iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** V **Month of publication:** May 2015

DOI:

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Modeling and Experimental Investigations of the Sound and Emissions performance for 4-stroke multi Cylinder diesel Engine with an Aqua Silencer

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Abstract— Purity of air is most important from the public health point of view, because every individual person breathes approximately 22000 times per day, inhaling about 15 to 22 Kg of air daily. Polluted air causes physical ill effect decides undesirable aesthetic and physiological effects. Air pollution can be defined as addition to our atmosphere of any material, which will have a deterious effect on life upon our planet. The main pollutants contribute by automobiles are carbon monoxide (CO), unburned hydrocarbon (UBHC), oxides of nitrogen (Nox) and Lead. Automobiles are not only source of air pollution, other sources such as electric power generating stations, industrial and domestic fuel consumption, refuse burning, industrial processing etc. also contribute heavily to contamination of our environment so it is imperative that serious attempts should be made to conserve earths environment from degradation. An aqua silencer is an attempt in this direction, it is mainly dealing with control of emission and noise. An aqua silencer is fitted to the exhaust pipe of engine. Sound produced under water is less hearable than it produced in atmosphere. This mainly because of small sprockets in water molecules, which lowers its amplitude thus, lowers the sound level. Because of this property, water is used in this silencer and hence its name as AQUA SILENCER. Due to this we reduce the noise and emissions from the exhaust.

Keywords—Aqua silencer, Exhaust pipe Activated carbon, Perforated tube, Water, Activated carbon

I. INTRODUCTION

Silencer is also termed as muffler. It is used for reducing the noise emitted by exhaust of an internal combustion engine, which is a major source of noise pollution. It becomes a more vital concern when used in residential areas or areas where noise creates hazard. Generally, noise level of more than 80-90 dB is injurious for human being. The main source of noise in an engine are divided in two parts, first is the exhaust noise and second is the noise produced due to friction of various parts of the engine. The engine exhaust noise is the most dominant. To reduce this noise, the most effective way of using a muffler in the engines. The level of noise reduction depends upon the design, construction and the working procedure of mufflers. If a car running without a muffler then the noise level is unbearable[1]. The most of the advances in the acoustic filters and exhaust mufflers came out in last four decades. Hence good design of the muffler should give the best noise reduction and offer optimum backpressure for the engine[2]. Backpressure is the extra static pressure exerted by muffler on the engine through the restriction in the flow of exhaust gases. The insertion loss is defined as the difference in the acoustic power radiated without and with the muffler fitted.

A. Introduction

Engine exhaust noise is controlled through the use of silencers and mufflers. Generally speaking, there is no technical distinction between a silencer and muffler and the terms are frequently used interchangeably. A silencer has been the traditional name for noise attenuation devices, while a muffler is smaller, mass-produced device designed to reduce engine exhaust noise.

B. Silencer Selection Factors

The use of an exhaust silencer is prompted by the need to reduce the engine exhaust noise. In most applications the final selection of an exhaust silencer is based on a compromise between the predicted acoustical, aerodynamic, mechanical and structural performance in conjunction with the cost of the resulting system.

C. Acoustical performance

The acoustical performance criterion specifies the minimum insertion loss (IL) of the silencer, and is usually presented in IL values for each octave band as well as an overall expected noise reduction value. The insertion loss is determined from the free-field sound pressure levels measured at the same relative locations with respect to the outlet of the unsilenced and silenced systems. The IL of a silencer is essentially determined by measuring the noise levels of piping systems before and after the insertion of a silencer in the exhaust stream.

IL data presented by most manufacturers will typically be based upon insertion of the silencer nto a standard piping system consisting of specified straight runs of piping before and after the silencer. Exhaust system configurations as well as mechanical design can have a substantial impact on the performance of and exhaust silencer and should be considered at the time of specification. Raw exhaust noise levels should be obtained from the engine manufacturer to determine the necessary noise reduction requirements of the proposed silencer. Specific installation conditions and exhaust noise levels will aid the manufacturer in determining the correct silencer to meet the required noise reduction. If a silencer is located outside of the room or housing in which the engine is installed, one must be cognoscente of the effects of 'break-out' noise from either the silencer body or associated piping system. Breakout noise can dominate the stack radiated noise, particularly for high-performance silencers that greatly reduce the noise transmitted downstream. A high-performance exhaust silencer may have extremely good IL performance, but utilization of a thin walled piping system may allow substantial noise to be radiated from the piping system before entering the silencer body. The effects of sound transmission through a mass layer are discussed in Chapter 25. One solution avoids potential breakout from dominating the overall noise levels is to ensure a balance between the exhaust silencer shell thickness and corresponding piping. Manufacturers will often incorporate a multiple layer shell on higher-grade silencers to increase the transverse transmission loss of the silencer.

D. Aerodynamic performance

The Aerodynamic performance criterion specifies the maximum acceptable pressure drop through the silencer (backpressure of the silencer). The exhaust flow rate and temperature from the engine manufacturer are required to accurately predict the backpressure of a silencer and piping system. Selection of an exhaust silencer based solely on the diameter of the connecting piping can often lead to improperly selected products that may present installation issues. Traditional head loss calculations utilizing standardized coefficients for sudden contraction and expansion of fluids can be used to approximate the pressure drop through a silencer and combined with the values obtained for the remainder of the piping system. More complex silencer internal structures should be analysed using Computational Fluid Dynamics (CFD) where traditional empirical calculations or assumptions may lead to inaccurate results. The pressure drop through silencers should be obtained from the manufacturer of the product upon submission of the required flow information.

E. Mechanical performance:

The Mechanical performance criterion specifies the material properties of the exhaust system to ensure that it is durable and requires little maintenance when incorporated into service. Material selection is especially important in cases involving high temperature or corrosive gases. Traditional carbon steels will typically be sufficient for the majority of applications using Diesel fuelled generators. Natural Gas engines will traditionally run at an elevated temperature above their Diesel counterpart, and may require a graded carbon or stainless steel that can maintain an element of structural performance at elevated temperatures. Aluminized steel is available from many silencer manufacturers and is often preferred for general applications. Aluminized steel is slightly more heat resistant than carbon steel and offers an increased resiliency to corrosion and is often selected as an economical alternative to specifying a stainless steel system. Regular periodic testing of a standby generator will subject the exhaust system to thermal cycles that can contribute to the premature corrosion of carbon steel

F. Reactive Silencer

Reactive silencers generally consist of several pipe segments that interconnect with a number of larger chambers. The noise reduction mechanism of reactive silencer is that the area discontinuity provides an impedance mismatch for the sound wave traveling along the pipe. This impedance mismatch results in a reflection of part of the sound wave back toward the source or back and forth among the chambers. The reflective effect of the silencer chambers and piping (typically referred to as resonators) essentially prevents some sound wave elements from being transmitted past the silencer. The reactive silencers are more effective at lower frequencies than at high frequencies, and are most widely used to attenuate the exhaust noise of internal combustion engines. A generic reactive engine silencer comprised of two proportionally sized chambers with a pair of interconnecting tubes is shown below

Volume 3 Issue V, May 2015
ISSN: 2321-9653

Fig 1.Reactive Muffler

G. Absorptive Silencer

The muffler is composed of a tube covered by sound absorbing material. The tube is perforated so that some part of the sound wave goes through the perforation to the absorbing material. The absorbing material is usually made of fiberglass or steel wool. The dampening material is protected from the surrounding by a supplementary coat made of a bend metal sheet. The advantage of this method is low back pressure with a relatively simple design. The inconvenience of this method is low sound damping ability compared to the other techniques, especially at low frequency. The mufflers using the absorption technique are usually sports vehicle because they increase the performances of the engine because of their low back pressure. A trick to improve their muffling ability consists of lining up several "straight" mufflers.

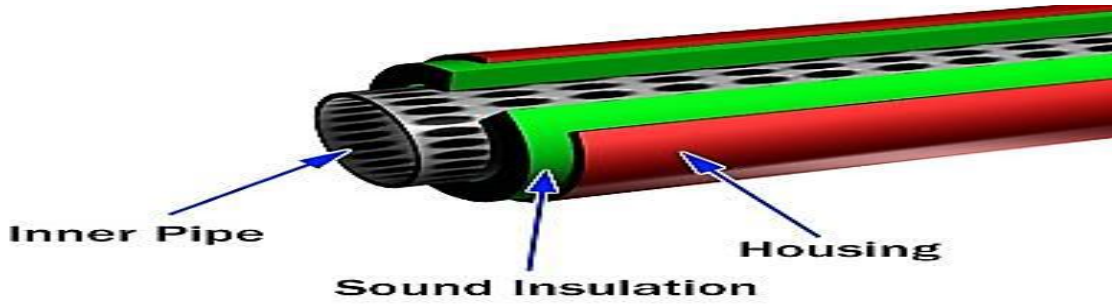


Fig 2: Absorptive Muffler

II. INTRODUCTION TO AN AQUA SILENCER

An aqua silencer System is designed to replace conventional single unit engine silencers on board structures. With its light weight and slender design, it offers a minimal 'footprint' while optimizing the entire exhaust system for low noise and reduced backpressure. It is used to control the noise and emission in IC engines. The reason why we go for aqua silencer is, in today life the air pollution causes physical ill effects to the human beings and also the environment. The main contribution of the air pollution is automobile releasing the gases like carbondioxide and unburt Hydrocarbon. In order to avoid this type of gases by introducing this aqua silencer. It is fitted to the exhaust pipe of the engine, Sound produced under water is less hearable than it produced in atmosphere. This 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 posses extra free valences so it has high absorption capacity. So absorb the gases from the engine and release much less position to the environment. The noise and smoke level is considerable less than the conventional silencer, no need of catalytic converter and easy to install.

In this silencer, the Charcoal and Water so it is called hybrid aqua silencer, and it is useful in automobile, industry, DG sets & DG machines, Marin and Boats also so, It is known as hybrid **universal aqua silencer.**

A. Aim and Scope Of Present Work

In the present work, conventional silencer, aqua silencer provisions were made for experimental evaluation. Calculated the efficiencies of the 4-stroke multi cylinder diesel engine with turbocharger and supercharger by using load test. By increasing the load gradually (2kg, 4kg, 6kg, 8kg, 10kg,) with the help of rope and brake drum loading system at idle rpm. Experimental tests provided a basis to design a control strategy able to meet general performance requirements.

Finally, the new control strategy was validated on the engine switch good results. An Aqua silencer is better than the conventional silencer. The result gives good performance characteristics.

III.MODELING OF THE AN AQUA SILENCER

A. *Introduction to CATIA V5*

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems directed by Bernard Charles. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems software suite.

1) *History:* CATIA (Computer Aided Three-Dimensional Interactive Application) started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault, at that time customer of the CAD/CAM CAD software to develop Dassault's Mirage fighter jet. It was later adopted in the aerospace, automotive, shipbuilding, and other industries. Initially named CATI (Conception Assisted Tridimensionnelle Interactive – French for Interactive Aided Three-dimensional Design), it was renamed CATIA in 1981 when Dassault created a subsidiary to develop and sell the software and signed a non-exclusive distribution agreement with IBM.

   a) In 1984, the Boeing Company chose CATIA V3 as its main 3D CAD tool, becoming its largest customer.
   b) In 1988, CATIA V3 was ported from mainframe computers to UNIX.
   c) In 1990, General Dynamics Electric Boat Corp chose CATIA as its main 3D CAD tool to design the U.S. Navy's Virginia class submarine. Also, Boeing was selling its *CADAM* CAD system worldwide through the channel of IBM since 1978.
   d) In 1992, CADAM was purchased from IBM, and the next year CATIA CADAM V4 was published.
   e) In 1996, it was ported from one to four Unix operating systems, including IBM AIX, Silicon Graphics IRIX, Sun Microsystems SunOS, and Hewlett-Packard HP-UX.
   f) In 1998, V5 was released and was an entirely rewritten version of CATIA with support for UNIX, Windows NT and Windows XP (since 2001).
   g) In the years prior to 2000, problems caused by incompatibility between versions of CATIA (Version 4 and Version 5) led to $6.1B in additional costs due to years of project delays in production of the Airbus A380.
   h) In 2008, Dassault Systèmes released CATIA V6. While the server can run on Microsoft Windows, Linux or AIX, client support for any operating system other than Microsoft Windows was dropped.
   i) In November 2010, Dassault Systèmes launched CATIA V6R2011x, the latest release of its PLM2.0 platform, while continuing to support and improve its CATIA V5 software.
   j) In June 2011, Dassault Systèmes launched V6 R2012.
   k) In 2012, Dassault Systèmes launched V6 2013x.
   l) In 2014, Dassault Systèmes launched 3DEXPERIENCE Platform R2014x and CATIA on the Cloud, a cloud version of its software.

B. *Design*

CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches. CATIA is able to read and produce STEP format files for reverse engineering and surface reuse.

C. *Procedure*

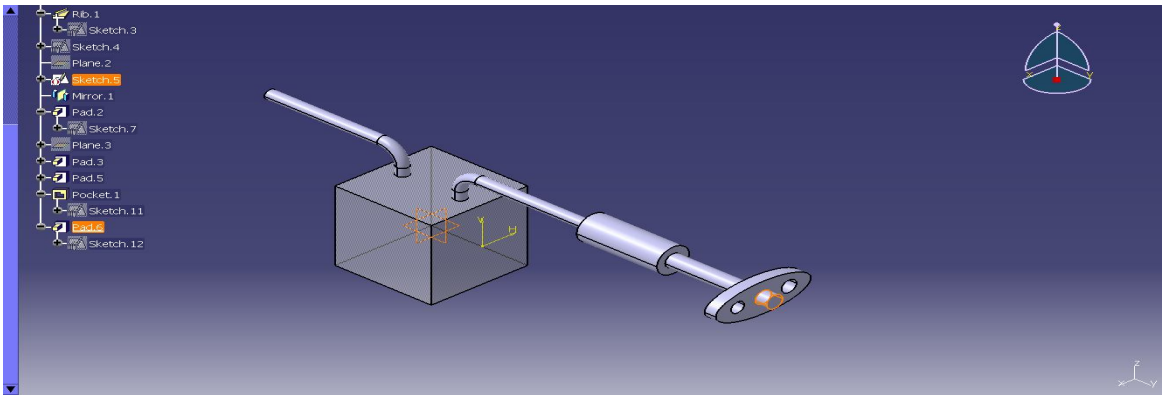


Fig 3.catia diagram

Step 1:- start
Step 2:- mechanical design
Step 3:- part design
Step 4:- plane(yz)
Step 5:-sketch[rectangle with 30*30cm]
Step 6:- select work bench
Step 7:- pad
Step 8:- sketcher 2
Step 9:-plane 2
Step 10:- rib(dimension with 30cm)
Step 11:- sketcher 3
Step 12:- mirror
Step 13:- pad
Step 14:- sketcher 4(plane)
Step 15:- draw a circle(dimensions 12cm * thickness 0.1cm)
Step 16:- exit work bench
Step 17:- pad
Step 18:- sketcher 5
Step 19:- pocket
Step 20:- sketcher 6
Step 21:- pad

IV. FABRICATION OF AN AQUA SIENCER

A. Fabrication of Water Container

1) Process

a) Here we using a thin sheet with thickness of 0.1cm

b) We used 6 sheets with 30X30 cm placed like a cube shape and connecting these sheets by using gas welding.

c) A small opening is provided at the Top of the container to remove the exhaust gases and a drain plug is provided at the bottom of the container for periodically cleaning of the container.

d) Also a filler plug is mounted at the top of the container.

Fig 4. Water container

B. Fabrication Of Silencer

1) Pipe Diameter Guidelines

Some basic exhaust pipe diameter guidelines for non-turbo cars are as follows:
1.500cc-2,000cc engines : 2-inch
2.100cc-2,500cc engines : 2.25-inch
3.600cc-3,000cc engines : 2.5-inch

Add half an inch to the pipe diameter to optimize for nitrous oxide use because of the increased exhaust gas volume. Remember this may be too big for optimal operation when you aren't on the bottle. For turbocharged engines, 2.5-inch is the minimum size

pipe that you would want to run, even for the smaller engines. For 2,000cc and bigger engines, 3-inch works well, and for bigger engines the biggest (usually 3.5-inch) you can find is appropriate. It is almost impossible to have too big of an exhaust on a turbo car. Range of chamber length according to ASHRAE Technical Committee 2.6 muffler grades and their dimensions, the requirement matches with the super critical grade.

IL = 35 to 45 dBA

Body/Pipe = 3 inch

Length/Pipe = 10 to 16
That is, 10 × pipe dia ≤ L ≤ 16 × pipe dia
10 × 1.5" ≤ L ≤ 16 × 1.5"
15" ≤ L ≤ 24"
Again the chosen length L = 15 inch, satisfies the above condition.

2) Process

a) In this project we use a absorptive type of muffler with exhaust pipe diameter is 1.25(inch).

b) Muffler length is 15(inch) and diameter of perforated tube is 8cm*38cm.the outer diameter metal sheet is 10cm*38cm.

c) Around the circumference of the perforated tube a layer of activated charcoal is provided and further a metallic mesh covers it.

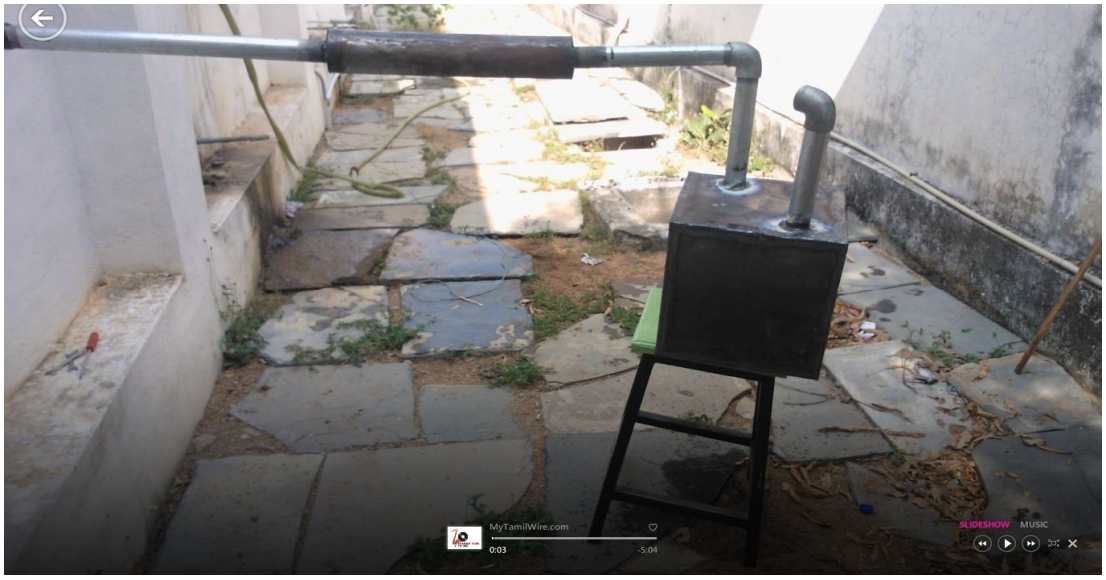


FIG 5. MUFFLER

V. EXPERIMENTAL SETUP

The Following equipment has been used for experimental work carried out in Thermal Laboratory.

Fuel tank
Burrette
Manometer unit
20. H.P four stroke multi cylinder diesel engine
Air intake
Exhaust gas outlet
Aqua silencer

Mechanical loading unit

Tests were carried out in a 20 H.P in-direct injection, compression ignition, engine fueled with diesel. The engine was modified in the way that by attaching turbocharger and supercharger. By increasing the pressure of intake air in the sense of turbocharging and supercharging processes. The results of engine with and without turbocharger and supercharger were analyzed in terms of performance and emissions.

A. Performance Test

A multi cylinder 4-stroke water-cooled diesel engine having 20 hp as rated power at 1500 rpm was used in the present work. The engine is coupled to an brake drum for loading it. A digital tachometer is used to measure the speed of the engine. The fuel flow rate is measured on volumetric basis using burette and a stopwatch.

Fig 6. Experimental setup

B. Engine Specifications

Engine	H.M Trucker
Type	Water cooled
Bore	73 mm
Stroke	90 mm
Maximum Power	20 HP
No. of cylinders	4
Injection timing	28^0 BTDC
Compression Ratio	16.5:1
Radius Of Dynamometer	207 mm
Belt thickness	7 mm

TABLE 1. ENGINE SPECIFICATIONS

Fig 7.Experimental loading set up of 20 hp diesel engine with mechanical loading

C. Present Work

In the present investigation, an attempt is made to evaluate the performance and emissions of a 20 H.P in-direct injection, naturally aspirated, conventional silencer. By using aqua silencers of method affect to improve the engine performance and reduces emissions in a similar way and compared to conventional silencer. Tests were also performed to investigate the effect of black smoke and Nox emissions and sound from exhaust gases . It was found that after implementing the an aqua silencer engine tended to eliminate Nox emissions& sound completely.

D. Experimental Procedure

The experimental procedure is carried out through the following steps:

1) Fill the fuel tank with clean diesel fuel.
2) Connect the mechanical loading as belt and brake drum.
3) Before starting the engine preheating of air with the help of heater plugs.
4) Start the engine by cranking the crank shaft by using the self-motor with battery.
5) Load the engine mechanically by adding the weights in terms of 2, 4, 6, 8, and 10Kgs.
6) With conventional silencer take down the manometer reading for air consumption, engine RPM, and sound intensity from simultaneously emissions readings are also tabulated.
7) With aqua silencer take down the manometer reading for air consumption, engine RPM, and sound intensity from simultaneously emissions readings are also tabulated.
8) After completion of experiment to stop the engine by using stop lever

E. Emissions Test

Fig.8 Emission indicator

1) *Automotive Emission Analyzer:* It is a product developed by QRO tech co. ltd, Korean based company. This equipment is used to measure the gas emission density of an automobile enabling to diagnose the automobile status and its preventive maintenance so that it can provide a function to prevent air pollution in advance. It is a five-gas analyzer, which can detect five gases viz. CO, HC, CO_2, O_2 and NOx. It also give air - fuel ratio and air surplus rate. It gives accurate and instantaneous results especially when compared to the similar commercially available equipment. Its high measuring range and good resolution meets the requirement that a research work needs.

2) *Specifications Of Automotive Emission Analyzer*

Measuring Items	CO, HC, CO_2, O_2, Air surplus rate, AFR NOx.
Measuring Method	CO, HC, CO_2, : Non Dispersive Infra Red (NDIR) Method O_2, : Electrochemical cell

Measuring Items	Measuring Range	Resolution	Display
CO	0.00~9.99%	0.01%	4 digit 7 segment LED
CO_2	0.00~20%	0.1%	4 digit 7 segment LED
Air Surplus Rate,	0.00~2.00	0.001%	4 digit 7 segment LED
HC	0~9999 ppm	1 ppm	4 digit 7 segment LED
O_2	0.00~25.00%	0.01%	4 digit 7 segment LED
AFR	0.00~99.0	0.1	4 digit 7 segment LED

3) Smoke Meter (AVL 437 C)

This is supplied by M/s AVL India Pvt. Ltd, Gurgaon. It is used to measure the emission of air pollution substances from diesel vehicle. It is used to check and approve emissions of auto ignition combustion engines and measures the opacity and absorption of the engine. Emissions of nitrogen dioxides are either slightly reduced or slightly increased depending on the duty cycle or testing methods. Biodiesel decreases the solid carbon fraction of particulate matter (since the oxygen in the fuel enables more complete combustion to CO_2), eliminates the sulphur fraction (as there is no sulphur in the fuel), while the soluble or hydrogen fraction stays the same or is increased. The life-cycle production and use of biodiesel produces approximately 80% less carbon dioxide and almost 100% less sulphur dioxide compared to conventional diesel. Biodiesel gives a distinct emission benefit almost for all regulated and non-regulated pollutants when compared to conventional diesel fuel but emissions of NO_x appear to increase from biodiesel. NO_x increases with the increase in concentration of biodiesel in the mixture of biodiesel and petro-diesel. This increase in NO_x may be due to the high temperature generated in the fairly complete combustion process on account of adequate presence of oxygen in the fuel. This increase in NO_x emissions may be neutralized by the efficient use of NO_x control technologies, which fits better with almost nil sulphur biodiesel than conventional diesel containing sulphur.

F. Deposit Formation Test

1) *Engine Deposits:* Deposit or carbon deposit may be defined as heterogeneous mixture made up of carbon residue (ash), carbonaceous mixtures (soot) and an oxygenated resinous organic material that bind together as mixture. In an internal combustion engine, carbon deposit results form incomplete combustion of fuel as well as thermal cracking of lubricating oil contaminants. It can also be formed as a consequence of flame quenching at the combustion chamber wall. Many studies have proved that deposit formation increases with the increasing unsaturated bonds in the fuel molecular structure. It also increases with increasing boiling point of a hydrocarbon fuel. Carbon deposit is formed in the combustion chamber as on the cylinder and piston heads and valves. Some recent data indicate the deposit formed in the combustion chamber increases NO_x emissions. This is due to the low thermal conductivity of deposit, especially a non-volatile deposit like ash, which produces higher in-cylinder temperature, and thus makes higher NO_x emissions. It was also investigated that excess deposit can impair engine performance and to a certain extent would cause engine failure.

Volume 3 Issue V, May 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Fig 9. Emission Test Machine Incorporated To Exhaust Pipe


Fig 10. Closer View of Emission Test Unit Connected To Engine Exhaust Valve

VI. RESULTS&DISCUSSIONS

A. *Performance And Emission Characteristics Of Diesel Engine*

TYPE OF TEST: CONVENTIONAL SILENCER FUEL USED: DIESEL

EMISSIONS TABLE:

S.no	Load (KG)	Co_2 (g/km)	Co (V %)	Nox (ppm)	HC (g/km)	O_2 (g\km)	Speed (RPM)
1	2	0.6	0.08	0	10	19.46	1080
2	4	0.62	0.08	0	10	20.40	1050
3	6	0.68	0.08	0	10	20.60	1024
4	8	0.7	0.1	0	12	20.72	995
5	10	4.9	0.15	1	24	21.00	990

Table 1. Emission characteristics

Volume 3 Issue V, May 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

B. Performance And Emission Characteristics Of Diesel Engine

TYPE OF TEST: WITH AN AQUA SILENCER *FUEL USED: DIESEL*

EMISSIONS TABLE:

S.no	Load (KG)	Co_2 (g/km)	Co (v%)	Nox (ppm)	HC (g\km)	O_2 (g\km)	Speed (RPM)
1	2	0.11	0.03	0	6	20.96	1065
2	4	0.15	0.03	0	6	20.89	1040
3	6	0.20	0.034	0	6	20.79	1022
4	8	0.23	0.04	0	10	20.92	998
5	10	2.1	0.065	0.5	14	20.91	985

Table 2.Emission characteristics

C. Performance And Sound Characteristics Of Diesel Engine

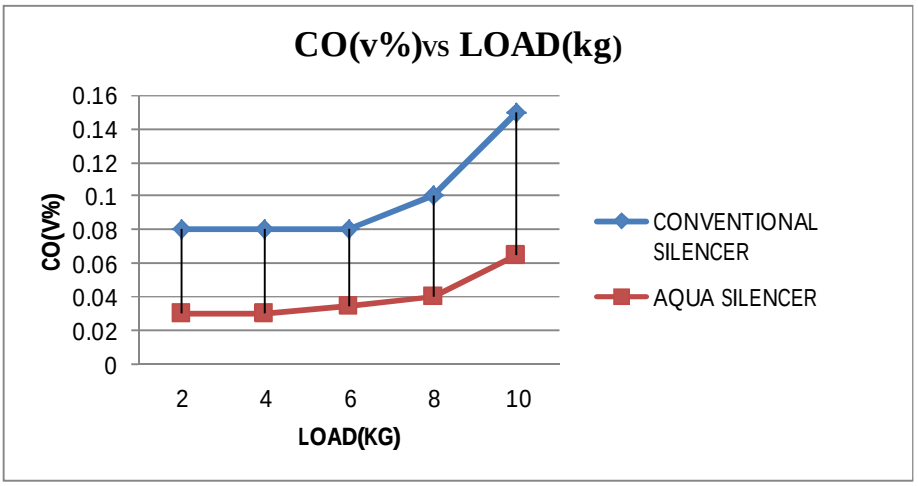
	With conventional silencer	**With an Aqua silencer**
Without any load	83db	75 db
50% load	84.5db	76.5 db
100% load	86 db	78 db

Table 3. Sound Characteristics

D. Graphs

EMISSION CHARECTERISTICS

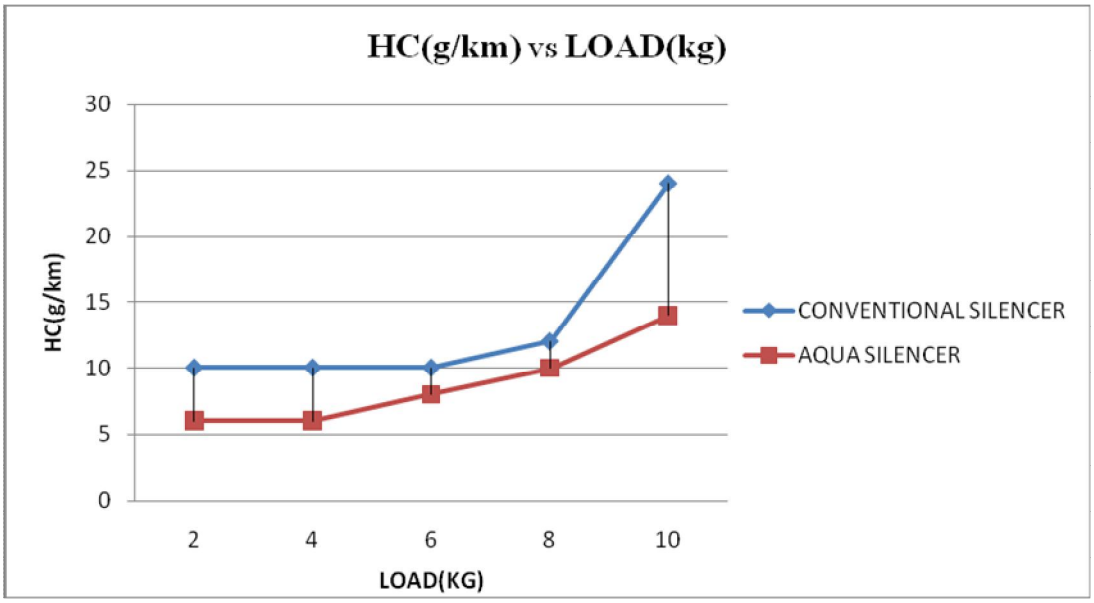
1) CO VS LOAD



Graph 1. (co vs load)

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.

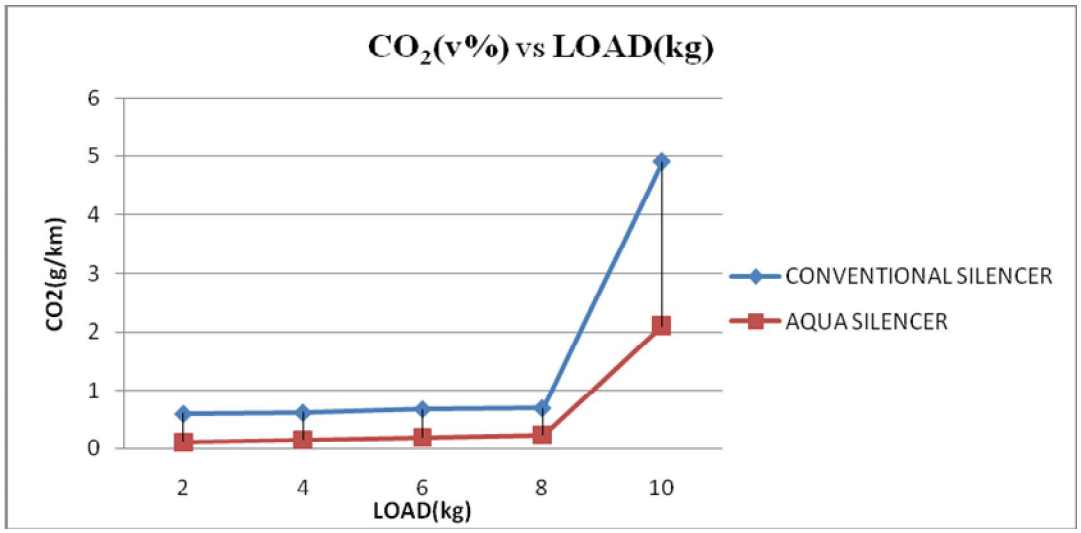
2) HC VS LOAD



Graph 2. (hc vs load)

From the above graph when the load increases the hydro carbons (HC) contaminations increases gradually by using conventional silencer. But in the aqua silencer the co contaminations decreases.

3) CO_2 VS LOAD



Graph 3.(co_2 vs load)

VII. CONCLUSION

According to our results an aqua silencer is more effective in the reduction of emission gases from the engine exhaust using perforated tube and charcoal. Using water as a medium the sound can be lowered and also by using activated charcoal in water exhaust emissions can be controlled to a greater level. The water contamination is found to be negligible in an aqua silencer.
It is smokeless and pollution free emission, eco-friendly and also it is economical. It can be also used both for two wheelers and four wheelers and also can be used in industries. From the obtained results the following conclusions:

A. It is found that the carbon monoxide (**co**) emission is reduced up to **53%** using an aqua silencer than that of before inculcating an aqua silencer.

B. And also, the unburned hydro carbon (**UBHC**) can be reduced 41**%,** CO_2 emission can be reduced upto 44% by using an aqua silencer than that of existing system.

C. The sound intensity is reduced upto 10 db by using aqua silencer than that of conventional silencer.

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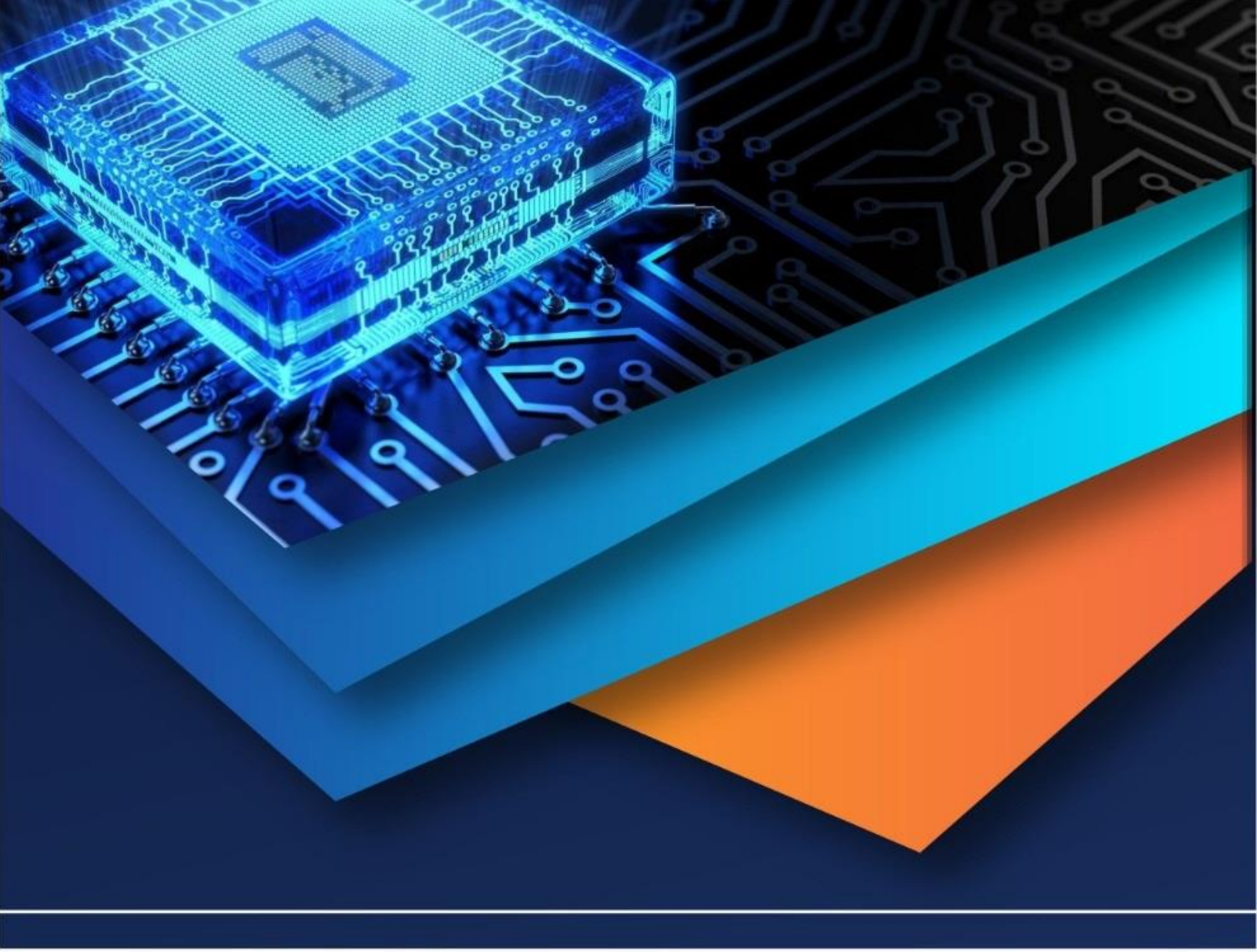

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