Performance Evaluation of Resonating Chamber Exhaust Silencer With Twin Chamber Inline VOC Emission Filter

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***Abstract*— One of the most obvious signs for many drivers is a deep or loud sound coming from their vehicle. Human desire for pollution free atmosphere, so need arises to control of air and noise pollution. The principal sources of noise in automotive engines are intake noise, radiator noise, combustion noise, exhaust noise, etc. Out of these, exhaust noise is predominant and it is to be controlled. Noise pollution affects human beings physiologically and psychologically. So the muffler is a part of the exhaust system of an automobile that plays a vital role. The objective of this study is to propose the design and manufacture the exhaust silencer which one reduces a large amount of noise level and back pressure of the engine along with pollution free gases. Experiment was carried out with the fabricated silencer. From experiment we get minimum noise 88 dba at no load condition and 98 dba at 100% throttle opening posion with maximum of 5100 rpm speed. The fabricated exhaust system was able to reduce noise. In this paper the arrangement of components, design and performance evaluation in terms of reduced noise are discussed .**

Index Terms- resonating chamber , in-line voc (volatile organic compound) emission filter.

INTRODUCTION

Muffler is a device used for decreasing the amoumt of noise (loud or unpleasant sound) emitted by exhaust of an internal combustion engine. The noise level greater than 80 dB which is injurious for human ears. Muffler should operate quietly in the background.When working muffler will funnel exhaust fumes outside and away from vehicle. If without using muffler we drive the vehicle, fumes emitted by engine exhaust could be stuck inside your vehicle this is most dangerous because exhaust fumes can be fatal over time. In modern vehicles, engine needs muffler to maintain the noise at optimum level along with necessary backpressure which helps to increase overall efficiency of engine and optimal speed. There would be unbearable amount of engine exhaust noise in our environment, if vehicles run without a muffler. Internal combustion engines plays a major part in the development of any country but with this engine, the problem of noise pollution arises. The main cause of this pollution is the exhaust noise. Noise is created because of the friction occuring inside the engines. As the engine rpm increases the pressure fluctuates and therefore the sound emitted is of a higher frequency. All noise emitted by an automobile does not come from the exhaust system. Intake noise, mechanical noise and vibration induced noise from the engine body and transmission are the contributors to vehicle noise emission . For an engine, mixture of air and fuel are burned into the combustion chamber, to run the vehicle. This process creates a number of emissions including carbon monoxide, nitrogen oxide, and nitrogen monoxide, which can be removed by the exhaust system. There is need to be arises that emitted gases from IC engine should enter into environment by reducing its toxic content. Mufflers and silencers are the same thing, but the former is a name more commonly found in North America.

I. METHODOLOGY

Proposed work aims to investigate the effect of reactive type resonator chamber muffler for IC engines. The proposed work is planned to be carried out in following distinct phases. Necessary data regarding project is collected, from available literature it is clear to find what others do on that topic and what should be done by us. After problem statement next point is design of particular muffler which is to be manufacture. In design part cost of product, durability, material to be used, durability etc. points are considered and then design is made. When design is completed next step is to manufacture the muffler. For that mtl. Procurement and process planning is required. In process planning time required for manufacturing muffler, mtl, cost per operation etc. points are to be into consideration. After manufacturing test and trial of model takes place with equipped set up and result analysis is done.

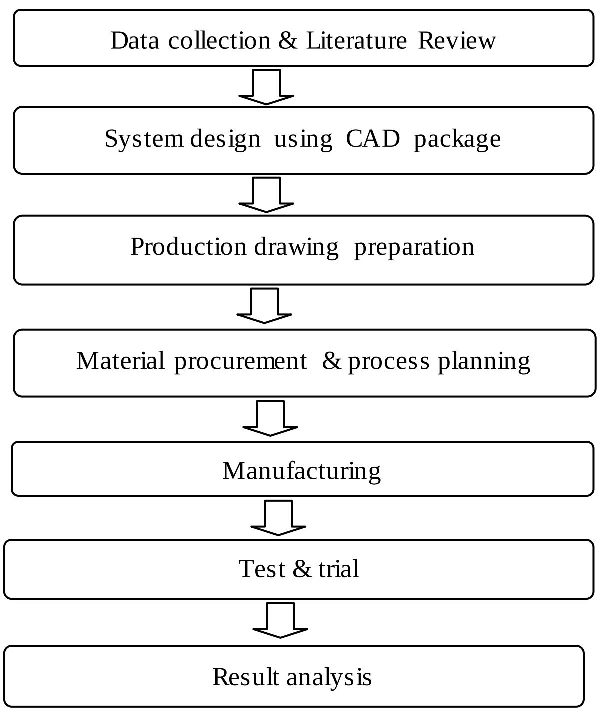

Fig. 1 Methodology for project work

II. LITERATURE REVIEW

The literature survey is the brief outline about the noise reduction technique used by silencer or muffler and to predict the performance of the muffler of the exhaust system.

Shubham Pal et. al.(3) designed a muffler in which the tunable resonator is used whose length can be varied by using a piston that can be set at different positions. At the different positions of resonator noise level is also measured to check the effect of variation of length of silencer that shows the smaller the resonator size better is insertion loss. and obtain the resonator attenuate low frequency noise which lies between 250 Hz to 500 Hz.

Jigar H chaudhri et.al. (7) studied different types of muffler and designing methods. After studying this methods and procedures for designing a muffler concluded that combination type of muffler is more efficient than reactive and absorptive mufflers.

Oke P.K. et. al.(8) presented an exhaust/silencer system, that is capable of reducing exhaust noise, was fabricated for use in a domestic generator. Experiment was carried out with the factory fitted silencer and the fabricated silencer. 8.06% of noise reduction was obtained with fabricated silencer compared to 4.16% obtained with the factory fitted silencer.

Erdem Özdemir et. al. (9) studied the length of each expansion chambers to understand the effects to the flow characteristics of a cross-flowed perforated and 3-expansion-chambered reactive muffler . It is observed that 30% of reduction in length of rear chamber did not make any difference on acoustic chracteristics with base muffler model. A decrease at the length of middle chamber prevents the cross flow and concluded that a greater pressure loss occur at this model.

Dirk Bosteels et. al.(10) presented new technologies, and this technologies will allow exhaust emissions from all engines, both on and non-road, to be lowered to the queer levels. This paper examines the state of emission control technologies currently available for all types of engine.

ZeynepParlar et. al.[18]have presented the perforated reactive mufflers which have an effective damping capability are specifically used for this purpose. New muffler is designed and analyzed with respect to both acoustics and back pressure and founds that an approximate error of 20% with numerical results compared to experimental results.

Based on the available literature it is found that reactive silencers, which are commonly used in automotive applications, towards the source reflects the sound waves back and prevents the sound waves from being transmitted along the pipe. The objective is to obtain a silencer with better acoustic performance in relation to its size or volume, as well as a reduction in the pressure to the flow of gases, i.e. while at the same time reducing the noise, it also minimizes the power it takes away from the engine of the vehicle. Therefore we are aiming at design a muffler which includes three principles i.e., reactive followed by absorptive type muffler and a side branch resonator.[5] The interesting part of the design is a muffler which can reduce noise as well as pollution.

III. BASIC REQUIREMENT OF MUFFLER DESIGN

The main cause for the pollution is the exhaust noise and the noise because of the friction occurring inside the engines, etc. Road traffic noise is occurred due to the blend of rolling noise which is arising from tyre road interaction and propulsion noise which is occurred due to comprising engine noise, exhaust system and intake noise etc.

The muffler is an acoustic sound proofing device designed to reduce the highly intensive sound of the sound pressure created by the engine exhaust. An unavoidable use of muffler is an increase of back pressure which decreases engine efficiency. For any vehicle following basic points are to be taken into consideration for mufflers efficient use.

i. Genaral Requirements

- Quiet
- Simple Maintenance
- Performance
- Compact Design
- Light Weight
- Easy Installation

ii. Specific Requirement

- Reduce the sound emissions
- Replaceable
- Doesn't increase backpressure
- Easy mounting within the budget
- Easy manufacturing

In addition to the above requirement with increase in number of vehicles running on the road, it has become an absolute necessity that there should be some additional arrangement to take care of the voc emissions that plays a decisive role in increasing respiratory diseases due to increase pollution by automotive vehicles :

IV. EXHAUST EMISSIONS

Emissions of air pollutants have been shown to have variety of negative effects on public health and the natural environment.

• Hydrocarbons

Hydrocarbon emissions occurs when fuel molecules in the engine partially burn or do not burn. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground-level ozone, a major component of smog. Ozone irritates the eyes, damages the lungs, and aggravates respiratory problems. A number of exhaust hydrocarbons are also toxic, with the potential to cause cancer,asthma,liver disease,lung disease.

• Nitrogen Oxides (Nox)

Under the high pressure and temperature conditions in an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides, collectively known as NOx. Nitrogen oxides, like hydrocarbons, are responsible to the formation of ozone. They also contribute to the formation of acid rain.

• Carbon Monoxide

Carbon monoxide (CO) is a product of incomplete combustion and occurs when carbon in the fuel is partially oxidized rather than fully oxidized to carbon dioxide (CO). Carbon monoxide reduces the flow of oxygen in the blood stream and is particularly dangerous to persons with heart disease.

• Carbon Dioxide

In recent years, the U.S. Environmental Protection Agency (EPA) has started to view carbon dioxide, a product of “perfect” combustion, as a pollution concern .Carbon dioxide does not directly impair human health, but it is a “greenhouse gas” that traps the earth’s heat and contributes to the potential for global warming.

These are the pollutants which are emitted by engine exhausts.

V. DESIGN CALCULATIONS

Specifications of the generator engine:

Make : Crompton Greaves

Model : IK-35

Engine Type : Two stroke Spark ignition engine

Diameter of Exhaust, d = 14 mm = 0.014 m

Bore 'diameter D : 35 mm = 0.035m

Piston Stroke length L : 35 mm = 0.035m

Capacity : 34 cc

Power out put : 1.2 BHP

Engine Speed N = 5500 rpm

Torque : 2.72 N-m @ 5000 rpm

Cooling : Air Cooled engine

Lubrication : Mist –via petrol

vi. Calculations Of Design Parameters

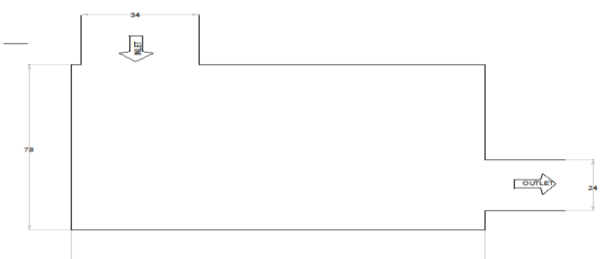

Fig. 2 characteristic dimensions of muffler

Working Volume, $V = \frac{\pi D^2 L}{4} = 33.65 \times 10^{-5}\ m^3$

Since the nominal diameters of the exhaust tubing and piping were to be made a little higher than that of the engine exhaust outlet (as stated above), then it necessary to calculate the area of the exhaust exit in order to determine the appropriate area of the exhaust tubing and piping of the fabricated silencer. Area of the exhaust exit $= \frac{\pi d^2 L}{4} = 1.54 \times 10^{-4}\ m^3$

Also, in order to determine the length of the fabricated silencer the length of the exhaust pipe, before the connection of the muffler, is required. This was determined from the relation (m. rehman, 2005): Length of the fabricated silencer $L = n\lambda/4$

Here from various experiments it has been found that the theoretical exhaust noise frequency is 200-500Hz.

Using the relation $\lambda = C/F$ getting wavelength as 0 .5 m and 0.6 m . As assumed frequency range i.e. at 200 and 500hz..By using relation $L = n\lambda/4$ we get muffler length as 4.9 to 17.7.

In second method by considering temperature of exhaust gases determining length of muffler. $0.5(49.03\sqrt{°R}) / 2\pi f \leq L \leq 2.6(49.03\sqrt{°R})/2\pi f$

where, $\sqrt{°R}$=absolute temperature of the exhaust gas

f = frequency of sound (Hz)

Let the temperature of exhaust is assumed to be 300º F or 759.7º R

Putting this value in above equation, one obtains,

$0.5(49.03\sqrt{759.7}) / 2\pi 270 \leq L \leq 2.6(49.03\sqrt{759.7}) / 2\pi 270$

$(0.4\ ft \leq L \leq 2.04\ ft)\ (4.8 inch \leq L \leq 24.48 inch)$

By considering both methods we select min value of lengh i.e. 4.8 inch.

According to ASHRAE Technical Committee 2.6

Considering supercritical grade following specifications are getting.

IL = 35 to 45 dBA

Body/Pipe = 3

Considering above specified values choose diameter of pipe 3inch.

VI. RESONATING CHAMBER EXHAUST SILENCER WITH TWIN CHAMBER INLINE VOC EMISSION FILTER.

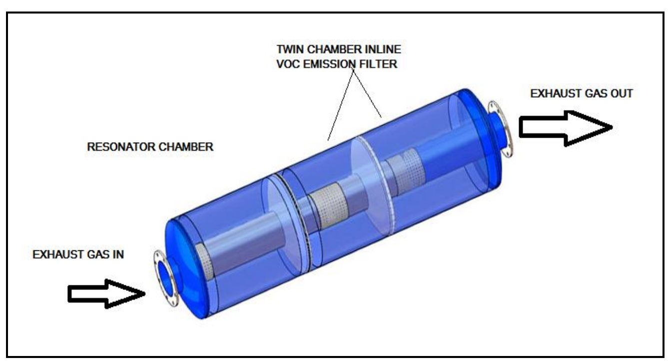

Fig. 3 Resonating Chamber Exhaust Silencer With Twin Chamber Inline VOC Emission Filter

Here the silencer is basically divided into two distinguished chambers namely :

a. Resonating Chamber :

Function of the resonating chamber is basically to reduce the noise , by use of thin layer brass sheet backed with glass wool to absorb the direct shock of the exhaust gas pulsating from the engine exhaust. This approach considerably reduces the length of the silencer as compared to the conventional perforated tube mufflers but also ensures that minimum back pressure will be encountered by the engine owing to angle of attack on the brass liner installed in the resonating chamber.

b. Twin Chamber Inline Voc Emission Filter :

The principal use of vapor phase activated carbon in the environmental field is for the removal of volatile organic compounds such as hydrocarbons, solvents, toxic gases and organic based odors. In addition, chemically impregnated activated carbons can be used to control certain inorganic pollutants such as hydrogen - sulfide, lead . Here in our case bamboo charcoal filter is infused in the twin chambers separated by perforated sheets. The actual arrangement of components in the resonating chamber exhaust silencer with twin chamber inline voc emission filter is as shown in figure below.

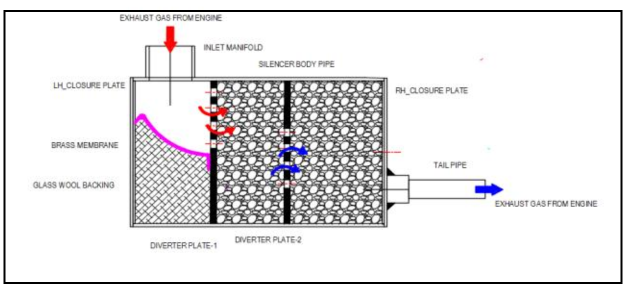

Fig. 4 Schematic of Resonating Chamber Exhaust Silencer With Twin Chamber Inline VOC Emission Filter.

The path of the exhaust gases is as shown in the figure above , the pulsating exhaust strikes the brass membrane and delivers its maximum energy to the membrane where in majority of noise is reduced due to shock absorbing tendency of membrane. The gas is further diverted by the diverter plate-1 into the first chamber of the voc emission filter that uses bamboo charcoal as filter material. The gases are then diverted into the second chamber through the diverter tube-2. The second stage of filteration takes place here and then the gases are discharged to the atmosphere via tail pipe.

VII EXPERIMENTAL SET-UP

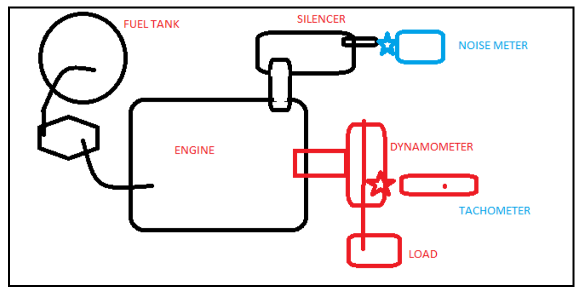

Fig. 5 Schematic of Test Rig.

The test rig. is self explanatory. In fuel tank petrol is used as working fluid. Fuel tank is attached to throttle valve. Main purpose of throttle valve is to regulate the supply of fuel. Exhaust end of this valve is connected to inlet of engine. At the engine exhaust silencer is attatched. By using noise meter we can measure the sound of exhaust of engine. Shaft is attached to engine on which rope dynamometer is mounted. Purpose of this arrangement is to apply load on rope and for taking the reading of speed vs. load. The rotating speed of dynamometer is measured by using tachometer.

Procedure For Trial

1. The engine is started .
2. The throttle is taken to full opening position to generate maximum rpm @no load condition.
3. Speed at engine output pulley is measured.
4. The noise at the silencer exhaust is measured.
5. The throttle is closed by 10% (i.e. 90 % throttle opening is maintained) approximately

6. Speed at engine output pulley is measured.
7. The noise at the silencer exhaust is measured.
8. Similar set of readings are repeated and tabulated in result table below.

Fig. 6 Experimental Set Up Of Silencer

Following instruments are used for measurement of output data.

i. Measurement of backpressure:

Exhaust backpressure can cause a variety of problems.

Fig. 5 Pressure Gauge

Anything that restrics exhaust flow will create excessive backpressure in the exhaust system. By using pressure gauge with a scale that reads zero to 15 psi, or zero to 100 kpa or higher.backpressure is measured . A small hole is drilled into exhaust pipe just ahead of convertor and attatching a fitting of pressure gauge .It is easy method to measure backpressure.but here we have to plug the hole afterwards with a self tapping screw or a small spot weld.

ii. Digital Tachometer : This is used to measure engine speed at various throttle openings. A tachometer is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine.

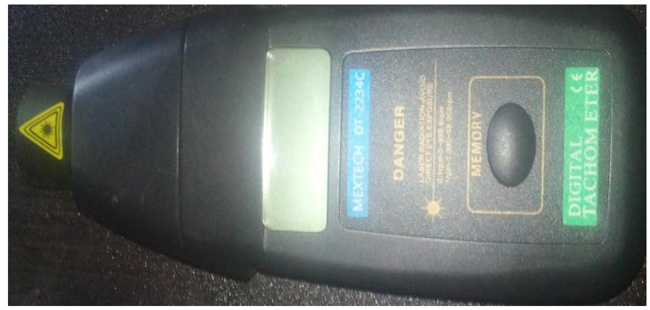

Fig. 7 Digital Tachometer

The device usually displays the revolutions per minute(RPM) on a calibrated analogue dial, but digital displays are increasingly common.

iii. Digital Noise Meter : This is used to measure noise at the exhaust of silencer at various throttle openings. A sound level meter is used for acoustic measurements. It is commonly a hand held instrument with a microphone .

Fig.7 Digital Noise Meter

The diaphragm of the microphone responds to change in air pressure caused by sound waves. This movement of diaphragm ,i.e. the sound pressure deviation (pascal pa), is converted into an electrical signal (volt V).

VIII. RESULTS AND DISCUSSIONS

Six runs of experiment were carried out and data on noise level and fuel consumption were recorded at 5 min interval.

Before the commencement of each run of experiment, the model was test-run until it went off so as to ensure that the fuel in the engine carburetor has been completely drained. This was done to obtain the actual fuel consumption during the experiment.

During each run of experiment, noise meter is used to measure noise levels.

Experimental results using the fabricated silensor.

Sr .No	% Throttle Opening	Speed (RPM)	Noise (DBA)
1	100	5100	98
2	90	4540	96
3	80	3850	93
4	70	3210	91
5	60	2980	89
6	50	2560	88

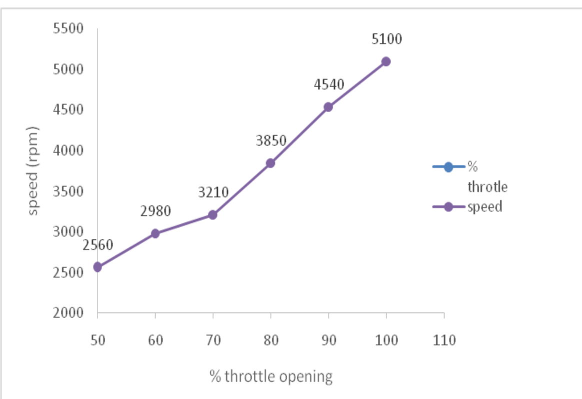

Fig. 8 Graph Of Engine Speed Vs Percentage Throttle Opening

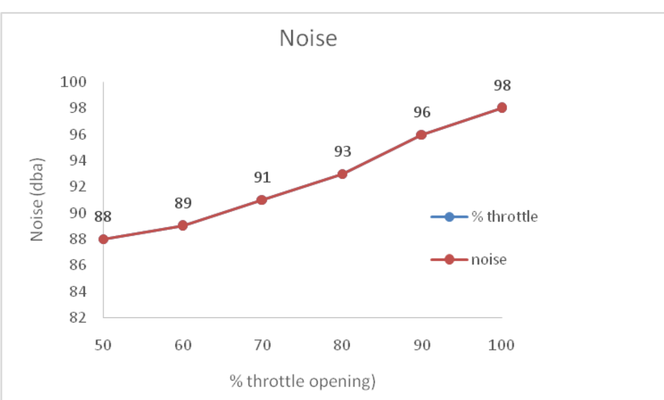

Fig. 9 Graph Of Exhaust Noise Vs Percentage Throttle Opening

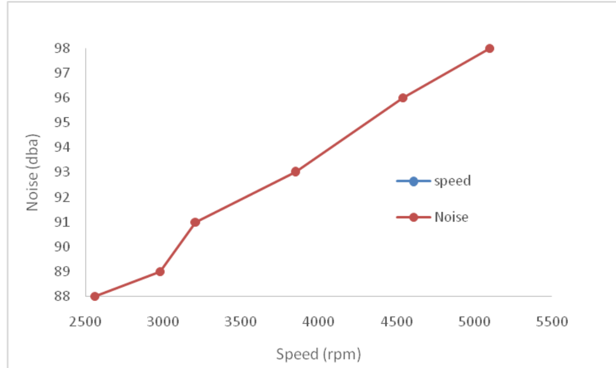

Fig. 10 Graph Of Exhaust Noise Vs Engine Speed at No Load Condition

The performance based on noise level and fuel consumption (throttle opening) using fabricated silencers is shown by figures 8,9 and 10 respectively.

Fig. 8 shows graph of speed vs. % throttle opening.It shows that with miimum value i.e. 50% throttle opening we get minimum speed i.e. 2560 rpm and with maximum value i.e. 100% throttle opening we get maximum speed i.e. 5100 rpm at no load condition. As speed of engine increases means to move piston cylinder arrangement at higher speed energy in form of fuel is more it requires more fuel .

Fig. 9 shows that the graph of exhaust noise vs. % throttle opening. It shows that with miimum value i.e. 50% throttle opening we get minimum exhaust noise i.e. 88 dba and with maximum value i.e. 100% throttle opening we get maximum noise i.e. 98 dba at no load condition. As speed of engine increases means to move piston-cylinder arrangement at higher speed energy in form of fuel is more and due to more fuel consumption exhaust gases goes out of system is more which produces high thrust and sound .

Fig. 10 shows that the graph of exhaust noise vs. engine speed. It shows that with miimum value i.e.at 2560rpm we get minimum exhaust noise i.e. 88 dba and with maximum value i.e.at 5100rpm we get maximum noise i.e. 98 dba at no load condition. As speed of engine increases means to move piston-cylinder arrangement at higher speed energy in form of fuel is more and due to higher speed there is friction takes place which considerably increases noise.

IX. CONCLUSION

A muffler should be designed to meet all the functional requirements namely minimum backpressure, be durable, produce desired sound , be cost effective. The interesting events of the design is designing a muffler which can reduce noise as well as pollution. from experient it can be seen that noise is directly proportional to engine speed and throttle opening. Depending on operating engine speed and maximum and minimum speeds individual muffler can be designed.In which resonating chamber reduces noise and twin chamber filter removes toxic gases. The minimum noise level obtained with fabricated muffler was found to be 88 dba at no load condition.Their will be many possible muffler design solutions are available for particular situation but design is proven itself only by its performance.

X. FUTURE SCOPE OF PROJECT

Further test are awaited with application of load on the engine shaft and thus the following characteristics will be plotted.

a) Effect of change in load on engine output speed.

b) Effect of change in load on exhaust noise.

c) Effect of change in load on exhaust emission of % free carbon.

d) Effect of change in load on exhaust emission of %carbon monoxide.

e) Effect of change in load on exhaust emission of % unburnt hydrocarbons.

XI. ACKNOWLEDGEMENT

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