Design and Analysis of Hybrid Aqua Silencer For Vehicle Exhaust Emission System

By

Teshome Kumsa

A Thesis Submitted to

Department of Mechanical Systems and Vehicle Engineering

School of Mechanical, Chemical and Material Engineering

Presented in partial fulfillment of the requirement of the degree of Masters in Automotive Engineering

Office of Graduate studies

Adama science and Technology University

Adama, Ethiopia

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DESIGN AND ANALYSIS OF HYBRID AQUA SILENCER FOR AUTOMOTIVE EXHAUST EMISSION

By

Teshome Kumsa Kurse

_____	_____	_____
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Internal Examiner	Signature	Date
_____	_____	_____
External Examiner	Signature	Date

CANDIDATE'S DECLARATION

I hereby declare that the thesis which is being presented entitled **"Design and analysis of Hybrid aqua silencer for automotive exhaust emission",** in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Engineering is an authentic record of my own work carried from February 2019 to June 2019 under the supervision of Mr. Mekonnen Liben (Assistant professor), Department of Mechanical and Vehicle Engineering, Adama science and Technology University, Ethiopia.

The matter embodied in this thesis has not been submitted by me for the award of any other degree or diploma. All relevant resources of information used in this thesis have been duly acknowledged.

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Student		

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

Name	Signature	Date
_____	_____	_____
Advisor		

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Firstly, I Thank God that helped me to manage and complete the study after passing through many challenges. All praise and many-many thanks to GOD who gave the strength and confident to me to complete the thesis entitled Design and analysis of Hybrid Aqua silencer for automotive exhaust emission.

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Generally, I would like to extend my thanks to all the above people and those who are not mentioned here but contributed their part a lot towards the success of this thesis.

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LIST OF ABBREVIATIONS AND ACRONYMS

SO_X	Oxides of sulphur
CO	Carbon monoxide
UBHC	Un-burnt hydrocarbon
NOx	Oxides of nitrogen
dB	Decibel
CAD	Computer aided design
IC	Internal combustion
HAS	Hybrid Aqua silencer
Pb	Lead
PM	Particulate matter
DPF	Diesel particulate filter
VERT	Vehicle emission regulation
CFR	Cylinder firing rate
EFR	Engine firing rate
Q	Volume flow rate
LHV	Lower heating value
Fc	Fuel consumption
Veg	Velocity of exhaust gas
kW	Kilowatt
P	Maximum pressure of gas
P_e	Absolute pressure of exhaust gas
CS	Conventional system/silencer/
HAS	Hybrid aqua silencer
AS	Aqua silencer

ABSTRACT

Global warming is increasing on our earth due to major increase in the air pollution. Air pollution is the most serious issue from the public health point of view as an every individual person breaths about 22,000 times a day, inhaling about 15 to 22 kg of polluted air daily which cause so much health effects according to research done. Further the air contamination contributes heavily to pollution of our environment so it is very important that severe attempts should be made to conserve earth's atmosphere from pollution. The main contributors to air pollution are gases released from external combustion engines (factories) and internal combustion engines (automobiles) are like carbon monoxide, unburned hydrocarbons etc. In view of addressing this major contributor, this thesis is focused on design of hybrid aqua silencer that minimizes Emission of polluting gases. Hybrid Aqua silencer is one of the attempts made to reduce the air pollution. The methods used are design and fabrication, experimental trials and analysis of the results. It is fitted to the exhaust pipe of engine or system. This system is used to reduce noise and control emission of harmful gases. In hybrid aqua silencer the main components are perforated tube which consists of number of different diameter holes to convert high mass bubbles to low mass bubbles. Generally there are three sets of holes used on this perforated tube. The charcoal layer which is pasted over perforated tube can control the emission using the activated charcoal and highly porous extra free valences. Lime water external to activated charcoal layer to reduce temperature and NOx emissions. Also, this hybrid aqua silencer reduces noise emission; because the sound produced under water have less amplitude than the sound produced in open atmosphere. This happens because in water molecules there are small notches which lowers amplitude of emitted gases and lower the sound level. So this layer is having high absorption capacity. This system itself acts as a silencer and catalytic converter. So there is no need of separate silencer and catalytic converter. This system is very cost effective and more economical. It does not give rise to any complications in assembling it. In general this study focuses deals with design and analyze hybrid silencer in more advantageous form. The values of exhaust gases released from the engine do not completely mixed to the atmosphere. After the study experiment has done shows the result CO, CO_2, UHC and O_2 diminished by 21.37%, 2.75% 44.57% and 0.911% respectively.

Keywords: Air pollution, Aqua silencer, Charcoal, Silencer, unburned hydrocarbons

CHAPTER ONE

INTRODUCTION

1.1 Background

Vehicles are a major source of environmental pollution after industries. Air contamination is serious issue from the public health point of view. Polluted air causes unexpected physical and physiological effects on human health. Air pollution can be defined as addition of unwanted material to our atmosphere, which will have a speedy effect on life of living things upon our planet. The main pollutants contributed by engine exhaust are carbon monoxide (CO), un-burnt hydrocarbon (UBHC), oxides of nitrogen (NOx) and Lead (Protsahan, 2013).

Emissions may be divided into two group; 1) Invisible emission and 2) Visible emission. Major emissions in exhaust gas are as follows:

1. Invisible emission.
    a) Un-burned hydro-carbon (HC).
    b) Oxides of carbon (CO_X).
    c) Oxides of sulphur (SO_X).
    d) Oxides of nitrogen (NO_X).
2. Visible emission
    a) Soot and Smoke (carbon particles).
    b) Particulates.

It is impossible to conclude simply by saying the only cause of air pollution is automobile specifically. This is because of that, there are other sources such as electric power generating stations, industrial and domestic fuel consumption, industrial processing etc. also contribute heavily to pollution of our environment, so it is mandatory that serious efforts should be made to conserve of our environment from deprivation.

Actually, engines are used for various purposes in power plants, automobiles, locomotives and in various manufacturing. Pollution in a sense not only the air emission part but also the noise produced should be in consideration. Noise created by these engines becomes a vital concern in domestic areas or areas where noise creates various hazard. Scientifically noise level an average of more than 80 dB is hazardous for human being naturally. The main sources of noise in an engine are the exhaust and that produced due to friction of various parts of the engine (Rishikesh Acharekar et al, 2016).

Even if this study may not deal with noise deeply, the noise and smoke level is considerable less than the conventional silencer further there is no need of catalytic converter and easy to install. Activated charcoal layer is highly porous and posse's extra free valences so it has high absorption capacity along with this lime water chemically reacts with the exhaust gases from the engine and release much less pollution to the environment. So in this type of hybrid system it absorbs the gases from the engine and releases much less portion to the environment (Dr. P.K.Sharma et al, 2017).

Diesel engines are playing a vital role in Road and sea transport, Agriculture, mining and many other industries. Considering the available fuel resources and the present technological development, diesel fuel is evidently necessary. In general, the consumption of fuel is an index for finding out the economic strength of any country. Inspire, we cannot ignore the harmful effects of the large mass of the burnt gases, which erodes the purity of our environment every day. It is especially so tried, in most developed countries like USA and Europe. While, constant research is going on to reduce the toxic content of diesel exhaust, the diesel power packs find the ever increasing applications and demand (P.Balashanmugam et al 2014).

This project is an attempt to reduce the toxic content of diesel exhaust, before it is emitted to the atmosphere. This system can be safely used for diesel power packs which could be used in inflammable atmospheres, such as refineries, chemical processing industries, open cast mines and other confined areas, which demands the need for diesel power packs. For achieving this toxic gases are to be reduced to acceptable limits before they are emitted out to this atmosphere, which otherwise will be hazardous and prone to accidents.

The principle involved is by bubbling the exhaust gas through the scrubber tank containing an alkaline solution; here the temperature of the gases is reduced, while most of the oxides of nitrogen in the exhaust are melted down to nontoxic. The highly dangerous carbon monoxide is not such an Endanger in diesel exhaust, as it does not exceed 0.2 percent by volume, whereas in petrol engines the CO content may be as high as 10 percent. A lime water container in the scrubber tank reduces the considerable percentage of sulfur dioxide (SO_2) presents in the exhaust (G. Balasubramanian, 2015).

1.2 Statement of the problem

In this study it is dealt with emission reduction mechanisms due to the environmental pollution what is observed around our living area by introducing the machine component called hybrid aqua silencer. Here targeting this study deeply about air emission rather than sound emission. The reason why we go for hybrid aqua silencer is, in today life the air pollution causes physical ill effects to the human beings and also to our environment. The main contributors to air pollution are exhaust gases from automobiles like carbon dioxide, unburnt Hydrocarbon, oxide of nitrogen etc. In order to avoid these types of gases introducing this aqua silencer is very essential at this moment. This hybrid aqua silencer system is designed to replace conventional single unit engine silencers on board structures. It is used to control the noise and emission in IC engines. It is fitted to the exhaust pipe of the engine. Sound produced under water is less hearable than produced in atmosphere. This is mainly because of small sprockets in water molecules, which lowers its amplitude thus, lowers the sound level. The emission can be controlled by using the activated charcoal layer and it is highly porous and possesses an extra free vacancy which renders it high absorption capacity. So, in this study it's tried to minimize the size of silencer as much as possible without affecting the weight of vehicle using some experimental chemicals ($Ca(OH)_2$) inside the components.

1.3 Objectives of the study

1.3.1 General objective of the study

The general objective of this thesis is to design and analyze the effectiveness of Hybrid Aqua silencer for emission reduction in vehicles.

1.3.2 Specific Objectives

The specific objectives are:

- To study the existing emission reduction mechanism.
- To design and model the new emission reduction mechanism.
- To prepare the part and assembly drawing of the system using AutoCAD.
- To prepare the prototype of the system.
- To test the functionality of the designed system and
- Compare the effectiveness with the Conventional system.

1.4 Significance of the thesis

The significance of the thesis work is as mentioned below:

- ❖ It helps in reducing the air emission as much as possible.
- ❖ Expected to be economical compared with the conventional silencer.
- ❖ Can be easily manufactured and maintained from local material.

1.5 Beneficiaries

Automotive industries, vehicle owners, researchers, society and country as a whole get benefitted with this work.

1.6 Scope of the study

This study targets on emission reduction and done it for gases like CO, CO_2, and UHC well. It is clear that by moderate amount the weight of the vehicle slightly increases due to the content of the designed component and it takes more space than the existing system. So this thesis is limited in modeling and analysis for four stroke single cylinder diesel engine air emission as initial.

1.7 Limitations of the study has been taken

In this study, weight of the vehicles increases due to Hybrid aqua silencer components. The researchers in this study detailed not calculate the thermal effects of the hybrid aqua silencer and assumed the weight of designed system negligible compared to the emission effects. Due to unavailability of instruments sound was not measured.

1.8 Structure of the thesis

The scope of the research is confined to develop a machine called aqua silencer for single cylinder diesel engine and check the effects by comparing with the existing silencer. Here the main target is not only the sound problem on the engine rather it concerned with the air emission/depletion/. The thesis will be organized and structured accordingly and it's detailed below:

Chapter -1: Introduces about the silencer and give some hints about the existing material that was used before with their components for more description. Not only this one here also the newly designed machine is also introduces in couple.

Chapter -2: Discusses the review of literature in silencer. It deals with the literature related to mechanisms used for emission reduction in simple and locally existing material without

affecting the cost and using small amount of chemicals for that purpose. In other way it covers the application of the exhaust emission reduction material called catalytic converter, (i.e. here in hybrid aqua silencer it's tried to eliminate the catalytic converter.)

Chapter -3: Discusses on materials and methods of the thesis. The overall specifications of the vehicle needed such as weight specifications, engine specifications and silencer specifications with the material properties and reaction takes place in that components is discussed. The CAD model of the hybrid aqua silencer also developed. In this chapter the theories and design constraint and parameters such as overall size of Hybrid Aqua silencer (i.e. length, width and volume), exhaust pressure, pipe length and diameter).

Chapter -4: It focuses on the result and discussion obtained from experiment on exhaust analyzer.

Chapter -5: Deals with the conclusion and recommendation depending on the result obtained.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The literature review has been referred from journals, reports, conferences and books. Some research papers were also referred to have information on the previous art of research. Thus, this chapter tries to discover previous studies and expedite it for the current study in this thesis.

2.2 Categorizations of Literature review

Literature review in this study was divided into the following four main categories;

1. Related literature reviews of this thesis work.
2. Previous experimental studies of vehicle emission reducing mechanisms.
3. Chemistry of charcoal and water when mixed with diesel exhaust and
4. Characterizations and specifications of vehicle emission standards.

Below are some of the reviewed literature has been done by some researchers:

Sarah Raj et al. (2016) discussed about silencer types in that the combined resonance and absorber type is the more effective type. In that project they made model and carried out the analysis. The outcome of this experimental analysis was that twin filter silencer is more effective and the water contamination was found to be negligible in aqua silencer.

P.Balashunmugam et al (2014) carried out the analysis in which how the lime stones are originally intended to reduce the toxic ingredients of the exhaust, gas through chemical reaction. It is evidently affected the flow of resistance and hence the combustion characteristics of the engine will finally contribute the increased toxic ingredients of the exhaust gas. Because of the introduction of the scrubber, the net length of the exhaust gas flow path is also increased which is again, against the original intention according to the study they conclude that water in scrubber tank can itself play an important role in absorbing the obnoxious products of combustion like the oxides of nitrogen. NO is converted into NO_2 after emission which highly toxic is mainly absorbed in the water scrubber.

Rahul.s.padval et al (2016) had proved in their experiment of an aqua silencer that water in a silencer reduces the sound. The system is very cheap and is use for four and two

wheelers. The performance of twin silencer is almost equivalent to the conventional silencer.

Alen.M.A et al (2015) investigated that how emission can be controlled by the activated charcoal and lime water. They compared the results between simple silencer and silencer with lime water and activated charcoal layer. They conclude that the silencer is more effective in the reduction of emission gases from the engine exhaust using perforated tube, lime water and charcoal layer. By using perforated tube the back pressure will remain constant and fuel consumption remain constant and sound level is reduced. Also by using activated charcoal in water we can control the exhaust emission to a greater level it is smokeless and pollution free emission equivalent to the conventional silencer.

S. Martin et al (2016) the experimenters have designed a muffler for sound attenuation. A passive muffler is categorized as either a reactive or a dissipative muffler dependent on two different mechanisms used to reduce engine noise. A reactive muffler is designed to reflect sound back to the engine compartment by introducing area discontinuities (like expansion or contraction in a duct), branches (like resonator) and flow reversals. This design provides a good sound attenuation for low to moderate frequency bands.

Rohit Thakre et al (2017) have done the research of Aqua Silencer and said that it is an advanced system which can be used along with or instead of a catalytic converter, using which exhaust emissions at tail pipe of an exhaust system can be easily lowered than specified levels, along with reducing undesirable noise at tail pipe. Also, the use of water decreases overall temperature of exhaust gases coming out via tail pipe, which may add to greenhouse gases. Overall emissions at tail pipe which contains harmful constituents like lead (Pb), carbon monoxide (CO), oxides of nitrogen (NOx) & un-burnt hydrocarbons (UBHC) can be lowered than existing levels using adsorption method, which uses activated charcoal to adsorb these harmful constituents.

Dr.P.K.Sharma et al (2017) the investigator of An Aqua Silencer said that it is fixed to the exhaust pipe of engine. The noise and smoke level is considerable less than the conventional silencer, it is inexpensive, no need of catalytic converter and easy to install. Air pollution can be defined as addition to our environment of any material, which will have a dexterous effect on life upon our planet. The main pollutants contribute by automobile are carbon monoxide (CO), unburned hydrocarbon (UHC), oxides of nitrogen (NOx) and Lead.

Santosh Kumar et al (2017) conducted the experiment which basically consists of a perforated tube which is installed at the exit of the exhaust from the engine, which may have holes of variable diameters. This is done to divide the gas molecules of large proportions to form gas molecules of smaller diameter. Theoretically, four or more sets of holes are made on the perforated tube using drilling. The other end of the perforated tube is sealed using a plug. A small coating of activated charcoal is provided all around the perforated tube using inner cylinder which holds the charcoal in place and separates the charcoal and lime water from the water in the Aqua Silencer. This unit is then placed in a container in which water is filled to a certain level.

Keval I. Patel et al (2014) made a complete study of how actually an aqua silencer works and made conclusions accordingly. The use of aqua silencer in reduction of toxic gases and noise versus the benefits that this silencer can give by their use is explained in this extract. The system under study consists of three units: a perforated tube, a charcoal layer, water. The procedure they follow may be first a perforated tube is installed at the end of the exhaust pipe. That perforated tube consists of number of holes of different diameters 8 mm, 4 mm and 2 mm. The water inlet, outlet and exhaust tube was provided in the shell. Using Adsorption method the Result have gotten were sound is reduced, CO is reduced 60 to 70 % compared to ordinary silencer, Engine efficiency increases with increase in flow rate of fluid, and it has Low cost. It gives smokeless and pollution free emission.

Akhil Anil Kumar et al (2016) did a complete investigation and analysis of how Aqua Silencer can affect the noise and toxic emission reducing capacity of an engines and explained the applications of engines with aqua silencer. A complete study of aqua silencer was made which included analysis of their work, structure and also their toxic emission and noise reduction capacities. Performance comparison of simple silencer, silencer with activated charcoal and silencer with activated charcoal and lime water was made. Aqua silencer is thermally effective and technically feasible for use as reduction noise and toxic emission of engine but certain improvements in the working of aqua silencer to fit in the application with the engine exhausting unit is essential. Lime water plays crucial role. Materials used for operations are, Perforated tube with activated charcoal, Aqua silencer (box type), and they have done analysis engine exhaust first with aqua silencer and second without aqua silencer. Increase in less toxic emission and noise reduction capacity and efficiency by the use of aqua silencer.

Parikshit K. Patel et al (2015) Here the investigators have prepare the experimental setup and study was been carried out in order to check the systems performance with the use of perforated tube in aqua silencer. The study aimed at bringing in ideas to reduce toxic emission and noise. The experimenter integrated an aqua silencer directly to exhaust of engine and studied the effect of such an alignment of aqua silencer on this operating constant exhaust system. For this study charcoal layer which was directly wrapped around the perforated tube were selected and tested. The effects of the charcoal layer for absorbing toxic gases and dissolving in water were checked. Also description about the mesh characteristics of this type of applications with the use of perforated tube in aqua silencer is given. Use of perforated tube's enhanced the systems performance. More the perforated tube diameters lesser the turbulence and contour. Study on the aqua silencer's shows that the use of perforated tube with charcoal layer proved to be more beneficial. Use of perforated tube in aqua silencer has a great effect on the system. Perforated tube reduces the sound and kept the constant back pressure.

Maruthi Prasad Yadav et al (2015) conduct a complete study on performance of different types of silencers and analysis of how aqua silencer can work also explained the some applications with aqua silencers. A complete study of aqua silencer (box type) was made which included analysis of their characteristics, performances and also their emission tests. Performance comparison of diesel engine with and without aqua silencer was made. Aqua silencer is thermally effective and technically feasible for use as noise and toxic gases reduction. Tests were performed to investigate the effect of black smoke and NOx emissions and sound from exhaust gases. It was found that after implementing the aqua silencer engine tended to eliminate NOx emissions and sound completely.

P K Pavan Kumar et al (2016) investigated that, the exhaust pipe coated with 20% activated carbon and refractory with baffles shows least HC emissions. When compared with the conventional exhaust pipe 66% of HC emissions are reduced due to the chemical adsorption of HC by the activated carbon. The chemical reaction oxidizes the hydrocarbon to carbon dioxide and water. There is also importance for the baffles as there is more surface area for adsorption of HC. Different chemical compounds can be used in various design of exhaust pipe to reduce the emissions from the exhaust gases by the works carried out in this regard. Work on an exhaust pipe coated with refractory and activated carbon is carried out and emission tests on the two stroke engine are carried out,

results showed that the composition of 20% activated carbon and 80% refractory reduced the CO and HC emissions considerably.

Anubhav Yadav et al (2018) conducted the experiment on charcoal based exhaust systems. The main pollutants emitted by the vehicles are CO, HC, NOx and sox. Automobiles are responsible for 80% of total co emissions, 36% of HCS, 44% of NOx, 4% of SOx and 18% of particulate matter. They have used activated charcoal and silica gel as it has a property of adsorption. This property is very useful as when various carbon and nitrogen content passes through it, it sticks to its surface, reacts with it and results in release of non-pollutant gases. According to our theoretical analysis and practical approach we found that our system efficiently reduced the percentage of harmful content from the automobile exhaust system. Testing of their project at PUC centre on Honda Shine 125cc Engine on 13 October 2017 PUC Report shows that the System successfully reduces the COx and HC at the respective rates.

Vijayabalan P et al (2016) conducted the experiment; they have successfully controlled emission of carbon dioxide from the diesel operated engines, which is about 9.266% of the overall emission from a vehicle. AVG gas analyzer is used to measure the content of gases and their percentage. Through this other gases has also been controlled like hydro carbon, nitrogen, carbon monoxide and particulate matter.

Ali Azam et al (2016) explained about diesel engines, like their low-operating cost, have high efficiency; reliability and durability because of this type of engines are especially used for heavy duty vehicles. The diesel motors are considered as the principle donor to ecological contamination these days. They are the main cause of several health problems. They contribute to global warming through Particulate Matter, Hydrocarbons (HC), Nitrogen Oxides (NOx) and Carbon Oxides (COx) emissions. Their presence causes a number of respiratory diseases. Various effective techniques are currently available for reducing PM, HC, COx and NOx.

(Source: Drived from getty images gallery)

Figure 2.1 (a) and (b) Three wheeler exhaust smoke (source: Camera).

Rashid Ali et al (2011) investigated the contents of diesel engine emissions and dialed with particulate matters by saying, PM 2.5 are a mixture of solid particles and liquid droplets in the air. Because of its small size, fine particulate matter can be deposited deep in the lungs where it can cause health problems. Studies have shown an association between particulate matter and premature mortality from respiratory and cardiovascular disease and increased incidence of respiratory illness particularly in children and the elderly. For adults with heart or lung conditions, exposure to fine particulate matter can cause more illness and in some cases premature death. More than 90% of the particulates found in diesel exhaust are fine particles.

Nikolas Hagemann et al. (2018) investigated and validated that Activated charcoal was initially “any form of carbon capable of adsorption”. Lastly, they generalize from their review historically used activated charcoal functions; it began with the use of charcoal as a sorbent being traced back to both the Roman and Chinese Empire, and potentially even further. From that the researcher validates how Romans realized that charcoal can purify water; a property we still utilize. However, despite this long history of charcoal’s use for purification, it took humans over 3000 years to optimize charcoal for the removal of specific contaminants.

On those studies done above no more size and weight reducing mechanism is explained. So this study looks the gaps and survey to react with size reduction using absorptive chemicals. Before saying more about the study, this study say something about the existing sound eliminating machine component called silencer and air emission reduction components like that of catalytic converter respectively.

2.3 Classifications of conventional silencers

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 sound proofing device designed to reduce the loudness of the sound pressure generated from the engine by way of acoustic quieting. The majority of the sound pressure produced by the engine is emanating out of the vehicle using the same piping used with 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 where in opposite sound waves cancel each other out (Sarath Raj et al, 2016).

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. Some vehicle owners remove or install an aftermarket muffler when engine tuning in order to increase power output or reduce fuel consumption because of economic or environmental concerns, recreational pursuits such as motorsport and hyper milling and/or for personal aesthetic acoustical preferences. Although the legality of altering a motor vehicle's OEM exhaust system varies by jurisdiction, in many developed parts of

the world, modification of a vehicle's exhaust system is usually highly regulated if not strictly prohibited (P. chinna Rao, 2016).

So the silencer type can be:

1. Baffle type
2. Wave cancellation type
3. Resonance type
4. Absorber type
5. Combined resonance & absorber type.

Each of them is explained with their application and differences on vehicles.

2.3.1 Baffle Silencer

It is generally cylindrical in shape with a number of baffles spot welded inside. There are many designs of baffles, but the principle in all cases is the same that is, closing in any direct passage for the gas. Major drawback of this type muffler is their low efficiency. Because of the restrictions provided to the flow by the baffles, the back pressure is increased, thus causing loss in engine power (Sarath Raj, 2016).

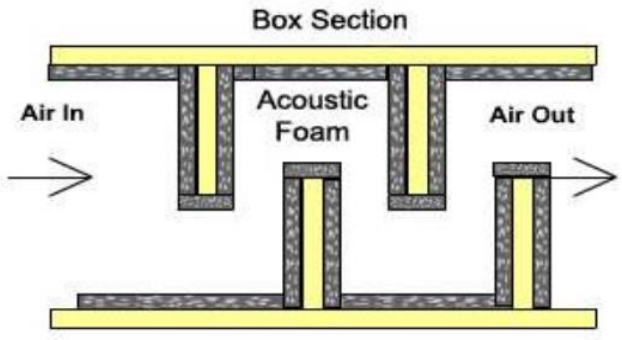

Figure 2.2 Baffle type silencers

2.3.2 Wave Cancellation Silencer

In this type, exhaust gases are divided into two parts. The lengths of these paths are so adjusted that after they come out of the muffler, the crests of one wave coincide with the troughs of the second wave, thus the cancelling each other and reducing the noise to zero theoretically. This is achieved if the lengths of the two passages differ by half the wave length. In practice this type of muffler does not eliminate noise completely, because this is possible only at one frequency for which muffler is designed, whereas the noise is a combination of different frequencies. However, appreciable noise reduction is achieved. In this the resistance to the main gas flow is very small as compared to the baffle type (Keval I. Patel, 2014)

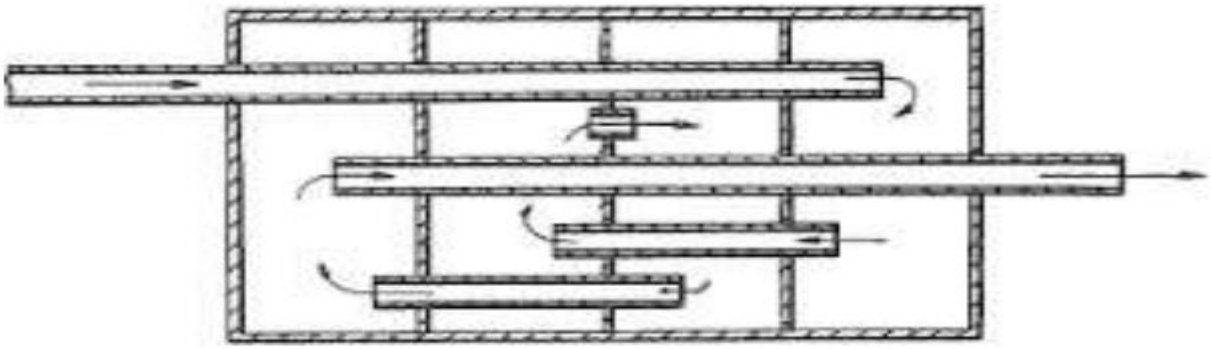

Figure 2.3 Wave cancellation type silencers

2.3.3 Resonance silencer

These are also called Helmholtz type, after the person who originated the idea. It consists of a number of Helmholtz resonators in series, through which a pipe containing access ports passes. The exhaust gases flow through this type and thus experience no resistance. Series of resonators eliminate the fundamental and higher harmonics of the engine noise (Rahul S. Padval et al, 2016).

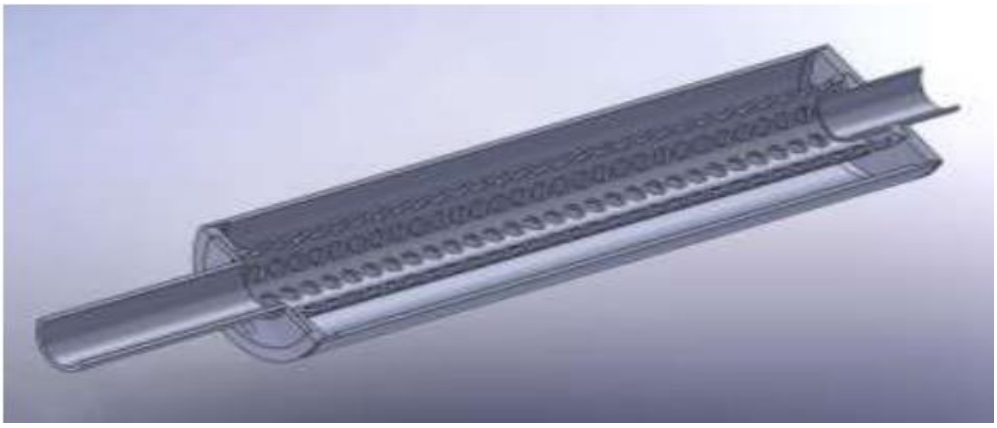

Figure 2.4 Resonator type silencers

2.3.4 Absorber Silencer

The sound absorbing material, usually fiber glasses, is placed in this case around perforated tube through which the exhaust gases pass. The sound is reduced by conversion into heat by the sound absorbing material. Such mufflers are commonly known as glass packs and are quite common in performance and raising cars due to their little resistance to flow. These essentially attenuate at higher frequency sounds and produce the deep, throaty sound usually associated with a high performance engine. A common design is a cylindrical can with a perforated tube which is surrounded by packing material (Sarath Raj, 2016).

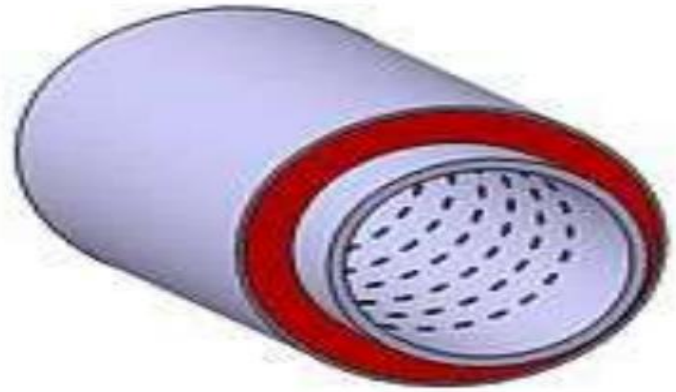

Figure 2.5 Absorber type silencers

2.3.5 Combined Resonance and Absorber type

It is seen that the absorber type muffler, has a drawback in that it is not efficient in reducing noise of low frequency. To obviate this defect, this is combined with a resonant chamber. It has been found that this type is more efficient than either the simple resonance or the absorber types (Sarath Raj, et al, 2016).

In general, here what have been discussed above are the types of silencer that can be used early for sound emission reduction only. (i.e to eliminate the sound frequency as much as possible depending on the engine types used for the purpose). Proceeding by saying this about the existing sound emission reducing mechanisms, let's see those systems used before for air emission reduction in both petrol and diesel engine vehicles on specific vehicles.

2.4 The catalytic converter systems

As the internal combustion engine utilizes the exhaust stroke to discharge the 'spent' gases via the exhaust system, the harmful emissions are passed through exhaust manifold then to a special muffler type looking device called a catalytic converter. After the emissions have passed through the converter they are passed through the rest of the exhaust system in the conventional manner and finally to the atmosphere. The catalytic converter's purpose is to reduce the original harmful emissions to negligible levels by means of catalyst controlled chemical reactions. Within the structure, the catalytic converter is a form utilizing a catalyst (Ralph H. Gonzales, et al. 2008).

This emission reducing mechanism which we call catalytic converter mostly used in the gasoline engine before as it is recognized from some literatures. But, in fact, what we have seen is that the diesel engine is mostly applicable for survival in our surroundings. Here, one basic asset that makes this component odd is that it's applicable at some extent of

temperature only. So our main target is to use this in diesel engine for more emission deduction, ensuring saved environment for living things survival.

Figure 2.6 Catalytic converter components (John matthey, 2009)

2.4.1 Components of the catalytic converter

There are three main components: First, the Monolith (also known as the substrate), a ceramic or metal structure constructed like a honeycomb, through which exhaust gases pass. Second, Wash coat, porous ceramic sponge like coatings applied in a thin layer to the monolith that multiplies the surface area to that of approximately two football pitches, over which the catalytic metals can be deposited. Third will be, the Catalyst, normally consisting of a mixture of Platinum and Rhodium although Palladium is used. They carry out the chemical reactions that purify the exhaust (John B. Heywood, ICE fundamentals).

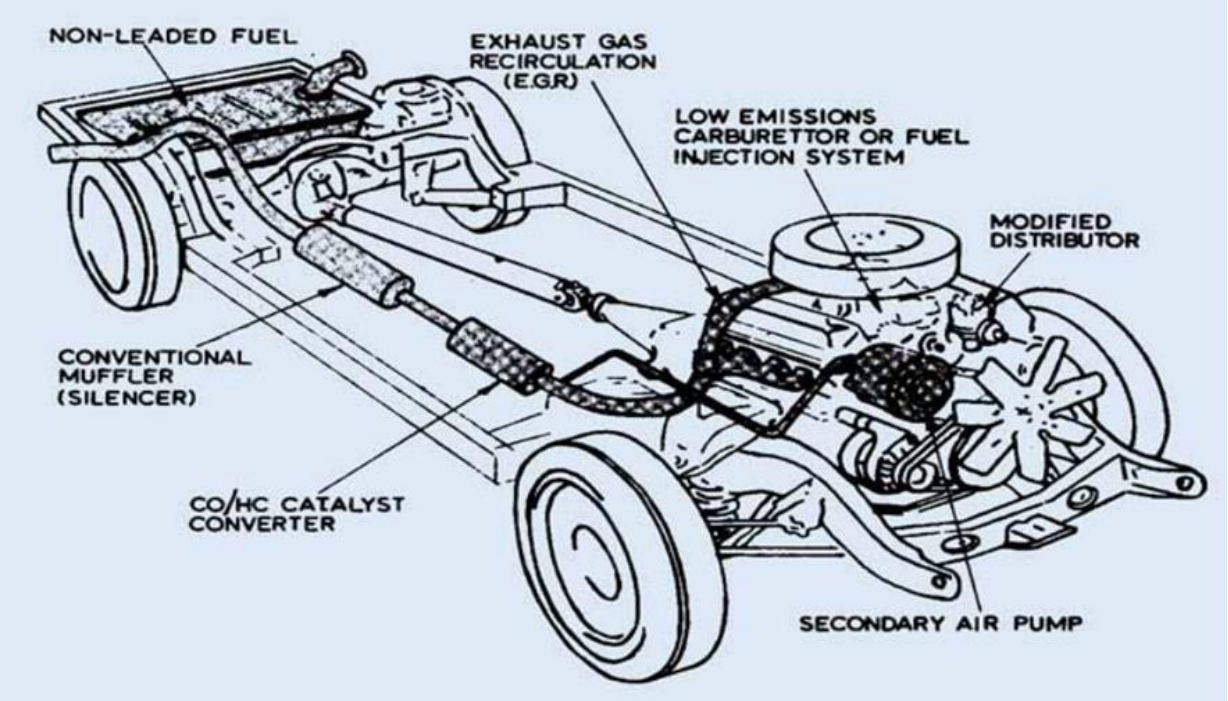

Figure 2.7 Johnson Matthew exhausts emission control system for vehicles (Johnson matthey, 2009).

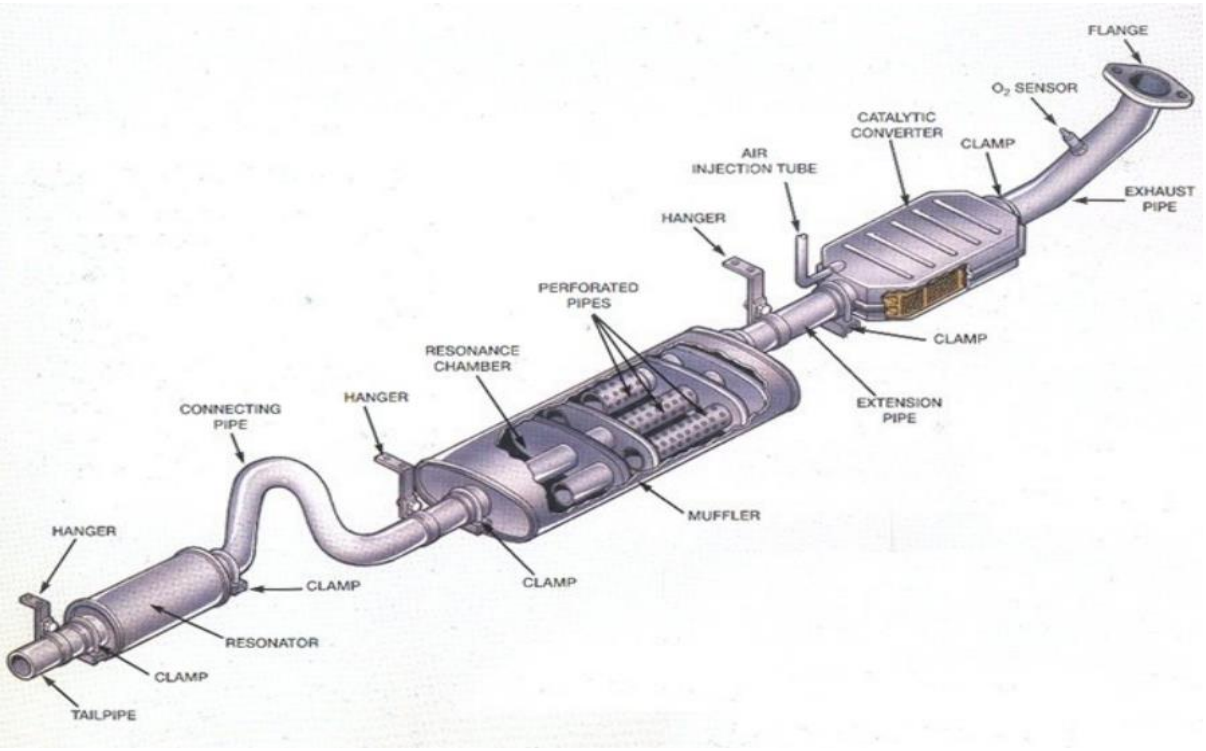

Figure 2.8 Combination of silencer and catalytic converter

The catalytic converter operates under some comfortable conditions depending on their design for functionality:

a. Working Temperature:

The catalyst starts operating once the monolith/substrate has attained a temperature of 250-270 °C, the temperature (commonly known as light-off) which a car will normally reach from cold start within a few seconds. Under normal operating conditions the catalyst maintains a temperature of between 400 - 600 °C. To work most effectively, a catalytic converter needs to reach an optimum temperature range of 250 ^{O}C - 427 ^{O}C. It may not reach this in a short journey.

Devises to pre-warm the catalyst are being developed which improve the overall performance of catalytic converters (http:www.compoundchem.com/vehicle emissions, 2015).

b. Stoichiometric Ratio:

For the catalyst to function properly, the engine must be idle stage at an ideal mixture of air and fuel (about 14.7:1 depending on the quality of the fuel).

c. Amount of catalysts used:

Platinum or Palladium accelerate the oxidation of hydrocarbons and carbon monoxide, while Rhodium reduces the oxides of nitrogen. As a general rule there are only between 1-2 grams of precious metals in every catalytic converter.

The idea is to create a structure that exposes the maximum surface area of catalyst to the exhaust stream, while also minimizing the amount of catalyst required since they are very expensive (John B. Heywood, ICE Fundamentals).

d. Reactions in a Catalytic Converter:

It is not precisely understood how platinum and rhodium work as catalysts but technically, the catalytic converter's action involves two types of reactions:

- Oxidation Reaction.
- Reduction Reaction.

- Oxidation Reaction: In a Catalytic Converter un-burned hydrocarbons are oxidized to water and carbon dioxide.

The Oxidation Catalyst:

The oxidation catalyst uses Platinum and Palladium to reduce the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a catalyst. This catalyst aids the reaction of the CO and hydrocarbons with the remaining oxygen in the exhaust gas.

For example: $2CO + O_2 = 2CO_2$

- Reduction Reaction: nitrogen oxides are reduced back into nitrogen, the major component of air. The catalyst in this chamber makes this possible. The converter uses two different types of catalysts, a reduction catalyst and an oxidation catalyst.

The reduction catalyst uses Platinum and Rhodium to help reduce the NOx emissions. When an NO or NO_2 molecule contacts the catalyst, the catalyst rips the nitrogen atom out of the molecule and holds on to it, freeing the oxygen in the form of O_2. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst, forming N_2.

For example: $2NO = N_2 + O_2$ *or* $2NO_2 = N_2 + 2O_2$

The Control System:

The control system basically monitors the exhaust stream and takes this information to control the fuel injection system. To do this, the catalytic converter is equipped with an oxygen sensor that tells the engine's computer how much oxygen is in the exhaust.

This allows the engine's computer to make sure that there is enough oxygen in the exhaust to allow the oxidization catalyst to burn the unburned hydrocarbons and CO.

In gasoline engines, catalytic converters are reliable and efficient at reducing pollution. They convert an estimated 90% of the hydrocarbons, carbon monoxide, and nitrogen oxides produced into less harmful compounds. However, catalytic converters are less efficient when used with diesel engines, which run colder than gasoline engines. Catalytic converters work best at higher temperatures (S.Prakash, 2018).

Here, in catalytic converter applications, the system itself is set by the catalyst to neutralize those harmful gases that come from the engine before it reaches the silencer to be released to the atmosphere. So this component is used only for air emission reduction only than sound reduction. From the study, in catalytic converter the catalysts deactivate more rapidly in two stroke engine cycles, that's because of the exhaust gas temperature so high and needs to be replaced frequently. For example, in some countries regulation on its durability, Taiwan and china initially set at 6000 km and at 15,000km today. The vehicle manufacturer gives an option to the durability test for 30,000 km, in southern Asia which is driven 120 km per day; 15,000 km is equivalent to less than six months of operation (Ralph H. Gonzales, 2008).

2.5 Design considerations of the study

The exhaust gas contains carbon di-oxide, sulphur di-oxide, carbon monoxide and other oxides of nitrogen. At full load, the temperature of the exhaust gas will lay anywhere between 500°c to 700°c. Whereas 200 ^{o}C to 300 ^{o}C with no load. Exhaust gases normally discharge at a temperature of around 420 ^{o}C. Scientifically, what we should have to know is while we design the exhaust temperature, the manufacturer property must keep. As the exhaust gas temperature higher, the thermal efficiency of the engine is lower. Since higher amount of heat energy is wasted through exhaust. Also, while measuring the specimen, the major three locations of exhaust gas temperature measurement are; inside the pipe, outside the pipe and before exhaust cooler.

The pressure of the exhaust gas depends upon so many factors: The design of exhaust gas manifold, magnitude of valve overlaps, engine speed, number of cylinders, the length of the exhaust gas flow path etc. (P. Balashanmugam et al, 2014).

The design of exhaust gas manifold is very important in case of high speed diesel engines. In order to maintain the exhaust gas pressure within the required limits, the exhaust gas manifold is designed so that, the gases, which come out of the cylinder flows very smoothly, before it is let out into the atmosphere. This is absolutely essential in order to maintain the back pressure within safe limits, so that the engine can be kept at the optimum operating level (Altair technology conference, 2015).

To be more precise, the speed of the engine is affected for a given specific fuel consumption rate and so the combustion characteristics of an engine are all affected. As a net result of the combustion is not proper and complete which results in the increased impurities or unburnt gases. By considering those problems as initial for the design the component should be designed safely.

This principle against the purpose of introducing any system whose sole object is reducing the very toxic property of the exhaust gas. So in this study it is implied that the introduction of any system reduces the toxic property of the exhaust gas shall not result in any effects in the opposite direction. So by introducing any component in the system the flow path length and the resistance to flow are indirectly increased. So the increase of back pressure is inevitable unless the increase in magnitude compensated in the design of the component itself.

Here in this study the exhaust gas has to pass through the perforated tube which is covered by activated charcoal (granular) and the water, which is filled in the outer shell tank.

In any case, the outlet from the engine shall be kept below the water level in the scrubber tank for that the gas will pass through the charcoal and water. The gas has no to push the water, in order to bubble through the water.

2.6 Back Pressure Limits

All engines have a maximum allowable engine back pressure specified by the engine manufacturer. Operating the engine at excessive back pressure might invalidate the engine life time specified by the manufacturer. To facilitate retrofitting of existing engines with Diesel Particulate Filters (DPF), especially using passive filter systems, emission control manufacturers and engine users have been requesting that engine manufacturers increase the maximum allowed back pressure limits on their engines (Santosh Kumar et al, 2017).

Mufflers generally result in maximum back pressures in the range of 6 kPa. In exhaust systems with a DPF, the back pressure can rise to significantly higher levels especially if the filter is heavily loaded with soot. The Swiss VERT program determined maximum back pressure limits in order to allow DPFs to be fitted to a wide variety of equipment. Table below outlines the VERT recommended back pressure limits for a range of engines sizes. The exhaust pressure for large engines was limited to low values due to valve overlap and high boost pressure consideration (Altair technology conference, 2015).

Table 2.1 VERT maximum recommended exhaust back pressure

(Santosh Kumar et al, 2017).

Engine Size	**Back Pressure Limit**
Less than 50 Kw	40 kPa
50-500 kW	20 kPa
500 kW and above	10 kPa

Engine manufacturers are usually much more conservative on their back pressure limits. For example, diesel generator set engines from Caterpillar, Cummins, John Deere and DDC/MTU ranging in size from 15 to over 1000 kW have back pressure limits ranging from 6.7 to 10.2 kPa. In setting back pressure limits, many factors must be taken into consideration. These include the effect on turbocharger performance; exhaust emissions, fuel consumption and exhaust temperature which are most commonly affect engine performance. The limit that a particular engine can tolerate will depend on specific design

factors and making general recommendations is difficulty (Altair technology conference, 2015).

So it should take care while designing the aqua silencer for engine emission reduction purpose.

2.7 Pollution types

In our encompassing various things dirty our condition. The real kinds of contamination are; air contamination, water contamination, soil contamination, light contamination and commotion contamination. Among those basic contamination types study mainly concerned with air, this generally released from motors. There may also sound pollution, but not mainly concerned with in detail.

2.7.1 Air pollution

Air pollution is defined as the presence of one or more contaminants in the atmosphere such as dust, fumes gas, mist, odors, smoke or vapor in quantities, of characteristics, and of duration. So diesel engine, like other internal combustion engines, converts chemical energy contained in the fuel into mechanical power. It's obviously discussed that diesel fuel is a mixture of hydrocarbons which during an ideal combustion process would produce only carbon dioxide (CO_2) and water vapor (H_2O). Indeed, diesel exhaust gases are primarily composed of CO_2, H_2O and the unused portion of the engine charge air.

The volumetric concentrations of these gases in diesel exhaust are typically in the following ranges: CO_2- (2 to 12%), H_2O- (2 to 12%), O_2- (3 to 17%) and N_2- balance (Balashanmugam, 2014).

Table 2.2 Adverse health effects of IC engine generated air pollutants

(Shaik Sameer et al, 2011).

Pollutants	**Short-term health Effects**	**Long-term health effects**
Carbon monoxide CO	Headache, shortness of breath, dizziness, impaired judgment, lack of motor coordination.	Effects on brain and central nervous system, nausea, vomiting, cardiac and pulmonary functional changes, loss of consciousness and death.

Nitrogen dioxide NO_2	Soreness, coughing, chest discomfort, eye irritation.	Development of cyanosis especially at lips, fingers and toes, adverse changes in cell structure of lung wall.
Oxidants	Difficulty in breathing, chest tightness, eye irritation.	Impaired lung function, increased susceptibility to respiratory function.
Ozone O_3	Similar to those of NO_2 but at a lower concentration.	Development of emphysema, pulmonary edema Sulfates Increased asthma attacks reduced lung function when oxidants are present.
Sulfates SO_4	Increased asthma attacks	Reduced lung function when oxidants are present.
TSP/Respirable suspended particulate/.	Increased susceptibility to other pollutants.	Many constituents especially poly-organic matter are toxic and carcinogenic, contribute to silicosis, brown lung.

In general the concentrations depend on the engine load, with the contents of CO_2 and H_2O increasing and that of O_2 decreasing with the increasing engine load. None of these principal diesel emissions (with the exception of CO_2 for its greenhouse gas properties) have adverse health or environmental effects. These pollutants are hazardous to human, plant as well as wild life and monuments. The pollutants with their effects on healthy as shortly discussed above (Shaik Sameer et al, 2011).

Due to incomplete combustion of the fuel, it produces more hydrocarbons which lead to air pollution. The noise and vibration problem is there in the CI engines. The maintenance cost of the CI engine is more as compared with the SI engines.

2.7.2 Sound pollution

Noise pollution or noise disturbance is the disturbing or excessive noise that may harm the activity or balance of human or animal life. The source of most outdoor noise worldwide is mainly caused by machines and transportation systems, motor vehicles, aircraft, and trains. Outdoor noise is summarized by the word environmental noise simply. Poor urban planning may give rise to noise pollution, since side-by-side industrial and residential buildings can result in noise pollution in the residential areas. It's obviously known that especially around urban areas, (i.e. where traffic congestion is become higher) (P. Balashanmugam et al, 2014).

2.8 Measurement of smoke

Visual judgments of smoke levels are not possible due to light effects under varying conditions, e.g. the visual assessment depends on gas velocity and background. There are two basic types of smoke meters, which are used to measure smoke density (G.Balasubramanian, 2015).

Those are Light extinction type and Filter darkening type.

The light extinction type of meters can measure both white and black smoke while the filter paper type meters can give only black smoke readings. The light extinction meter can be used for continuous measurements while, the filter type can be used only under steady state conditions.

i. Bosch smoke meter

Borsch smoke meter is filter darkening type. A measured volume of exhaust gas is drawn through a filter paper, which is blackened, to various degrees depending upon the amount of carbon present in the exhaust. The density of soot is measured by determining the amount of light reflected from the sooted paper the diameter of the filter paper. The diameter of the filter paper, the sample volume, etc. all is well defined (Roktash kumar, 2016).

ii. Van Brand Smoke Meter

Van Brand Smoke Meter is also filter darkening type. The exhaust sample is passed at a constant rate through a strip of filter paper moving at a preset speed. Bosch and Van Brand smoke meters differ in the Bosch the amount of light reflected is the measure of smoke level while in the Van brand amount of light passing through the filter to indicate smoke level (http://archive.org/stream/dtic).

iii. Hartridge smoke meter

This smoke meter works on the light extinction principal. The amount of light passed through this smoke column is used as an indication of smoke level. This smoke density is defined as the ratio of electric output from the photocell or solar cell when sample is passed through the column to the electric output when clean air is passes through it. The output from the solar cell is fed to a micro voltmeter and light source is provided with control to vary the amount of light, if needed, because of any change in the tube characteristics due to prolonged used of the meter. This type of meter is useful for continuous testing and can be used in vehicle (P.Balashanmugam, 2014).

iv. UTAC smoke meter

This also works on the light extinction principle, but it differs from the Hartridge meter in that in this meter whole of the exhaust gas is passed through the meter to avoid any sampling error. However, this is not very suitable for large engines due to its prohibitive size. The U.S.A. Public Health Service (PHS) has also developed a similar smoke meter (Pudarshan Dilip Pangavhane et al, 2013).

2.8.1 Mechanisms of Smoke Control

The above discussions clearly indicate that the only emission measuring method available, to control the smoke level of a diesel engine is as follows:

1. Derating

An engine can be derated by restricting its operation to lower levels of power production than normal for the given application. Derating reduces cylinder pressures and temperatures and thus lowers NOx formation rates. Although NOx exhaust concentrations (i.e., moles of NOx per mole of exhaust) are reduced, it is quite possible for this reduction to be no greater than the power decrease. Thus NOx emissions are less responsive to derating for turbocharged engines. Derating also reduces the engine's operating temperature, which can result in higher CO and HC emissions. One significant disadvantage of derating is that spare engine capacity may be needed which could require a large capital investment (R.K.Rajput, 2010).

2. Maintenance

Maintaining the engine in a proper way especially the injection system will not only result in significantly reduced smoke but also keep the performance of the engine at its best. However, the strict air pollution regulations can expedite development in this direction.

3. Smoke Suppressant Additives

Some barium compounds if used in fuel reduce the temperature of combustion, thus avoiding the soot formation, and if formed they break it into fine particles, thus appreciably reducing smoke. However, the use of barium salts increases the deposit formation tendencies of engine and reduces the fuel filter life.

4. Catalytic mufflers

Unlike petrol engine the use of catalytic mufflers are not very effective. There is a very small effect on engine smoke. Such devices need much development before they can be used in practice (R.K.Rajput, 2010).

5. Fumigation

Fumigation consists of introducing a small amount of fuel into the intake manifold. This starts pre-combustion reactions before and during the compression stroke resulting in reduced chemical delay because the intermediate products such as peroxides and aldehydes react more rapidly with oxygen than original hydrocarbons. The Fumigation rate of about 11 to 15 percent gives best smoke improvement. However, this improvement varies greatly with engine speed. At low engine speeds 50 to 80 percent smoke reduction is obtained. These decreases as speed increases until a speed at which there is no effect of fumigation (McCray, James).

In general from those reviews the researcher have observed that, late researchers only concerned with emission parts of petrol engines mostly, they do not concern that much on the size of the silencer and catalytic converter in diesel engines. So as much as possible dealer will try to diminish the size what has been used before. Additionally, since this technology does not develop in our country, this is the first to react to this technology here.

2.9 Components of Hybrid Aqua silencer

2.9.1 Activated Carbon (Charcoal)

Activated carbon, also called activated charcoal, is a form of carbon processed to have small, low volume pores that increase the surface area presented for adsorption or chemical reactions; activated is sometimes substituted with active.

Due to its high degree of micro porosity naturally, just one gram of activated carbon (powder form) has a surface area in excess of 450 m^2, as determined by gas adsorption. In the form of granular it doesn't took that much area coverage because of bigger in size even

if it is solid like a powder form of activated charcoal. An activation level sufficient for useful application may be attained solely from the high surface area; however, further chemical action often enhances adsorption properties. Activated carbon is usually derived from charcoal and is sometimes utilized as bio char. Generally activated carbon is material of very high surface area made up of millions of pores and is well known as "molecular sponge" by microscopic view (Protsahan Pradhan, 2013).

Figure 2.9 Activated carbon

Properties of activated carbon which makes odd naturally are:

- High surface area,
- Very low density and
- High adsorbing capacity (especially hydrocarbons).

The aqua silencer is fully based on use of water in it, here the exhaust gases get dissolved in water and the remained gases get accumulate in Activated carbon and finally we got processed gasses and distilled gases to our environment.

2.9.2 Water

Water is the chemical substance with chemical formula H_2O, it is tasteless, odorless liquid water has weak absorption bonds at wave lengths of around 730nm which cause it to appear to have a blue colour. Unlike other analogous hydrides of the oxygen family, water is primarily a liquid under standard conditions due to hydrogen bonding. Water also has high adhesion properties because of its polar nature.
(http://en.wikipedia.org/wiki/properties_of_water).

Thermal properties of water (Dr. P.K.Sharma et al, 2017).

Maximum density -1000 Kg/m^3

Specific weight -9.80 kN/m^3

Freezing point -0^oC

Boiling point -100^0C

Latent heat of melting -334 kJ/kg

Latent heat of evaporation -

$2.270x10^3kJ/Kg$

Specific heat -$4.187kJ/Kg.^0K$

Thermal evaporation- 4^0C to 100^0C.

Figure 2.10 Water for HAS

2.9.3 Perforated tube

The perforated tube consists of number of holes of different diameters. It is used to convert high mass bubbles to low mass bubbles. The charcoal layer is pasted over the perforated tube. Perforated tube is tube generally made up of stainless steel and have holes punched or drilled around its periphery. These tubes are provided to guide the flow and hence their main function is to reduce the backpressure of the engine. However, with the appropriate design of perforated tube it is possible to increase the transmission loss of the muffler (Anubhav Yadav, 2018).

Backpressure is essential for the performance of a silencer. Pressure drop of exhaust system includes losses due to piping, silencer, and termination. The most critical component regarding backpressure of any commercial muffler is cross flow perforated tube in which the diameter of the perforated tube hole and porosity of the perforations are most critical. If the diameter of the hole increases the backpressure decreases sharply by

40%. The change in diameter of holes has remarkable effect on back pressure (Rahul S. Padval, 2016).

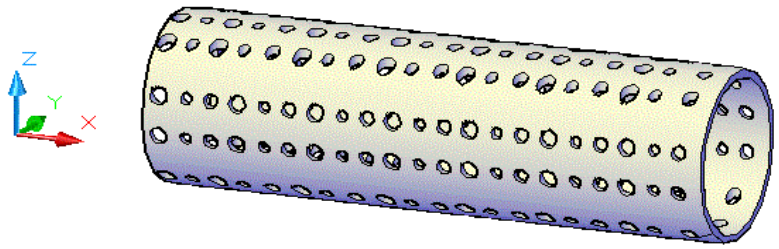

Figure 2.11 Perforated tubes

2.9.4 Lime powder

Saturated solution of calcium hydroxide is known as Lime water. Some amount of Calcium hydroxide Ca (OH) $_2$ is soluble in water (1.5 g/L at 25 °C). Pure limewater is crystalline, odorless and colorless. Limewater is prepared by stirring allowable calcium hydroxide in pure water, and filtering off the allowable insoluble Ca $(OH)_2$. When calcium hydroxide particles dissolve in pure water then it looks like milky, hence its name known as milk of lime. It is an alkaline solution (with a pH of 12.3) (Sarath Raj et al, 2016).

Figure 2.12 Lime powder

2.9.5 Outer Shell

The whole setup was kept inside the outer shell. It is made up of iron or steel. The water inlet, outlet and exhaust tube was provided in the shell itself. Material selection of the

outer shell is the crucial parameter because of the consideration of heat conductivity, corrosiveness and cost (Alen.M.A, 2015).

Requirement of good shell material selection:

1. Its thermal conductivity.
2. The thermal conductivity of material must not be high enough so that it will liberate all of its heat and will cause less effective temperature for necessary reactions.
3. The material should have good resistance to corrosiveness and erosion.

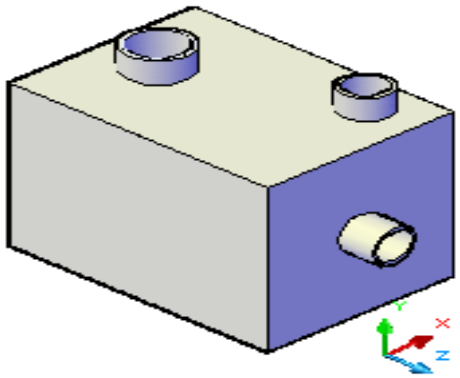

Figure 2.13 Outer shell

2.9.6 Non return valve

The non-return valve is a mechanical device a valve, which normally allows fluid (liquid or gas) to flow through it in only one direction.

They have two ports, one as an inlet for the media and one as the output for the media. Since they only allow media flow in one direction, they are commonly referred to as ‘one way valves’ or ‘non return valves.’ The main purpose of a check valve is to prevent backflow in the system (An IBG Group Company, 2018).

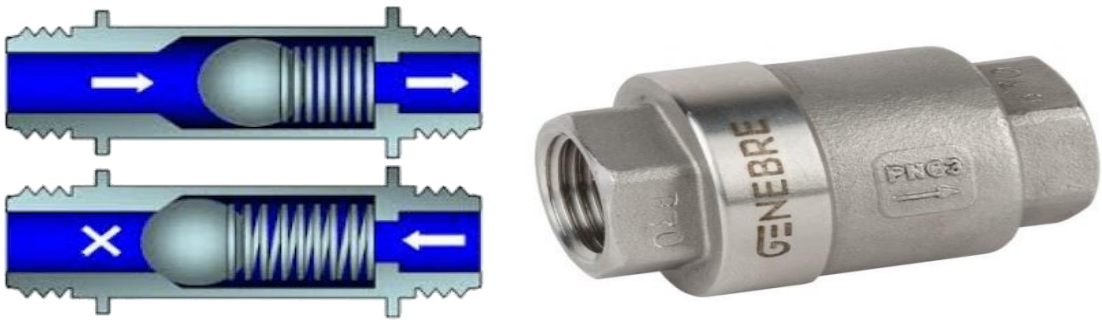

Figure 2.14 Non-return valve

They require a higher pressure on the input side of the valve than the output side to open the valve for operation of the needed capacity and direction. When the pressure is higher on the outlet side (or the input side pressure is not high enough), the valve will close. Depending on the valve type, the closure mechanism is different.

As it was descried above in the designed system, Hybrid Aqua silencer it was filled with water and it is directly connected to the exhaust pipe of the engine. Since everything between the silencer and exhaust manifold is omitted, there is a chance for the water to get enter into the engine cylinder through the exhaust manifold pipe. To avoid this problem, Non return valve is used. It allows the flow of fluid in one direction only. It's mounted on the outer side of the designed system, pipe which is welded on outer shell of Hybrid aqua silencer.

2.10 Research gap

In general from those reviews researcher have observed some gaps and try to avoid it. i.e late researchers only concerned with emission parts of petrol engines mostly, they do not concern that much on the size of the silencer and catalytic converter in diesel engines comparing with the conventional system. So as much as possible this study tries to diminish the size what has been used before by adding lime water. (i.e pure water mixed with Ca $(OH)_2$) on wood charcoal produced locally.

Additionally, since this technology does not developed, this is the first to react to the technology here.

CHAPTER THREE

MATERIAL AND METHODS

3.1 Materials

In order to successfully accomplish the specific objectives of the study different materials and components are selected. The materials needed for the execution of this work are listed in table 3.1 below.

Table 3.1 Materials used for production of Hybrid aqua silencer

S NO.	Items	Materials
1.	Outer and inner shell/cover/	Stainless steel sheet metal
2.	Lime water	Water and lime powder ($Ca(OH)_2$)
3.	Perforated tube	Stainless steel
4.	Non return valve	Steel
5.	Pipe /inlet and outlet/	Stainless steel
6.	Activated carbon	Wood Charcoal and Lime

3.1.1 Stainless Steel Sheet metal

The materials used in this thesis must be corrosion resistant and easily machinable etc. So material which have those properties and available is stainless steel. Thus the same is applied in this thesis and should pass through various manufacturing process such as drilling, grinding and welding. Thus, the material is selected by considering following aspects like corrosion resistance, electrical and thermal conductivity, reflectivity, ductility, odorless, recyclability, weld ability (Dr.P.K.Sharma et al, 2017)

Corrosion Resistance: stainless steel is alloy having chromium content in it which is corrosion resistive in nature. Hence the stainless steel is used for aqua silencer.

Electrical And Thermal Conductivity: Stainless steel is an excellent heat and electricity conductor and in relation to its weight is almost twice as good as copper. This has made stainless steel the most commonly used material to make for implementation of practical use.

Reflectivity: Stainless steel is a good reflector of noticeable light as well as heat, and that together with its low weight makes it an ideal material for reflectors in, for example, light fittings or rescue blankets.

Ductility: Stainless steel is ductile and has a low melting point and density. In a liquid condition it can be processed in a number of ways. Its ductility allows products of Stainless steel to be basically formed close to the end of the product's design.

Odorless: Stainless steel is the metal itself is non-toxic and releases no odours or taste substances which make it ideal for packing sensitive product's design.

Recyclability: Stainless steel is 100 % recyclable with no downgrading of its qualities. The re-dissolving or re-melting of Stainless steel requires little energy only about 4 percent of the energy required to produce the primary metal initially is needed in the reprocessing process.

Weld-ability: Stainless steel has high degree of weld ability. Hence it is used in many industrial applications. The above main properties of stainless steel make it more crucial material. So as a general stainless steel has a good property to attain for the expected components of aqua silencer.

3.2 Methods

For the success of my study using data is very crucial method. The data/source I took may both primary and secondary sources. For the study purpose both primary and secondary data are used. To achieve the objectives we used both primary and secondary sources. The primary and secondary data have been collected to cover every aspect of the study.

3.2.1 The Primary survey

Primary resources are original and relevant to the topics of the research study so the degree of accuracy is very high. Its reliability is very high because these are collected by the concerned and reliable party. Among the primary sources which are used in this study are; Visual observation, the researcher have observed different factory emissions to our environment without using any safety mechanism which saves our environment from degradations. So depending on this idea the researcher play his part to design this hybrid aqua silencer which deals with emission. Interview to local vehicle service garage and driver, at the time of thesis work gaps researcher collects information by asking the technicians, 'which vehicles use catalytic converter to reduce the environmental pollution? More technicians didn't identify the purpose of catalytic converter and how it's used for saving the environment. But, some in small number those who know about it reply me 'mostly gasoline engine modern vehicles use this component for that function.' The reason is modern vehicles in average gasoline engine vehicles. The detail question is explained on appendix-F.

Additionally, on this primary sources the researcher uses experimental work based on application of the desired part. Based on visual observations and interview to local vehicle service garage, the researcher has decided to device a means of emission reduction specifically from diesel engines. For this single cylinder, four stroke diesel engines was selected for the experiment to capture the emission. Thus, with this regard the experiment had been conducted in a laboratory on diesel engine at Dilla University.

3.2.1 Fabrication and set up of HAS for experiment

Flow chart of the thesis procedures

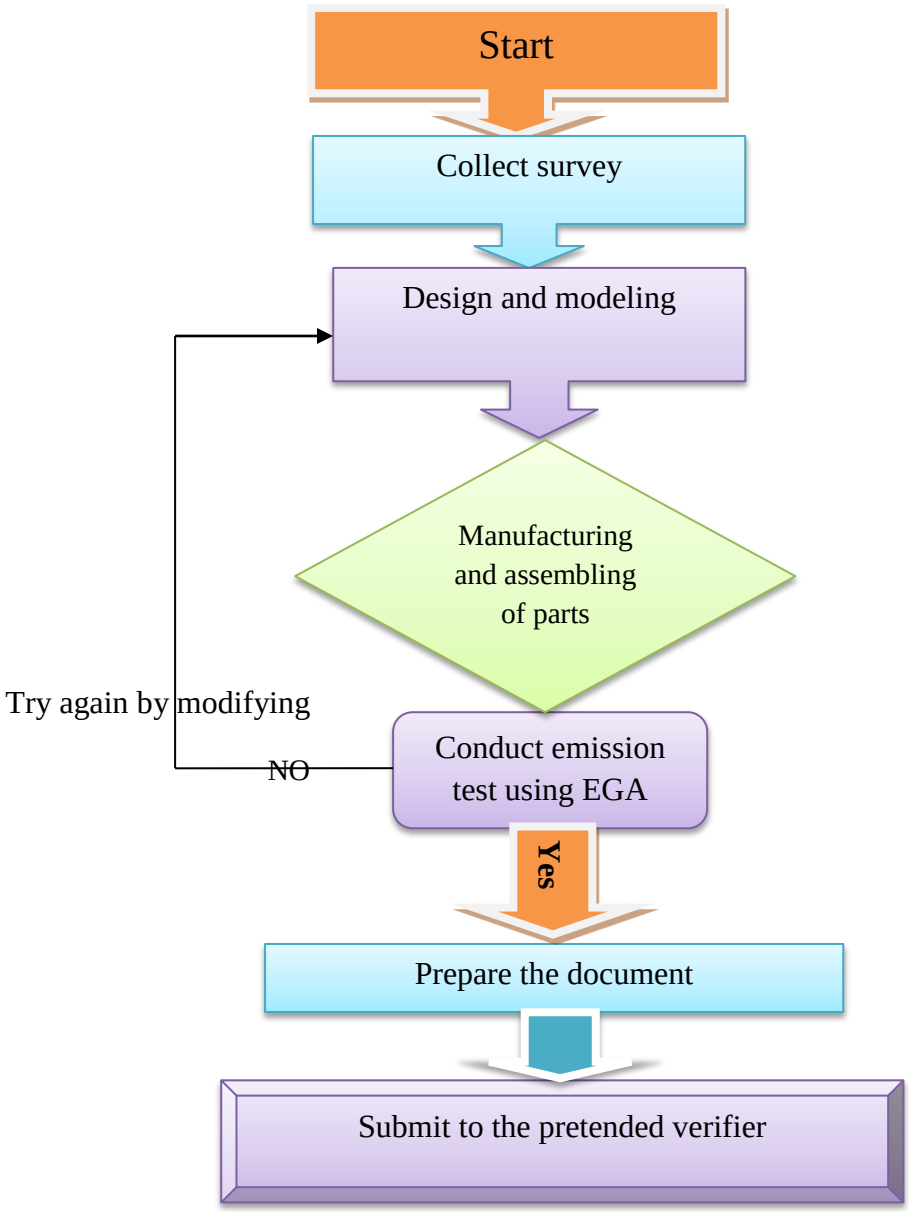

Figure 3.1 Flow charts of the thesis procedures

For the case of testing the designed components using the steps:

1. Preparing sheet metal with 2mm thickness.

Figure 3.2 Sheet Metal

2. Preparing by cutting grinder and other cutting machines for internal (charcoal carrier) and external (outer shell).
3. Using rolling machine prepare sheet metal for perforated tube which breaks the emission by bubbling and make hole in different diameter.
4. Prepare wood charcoal (granular) and Ca $(OH)_2$ by mixing and distilling for some minutes.
5. Then putting inside the charcoal carrier (internal box) which surrounding the perforated tube and cover it.
6. Weld the outer shell which carries the lime water by the dimension done on step-2.

Figure 3.3 Welded parts of HAS model

7. By mixing water and Ca(OH)2 with the ratio of 1.5 gram per Liter of pure water (1.5gm/l) stays for 24 hr.

Figure 3.4 Mixing calcium hydroxide with pure water

8. Poring through liquid entrance per amount in lime water container.

Figure 3.5 Adding lime water to the tank**.**

9. Before testing, a variety of checks and tasks have been carried out. The engine was inspected visually for any problems, engine lubricating oil was replaced with new SAE 40 oil, the engine coolant was filled to the optimum level in the expansion tank which is feed by external pump, the air intake system and test area were cleaned properly.

Figure 3.6 Check up and adjust the exhaust gas analyzer before test start

10. Lastly, preparing engine setup and mounting the designed system on exhaust, check the emission test with different speed of the engine. Additionally see appendix -A for experimental procedures.

Figure 3.7 Start test by inserting exhaust gas analyzer sensor in HAS

Figure 3.8 a) Single cylinder diesel engine setup and

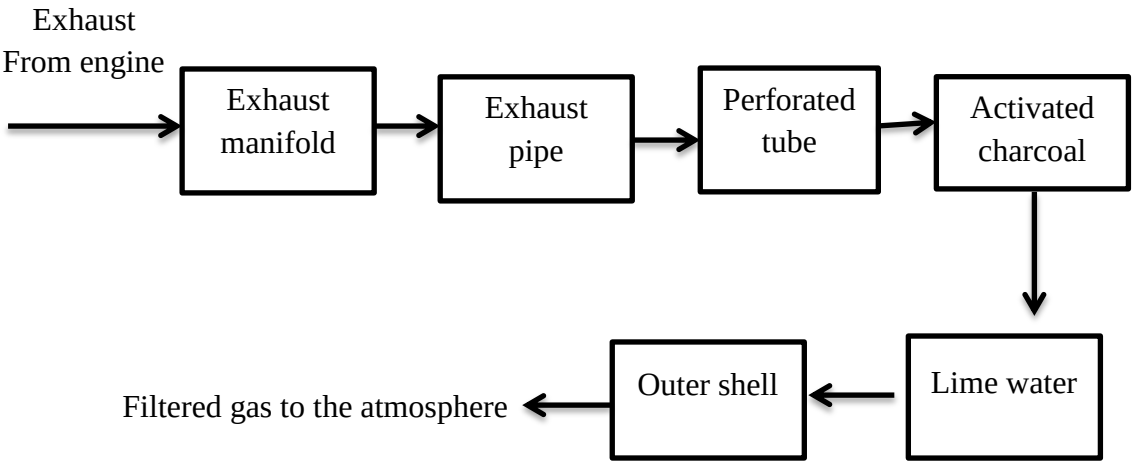

Figure 3.8 b) line diagram of engine exhaust HAS setup

Figure 3.9 Exhaust gas analyzer

3.2.2 The secondary survey

Secondary data were the data collected by a party not related to the research study but collected these data for any other purpose and at different time in the past. This is also used to gain initial insight into the research problem. It's also more advantageous because of it is cheaper and faster to access. Additionally, it provides a way to access the work of the best scholars all over the world. Among the secondary sources the researcher in this thesis used; referring books, different automobile and emission related books. By referring that researcher jotted output from the study. Discussion with an advisor, like reference books in the study if some problems happened or the way I am holding is correct or incorrect advisor is my best guidance as a secondary survey. Referring different internet links**,** in addition to reference books and advisor support using different links for searching emission related journals, publications, joining with different website using scholars for my targets. From different websites and published journals the researcher has got the different comparisons for conventional emission reduction mechanisms and aqua silencer. Different experiments have done with different engine capacity.

In this Pollution Control mechanism using Aqua Silencer, when the exhaust gases enter into the perforated tube it converts high mass bubbles to smaller (molecules) due to the small diameter of holes. After that they pass through a charcoal layer which again purifies the gases. It is highly porous and possesses extra free valences so it has high absorption capacity. Next to passing through the charcoal layer some of the gases may dissolve into the lime water and finally the exhaust gases escape through the opening into the atmosphere.

3.3 Methods to Avoid Water Pollution in Aqua Silencer

3.3.1 Lime Water Wash Method

The water is treated with the calculated quantities of slaked lime. Lime can neutralize any acid present in the water, SO_2 gases are removed from the flue gases forming calcium sulphite $CaSo_2$. The precipitates dissolved carbon dioxide as calcium carbonate and converts bicarbonate ions into carbonates

Effects of dissolved gases on water:

The water is a best absorbing medium to use in silencer for dissolve toxic gases in water and reduce it completely. After these gases dissolved in water they form acids, carbonates, bicarbonates etc.

 Action of dissolved SO_2:

When SOx is mixed in water, it form SO_2, SO_3, SO_4, H_2SO_4 i.e. sulfur Acid (H_2SO_3), it forms Hydrogen Sulphide which causes carious egg smell, acidify and corrosion of metals.

 Action of dissolved CO_2:

The dissolved carbon dioxide forms carbonates and bicarbonates at lower and higher pH. This levels in between 40 - 400 mg/lit. When carbon dioxide mixes with water it form Carbonic acid and it is corrosive to metals and also causes greenhouse effect.

 Effect of dissolved NOx: The NOx in exhaust gas under goes Oxidation to form Nitrate, Nitrite, Nitric acid, ammonia. This synthesis of protein and amino acids is affected by Nitrogen. Nitrate usually occurs in trace quantities in exhaust gas (Akhil Anil Kumar et al, 2016).

3.3.2 Adsorption method

Adsorption is the adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid to a surface. This process creates a film of the adsorbate on the surface of the adsorbent. This process differs from absorption in which a fluid (the absorbate) is dissolved by or perimeters a liquid or solid (the absorbent), respectively. Adsorption is a

surface phenomenon while absorption involves the whole volume of the material. The term sorption encompasses both processes, while desorption is the reverse of it. Hence, Pollution Control Hybrid Aqua Silencer reduces noise and pollution (Alen M.A, 2015).

On this study both lime water wash method and adsorption mechanism is used where ever needed place area.

3.3.3 Chemical reaction of exhaust gases with lime water

The empirical chemical formula for diesel fuel is $C_{12}H_{23}$ and during incomplete combustion the exhaust products are CO_2, H_2O, N_2, O_2, CO, H_2, H, OH, NO, CH_4. In order to make a combustion fuel, air and heat are required. The incomplete combustion chemical reaction for diesel fuel is as follow:

$$C_{12}H_{23}+\lambda a_{th}(O_2+3.76N_2) = n_1CO_2+n_2H_2O+n_3N_2+n_4O_2+n_5CO+n_6H_2+n_7H+n_8O+n_9OH+n_{10}NO+n_{11}CH_4$$

Where, λ is lambda the equivalence ratio for air fuel. For rich mixture λ from 0 to 0.5, between 0.5 to 1.6 is combustible zone and beyond 1.6 it is lean mixture for diesel engine. An a_{th} is the theoretical air for diesel engine it is 17 to 80. Coefficients n_1, n_2, n_3… n_{11} are mole numbers for each product gases (Helmut Tschoeke, 2010).

The chemical reactions taking place inside the mufflers are as follow:

Reaction: 1

The obnoxious product of combustion is NOx which is the oxides of Nitrogen. Water will absorb the oxides of Nitrogen to a larger extent.

The following chemical reaction will enhance the proof, for the above statement.

$$NO + 2H_2O \rightarrow 2HNO_2 + 2HNO_3 \text{ (Diluted)} \ldots\ldots\ldots\ldots\ldots\ldots \text{I}$$

Reaction: 2

If a small amount of lime water is added to scrubber tank, the further reaction takes place as follows:

$$Ca(OH)_2 + 2HNO_3 \rightarrow Ca(NO_3)_2 + 2H_2O$$

$$Ca(OH)_2 + 2HNO_3 \rightarrow Ca(NO_2)_2 + 2H_2O \ldots\ldots\ldots\ldots\ldots\ldots \text{I}$$

Reaction: 3

When the carbon dioxide present in the exhaust gas comes in contact with the limewater, calcium carbonate will precipitate. The calcium carbonate when further exposed to carbon dioxide, calcium bicarbonate will be precipitated.

The following is the chemical reaction (Sarath Raj, 2016).

$$Ca(OH) + CO_2 \rightarrow CaCO_3 + H_2O$$

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2 \ldots\ldots\ldots\ldots\ldots\ldots \text{III}$$

Reaction: 4

The sulphur dioxide present in the diesel exhaust also reacts with the limewater. But the small trace of sulphur dioxide makes it little difficult to measure the magnitude of the chemical reaction, accurately. The following equation gives the chemical reaction and calcium sulphate will precipitate.

$$Ca(OH)_2 + SO_2 \rightarrow CaSO_3 + H_2O \quad \text{……..…IV}$$

Reaction: 5

From calcium carbonate, calcium sulphate will precipitate and CO_2 will be a by-product. Because of the small percentage and SO_2 presence, the liberation of Carbon dioxide is very less. But the liberated CO_2 will again combine with $CaCO_3$ to form calcium bicarbonate.

$$CaCO_3 + SO_2 + H_2O \rightarrow CaSO_3 + CO_2 + H_2O \quad \text{……..……V}$$

Now calculate the pressure and volume of exhaust gas by using ideal gas equations which is

$$PV = mRT \quad \text{…….} (3.1)$$

Where, P is pressure in Pa, V is volume in m^3, m is mass in kg, R is gas constant and T is temperature in K.

First of all, calculate mass for each gas, the mass substance is the number of mole multiplied by the molecular weight.

Table 3.2 Exhaust gas mass (John B. Heywood, ICE fundamental book)

NO	Product gases	No of mole in mole(n)	Molecular weight in kg/mole(M)	Mass = n x M in kg
1	CO_2	1.5	44	0.066
2	H_2O	11.5	18	0.207
3	CO	10.5	28	0.294
4	N_2	47	28	1.316

Now calculate the gas constant(R) for each gas.

$$R = Ru/M \quad \text{……..……} (3.2)$$

$RCO_2 = Ru/MCO_2 = 8.314/44 = 0.188 KJ/Kg.K$ the same procedure done for the rest three gases H_2O, CO and N_2 the results are 0.461, 0.296 and 0.296 respectively.

By taking the average of all:

$$R_{total} = RCO_2 + RH_2O + RCO + RN_2$$

R_{total} = 1.241/4 KJ/Kg.K = 0.31025 KJ/Kg.K

Finally calculate the volume of each gas.

Table 3.3 Exhaust gas volume (John B. Heywood, ICE fundamental book)

No	Product gases	Density of each gases in kg/m^3	Mass of exhaust gas in kg	Volume in $\rho \times m$ m^3
1.	CO_2	1.98	0.066	0.03333
2.	H_2O	1000	0.207	0.207×10^{-3}
3.	CO	1.14	0.294	0.258
4.	N_2	1.251	1.316	1.052

V_{total} = 0.03333 + 0.000207 + 0.258 + 1.052 =1.343 m^3

Now calculate the pressure produced by the exhaust gas using equation:

$$P = \frac{mRT}{V} = \frac{1.88Kg \times \frac{310.25J}{Kg}.K \times 823K}{1.343\ m^3} = 358\text{kPa}.$$

3.4 Engine specification selected for study

This engine size is selected for the case of this study only. The experiment is done on laboratory engines.

Table 3.4 Single cylinder engine specifications

S. NO	Description	Value
1.	Engine type	4stroke forced air & oil cooled C.I Engine
2.	No of cylinders	One
3.	Bore	86 mm
4.	Stroke	77 mm
5.	Engine displacement	447.3cc
6.	Compression ratio	24+/-1:1
7.	Max. Engine power	6.62kw at 3400 engine rpm.
8.	Max. Torque	23N.m at 2000 engine rpm.
9.	Idling speed	1250+/-150rpm

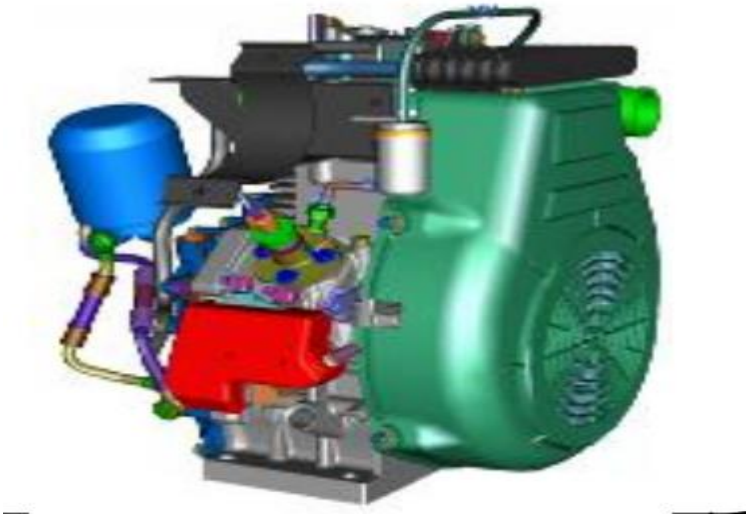

Figure 3.10 Four stroke single cylinder engine

3.4.1 Fundamental dimensions of the designed components

To find fundamental frequency,

Cylinder firing rate;

$$CFR = \frac{RPM}{60}$$ – For two stroke engine. …… (3.3)

(Paul Nieuwenhuis, 2017).

$$CFR = \frac{RPM}{2\times60}$$ – For four stroke engine……..…… (3.4)

Where, CFR is cylinder firing rate, RPM is revolution per minute

So using for four stroke single cylinder Engine:

$$\text{CFR} = \frac{\text{RPM}}{120} = \frac{3400}{120} = 28.33\text{Hz}$$

Engine firing rate (EFR):

$$EFR = Number\ of\ cylinder \times CFR$$…….. (3.5)

$$\text{EFR} = 1 \times 28.33 = 28.33\text{Hz}$$

Muffler volume calculations

Swept volume (Vs):

$$Vs = \frac{\pi}{4} \times D^2 \times L$$ ……..…….. (3.6)

$$\text{Vs} = \underline{447.05\text{cm}^3}$$

While, D is the muffler diameter, L is the length of muffler.

Volume to be consider for calculations,

$$Volume = Number\ of\ cylinder \times \frac{Vs}{2}$$ ……..…….. (3.7)

Volume = $223.52 cm^3$

Silencer volume (Vm):

$$Vm = Factor \times Considered\ volume \quad \text{..... (3.8)}$$

$$V_m = 25 \times 0.2235 \text{ ltr} = 5.59 \text{ ltr.} = 55888.125 cm^3$$

i.e. Volume can be changed on the space constraints.

Volumetric efficiency (ηv)

$$(\eta_v = \frac{m_a}{\rho_a \times v_d}) \text{..... (3.9)}$$

$$\eta_v = \frac{0.00050 kg}{(1.181 kg) \times (0.0004473 m^3)} = \underline{94.65\%}$$

Whereas, m_a is mass of air, ρ_a is density of air and V_d is displacement volume.

Here 'l' can be determined from different research and as per the size. So, in this study it is taken 350mm.

Volume flow rate (Q) = Swept volume × Number of intake stroke per hour

$$Volume\ flow\ rate = \frac{\pi}{4} \times d^2 \times l \times \frac{rpm}{2} \times 60 \text{ ..... (3.10)}$$

Q = 45.599 m^3/hr. = $\underline{0.01266 m^3}$/sec

From the design to increase flow rate, diameter of exhaust pipe from the exhaust manifold till it reaches the outer shell of the designed body is smaller than the diameter of perforated tube.

Then, Area of the exhaust pipe will be calculated first. Before it reaches the Hybrid aqua silencer, the pipe area will be:

$$A = \pi rh \text{..... (3.11)}$$

So from the existing silencer components, tail pipe diameter is 2cm and 100cm length.

Again from the existing exhaust tail pipe diameter is the same with the inlet to the muffler with d=2cm and 10cm length

$$A = \pi \times 2cm \times 10cm$$

$$A = 62.8 \text{ } cm^2$$

The new designed components dimension was calculated as follow. Since the components are described on previous chapter their dimension can be:

Volume of outer shell (V_2): V= b x l x w..... (3.12)

V_2 = 35cm x 26cm x 20cm

V =18,200cm^3

Volume of inner box which covers the charcoal (V_1);

V_1 = 35cm x 12cm x 12cm

$$V_1 = 5{,}040\ cm^3$$

Volume of the perforated tube inside the shell (V_o):

$$V_o = \pi r^2 h + \tfrac{1}{3}\pi r^2 \quad \text{..... (3.13)}$$

$$V_o = 894.9\ cm^3$$

From those calculations, the volume of charcoal (V_{ch}) which covers the perforated tube inside the inner shell can be;

$$V_{ch} = V_1 - V_o$$

$$V_{ch} = 4145.1\ cm^3$$

To calculated the contents of water needed inside the outer shell, in which the inner shell is covered; first lets calculate the volume which is free (i.e. outer the charcoal container).

$$V_{free} = V_2 - V_1$$

$$V_{free} = 12{,}960\ cm^3$$

Whereas; Vo volume of perforated tube, V_1 volume of inner box, V_2 volume of outer shell, V_{ch} volume of charcoal and V_{free} volume on which is released and left free.

(Note: Here all acronyms are given by me for the sake of calculation.)

General weight of the designed components is:

Weight = outer shell + inner shell +charcoal + lime water

= 8.223 + 2.278 + 1.5 + 4 = 16Kg (Assuming 1ltr = 1kg).

To calculate about the exhaust gas properties:

Fuel consumption capacities of the engine while it concerned with the exhaust pressure;

$$F_c = \frac{P}{\frac{LHV}{3600}\times\frac{E}{100}} \quad \text{..... (3.14)}$$

$$= \frac{6620\ W}{\frac{46500 kJ/kg}{3600}\times\frac{35}{100}}$$

$$F_c = 1.464 kg/kWhr$$

Air flow and Exhaust flow;

Air flow,

$$F_a = F_c \times AFR \quad \text{..... (3.15)}$$

Fa= 33.672 kg/hr.

Exhaust flow,

$$F_{eg} = F + F_a \quad \text{..... (3.16)}$$

$$F_{eg} = 35.136 kg/hr$$

Molecular weight of gas is approximately 28g/mol.

So that to calculate the velocity of exhaust gas, Veg:

$$V_{eg} = \frac{F_{eg}}{M_{Weg}} \times \frac{22.417(T+273)}{273} \times \frac{1.107}{P} \quad \text{(3.17)}$$

OR

$$V_{eg} = \sqrt{\frac{T \times R}{Mweg} \times \frac{2 \times \gamma}{\gamma - 1} \times \left(1 - \left(\frac{Pe}{P}\right)^{\frac{\gamma-1}{\gamma}}\right)} \quad \text{(3.18)}$$

Whereas; Fc fuel consumption capacity, P Maximum power of the engine, LHV Lower heating values of diesel fuel, E thermal efficiency of diesel (30 -35%), F_a Air flow, F_{eg} flow of exhaust gas, Veg Velocity of exhaust gas, T absolute temperature of inlet gas, R Molar mass constant (8.314 J/Mol. K), P_e absolute pressure of exhaust gas at nozzle exit, γ Isentropic heat expansion factor (for dry air 1.398 ≅ 1.4).

3.4.2 Data analysis

From the experiment the exhaust gas back pressure, CO, UHC, CO_2 and O_2 emission data were collected. These data were tabulated in accordance with specified respective engine speed. The Fc was calculated manually from volumetric fuel flow rate and all dimensions of the HAS are designed manually by taking some dimensions from the existing (conventional) silencer. All tests are done on single cylinder diesel engine using different engine speed (rpm) for emission testing. From this data, graphs which include performance and emission characteristics were plotted, by using computer program (Microsoft Office Excel). Finally, the comparison of overall performance and emission characteristics will be done with specific standard value of diesel fuel on a given test engine.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Introduction

The exhaust gas is the end product of the combustion systems in the internal combustion engines. It can be whether the vehicle is in the dynamic condition and sometimes when the engine is at idling stage. With the help of some instrument like exhaust gas analyzer, the output can be developed using excel sheet. The main objective is to determine the effect of vehicle exhaust gases on environmental degradation. Another objective is to identify more lifesaving mechanism in our survival where more traffic contingency may happen.

Silencer and exhaust system are those principle segments of the vehicles and it is incorporated with the motor ventilation system. An outflow of the vehicle exhaust originates from either not completely consuming of fuel or spillage of the fuel tank. So the fundamental accentuation of this investigation and configuration is mainly on the possibly diminishing this outflow in the more proper rate. The current discharge diminishing systems may utilize two unique parts, for example exhaust system and silencer in various zones and positions with resonator. Anyway the earth is stacked again by the discharge from the vehicles still. From various looks into for gas and diesel motor CO, UHC, NOx, Lead and so on are the principal natural dirtying operator. The learning of those dirtying specialists in our encompassing is therefore critical to decide the arrangement by increasingly safe strategy.

According to the goals of the proposition investigations are performed. Properly the examination is performed by accepting the vehicle is in development. After the segment gets together is finished by utilizing CAD, the whole segment is produced. The investigation should be possible utilizing the machine called exhaust gas analyzer.

Here, what is generally known is when fuel is added to the motor intensity of the vehicle can be the result of fuel combusted in the barrel whether petroleum or diesel. In any case, it is difficult to use by trading the two fills on a similar motor for delivering power. At the point when diesel fuel is scorched in the chamber it is part into carbon dioxide and water.

Diesel motors convert the substance vitality in fuel to mechanical vitality. Vitality is discharged in a progression of burnings as fuel responds with oxygen from the air.

The chemical equation of diesel fuel combustion is:

$$4C_{12}H_{23} + 71O_2 = 48\ CO_2 + 46H_2O$$

The gas coming from the exhaust of a car should almost always be clear in color, with the exception of diesel at times of heavy use. When there is smoke coming from the exhaust system of a vehicle, it signals an issue with the internal workings of the motor (htt p://www.buyautoparts.com/howto/exhaust-smoke.htm, 2019).

4.2 Engine performance characteristics Vs perforated tube hole diameter

4.2.1 Back pressure (kPa) and hole diameter (mm)

From the analysis, it is observed that perforated tube hole diameter can determine the back pressure of the engine exhaust gas. However, if the diameter of each hole is bigger the back pressure may decrease, but to avoid breakdown of the exhaust gas particles not occur properly (i.e. the emission reducing capacity of the material may diminish). So by evaluating those two problems, here three holes with different diameters for each of them can be used in a number. Concerning the capacity of perforated tube in different diameter can be analyzed that since the pipe from the exhaust manifold to the non-return valve is smaller than the diameter of perforated tube no more back pressure is shown.

4.3 Results from Exhaust emissions Vs Load

Here the load is the mass applied on the engine for test at different time.

4.3.1 Emission test for carbon monoxide (CO) with different load

Carbon monoxide emissions refer to incomplete combustion. CO is one of the emission gases which deteriorate the air quality. Here over it specifies as the load on the vehicle increases the CO emission increases slightly.

Table 4.1 CO Vs Loads

	Load (kg)	2	4	6	8	10
CO Emissions (%V)	Conventional Silencer	0.08	0.08	0.08	0.1	0.15
	Hybrid Aqua Silencer	0.03	0.03	0.035	0.04	0.061

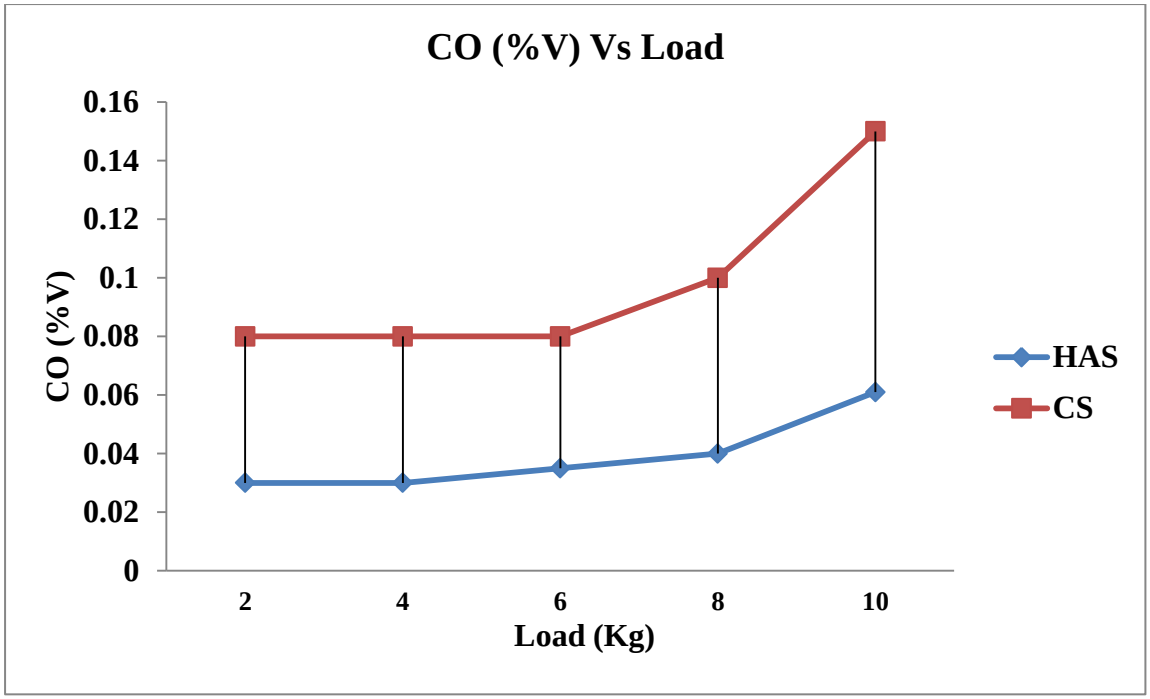

Figure 4.1 CO Vs Load

From this it is observed that about 55% CO emission is reduced using hybrid aqua silencer than conventional system. CO emissions of diesel were higher at lower engine rpm with maximum record at 1800 rpm on this experiment and decreases at higher rpm with slight increment of load. Basically higher CO emissions are at lower engine rpms because rich air mixture in combustion chamber which leads to incomplete combustion.

From the above graph when the load increases the CO contaminations increases gradually by using conventional silencer. But in the aqua silencer the CO contaminations decreases comparatively.

4.3.2 Emission test from carbon dioxide (CO_2) Vs loads

Like that of CO emissions CO_2 emissions also increases slightly with the increments of loads on the engine, but after reaching some point the CO_2 emissions increase highly.

Table 4.2 CO_2 Vs Loads

	Load (Kg)	2	4	6	8	10
CO_2 Emissions (%V)	Conventional Silencer	0.532	0.42	0.41	0.45	2.01
	Hybrid Aqua Silencer	0.09	0.22	0.33	0.37	1.27

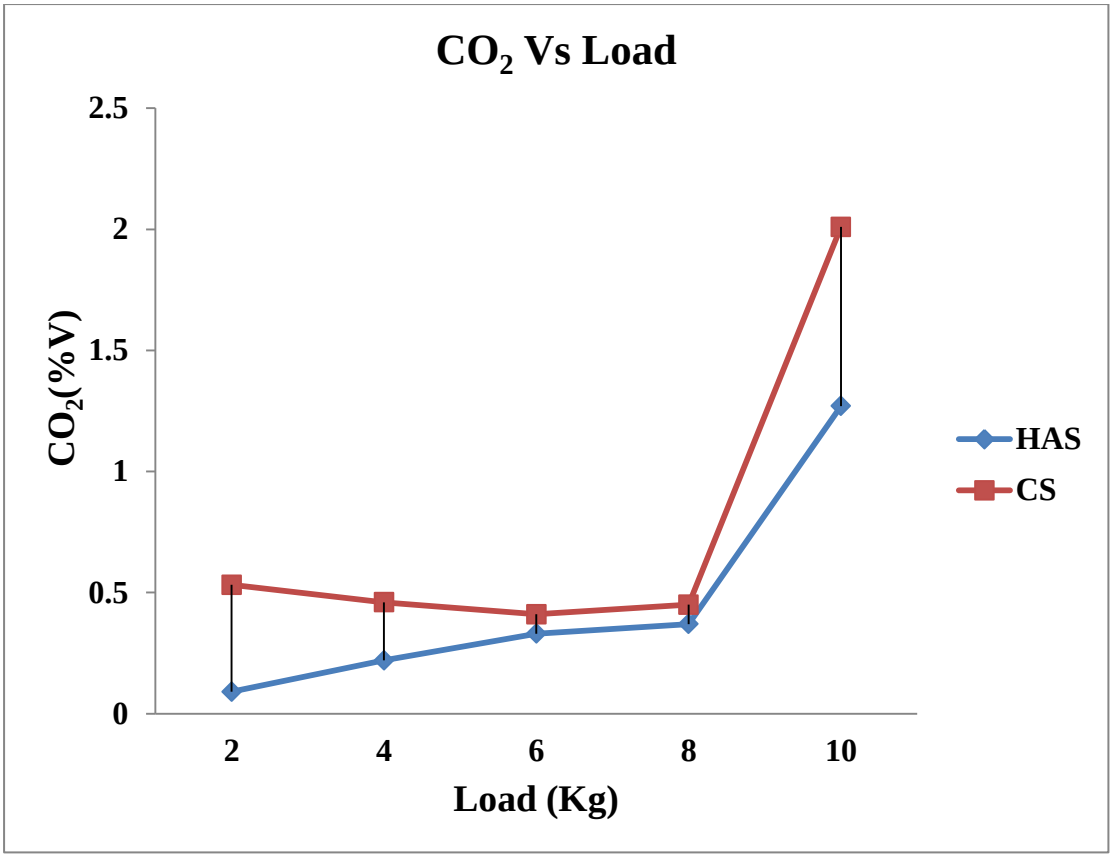

Figure 4.2 CO2 Vs Load

Here also about 46% of CO_2 emission can be reduced by using Hybrid Aqua silencer than conventional system as observed from the shown diagram.

4.3.3 Emission test from unburned hydrocarbon (UHC) Vs loads

Normally, from its science fuels added to the fuel tank which used for power production after combustion doesn't burn completely. So, excess amount of fuel is emitted to the air which covers our surrounding. (i.e) its slowly increase in emission Vs loads applied on the engine to survive from place to place in order to successfully apply what it has been designed for.

Table 4.3 UHC Vs Loads

Load (Kg)	2	4	6	8	10
Conventional silencer	6	6	8	10	14
Hybrid Aqua silencer	4	4	2	3	10

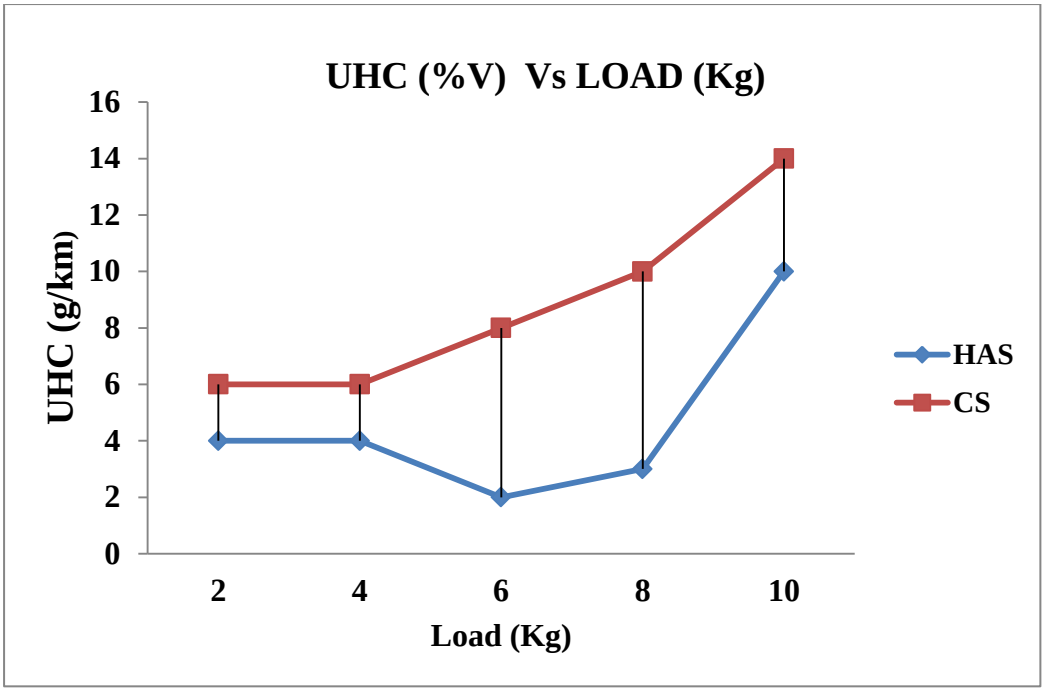

Figure 4.3 HC Vs Load on diesel engine

On UHC Vs Load graphs the UHC emissions can be reduced by 43% as shown on excel figure above which can be displayed on the digital reader called exhaust gas analyzer.

4.4 Results from exhaust emission Vs Engine speed (rpm)

With different engine speed experiment has been conducted. The results of emissions are tabulated as per speed of specific experiments.

4.4.1 Emission from UHC Vs Engine Speed (rpm)

The following results are obtained as shown in table 4.4.

Table 4.4 UHC (ppm) Vs engine speed (rpm)

Engine speed (rpm)	1993	2123	2322	2788	3031
With Hybrid aqua silencer	16	19	24	22	16
Without hybrid aqua silencer	33	38	44	33	27

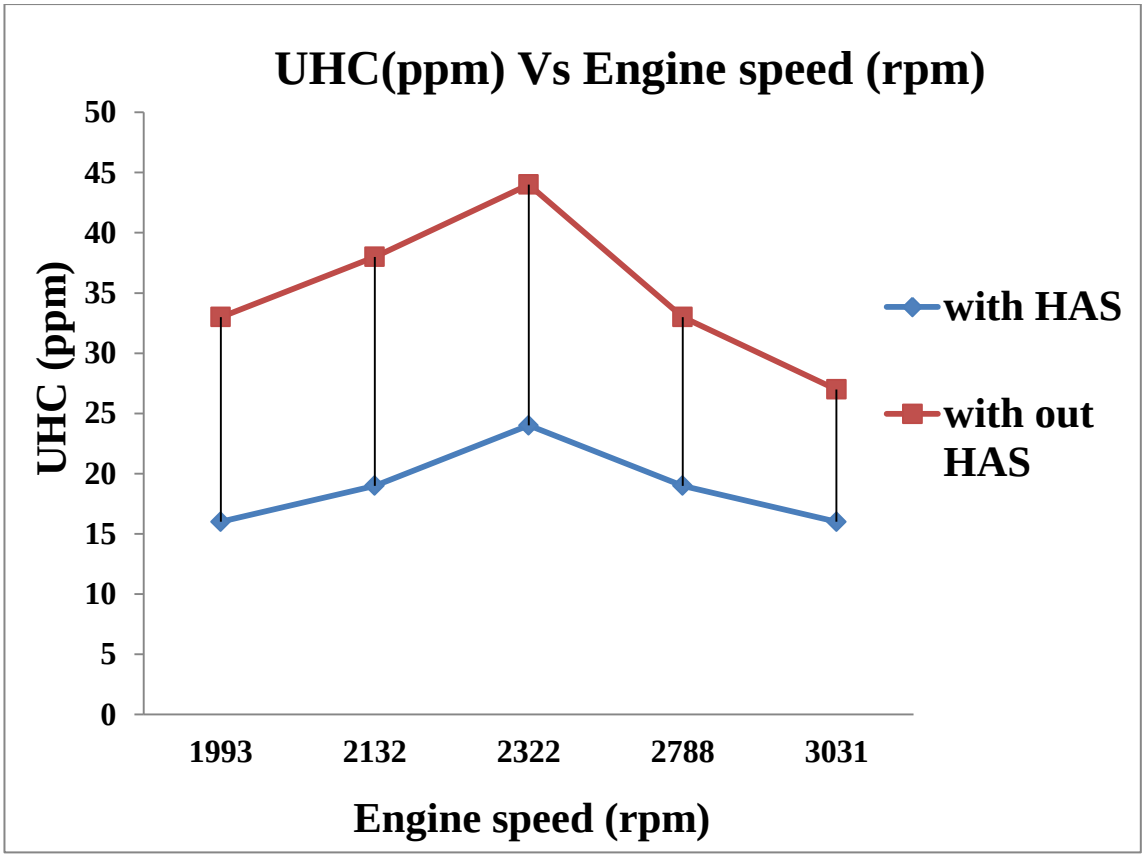

Figure 4.4 Relationships of UHC and engine speed

4.4.2 Emission from Carbon monoxide (CO) Vs Engine Speed (rpm)

The result of the experiment at different speed is shown in tale 4.5 and figure 4.5.

Table 4.5 CO Emissions (%V) and Engine Speed (rpm)

Engine speed (rpm)	1993	2132	2322	2788	3031
With hybrid aqua silencer	0.097	0.102	0.117	0.089	0.066
Without hybrid aqua silencer	0.130	0.141	0.161	0.093	0.074

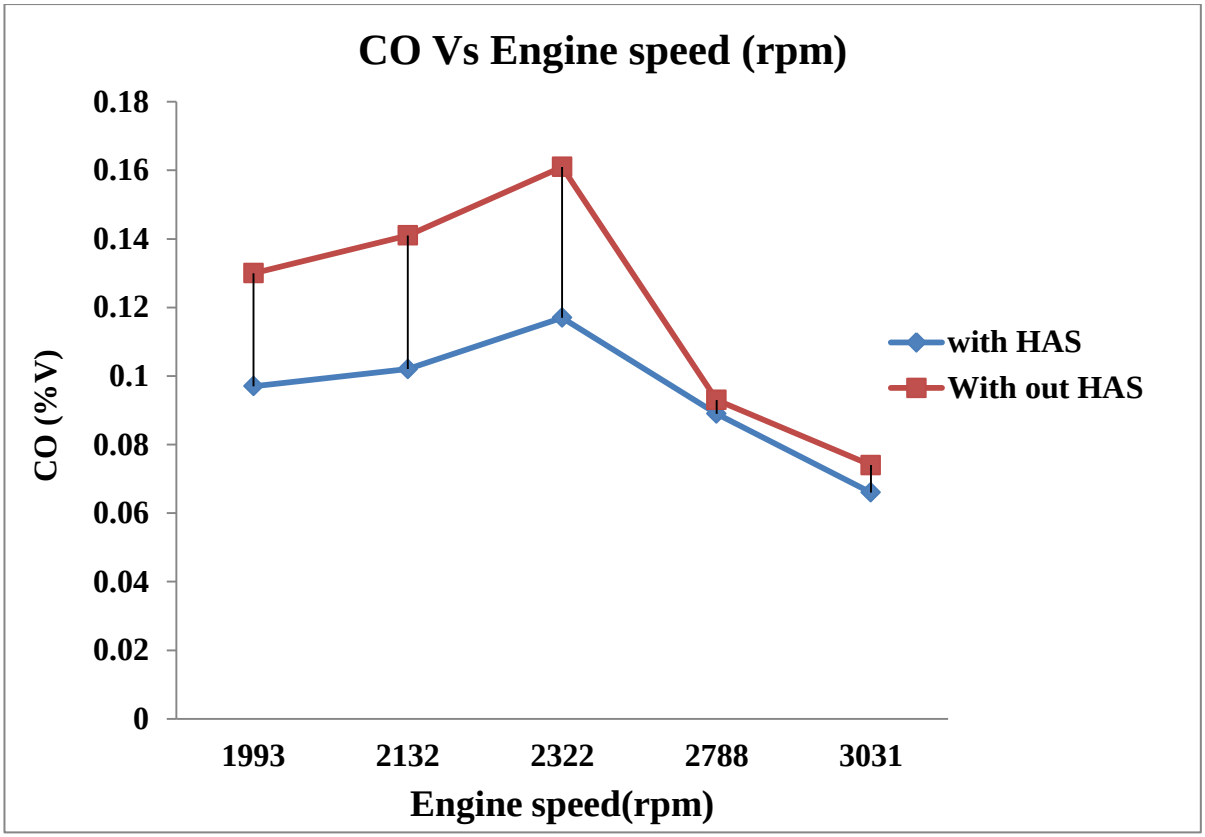

Figure 4.5 Relationships of CO emission and engine speed

Here from the result is observed that as the engine speed increases the carbon monoxide emission increased. The reason is as speed increases the engine is subjected to load from the exhaust gas resulting in poor combustion. This can be taken as drawback of a new design. To eliminate tis an additive is employed.

4.4.3 Emission from Carbon dioxide (CO_2) and Engine Speed (rpm)

The higher percentage of CO_2 in combustion process indicates complete combustion in the combustion chamber. This happens because the oxygen molecules (^{-}OH) in diesel and the additive react with CO and produce more CO_2. The result of the experiment is shown in table 4.6 and figure 4.6.

Table 4.6 Engine speed and CO_2 emissions

Engine speed (rpm)	1993	2123	2322	2788	3031
With Hybrid aqua silencer	2.87	2.95	3.02	3.44	3.65
Without hybrid aqua silencer	3.22	3.28	3.22	3.37	3.44

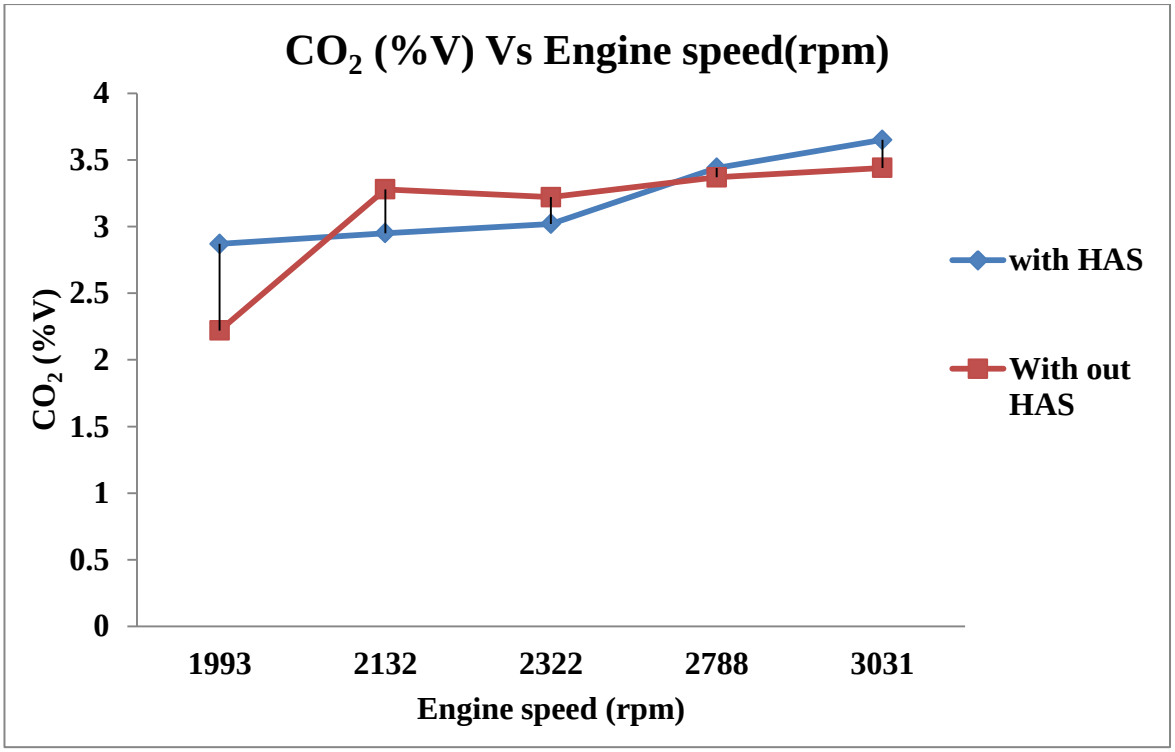

Figure 4.6 Relationships of CO_2 emissions and engine speed

According to figure 4.6 there is decrease in CO_2 emissions with use of aqua silencer than the existing silencer. The amount of CO_2 adsorbed by charcoal layer is around 40-50% which is plays crucial role in environment. So it can be stated that aqua silencer effectively reduces CO_2 coming out of the engine exhaust which causes greenhouse effect.

4.4.4 Oxygen (O_2) and Engine speed (rpm)

The results of O_2 and Engine speed are shown detail on Table 4.7 and figure 4.7.

Table 4.7 oxygen Vs Engine speed (rpm)

Engine speed (rpm)	1993	2123	2322	2788	3031
With Hybrid aqua silencer	17.08	16.89	16.72	16.31	16.05
Without hybrid aqua silencer	16.65	16.57	16.51	16.32	16.26

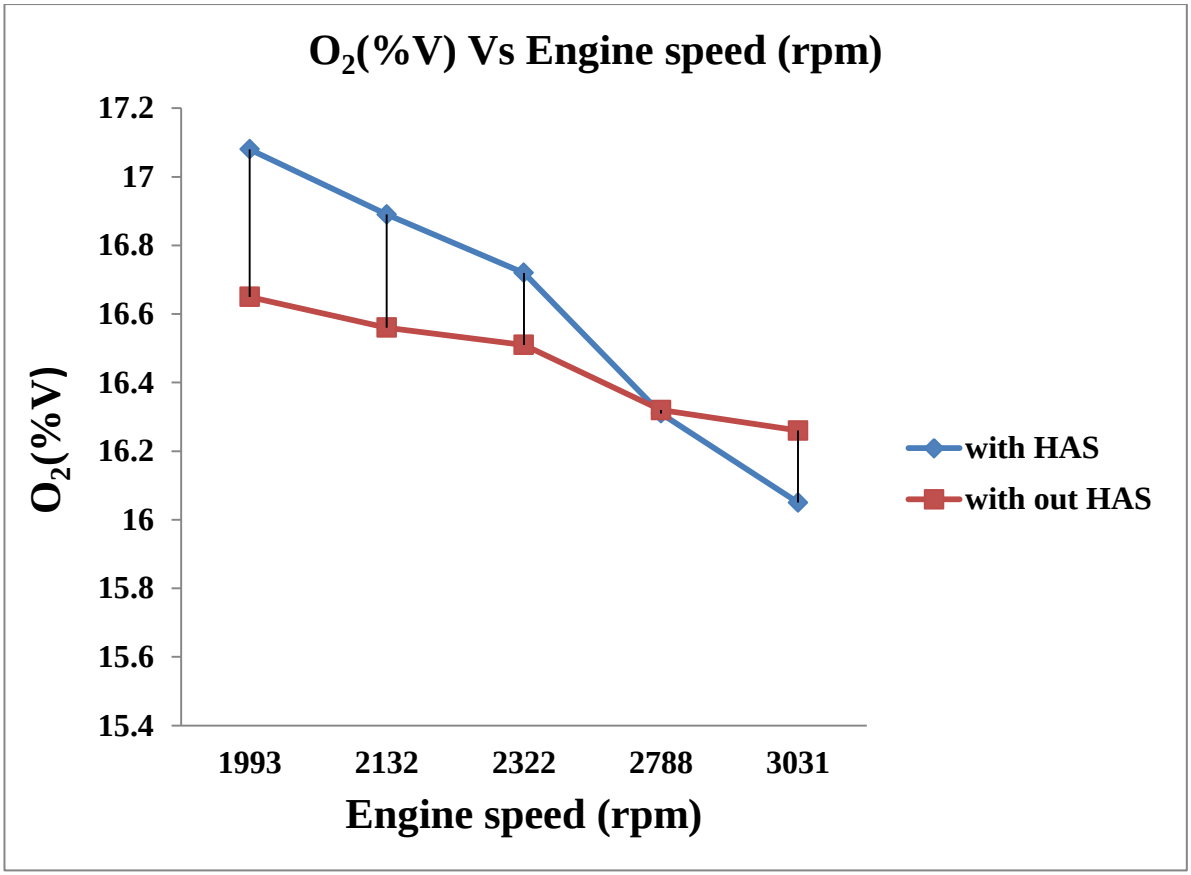

Figure 4.7 Oxygen and Engine speed

The result discusses that as the engine speed increases, engine temperature increases and fuel approaches complete combustion. So that amount of oxygen decreases slightly as shown on fig. 4.7. This is because of the other gases cover more area.

4.5 Validations for all conventional, Aqua and Hybrid aqua silencers

4.5.1 Validations for carbon monoxide CO (%V)

From the experiments been conducted above exhaust emissions, comparisons for validation of CO and UHC emissions is done with the previous study results. Validation of CO with the previous study result is shown in figure 4.8.

Table 4.8 Validations of carbon monoxide out with previous work studied

From previous study				From currently work study
No.	Engine speed (rpm)	CO (%V)		CO (%V)
		Conventional silencer	Aqua silencer	HAS using lime water
1.	1993	0.130	0.113	0.097
2.	2132	0.141	0.105	0.102
3.	2322	0.161	0.153	0.117
4.	2788	0.099	0.091	0.089
5.	3031	0.074	0.067	0.066

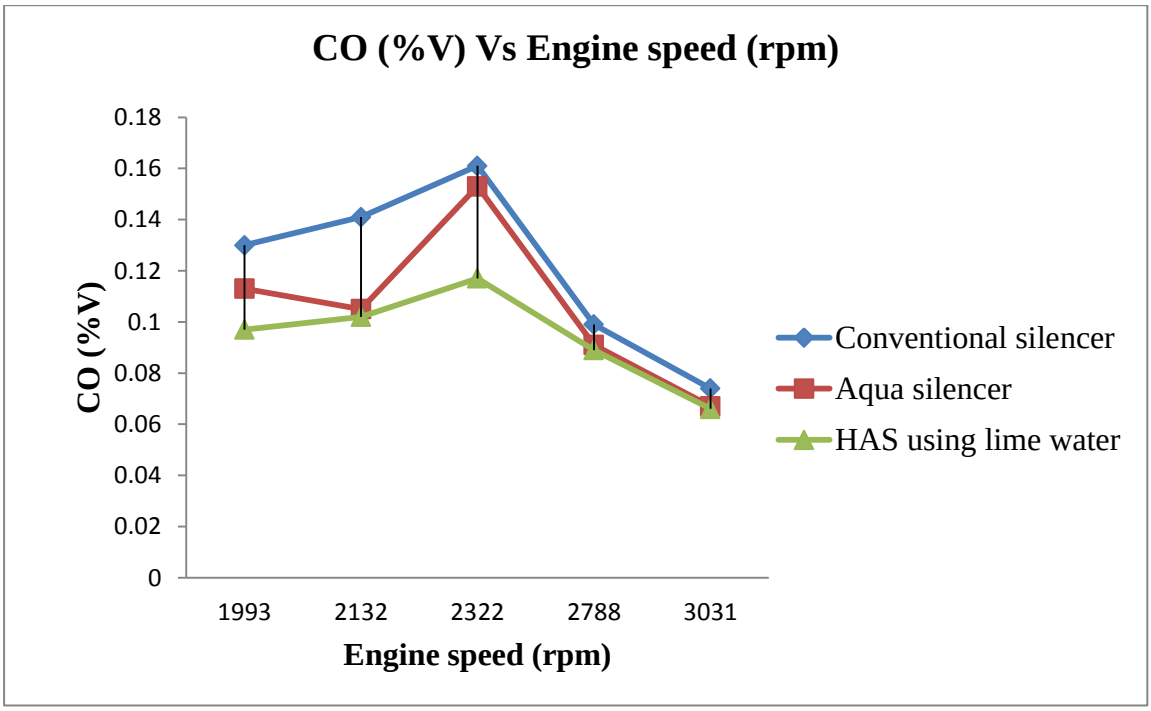

Figure 4.8 Validations for CO emissions

As observed from table 4.7 and fig. 4.7 that aqua silencer using lime water has shown remarkable decrease of CO when compared with conventional and aqua silencer without lime water. Therefore the result can be taken as reliable.

4.5.2 Validation for unburned hydrocarbon UHC (ppm)

UHC is also one of the emission types which are released from the internal combustion engines using diesel fuels specially. Around 70-80% of unburnt hydrocarbons get adsorbed in aqua silencer.

Table 4.9 Validations of unburned hydrocarbon with previous work

From previous work studied				From currently work study
No.	Engine speed (rpm)	UHC (ppm)		UHC (ppm)
		Conventional silencer	Aqua silencer	HAS using lime water
1.	1993	490	78	16
2.	2132	430	72	19
3.	2322	347	65	24
4.	2788	290	52	22
5.	3031	278	47	16

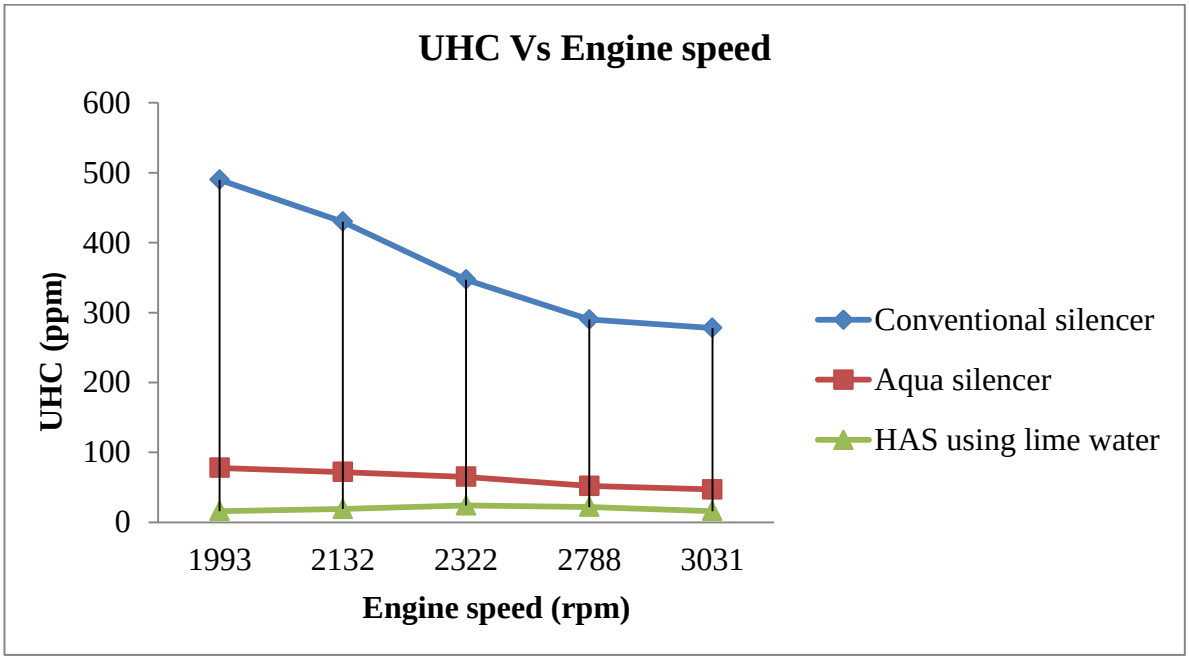

Figure 4.9 Validations for UHC emissions

On conventional system the UHC content decreases highly at varied engine speed. But when we see for AS and HAS initially there is low emitting gases content it also decreases as the engine speed increases slowly. So that if the temperature is decreased the amount of UHC gases discouraged to increase.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Summary

- The main intention of this thesis is reducing environmental emission using the locally available material like activated charcoal, water and a perforated tube by some amount. Present used material for emission reduction is the catalytic converter for modern light vehicles which contains different elements like platinum, palladium and rhodium which are expensive.
- Since our country is parts of the developing country it may consume a lot of periods for simple service of catalytic converter in our country. The analyses are done on stationary engines in the laboratory with different engine speed (rpm). An exhaust gas analyzer demonstrates that the outcomes are appeared above individually.

5.2 Conclusion

From the different experiments conducted the following conclusions as drawn.

- The overall studies are based totally on the findings about emission reducing methods. In this work, a four stroke single cylinder diesel engine, emission absorber is modeled using AutoCAD software and also prepared prototype for demonstration. The performance and exhaust emission tests were done on single cylinder four strokes CT 110 diesel engine at Dilla University.
- Its emission absorbing properties are studied using an emission analyzing device called an exhaust gas analyzer. The device is digital and display by sensing the gas content.
- From the experiment done on the models for outflow decreasing components, it is observed that the content of CO completely increases with the speed of the diesel engine we used for experimental setup while UHC decreases slightly with the input speed set. Thus, when we close for CO_2 it demonstrates the turnaround of CO and UHC on the chart above. The reality is shown on the fuel consumed while running the engine with the needed speed.
- Emission test for CO versus various loads has shown about 5% emission reduction with hybrid aqua than conventional system.
- As a general for CO, UHC and CO_2 their atmospheric polluting capacity diminished as well compared with conventional systems.
- Emission for UHC shows variability, this is because of water temperature.

- Generally, from the observation and readings this hybrid aqua silencer is more valued than the existing conventional system except its weight.

5.3 Recommendation

I would like to suggest the future researchers should hold to do on this area and try to reduce the problems of environmental pollution in Ethiopia. Proper right here the thesis is finished for first-class single cylinder inner combustion engine motors.

Finally, I recommend the department of Mechanical systems and vehicle engineering of Adama science and Technology University to set up the emissions testing laboratory which is very important to make a research work on different source and putting off the emissions which is degrading our environment. So that undergraduate students, postgraduate students, staff members and different scholars can participate in 'how to preserve the surrounding from emission' and associated research work activities.

5.4 Future Work

The research may be extended in the destiny in the following areas.

- Actually this work is simplest attempt for starting, so it will be better if it will be done for heavy duty vehicles.
- In Ethiopia such an entire lot of industries are developing inside the intervening time and near future. It's moreover feasible to attempt for outdoor combustion engines with the beneficent aid of the usage of this mechanism for environmental saving. This is because in more industries they don't give attention for environmental degradation rather than getting wealthy through product obtained. So environmental conservation is the very necessary obligation for living things survive.
- The researcher who will try to improve the design should concern serviceability of the components as much as easy for user during changing the internal parts of it.

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Appendix -A- Engine test experimental procedures

Startup procedures

1. Turn laboratory ventilation fans very high.
2. Check engine oil.
3. Visually inspect test stand and engine (oil/fuel leaks, disconnected wires, etc).
4. Check fuel level.
5. Close laboratory doors.
6. Start eddy current dynamometer.
7. Check warning lights on console.
8. Pull the fuel control back.
9. Turn on ignition switch.
10. Start engine.
11. Arrange the RPM (to 1993) of engine as much possible for test.
12. Inserting exhaust gas analyzer sensor in exhaust pipe.
13. Read from display the result.
14. Repeat step 11 to 13 for engine RPM of 2132, 2322, 2788 and 3031.

Shut down procedures

1. Idle the engine for at least 3 minutes after any testing.
2. Turn off ignition and dynamo console power.

   CAUTION: exercise extreme care when entering laboratory. The engine will be very hot.
3. Check engine for any leaks or obvious problems.
4. Turnoff laboratory ventilation fans.

Appendix -B -Dimensions for groove connections of non-return valve

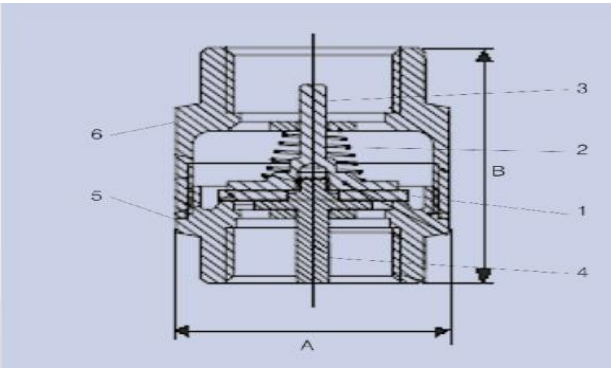
This annex contains the dimensions of valve connections for use with pipe couplings.

Valid for cutting machined connections of malleable iron, cast ductile iron, steel or cast steel with 350 N/mm^2 minimum tensile strength [24].

Nominal size		Nominal outer diameter in mm	Nominal outer diameter in mm		Pipe length up to groove in mm	Groove width in mm	Diameter at groove ground in mm	
			max.	min.	± 0,76	± 0,76	max.	min.
DN	25	33.7	33.73	33.07	15.87	7.92	30.23	29.85
DN	32	42.4	42.57	41.76	15.87	7.92	38.99	38.61
DN	40	48.3	48.74	47.78	15.87	7.92	45.09	44.70
DN	50	60.3	60.94	59.72	15.87	7.92	57.15	56.77
DN	65	76.1	76.85	75.35	15.87	7.92	72.26	71.80
DN	80	88.9	89.79	88.11	15.87	7.92	84.94	84.48
DN	100	114.3	115.44	113.51	15.87	9.52	110.08	109.58
DN	125	139.7	141.10	138.91	15.87	9.52	135.48	134.97
DN	150	168.3	169.85	167.49	15.87	9.52	163.95	163.40
DN	200	219.1	220.65	218.29	19.05	11.13	214.40	213.77
DN	250	273	274.62	272.26	19.05	12.70	268.27	267.59
DN	300	323.9	325.42	323.06	19.05	12.70	318.29	317.53

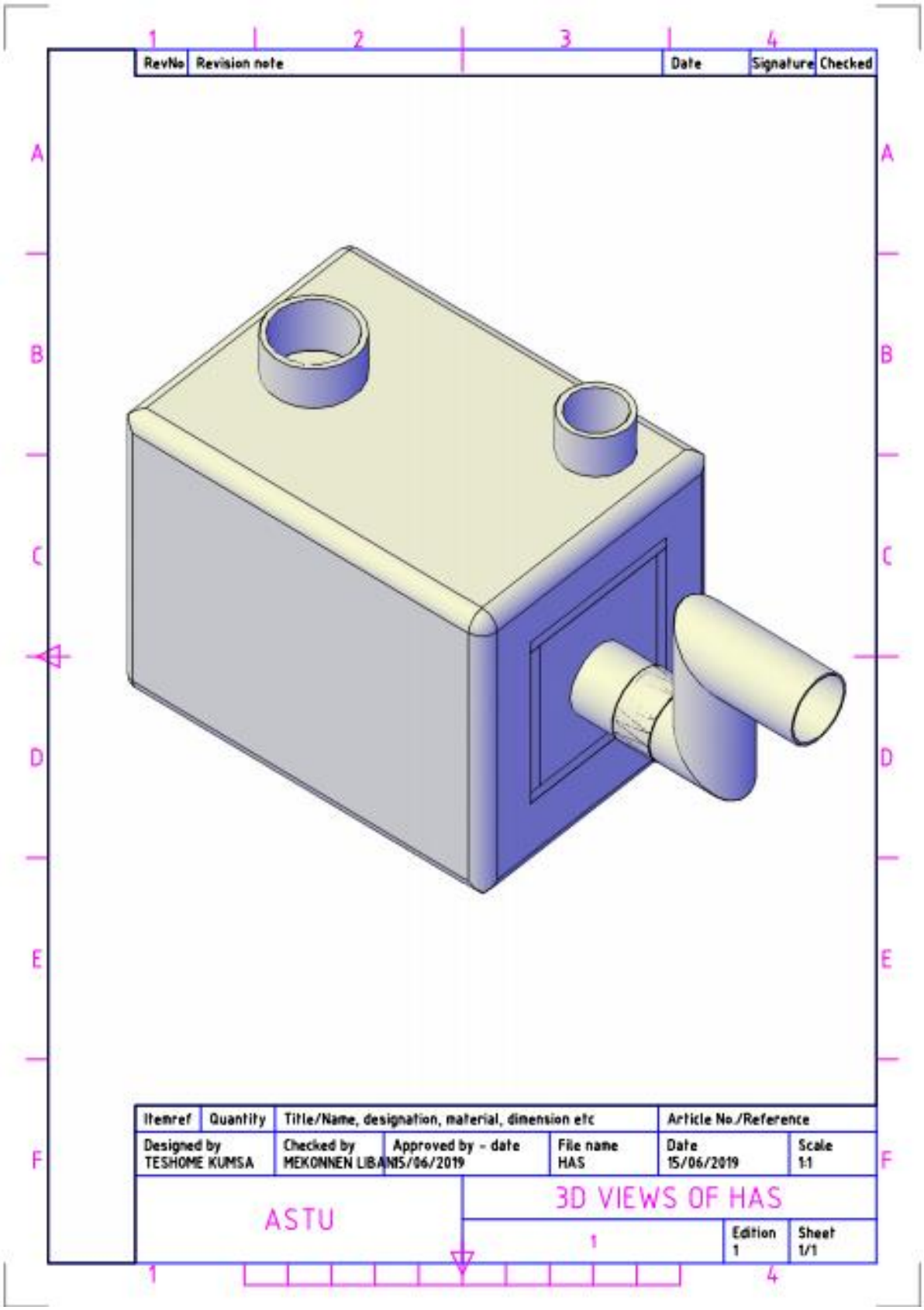
Remark 1: Groove shoulder flash-free with cutting up to max. 0.3 mm x 45°.
Remark 2: Groove ground with radius up to max. 0.8 mm.

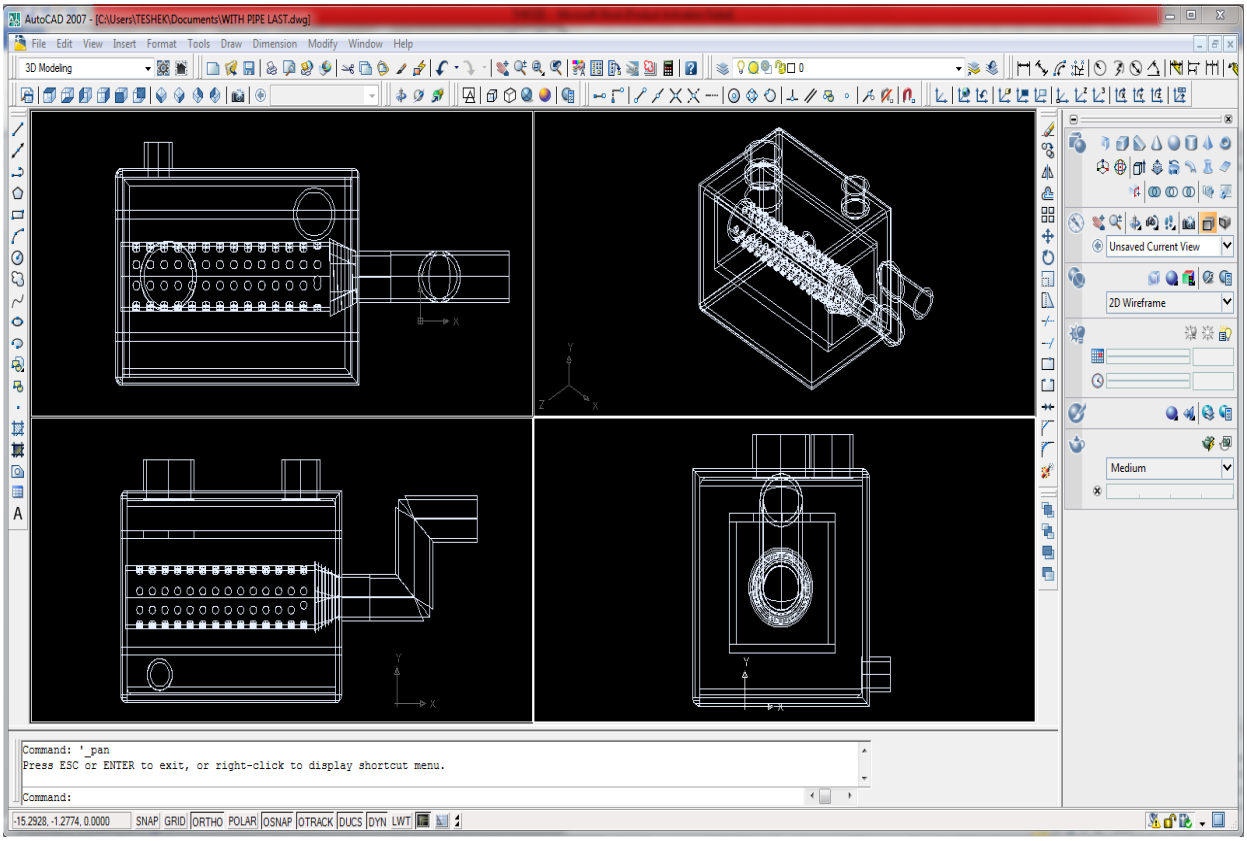
Material specifications



No.	Component	Material	Specification
1.	Seat	EPDM	EN 2430:1995
2.	Spring	Stainless Steel	ISO.15510
3.	Spindle core (Upstream)	Brass	EN 12165 CW617N-DW
4.	Spindle core (Downstream)	Brass	EN 12165 CW617N-DW
5.	Bonnet	Brass	EN 12165 CW617N-DW
6.	Body	Brass	EN 12165 CW617N-DW

Appendix -C -Pictorial drawing of the study

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3D Modeling
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2D Wireframe
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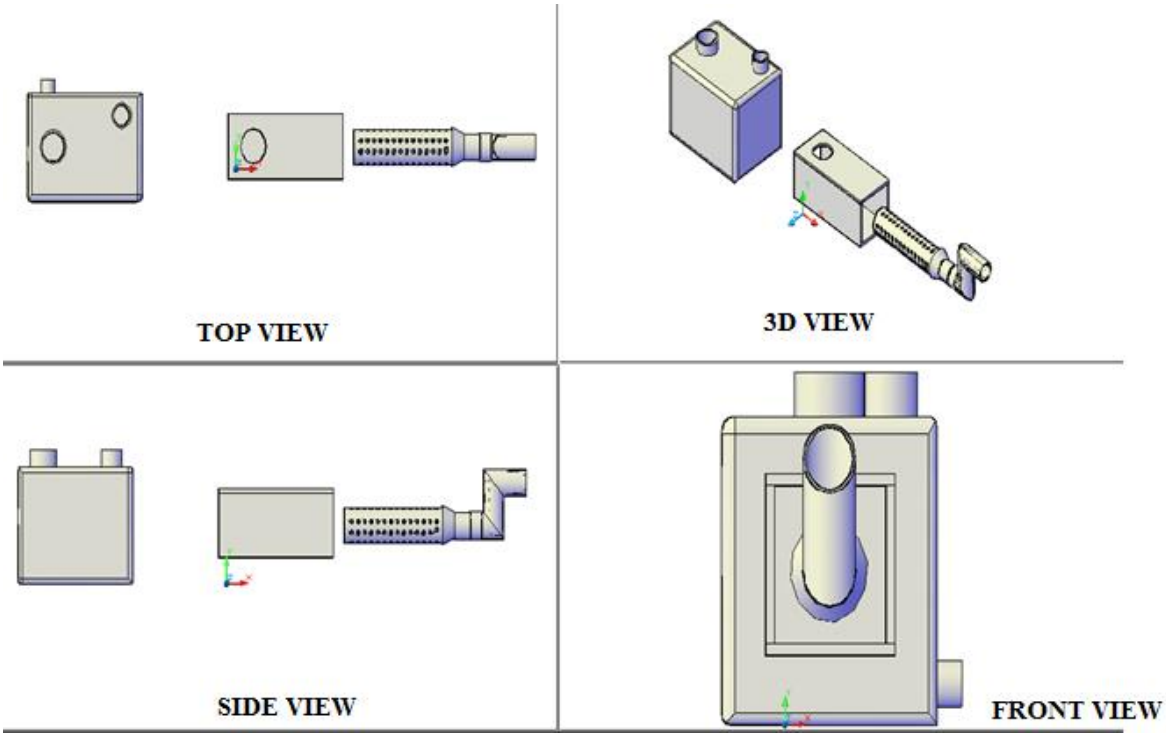
TOP VIEW
3D VIEW
SIDE VIEW
FRONT VIEW

Appendix -D - Photos when doing prototype and experiment


gunt
CT 110

Appendix –E

a). CT 110 Test stands for small combustion engine specification

S.NO.	CT 110 Test Stand For Small Combustion Engine Specification And Technical Data	DIMENSIONS
1.	Engine model	1B30-2
2.	Number of cylinder	1
3.	Length x width x height	370mm x 330mm x 450 mm
4.	Company	Hatz
5.	Weight	35Kg
6.	Fuel	CT 100.22 Diesel
7.	Bore	80mm
8.	Stroke	69mm
9.	Crank length	34.5mm
10.	Rod length	114.5mm
11.	Output power at 3500 min^{-1}	5.5kW
12.	Oil capacity	1.1L
13.	Stop solenoid	12V
14.	Compression ratio	22:1
15.	Engine type	Air cooled single cylinder 4-stroke Diesel Engine

b). Exhaust gas analyzer specifications

NO.	Gaseous components	Range	Accuracy	Resolution
1.	Carbon monoxide (CO)	0-10% vol.	0.06% Vol.	0.01% vol.
2.	Carbon dioxide(CO_2)	0-20% vol.	0.30% Vol.	0.1% vol.
3.	Hydrocarbon(HC)	0-2000 ppm	4 ppm	1 ppm
4.	Oxygen(O_2)	0-22% vol.	0.10% vol.	0.01% vol.
5.	Nitrogen dioxide(NO_x)	0-5000 ppm	25 ppm	1 ppm

Appendix -F: Interview with Society

Adama Science and Technology University

School Of Mechanical, Chemical and Material Engineering

Department Of Mechanical System and Vehicle Engineering

Key information interview attendant to local residents and workers

The principal objective of this key informant interview is to explore the extent to which type of vehicles engine emission is increased and how it formed. The study is conveyed for academic purpose. Hence, the responses from respondents are confidential and cannot be traced to the persons who provided them.

i. Age of respondent: _____ Sex:_____

ii. What is the level of education? _____

iii. Work of the respondent:_____

QUESTIONS

1. How do you see environmental emissions?
2. What are the main polluting agents you think?
3. Which type of vehicles pollutes the environment?
4. What is catalytic converter?