Defining the problem

The major steps in pre processing are given below:

- Define key points/lines/areas/volumes
- Define element type and material/geometric properties
- Mesh lines/areas/volumes as required

The amount of detail required will depend on the dimensionality of the analysis (i.e. ID, 2D, axi-symmetric. 31). Solution: assigning loads, constraints and solving; here we specify the loads (point or pressure), constraints (translational and rotational) and finally solve the resulting set of equations.

2. Postprocessing:

Further processing and viewing of the results; in this stage one may wish to see:

- Lists of nodal displacements
- Element forces and moments
- Deflection plots
- Stress contour diagrams.

Ansys uses certain inputs and evaluates the product behavior to the physics that you are testing it in. It is a general purpose software used to simulate the interactions between various physics like dynamics, statics, fluids, electromagnetic, thermal, and vibrations. ANSYS typically creates the user an opportunity to create a virtual environment to simulate the tests or working conditions of the products before manufacturing the prototypes This would certainly reduce the cost of producing prototypes and mainly the time. In this competitive world the accuracy and time are the most deciding factors for the company or the organization to sustain. ANSYS helps in increasing the accuracy and decreasing the time of outcome of the final product.

The ANSYS Workbench platform automatically forms a connection to share the try for both the fluid and structural analysis, minimizing data storage and making it easy study the effects of geometry changes on both analyses. In addition, a connection is formed to automatically transfer pressure loads from the fluid analysis to the structural analysis.

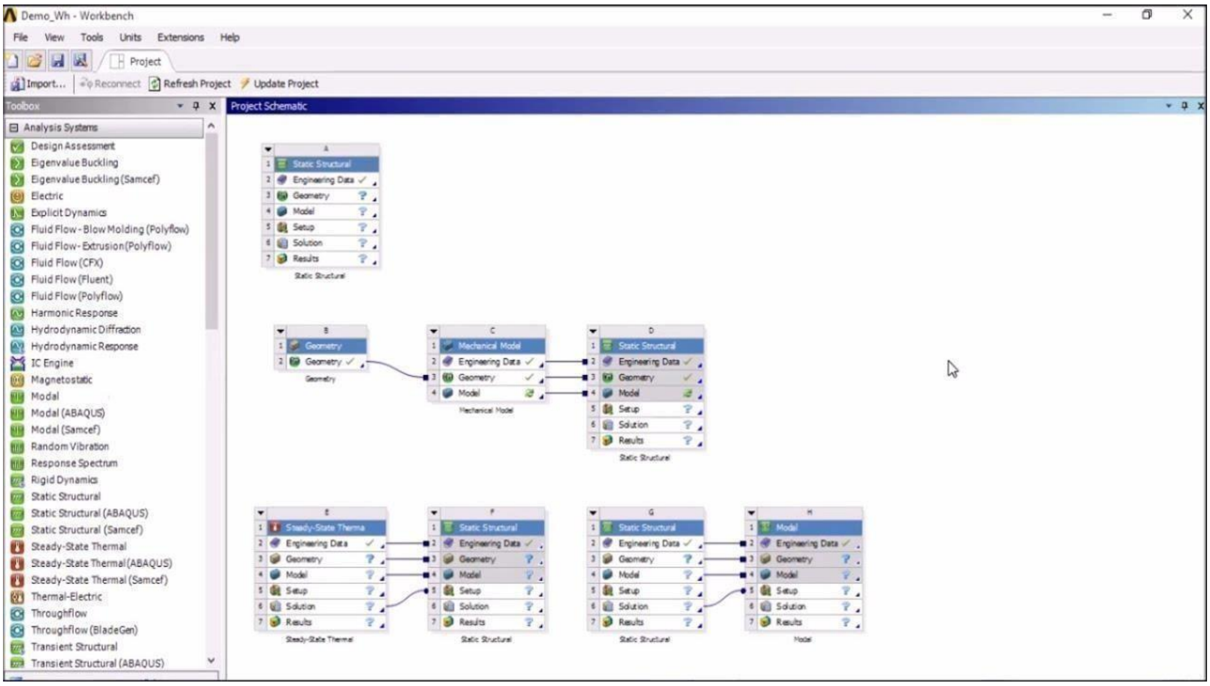


Fig :3.2 Steps and levels ofansys workbench

ANSYS Workbench Features:

Bidirectional, parametric links with all major CAD systems.

- Integrated analysis focused geometry modelling, repair, and simplification via ANSYS Design Modeller.
- Highly automated, physics-aware meshing.
- Automatic contact detection.
- Unequalled depth of capabilities within individual physics disciplines.
- Unparalleled breadth of simulation technologies.
- Complete analysis systems that guide the user start to finish through an analysis.
- Comprehensive multi physics simulation with drag-and-drop case of use.
- Flexible components enable tools to be deployed to best suit engineering intent.
- Innovative project schematic view allows engineering intent, data relationships, and the state of the project to be comprehended at a glance.
- Complex project schematics can be saved for re-use .
- Pervasive, project-level parameter management across all physics.
- Automated what-if analyses with integrated design point capability.
- Adaptive architecture with scripting and journaling capabilities and API's enabling rapid integration of new and third-party solutions.

ADVANTAGES**:**

- ANSYS can import all kinds of CAD geometries (3D and 2D) from different CAD software's and perform simulations, and also it has the capability of creating one effortlessly, ANSYS has inbuilt CAD developing software's like Design Modeller and Space Claim which makes the work flow even smoother.
- ANSYS has the capability of performing advanced engineering simulations accurately and realistic in nature by its variety of contact algorithms, time dependent simulations and non linear material models.
- ANSYS has the capability of integrating various physics into one platform and perform the analysis. Just like integrating a thermal analysis with structural and integrating fluid flow analysis with thermal and structural, etc.

- ANSYS now has featured its development into a product called ANSYS AIM, which is capable of performing multi physics simulation. It is a single platform which can integrate all kinds of physics and perform simulations.
- ANSYS has its own customization tool called ACI which uses python as a background scripting language and used in creating customized user required features in it.
- ANSYS has the capability to optimize various features like the geometrical design, boundary conditions and analyse the behaviour of the product under various criteria.

3.7 ANSYS FLUENT:

The advancement of computing facilities has led to the development of advanced software packages and tools for solving various practical engineering problems. One such advancement is the development of various computational fluid dynamic (CFD) software with different numerical solver methods. These computational methods are identified as suitable tools for solving various engineering problems. They also have various advantages over the traditional physical modelling. One such CFD software tool is ANSYS Fluent.

ANSYS Fluent provides comprehensive modelling capabilities for a wide range of incompressible and compressible, laminar and turbulent fluid flow problems. Steady-state or transient analyses can be performed Examples of ANSYS Fluent applications include laminar non-Newtonian flows in process equipment; conjugate heat transfer in turbo machinery and automotive engine components; pulverized coal combustion in utility boilers; external aerodynamics, flow through compressors, pumps, and funs; and multiphase flows in bubble columns and fluidized beds.

GOVERNING EQUATIONS OF FLUID FLOW:

The governing equations of fluid flow represent mathematical statement of the conservation laws of physics. Each individual governing equations represents a conservation principle. The fundamental equations of fluid dynamics are based on the following universal laws of conservation.

They are,

- Conservation of Mass
- Conservation of Momentum.
- Conservation of Energy

3.8 WHAT IS CFD?

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to analyze and solve problems that involve fluid flows. Computers are used to perform the calculations required to simulate the free-stream flow of the fluid, and the interaction of the fluid (liquids and gases) with surfaces defined by boundary conditions.

CFD is based on the Navier-Stokes equations. Arising from applying Newton's second law to fluid motion, together with the assumption that the stress in the fluid is the sum of a diffusing viscous term and a pressure term, these equations describe how the velocity, pressure, temperature, and density of a moving fluid are correlated.

Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial validation of such software is typically performed using experimental apparatus as wind tunnels. In addition, previously performed analytical or empirical analysis of a particular problem can be used for comparison. A final validation is often performed using full scale testing, such as flight tests.

Use of CFD Analysis**:**

With a CFD analysis, we can understand the flow and heat transfer throughout a design process. The basic methodology for any engineering CFD analysis is based on a few procedures:

Understanding flow model- Flow separations, transient effect, physical interactions

Proving assumed model - Experimental results validation, parametric studies, structural simulations.

Model optimizing- Reducing pressure drops, flow homogenization, improving laminar and turbulent mixing.

Without numerical simulations of fluid flow, it is very difficult to imagine how:

- Meteorologists can forecast the weather and warm of natural disasters.
- Vehicle designers can improve aerodynamic characteristics.
- Architects can design energy-saving and safe-living environments.
- Oil and gas engineers can design and maintain optimal pipes networks.
- Doctors can prevent and cure arterial diseases by computational hemodynamic.

Advantages of CFD**:**

A) Gain insight into systems that might be difficult to test through experimentation.

B) Foresee performance and optimize the design accordingly. Without modifying or installing real systems, CFD simulation can forecast which changes in design are most vital for improving performance.

C) Predict mass flow rates, pressure drops, heat transfer rates, and fluid dynamic forces such as lift, drag and pitching moments.

D) Lower costs by using CFD simulations instead of physical experimentation to retrieve essential engineering data.

E) Introduce engineering data early in the design process. Simulations can be executed in a far shorter period of time when compared to physical testing.

F) Simulate real conditions. Some flow and heat transfer processes cannot be physically tested, e.g. hypersonic flow. But CFD provides the ability to theoretically simulate any physical condition.

G) Simulate ideal conditions. CFD permits great control over the physical processes, and offers the ability to isolate specific phenomena for study.

CHAPTER 4

DESIGN ANALYSIS AND SIMULATION

DESIGN ANALYSIS AND SIMULATION

This project is based on improving the efficiency of Diesel Engine Muffler. A muffler is a device for decreasing the amount of noise emitted by the exhaust of an internal combustion engine. This whole process is carried out by designing and using flow simulation through the muffler. Two muffler designs have been modelled and CFD gas flow simulation has been carried in both of them at various boundary conditions. The geometry of the model is prepared in CATIA V5 and analysis is carried out in ANSYS FLUENT using Computational Fluid Dynamics(CFD).

Boundary Conditions:

1.Velocity at inlet is taken as 10.9748 m/s.

2.Pressure at outlet is considered as Zero Pa.

The Transition SST(4 equation) model is enabled for models.

Model dimensions are as follows:

Diameter of shell=150 mm; Diameter of outlet pipe = 42.1 mm;

Total length (Inlet pipe) = 192 mm;

Total length (Outlet pipe) = 192 mm;

Length of Inlet pipe (till shell wall) = 85 mm;

Length of Outlet pipe (outside shell wall) = 85 mm;

For reference values following data has been considered for air in both the models which has been computed from inlet.

Table 4.1 Reference values considered for Air

Area (m^2)	0.00139
Density (kg/m^3)	0.696
Enthalpy(J/kg)	503400
Length(m)	0.384
Pressure(Pa)	300000
Temperature(k)	500
Velocity(m/s)	10.9748
Viscosity(kg/ms)	2.7e-05
Ratio of specific Heats	1.4

Continuity equation (Navier-Stokes) is one of basic conservation equations on which code ofFluent software bases.

According to law of conservation of mass in a closed physical system mass of medium cannot neither increase nor decay. Assumption of fluid stream continuity leads to the conclusion that it covers all space of flow (there is so called homogenous flow). On the basis of those assumptions we can make balance mass and in the result we obtain following equation of flow continuity:

$$\partial \rho / \partial t + \nabla .(\rho v) = 0$$

where:
t -time [s],

v- fluid flow rate [m/s],

Navier-Stokes equation is used for description of principle of conservation of mass and momentum of flowing fluid.

One of the major parameters for determination of muffler performance is transmission loss. It is the difference between the power incident at the inlet of a muffler and that transmitted downstreamat the outlet and expressed in the unit of decibel. For better noise attenuation a higher value of transmission loss is desired. Mathematically, transmission loss is represented as follows:

$$T.L = 10\log_{10}\left|\frac{S_i {p_i}^2}{S_o {p_o}^2}\right|$$

where,

Si and So are the cross-sectional areas of the inlet and outlet of the muffler. pi and po are the acoustic pressure of the incident wave at the inlet of the muffler and transmitted wave at the outlet ofthe muffler respectively.

In the present case where the inlet and outlet of the muffler are of equal cross- sectional areathe above formula can be represented in modified formas follows:

$$T.L = 20\log_{10}\left|\frac{p_i}{p_o}\right|$$

4.1 CATIA MODELS:

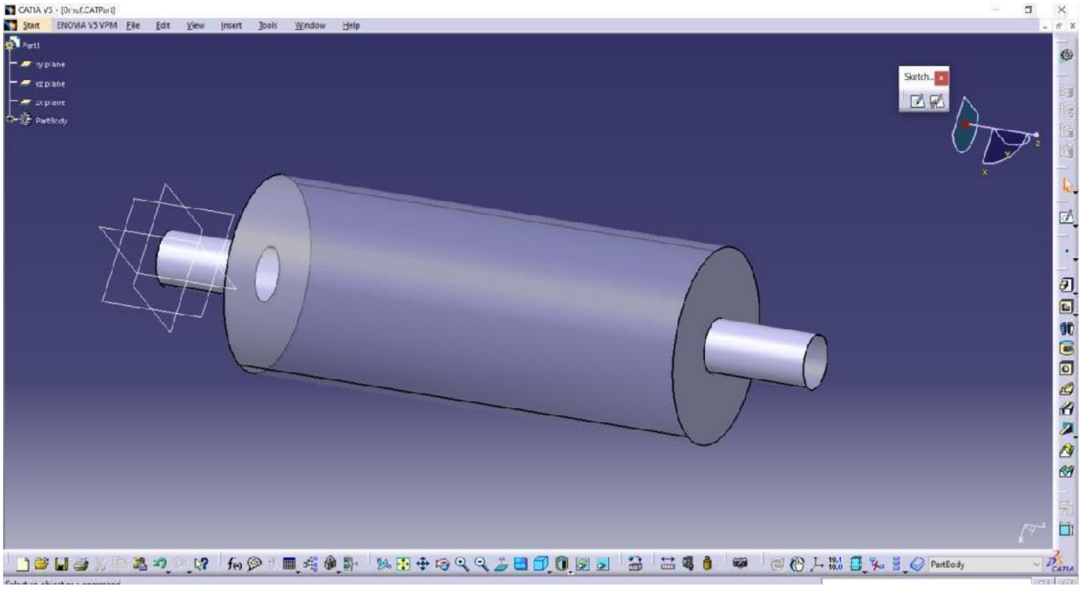


Figure 4.1 Model with no perforations and with no extended inlet and outlet pipes

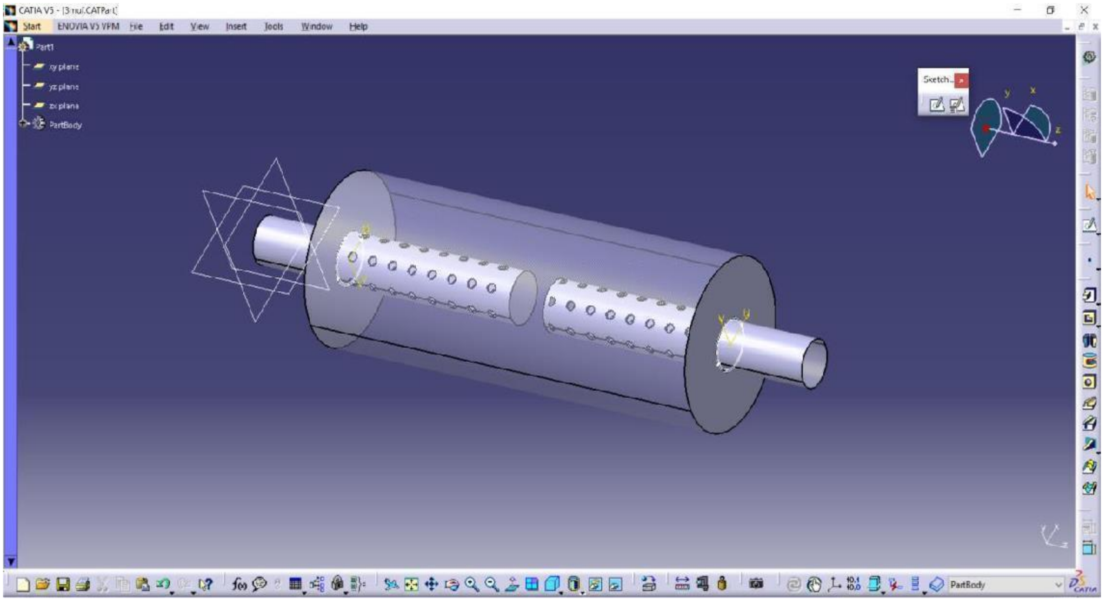


Figure 4.2 Model with perforations (Inlet and outlet pipe ends closed)

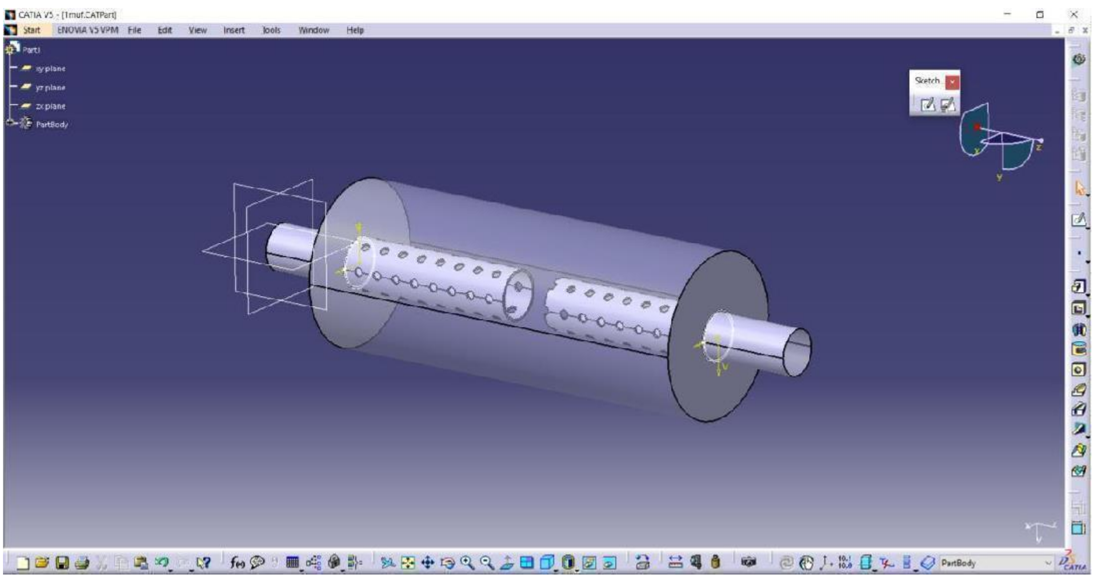


Figure 4.3 Model with perforations (Inlet and outlet pipe ends opened)

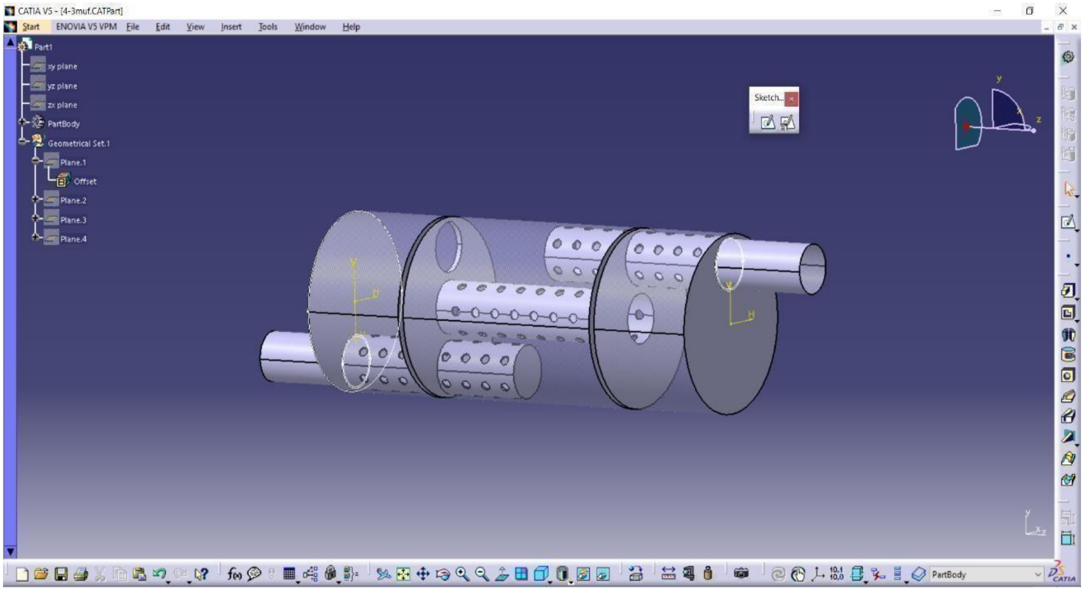


Figure 4.4 Model with perforations(Inlet and outlet pipe ends closed)

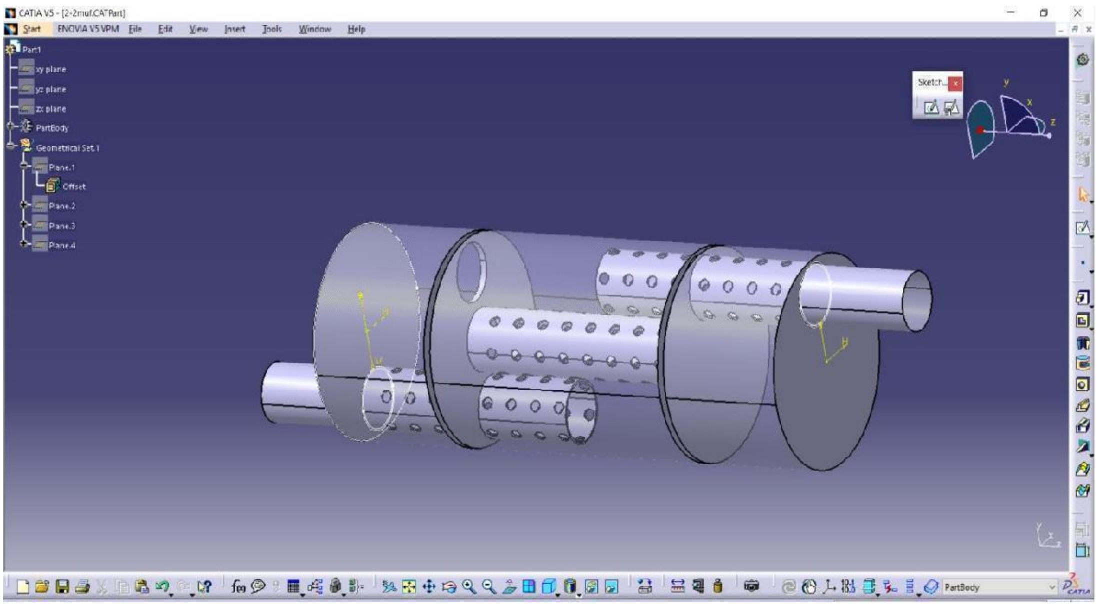


Figure 4.5 Model with perforations (Inlet and outlet pipe ends opened)

4.2 IMPORTED MODELS IN ANSYS:

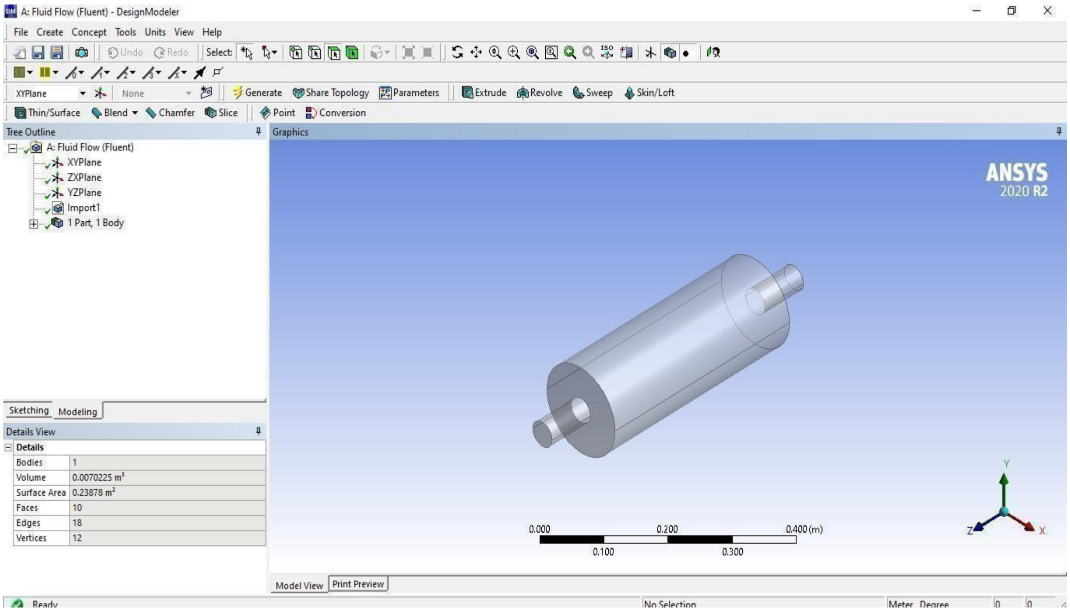


Figure 4.6 Imported Model M1 from Catia in Ansys

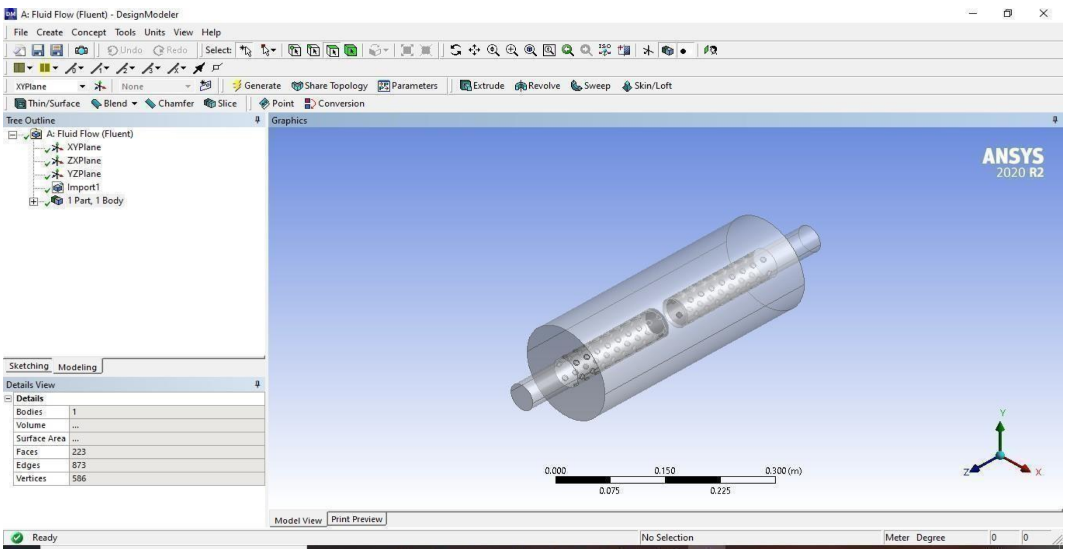


Figure 4.7 Imported Model M2 from Catia in Ansys

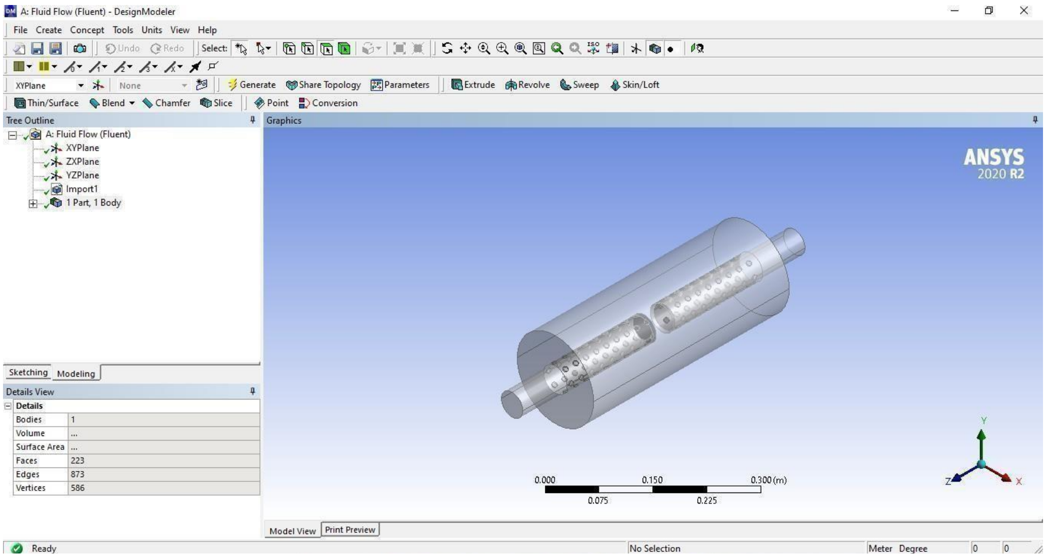


Figure 4.8 Imported Model M3 fromCatia in Ansys

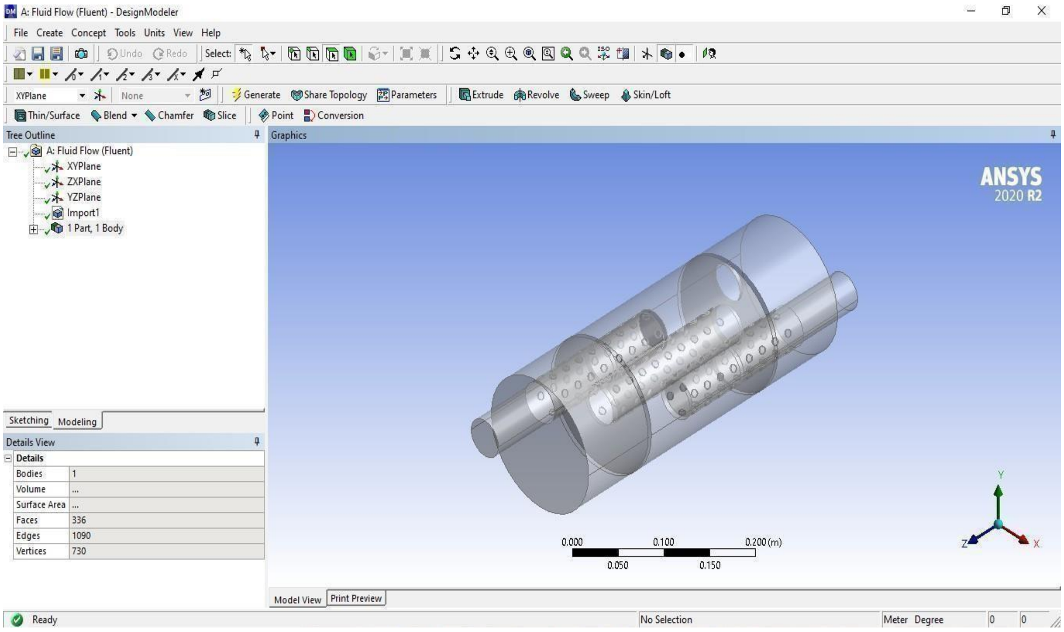


Figure 4.9 Imported Model M3 fromCatia in Ansys

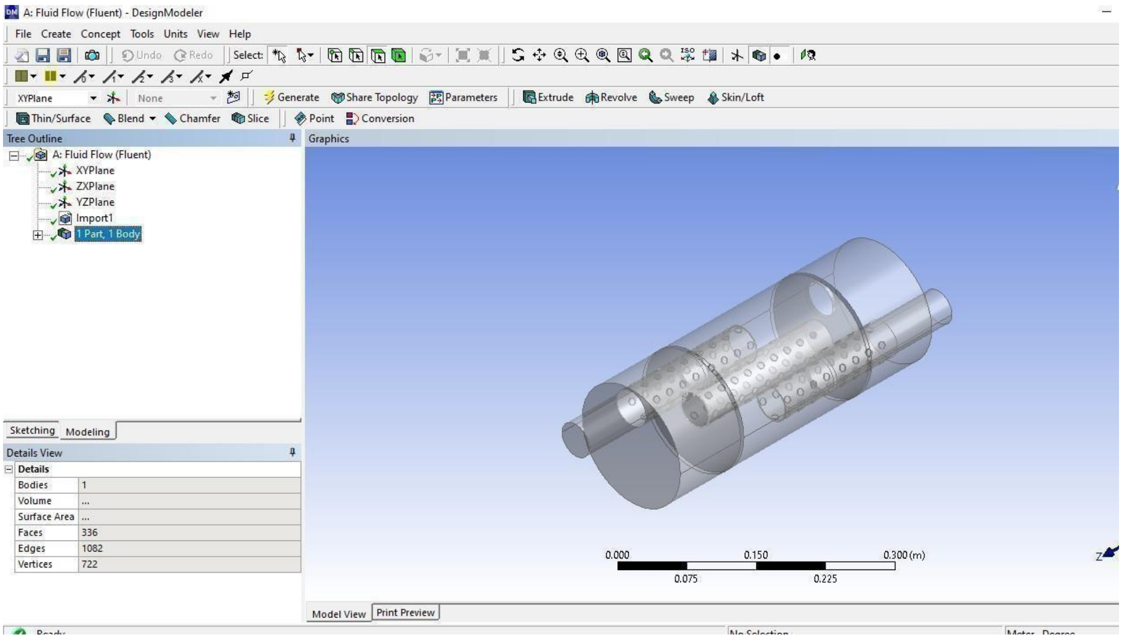


Figure 4.10 Imported Model M5 from Catia in Ansys

4.3 MESHING:

Ansys provides general purpose, high performance, automated, intelligent meshing software that produces the most appropriate mesh for accurate, efficient multi physics solutions from easy, automatic meshing to highly crafted mesh Smart defaults are built into the software to make meshing a painless and intuitive task, delivering the required resolution to capture solution gradients properly for dependable results.

Ansys meshing solutions range from easy, automated meshing to highly crafted meshing Methods available cover the meshing spectrum of high order to linear elements and fast tetrahedral and polyhedral to high quality hexahedraland mosaic.

Ansys meshing capabilities help reduce the amount of time and effort spent to get to accurate results. Since meshing typically consumes a significant portion of the time it takes to get simulation results, Ansys helps by making better and more automated meshing tools.

Whether performing a structural, fluid or electromagnetic simulation, Ansys can provide us with the most appropriate mesh for accurate and efficient solutions. The below image gives us a glimpse of Ansys meshing.

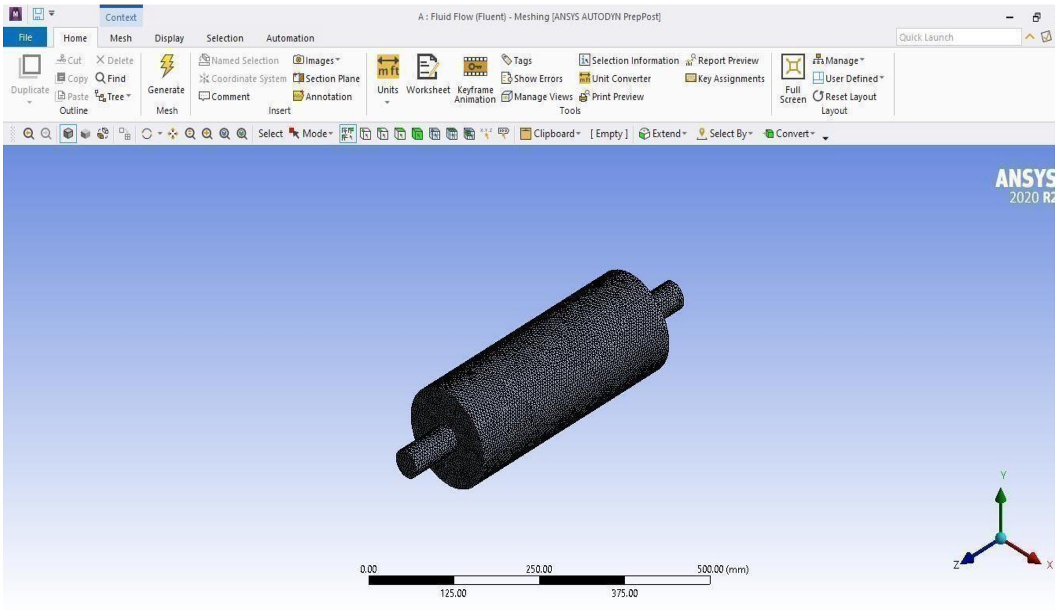


Figure 4.11 Meshing of M1

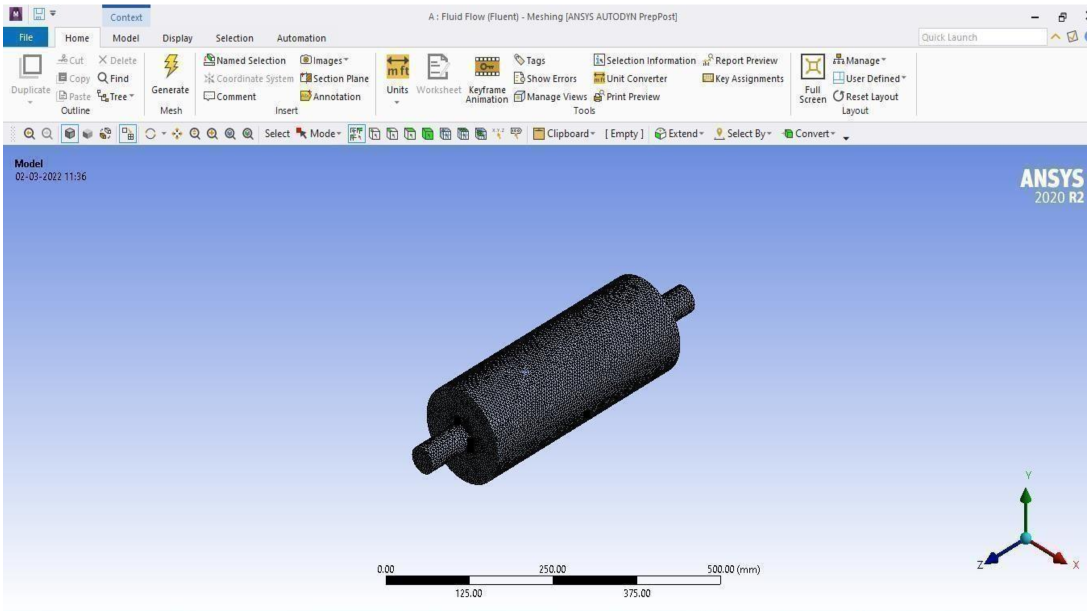


Figure 4.12 Meshing of M2

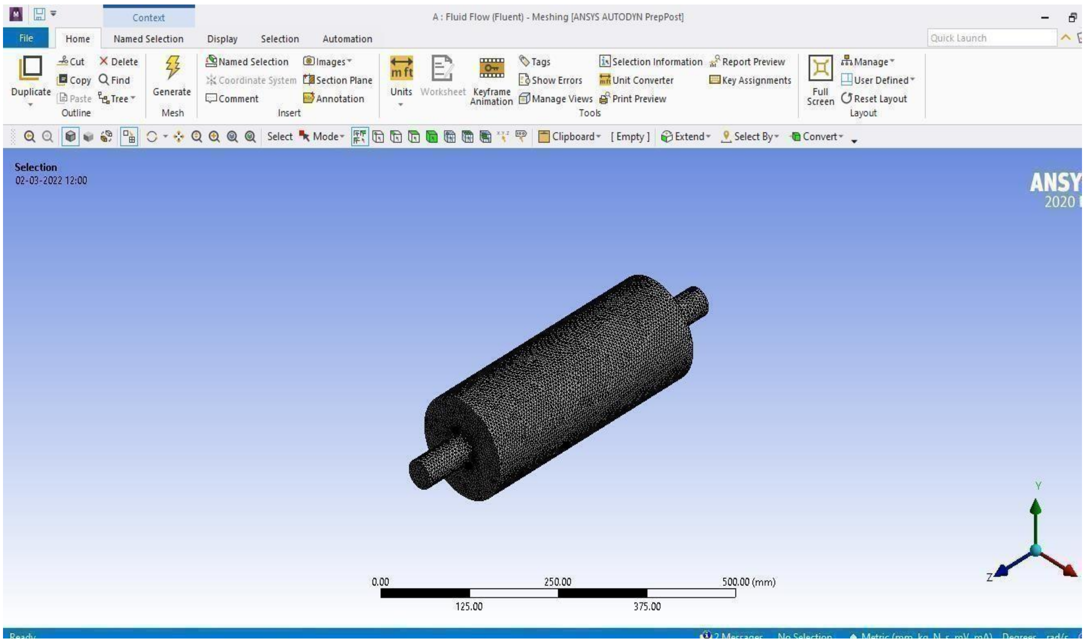


Figure 4.13 Meshing of M3

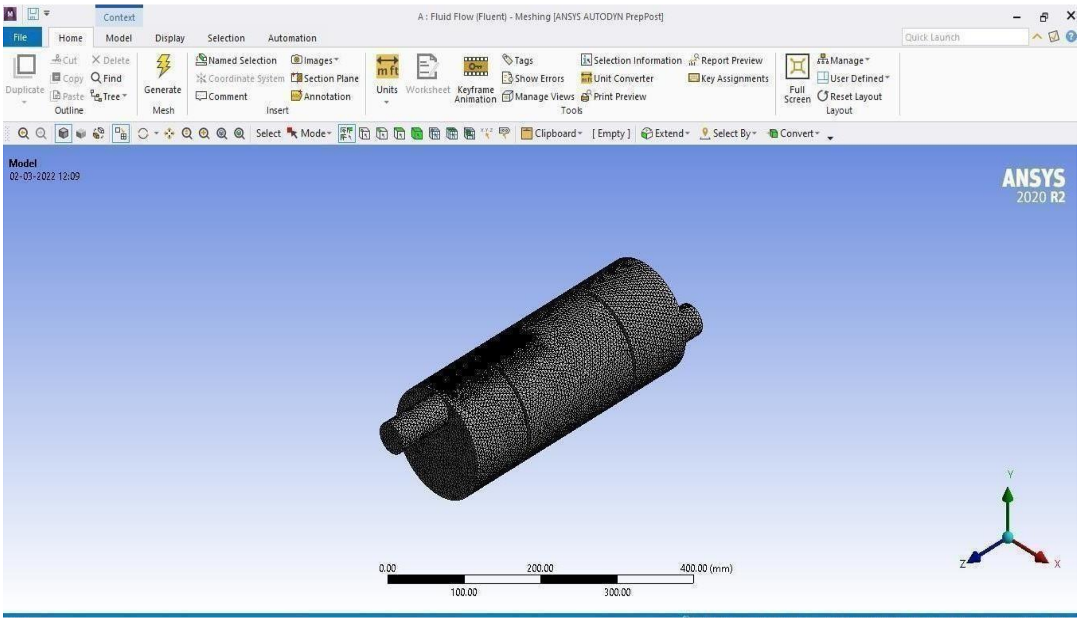


Figure 4.14 Meshing of M4

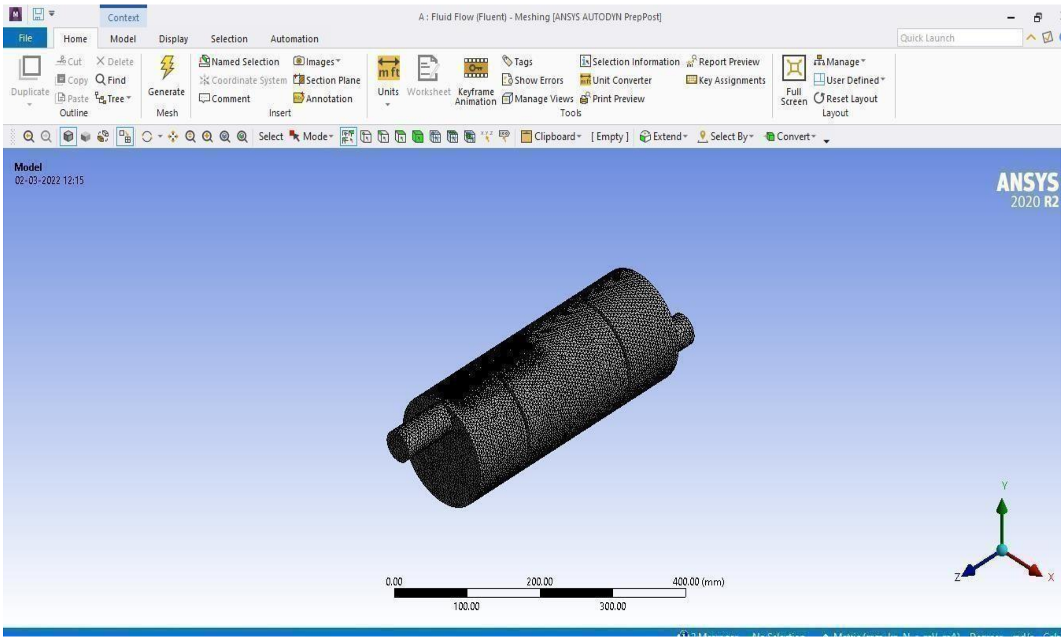


Figure 4.15 Meshing of M5

CHAPTER 5

RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSION

5.1 Case 1:Model with no perforations and with no extended inlet and outlet pipes

5.1.1 Pressure Contour:

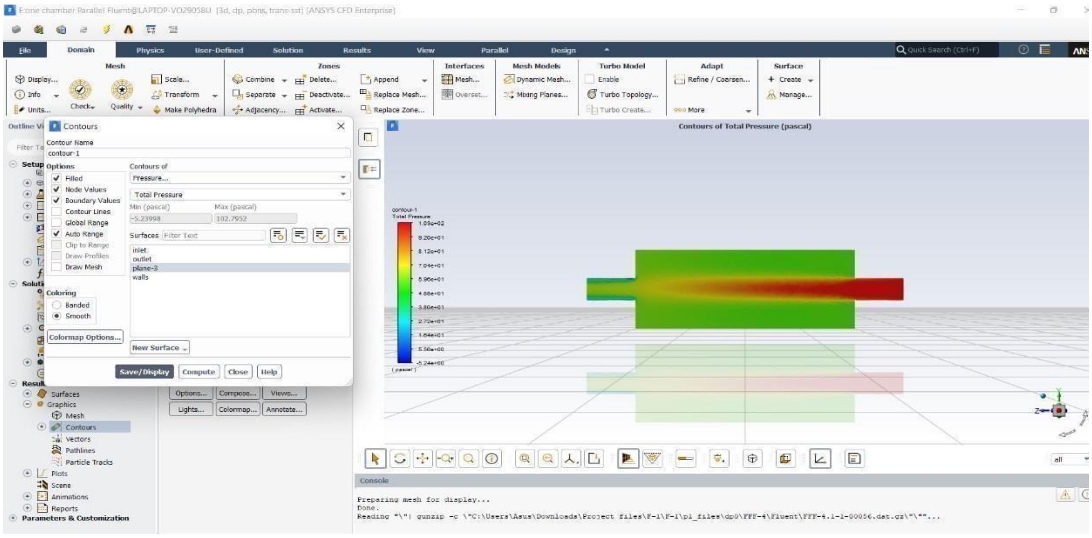


Figure 5.1 Total Pressure Contour

From the figure 5.1, it can be observed that the pressure is decreasing from inlet to Outlet. Inlet pressure is 104 Pa and Outlet pressure is 66 Pa.

5.1.2 Velocity Contour:

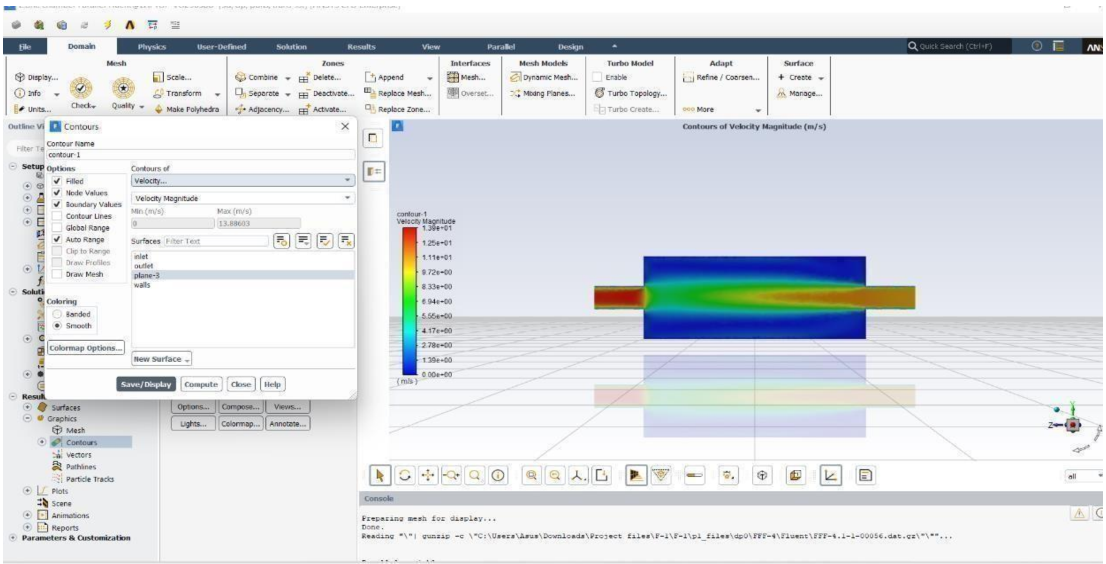


Figure 5.2 Velocity Contour

From the figure 5.2, it can be observed that the velocity is increasing from inlet to Outlet. Inlet velocity is 10.9748 m/s and Outlet velocity is 13.73 m/s.

5.2 **Case 2**: Model with perforations (Inlet and outlet pipe ends closed)

5.2.1 Pressure Contour:

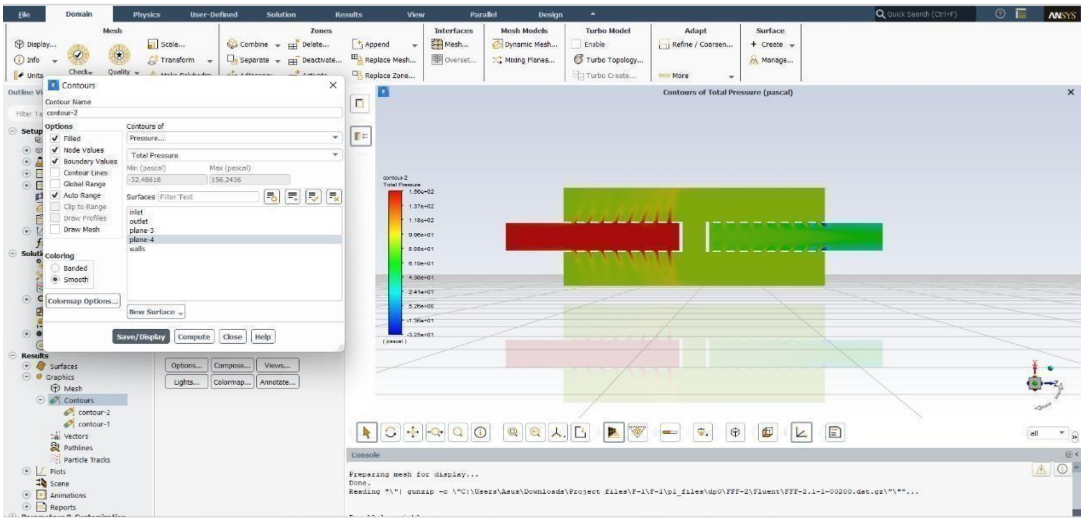


Figure 5.3 Total Pressure Contour

From the figure 5.3, it can be observed that the pressure is decreasing from inlet to Outlet. Inlet pressure is 156.40 Pa and Outlet pressure is 61.11 Pa.

5.2.2 Velocity Contour:

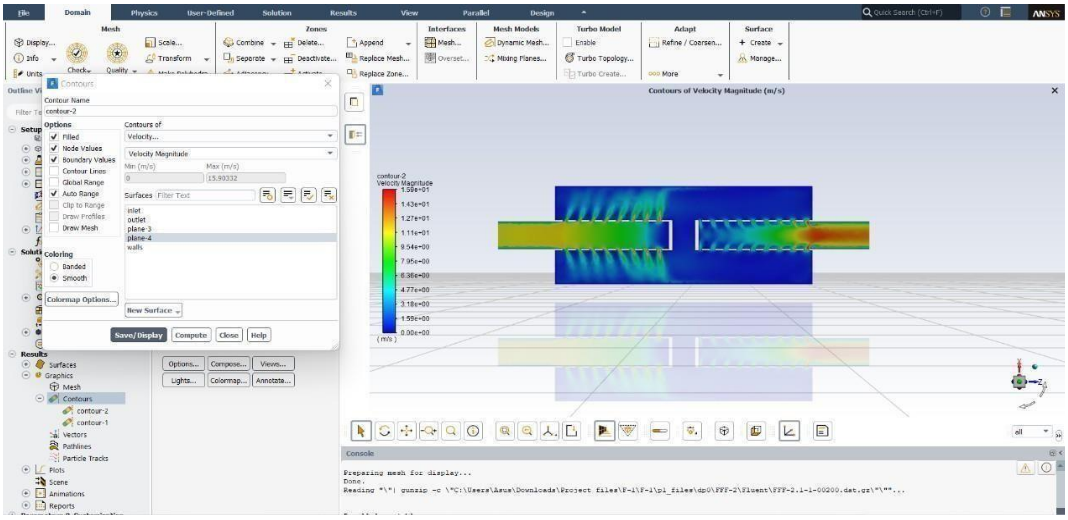


Figure 5.4 Velocity Contour

From the figure 5.4, it can be observed that the velocity is increasing from inlet to Outlet. Inlet velocity is 10.9748 m/s and Outlet velocity is 13.35 m/s.

5.3 **Case 3**: Model with perforations(Inlet and outlet pipe ends opened)

5.3.1 Pressure Contour:

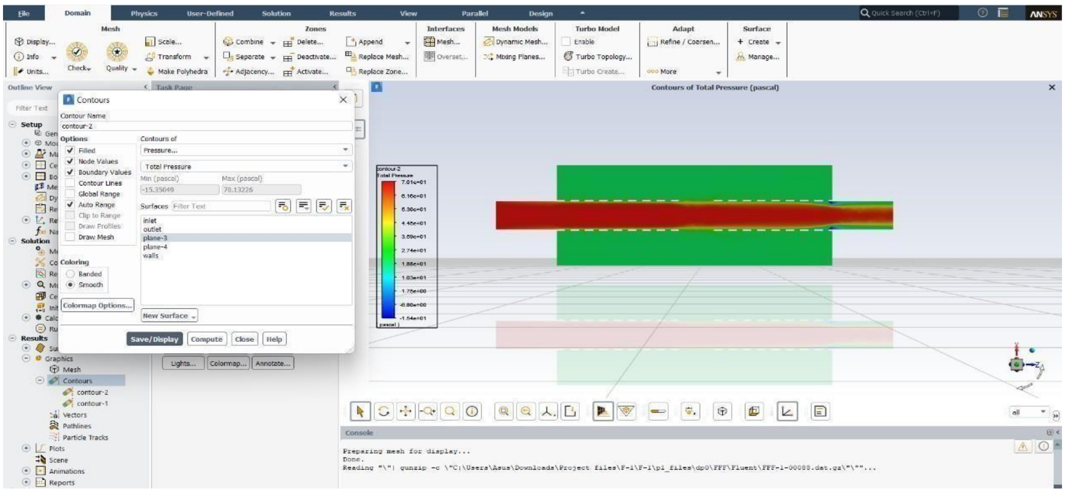


Figure 5.5 Total Pressure Contour

From the figure 5.5, it can be observed that the pressure is decreasing from inlet to Outlet. Inlet pressure is 70.18 Pa and Outlet pressure is 69.16 Pa.

5.3.2 Velocity Contour:

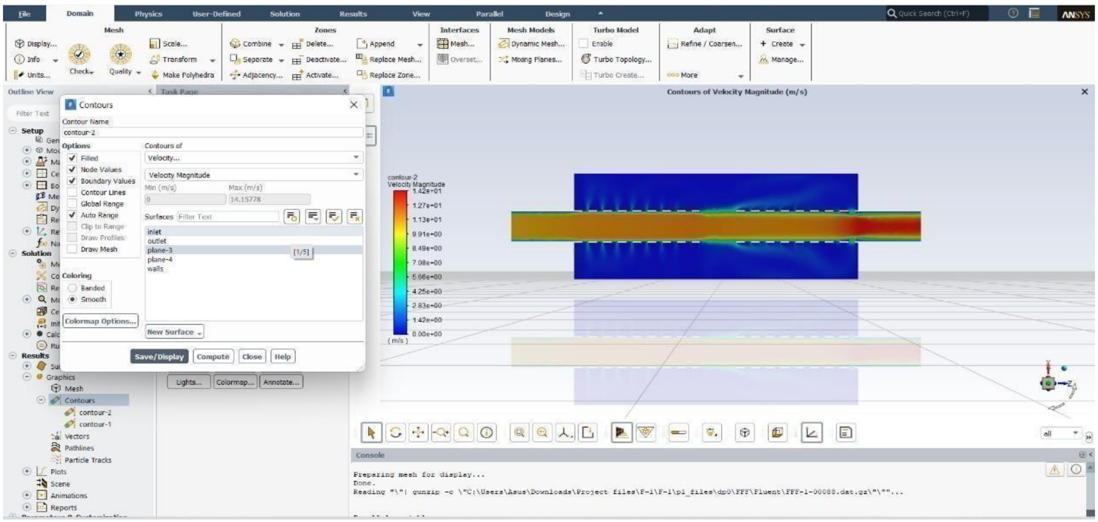


Figure 5.6 Velocity Contour

From the figure 5.6, it can be observed that the velocity is increasing from inlet to Outlet. Inlet velocity is 10.9748 m/s and Outlet velocity is 14.09 m/s.

5.4 **Case 4**: Three Chambered model with perforations(Inlet and outlet pipe ends closed)

5.4.1 Pressure Contour:

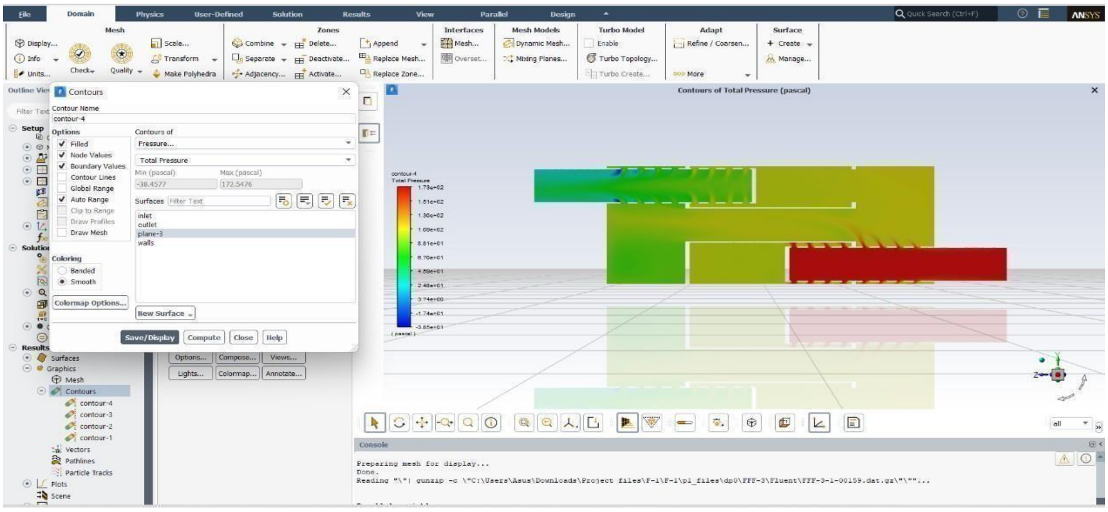


Figure 5.7 Total Pressure Contour

From the figure 5.7, it can be observed that the pressure is decreasing from inlet to Outlet. Inlet pressure is 172.87 Pa and Outlet pressure is 54.92 Pa.

5.4.2 Velocity Contour:

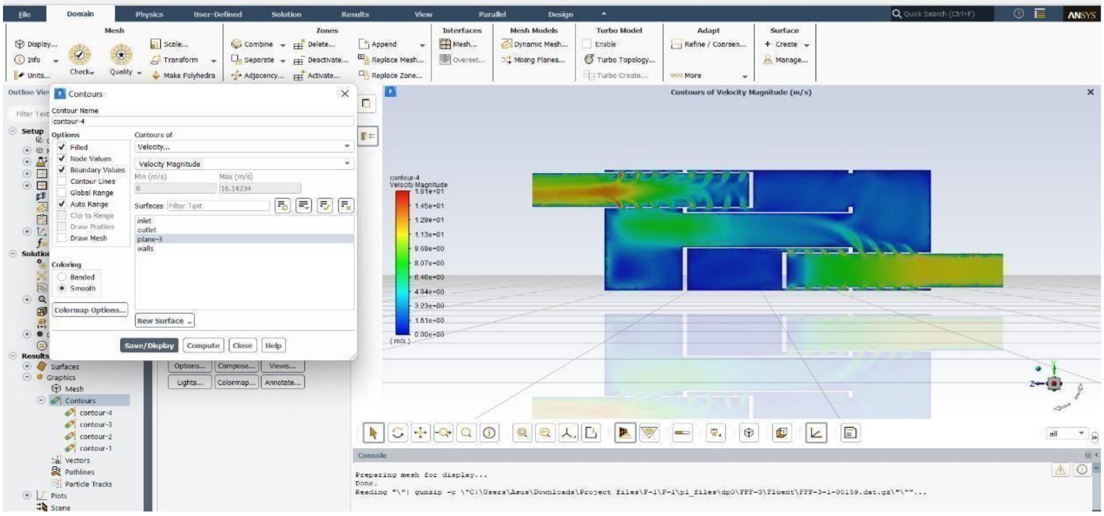


Figure 5.8 Velocity Contour

From the figure 5.8, it can be observed that the velocity is increasing from inlet to Outlet. Inlet velocity is 10.9748 m/s and Outlet velocity is 12.55 m/s.

5.5 **Case 5**: Three Chambered model with perforations(Inlet and outlet pipe ends opened)

5.5.1 Pressure Contour:

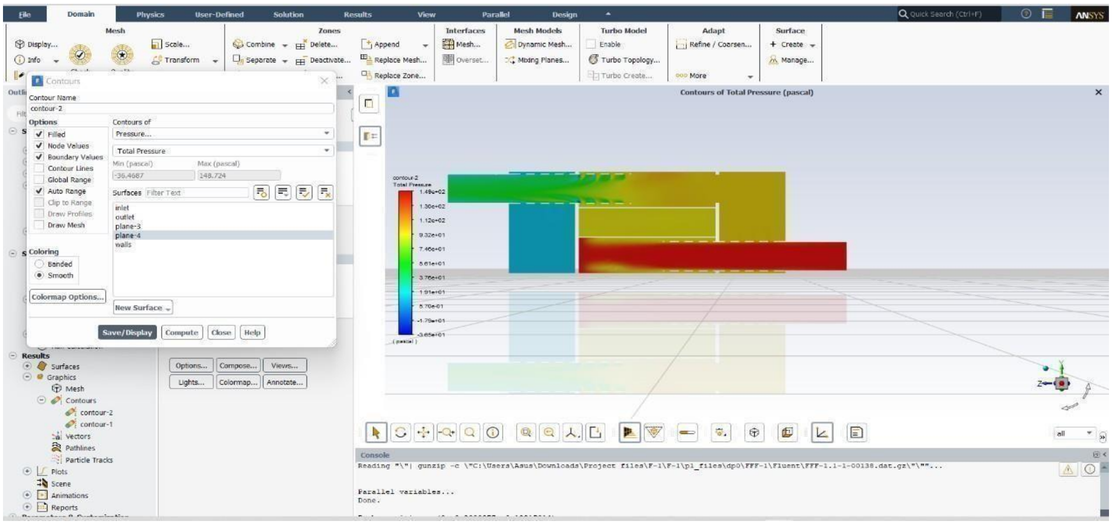


Figure 5.9 Total Pressure Contour

From the figure 5.9, it can be observed that the pressure is decreasing from inlet to Outlet. Inlet pressure is 148.91 Pa and Outlet pressure is 56.06 Pa.

5.5.2 Velocity Contour:

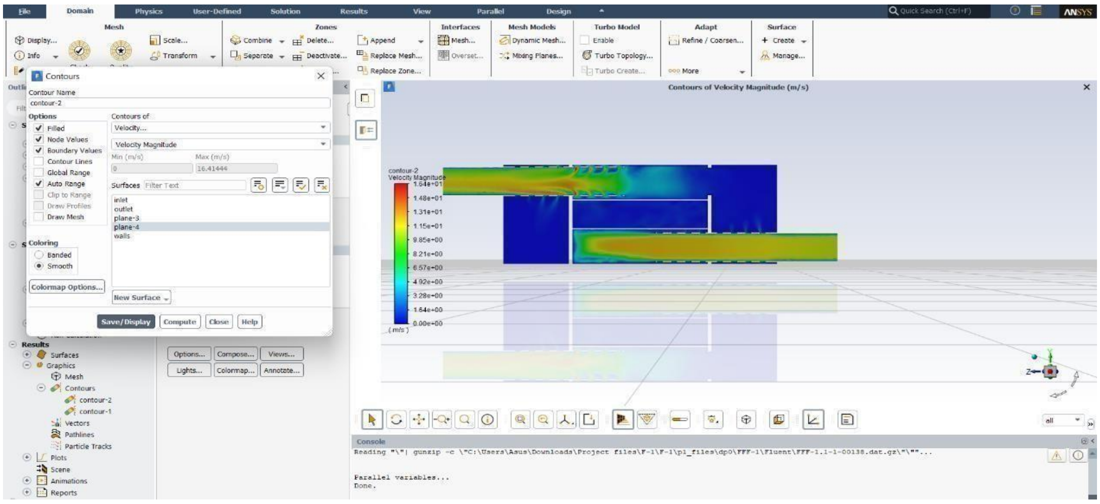


Figure 5.10 Velocity Contour

From the figure 5.10, it can be observed that the velocity is increasing from inlet to Outlet. Inlet velocity is 10.9748 m/s and Outlet velocity is 12.69 m/s.

RESULTS

Table 5.1: CFD analysis results of each models

Model no:	Acoustic Power Level(dB)	Pi (Pa)	Po (Pa)	TL=20log10(Pi/Po)
Model 1	45.25	104	66	3.94
Model 2	66.19	156.4	61.11	8.16
Model 3	50.98	70.18	69.16	0.12
Model 4	71.1	172.87	54.92	9.95
Model 5	65.86	148.91	56.06	8.48

1. Pressure contour and Velocity contours have been obtained for the Five muffler models using CFD analysis.
2. Acoustic Power levels , Transmission losses are also determined for each of the five models.
3. As Shown in the table 5.1 we can observe Model 1 i.e Muffler design with no extended inlet and outlet pipes inside the chamber has the least Acoustic power level of 45.25 dB
4. But for Model 1 the Transmission loss is at low rate (3.94) as a result the efficiency of the muffler will be poor.
5. For Model 4 i.e Three chambered muffler (with inlet and outlet pipe ends closed) the Transmission loss is at a high rate (9.95) as a result the efficiency will be great for this model
6. But for Model 4 the Sound emission is at a large rate 71.1dB which is not preferable.
7. Taking the considerations of back pressure, As back pressure in Model 3 is less. Model 3 is the best optimum muffler model with a acoustic power level of 50.98 dB.

CHAPTER 6

CONCLUSIONS

CONCLUSIONS

A numerical analysis is carried out on acoustical and flow behaviour analysis of various muffler designs and the following conclusions are made.

1. The increase in restriction to the flow is found to increase the back pressure.
2. From the various cases considered for best possible muffler designs, 3rd case is found to be a preferable choice at it is having least transmission losses.
3. Acoustic power level comparison of different cases shown least APL value for 1st case. But this is not considered as suitable design because of high pressure drop and transmission loss.
4. Greater the installation of baffle plates , greater the generation of back pressure.
5. Pressure decreases from inlet pipe to outlet pipe.
6. Velocity increases from inlet pipe to outlet pipe.
7. As Exhaust gases from the exhaust manifold travel with a high velocity they tend to travel through larger openings in the muffler.

FUTURE SCOPE:

1. Installation of baffle plates and changing their positions in order to find the muffler with maximum efficiency.
2. Performing strength and thermal analysis on the muffler.
3. Changing the Perforations shapes and position to achieve better results.
4. Analyzing the performance of a muffler by using different kinds of materials.

REFERENCES:

[1] Amit Kumar Gupta, Dr. Ashesh Tiwari, “Enhancement on Sound Transmission Loss for Various Positioning of Inlet and Outlet Duct of the Muffler” I.J. Engineering and Manufacturing, 2015, 4, 1-11 Published Online November 2015 in MECS (http://www.mecs-press.net) DOI: 10.5815/ijem.2015.04.01

[2] Ayush Lal. Pratik Vanarse. Nikhil Jadhav. Kaushik Yemu, Prof. Amar Pandhare "CFD Analysis of Flow through Muffler to Select Optimum Muffler Model for Cl Engine" Smt. Kashibai Navale College of Engineering. Pune, Maharashtra, India. International Journal of Latest Trends in Engineering and Technology(IJLTET) (2014)

[3] Balraj D.Kawade, Niranjan D.Khaire,Swapnil S.Kulkarn, “Study of Automobile Silencer Design to evaluate Generic norms for Vibration” International Journal of Scientific Research and Management Studies (IJSRMS) ISSN: 2349-3771 Volume 3 Issue 2, pg: 104-112

[4] Prof. Bharat S. Patel, Mr. Kuldeep D. Patel, “A Review paper on Catalytic Converter for Automotive Exhaust Emission”, International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11 (2012).

[5] Jayashri P. Chaudhari, Amol B. Kakade "Design, Development and Analysis of Absorptive Muffler with Ammonia Pulsator for IC Engine" Journal Page No 429-434

[6] M. Rajasekhar Reddy, Dr K. Madhava Reddy, “Design And Optimization Of Exhaust Muffler In Automobiles”, International Journal Of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 5, September- October 2012, pp.395-398

[7] Munjal, M.L. (1998). Analysis and design of mufflers. Journal of Sound and Vibration, 211(3): 425-433. https://doi.org/10.1006/jsvi.1997.1309

[8] Rahul D. Nazirkar, S.R.Meshram, Amol D. Namdas, Suraj U. Navagire, & Sumit S. Devarshi "Design & Optimization Of Exhaust Muffler & Design Validation" Sinhgad Institute of Technology, Lonavala-410401, India Oct.-2014.

[9] S.Balamurugan, N Jeyaprakash & K.Manikandan "Design and Fabrication of Muffler for Four Stroke Diesel Engine" (ISSN: 2277-1581) Volume No.4 Issue No.3, pp. 136-140 01 March, 2015.

[10] Mr. Sanchit Babarao Dhotre, Prof. S.L.Shinde. “Analysis of Automotive Exhaust Muffler Silencer Using FEA & Experiment” International Engineering Research Journal Page No 657-663

[11] Sandeep G Thorat*, B S Kothavale. Swapnil S Hatwalane and Dhiraj Bhaskar "Review paper on Design and Development of Muffler to Optimize Transmission Losses" MIT College of Engineering. Savitribai Phule Pune University, India, (March 2016)

[12] Shital Shah,Saisankaranarayana K,Kalyankumar S.Hatti,Prof. D. G.Thombare , “A Practical Approach towards Muffler Design, Development and Prototype Validation”, SAE International Journal of Engines · September 2010

[13] Suyog S. Mane ,Prof . S.Y. Bhosale, Prof. H.N. Desh Pande, “CFD Analysis of Back Pressure of Reactive Muffler”, International Journal of Innovations in Engineering Research and Technology[IJIERT] ISSN:2394-3696 VOLUME 3, ISSUE 12, Dec.-2016

[14] Sweta Baruah, Sushovan Chatterjee , CFD Analysis on an Elliptical Chamber Muffler of a C.I. Engine, International Journal of Heat and Technology Vol. 37, No. 2, June, 2019, pp. 613-619

[15] Ujjal Kalita, Abhijeet Pratap. Sushil Kumar "Absorption Materials Used In Muffler A Review Lovely Professional University, Phagwara, Punjab, India March 2015.

Modelling and Analysis of Diesel Engine Muffler using CFD Analysis

K.Satyanarayana[1], Rohit Yadav[2],P.V.N Lohith[3],D.Yasoda[4], A.Bharadwaj[5], K. Jeevan[6], K. Viswanath Allamraju[7]

[1]Assistant Professor, Department of Mechanical Engineering, ANITS (A), Sangivalasa-531162, Bheemunipatnam, Visakhapatnam , Andhra Pradesh, India
ksnarayana.me@anits.edu.in
[2,3,4,5,6] Student, Department of Mechanical Engineering, ANITS (A), Sangivalasa-531162, Bheemunipatnam, Visakhapatnam , Andhra Pradesh, India

[7]Associate Professor, Department of Mechanical Engineering, Institute of Aeronautical Engineering, Hyderabad, Telangana, India-500043, nathnitw17@gmail.com

**Registered Email id: yasodadammu@gmail.com*

Abstract

Noise pollution is the major drawback of I.C engines. Exhaust systems focus majorly on reducing the emission of pollutants into atmosphere and also on controlling the sound that comes through exhaust. The device used for reducing the sound is called as Muffler and the device used for controlling the emissions is called catalytic convertor. Mufflers make use of different techniques and components to reduce the noise, usually the noise is reduced when the transmission loss increases inside the muffler. In this work focus was laid on altering the design of a muffler to further reduce the noise and increasing the performance of the muffler. This is carried out by designing and using flow simulation through the muffler. Three muffler designs have been modeled and CFD gas flow simulation has been carried in both of them at various boundary conditions. Based upon the gas flow through them, on comparison , selected the optimum model, for which the performance is best and sound reduction is maximum. The geometry of the model is prepared in CATIA V5 and analysis is carried out in ANSYS FLUENT using Computational Fluid Dynamics (CFD).

Keywords: *Exhaust System, Sound, Muffler, Transmission Loss, Catalytic Converter Catia, Ansys*

1. Introduction

A muffler is a device for decreasing the amount of noise emitted by the exhaust of an internal combustion engine. The muffler is engineered as an acoustic soundproofing device designed to reduce the loudness of the sound pressure created by the engine by way of acoustic quieting [1-2]. Some researchers studied the contact stress analysis and mechanical properties of composite materials[3-5]. The majority of the sound pressure produced by the engine is emanated out of the vehicle using the same piping used by the silent exhaust gases absorbed by a series of passages and chambers lined with roving Fiberglass insulation and/or resonating chambers harmonically tuned to cause destructive interference wherein opposite sound waves cancel each other out An unavoidable side effect of muffler use is an increase of back pressure which decreases engine efficiency. This is because the engine exhaust must share the same complex exit pathway built inside the muffler as the sound pressure that the muffler is designed to mitigate. Automotive mufflers usually have a circular or elliptical cross section[6-9]. A circular shaped cross section is best suited in a vehicle as it delays the onset of higher order modes. Most formulas that are used to predict the transmission loss of a muffler assume plane wave propagation. The properties of the following designs are only valid up to the cut off frequency, where higher order modes occur.

2. Geometric Modelling

The total length of the muffler model is 384 mm. The 3D geometry of models prepared in 'CATIA V5 R21', Geometric models have been constructed on the basis of dimensions below.

2.1 Model dimensions :

- Diameter of shell=150 mm;
- Diameter of outlet pipe = 42.1 mm;
- Total length (Inlet pipe) = 192 mm;
- Total length (Outlet pipe) = 192 mm;
- Length of inlet pipe (till shell wall) = 85 mm;
- Length of outlet pipe (Outside shell wall) = 85 mm

Three models are considered for comparison:-

For the 1st model, Muffler with no perforations and with no extended inlet and outlet pipes

For the 2nd model, Muffler with perforations (Inlet and outlet pipe ends closed)

For the 3rd model, Muffler with perforations (Inlet and outlet pipe ends opened)

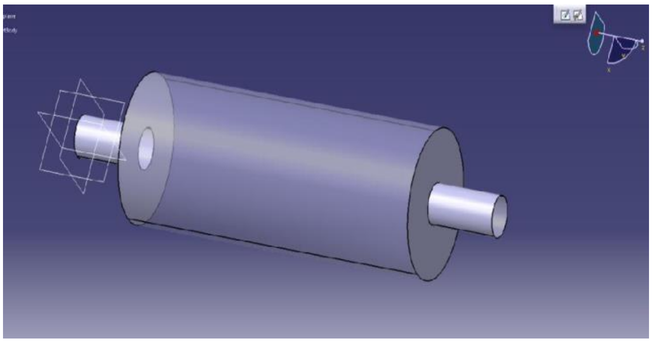


Figure 1. Model 1 with no perforations and with no extended inlet and outlet pipes

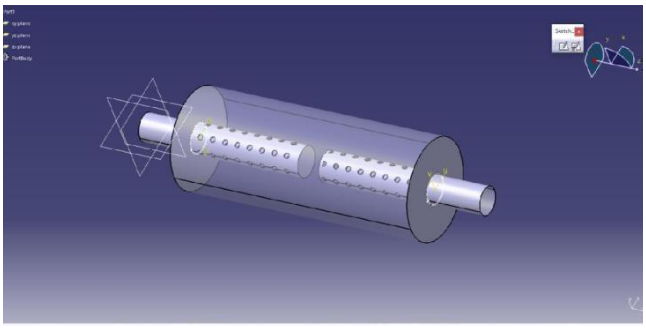


Figure 2 . Model 2 with perforations (Inlet and outlet pipe ends closed)

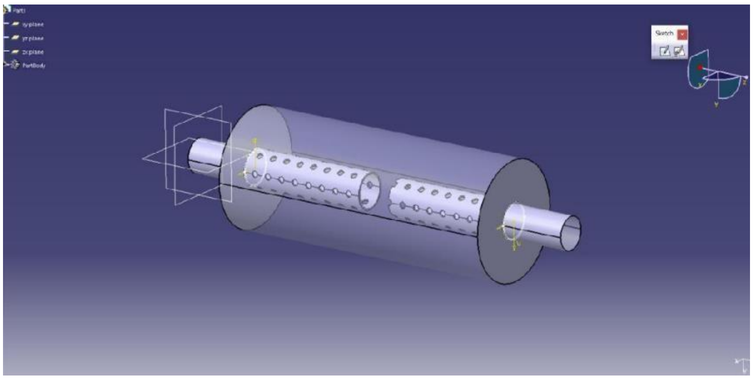


Figure 3. Model 3 with perforations (Inlet and outlet pipe ends opened)

3. Design Analysis

When the exhaust gases from inlet pipe pass through the perforations inside the shell, the gases get scattered indifferent directions. After reflection from the inside surface of the shell, the sound cancellation of waves occurs. The gases pass through the perforations multiple times and even get reflected from the shell surface[10-12]. Due to the combined effect of these, the level of sound at the muffler outlet is reduced significantly. The flow through the muffler and variation of various parameters such as velocity and pressure along the length of the model can be accurately demonstrated with the help of CFD analysis which display accurate results within a short span of time.

3.1 Boundary Conditions

1. Velocity at inlet is 10.9748 m/s.

2. Pressure at outlet is considered as Zero Pa.

3.2 CFD Analysis of Flow

Continuity equation (Navier-Stokes) is one of basic conservation equations on which code of Fluent software bases. According to law of conservation of mass in a closed physical system mass of medium cannot neither increase nor decay. Assumption of fluid stream continuity leads to the conclusion that it covers all space of flow (there is so called homogenous flow). On the basis of those assumptions we can make balance mass and in the result we obtain following equation of flow continuity:

$$\partial\rho/\partial t + \nabla.(\rho v) = 0 \qquad (1)$$

Navier-Stokes equation is used for description of principle of conservation of mass and momentum of flowing fluid. One of the major parameters for determination of muffler performance is transmission loss. It is the difference between the power incident at the inlet of a muffler and that transmitted downstream at the outlet and expressed in the unit of decibel [13-16]. For better noise attenuation a higher value of transmission loss is desired. Mathematically, transmission loss is represented as follows:

$$T.L = 10\log_{10}\left|\frac{SiPi^2}{SoPo^2}\right| \qquad (2)$$

In the present case where the inlet and outlet of the muffler are of equal cross-sectional area the above formula can be represented in modified form as follows:

$$T.L = 20\log_{10}\left|\frac{p_i}{p_o}\right| \qquad (3)$$

For reference values following data has been considered for air in both the models which has been computed from inlet

Table 1. Reference values

Area (m^2)	0.00139
Density (kg/m^3)	0.696
Enthalpy (J/kg)	503400
Length (m)	0.384
Pressure (Pa)	300000
Temperature (K)	500
Velocity (m/s)	10.9748
Viscosity (Kg/ms)	2.7e-05
Ratio of specific Heats	1.4

4. Results and Discussion

CFD analysis for the Five muffler models has been performed in ANSYS FLUENT 20 to obtain contours of pressure, velocity, stream lines and acoustic power level. The results obtained from CFD analysis are demonstrated below.

4.1 Model 1 (Muffler with no perforations and with no extended inlet and outlet pipes)

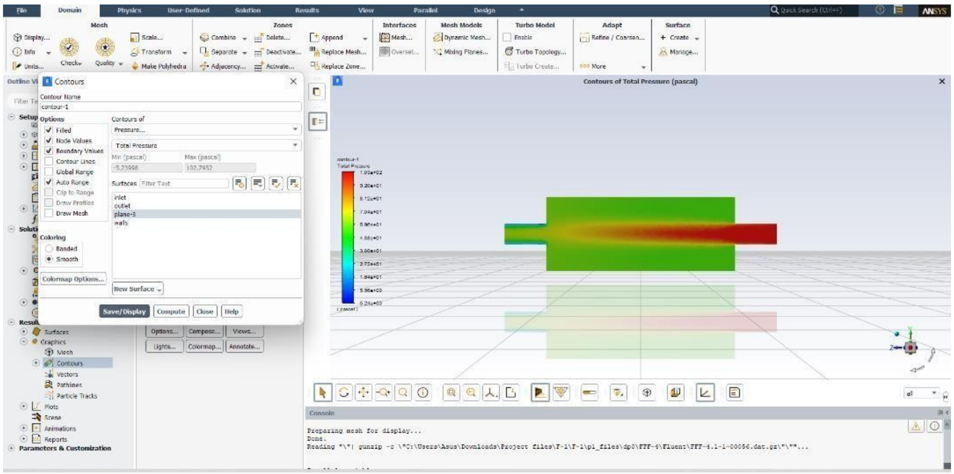


Figure 4. Total Pressure Contour of Model 1

From Figure 4 it can be observed that the pressure is decreasing from inlet to Outlet. Inlet pressure is 103.12 Pa and Outlet pressure is 65.71 Pa.

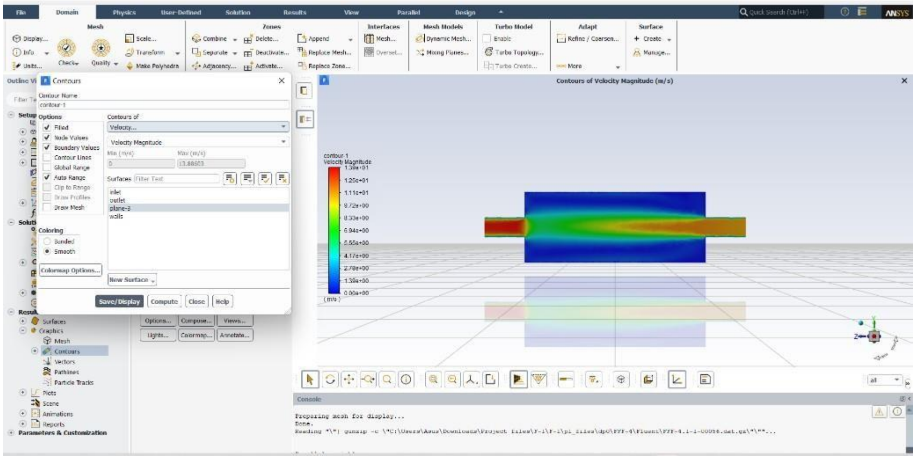


Figure 5. Velocity Contour Model 1

From Figure 5 it is observed that velocity is increasing from Inlet to Outlet .Inlet velocity is 10.9748 m/s and Outlet velocity is 13.73 m/s.

4.2 Model 2(Muffler with perforations (Inlet and outlet pipe ends closed))

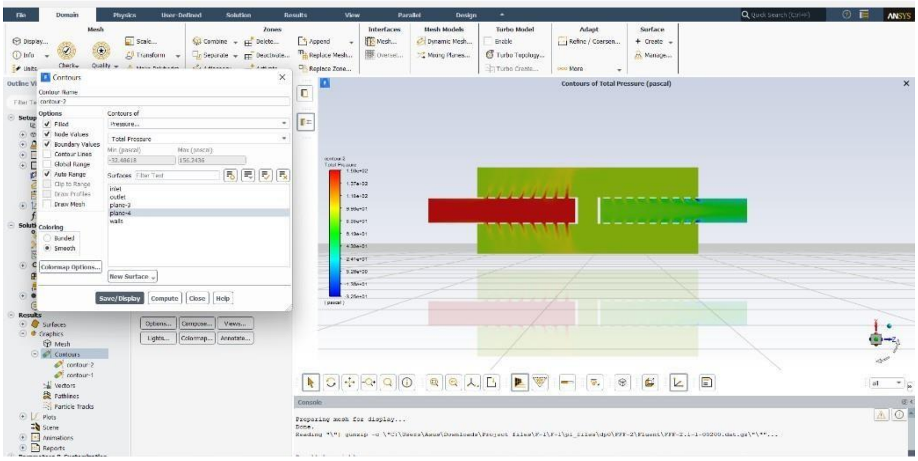


Figure 6. Total Pressure Contour Model 2

From Figure 6 it can be observed that the pressure is decreasing from inlet to outlet. Inlet pressure is 156.40 Pa and outlet pressure is 61.11 Pa.

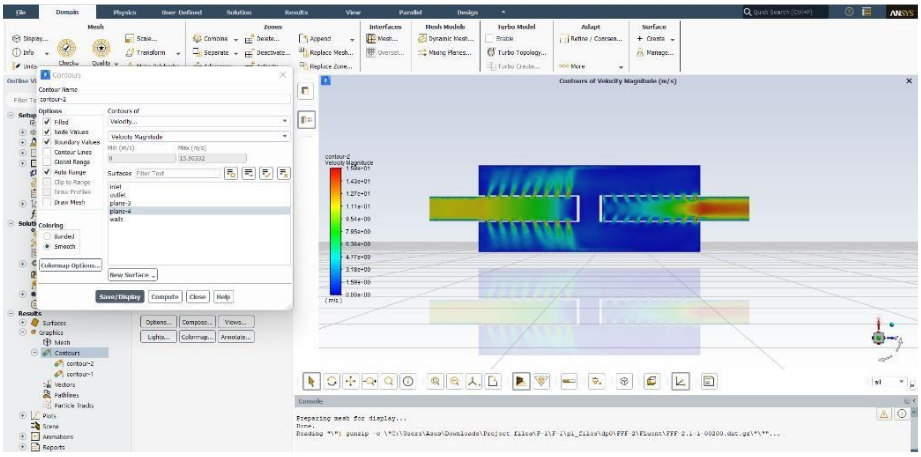


Figure 7. Velocity Contour Model 2

From Figure 7, it can be observed that velocity is increasing from inlet to outlet. Inlet velocity is 10.9748 m/s and outlet velocity is 13.35 m/s.

4.3 Model 3(Muffler with perforations (Inlet and outlet pipe ends opened)

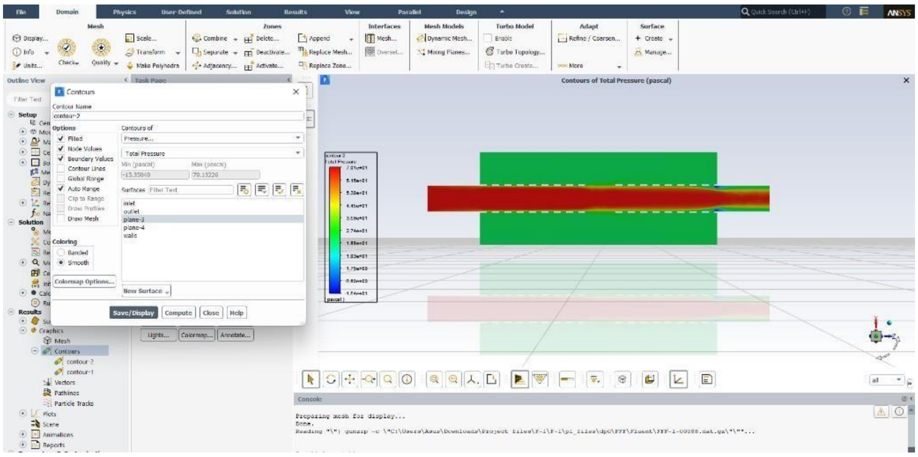


Figure 8. Total Pressure Contour Model 3

From Figure 8, it can be observed that pressure is decreasing from inlet to outlet. Inlet pressure is 70.18 Pa, outlet pressure is 69.16 Pa.

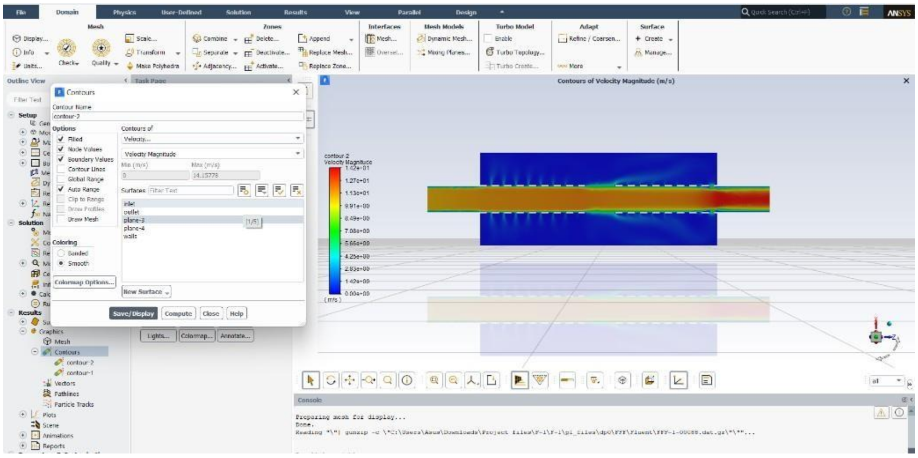


Figure 9. Velocity Contour Model 3

From Figure 9, it can be observed that velocity is increasing from inlet to outlet. Inlet velocity is 10.9748 m/s and outlet velocity is 14.09 m/s.

Table 2. CFD analysis results on each models

Model no:	Acoustic Power Level (dB)	Pi (Pa)	Po (Pa)	TL=20log10(Pi/Po)
Model1	45.25	104	66	3.94
Model2	66.19	156.4	61.11	8.16
Model3	50.98	70.18	69.16	0.12

5. Conclusions

A numerical analysis is carried out on acoustical and flow behaviour analysis of various muffler designs and the following conclusions are made.

1) The increase in restriction to the flow is found to decrease the acoustic noise. But at the same time there is a dramatic increase in back pressure.
2) From the various cases considered for best possible muffler designs, 3rd case is found to be a preferable choice at it is having least transmission losses.
3) Acoustic power level comparison of different cases shown least APL value for 1st case. But this is not considered as suitable design because of high pressure drop and transmission loss.

7. References

[1]. Munjal, M.L. (1998). Analysis and design of mufflers. Journal of Sound and Vibration, 211(3): 425-433. https://doi.org/10.1006/jsvi.1997.1309

[2]. M.Rajasekhar Reddy, DrK.Madhava Reddy, "Design And Optimization Of Exhaust Muffler In Automobiles", International Journal Of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 5, September-October 2012, pp.395-398

[3]. K Viswanath Allamraju , Mechanical Properties and Contact Stress analysis between Pin and Sidewall of AA3003 during Dwelling by using FSW, Materials Today: Proceedings, Volume 18, Part 7, 2019, Pages 3643-3650.

[4]. K Viswanath Allamraju , Mechanical behaviour of nano jute filler glass fiber self healing and epoxy resin composite, Materials Today: Proceedings, Volume 5, Issue 9, Part 3, 2018, Pages 20278-20284.

[5]. Mr. Jigar H. Chaudhari " Muffler Design for Automotive Exhaust Noise Attenuation - A Review" Int. Journal of Engineering Research and application, ISSSN:2248-9622, Vol. 4, pp.220-223,2014

[6]. Rahul D. Nazirkar, "Design & Optimization of Exhaust Muffler and Design Validation" International Conference, 01st June-2014, ISBN: 978-93-84209-23-0

[7]. Amar P. Pandhare, Dr. Atul S. Padalkar, Experimental And Simulation Study Of Diesel Engine For Lower Exhaust Emissions, SAE Paper 2013 ISSN 0148-7191.

[8]. SwetaBaruah, SushovanChatterjee , CFD Analysis on an Elliptical Chamber Muffler of a C.I. Engine, International Journal of Heat and Technology Vol. 37, No. 2, June, 2019, pp. 613-619

[9]. UjjalKalita and AbhijeetPratap, " Absorption Materials Used In Muffler A Review" International Journal of Mechanical and Industrial Technology ISSN 2348-7593 Vol. 2, Issue 2, pp: (31-37), Month: October 2014 - March 2015.

[10]. S.Balamurugan, N Jeyaprakash&K.Manikandan "Design and Fabrication of Muffler for Four Stroke Diesel Engine" (ISSN: 2277-1581) Volume No.4 Issue No.3, pp. 136-140 01 Mar2015.

[11]. Jayashri P. Chaudhari, Amol B. Kakade "Design, Development and Analysis of Absorptive Muffler with Ammonia Pulsator for IC Engine" Journal Page No 429-434

[12]. Sunil And Dr Suresh P M "Experimental Modal Analysis Of Automotive Exhaust Muffler Using Fem And FFT Analyzer" International Journal of Recent Development in Engineering and Technology Volume 3 Issue 1,page 185-187 ISSN 2347-6435, 2014.

[13]. K .Satyanarayana, T.V. HanumanthaRao, I Niranjan Kumar, P.V.J Mohan Rao, V.V.S. Prasad,"Response optimization of four stroke variable compression ratio diesel engine cylinder head with stress analysis"Materials Today: Proceedings, Volume 5, Issue 9, Part 3, 2018,Pages 19497-19506,ISSN 2214-7853,

[14]. K. Satyanarayana, P. V. J. Mohan Rao, I. N. Niranjan Kumar " Some studies on Mathematical Modeling and Dynamic stress analysis of a Variable Compression Ratio Diesel Engine Crankshaft" JVE INTERNATIONAL LTD. ISSN PRINT 2351-5279, ISSN ONLINE 2424-4627, KAUNAS, LITHUANIA , vol 4.1 March 2018 ,(

Pages1- 10),

[15]. K.Satyanarayana, S.V.UmaMaheswaraRao, Viswanath.A. K, T.V.HanumantaRao "Quasi-dynamic and thermal analysis of a diesel engine piston under variable compression" Materials Today, Volume 5, Issue 2, Part 1,2018, Pages 5103-5109.

[16]. K Satyanarayana, A K Viswanath, TVH Rao, SVUM Rao "Investigation of the Stresses Induced in Crank Shaft AISI E4340 Forged Steel" Procedia Engineering vol. 173, pages 1672-1677, ISSN 1877-7058.

[17]. Prof. Amar Pandhare, "CFD Analysis of Flow through Muffler to Select Optimum Muffler Model for Ci Engine", Vol. 4 Issue 1 May 2014, ISSN: 2278-621X