Experimental Investigation on Single Cylinder Four Stroke Engine Using Aqua-Silencer System

Vishwambhar D. Chavan[1], Tejas V. Desai[2], Prathamesh R. Gidaye[3], Tushar V. Surve[4]
Mechanical Engineering Department
Rajendra Mane College Of Engg. & Technology

Abstract- *Enhanced Living Standard have led to increase in number of Vehicles. Increasing Number of Vehicles and hence drastically increasing pollution is major issue in front of developing country like India. With reference to Euro standards for emission control we have also formulated emission standards named asBharat stage (BS) Emission Norm. We have accepted BS IV Standard but majority of the vehicle which are running on road are manufactured under BS III Standards. This is contradictory to motive of accepting BS IV emission standards.*

Hence we are searching for a way out to meet BS IV standards with BS III vehicles with Minor alteration. Considering Indian Market condition this method should be cost effective, at the same time it should not hamper engine performance.

There are two possible ways, either we can restrict formation of this harmful pollutants or we can eliminate them after formation. In this paper we are focusing on the second way that is, how we can eliminate the pollutants after combustion. This paper contents combustion phenomenon in IC engine, Direct and Indirect Pollution from vehicle, Ways to eliminate pollutants after combustion and general methodology to achieve results using aqua-silencer. Result and outcomes will be discussed elsewhere.

Keywords- Aqua-silencer, Combustion Phenomenon, Emission Control,Noise control.

I. INTRODUCTION

Now a days, Internal Combustion Engine plays major role in transportation. Number of two wheelers has increased drastically in this decade, hence scope of this paper is confined to single cylinder four stroke engine. This engine is widely used in motorcycles running on the road. Petrol and Diesel are the Principal Fuel used for Internal Combustion Engine. Vehicles running on the road are among major sources of air pollutants.

To get useful power output combustion of fuel is necessary in IC Engine, but this generates byproducts like CO_2,CO, H_2O, NO_x,SO_2, Particulates, etc. Among this HC and CO2 are responsible for global warming, NOx may cause various health hazards and contribute to Global Warming and other major issues like Acid Rain.

To reduce pollution, government have set some regulations with reference to EURO standards for Emission Control. Currently we have accepted BS IV Standards all over the India. Actually majority of the vehicles running on the road are manufactured under BS III Standards. This is contradictory to main motive behind accepting BS IV Standards for emission Control.

This creates necessity of Low emission IC Engines or Methods to reduce IC Engine Emissions. We can follow two ways for reduction of amount of the pollutants – either we can restrict formation of the pollutants or eliminate pollutants after formation.

To study how pollution can be reduced, we should know process of formation of the pollutants, favorable conditions for the formation of this pollutants, so that we can restrict such a condition and in turn the Pollution.

In this paper we will focus on methods to eliminate pollutants after formation and we will see Aqua- silencer method to reduce Emission of NOx in detail. In the aqua-silencer system emission is controlled by activated charcoal layer around perforated tube and lime water. The charcoal layer having high capacity to absorb emission gases from engine. These type charcoal layer with lime water reacts chemically with emission gases and change the chemical structure of emission gases. Other advantage of aqua-silencer is that, it can also suppress engine noise to sufficient low level.

II. COMBUSTION IN IC ENGINE

In Internal Combustion Engine chemical energy of the fuel is converted to Thermal energy during combustion and this thermal energy is further converted to mechanical energy available at the output shaft. Conventional IC Engine fuels are mixtures of different hydrocarbons. Combustion product includes $CO_2$and H_2O mainly.

Theoretical/Complete Combustion Reaction-

Byproducts Mainly Contains $CO_2$and H_2O. For example if we consider Octane -

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$

Incomplete combustion of Hydrocarbons –

Incomplete combustion of hydrocarbon may lead to generation of CO (Carbon Monoxide) or Carbon particles.

$$2C_8H_{18} + 9O_2 \rightarrow 16C + 18H_2O$$
$$2C_8H_{18} + 17O_2 \rightarrow 16CO + 18H_2O$$

Normal Combustion Process considering involvement of Nitrogen -

At Lower Combustion Temperature Nitrogen will remain Inert. As in following equation-

$$C_8H_{18} + 12.5(O_2 + 3.76N_2) \rightarrow 8(CO_2) + 9(H_2O) + 47N_2$$

At Higher Combustion Temperature Nitrogen will Get Oxides and will form NO_x. Rate of production of NO_x

Will go on increasing with the temperature.

$$C_8H_{18} + \left(12.5 + \frac{x}{2}\right)O_2 + xNO \rightarrow 8CO_2 + 9H_2O + xNO_2$$

III. SI ENGINE EMISSIONS

SI engine emissions can be divided into three categories as – Evaporative emissions, Crank Case Emission and Exhaust Emission.

Evaporative Emission

This are due to evaporation of fuel. This emissions can cause even when vehicle is at rest or even during refueling. This emissions will contain unburnt hydrocarbons. This losses increases with surrounding temperature.

Crankcase Emission

This will mainly contain blow by products accumulated in crankcase. This will comprise of unburnt hydrocarbons and other combustion byproducts.

Exhaust Emission

This is major source of emission from IC Engine. In SI engine during normal starting or col starting richer mixture is provided to engine. As evaporation rate is lower most of the fuel part will remain unburnt and CO and HC will appear in exhaust. Generally in normal operating range SI Engine is supplied with stoichiometric or slightly richer mixture. This will lead to higher peak temperature and hence NO_x is generated.

IV. POLLUTANTS FROM IC ENGNE - FORMATION AND AFFECTS

Major pollutants from IC engine include – CO, HC and NO_x, CO_2,etc.

Carbon Monoxide:

Carbon Monoxide is colourless poisonous gas. Carbon Monoxide is intermediate product of Combustion of Carbon. If sufficient oxygen is not available for the complete combustion of carbon into CO_2, it will result in formation of CO. Second Reason for Formation of CO is dissociation. At high temperature Products formed are unstable and before establishing equilibrium following dissociation reaction will take place –

$$H_2O + O_2 \leftrightarrow 2(1-x)H_2O + 2xH_2 + xO_2$$

x is the fraction of the H_2O dissociated,

$$CO_2 \leftrightarrow (1-y)CO_2 + yCO + \frac{y}{2}O_2$$

Y is the fraction of the CO_2 dissociated,

As this burnt gases cools down to exhaust temperature most of the CO reacts with Oxygen forming CO_2. However some part of the CO will still remain in the exhaust.

Hydrocarbons:

This are emitted due to Direct Evaporation or due to incomplete Combustion of fuel. HC emission is directly related to Combustion chamber design and Operating variable like Air-Fuel Ratio. Direct evaporative loss is also a major reason behind Hydrocarbon Emission

Oxides of Nitrogen (NO_x)

Higher Cylinder Temperature during fuel rich combustion is main reason for the formation of the NO_x. Mainly NO_xwill include NO, NO_2. Many other oxides like N_2O_3, N_2O_4 andN_2O_4 are also possible. Following reaction will occur during formation of NO_x-

$$N_2 + O_2 \rightarrow 2NO$$
$$N_2 + 2H_2O \rightarrow 2NO + 2H_2$$

V. METHODS TO ELIMINATE POLLUTNTS AFTER COMBUSTION

As mentioned earlier there are two methods of reducing pollutants from Exhaust gases – Restrict Production of Pollutants or eliminate them after production. In this paper we will focus on second alternative of eliminating pollutants after combustion. There are various methods used as –

Non-selective Catalytic Reduction:

This technique is used since last 15 years to control NO_x. Researchers have claimed that 98% reduction s possible with this arrangement. But main condition to be fulfill to get maximum effectiveness is that, Engine should work near its stoichiometric range. In leaner condition effectiveness decreases to great extent.

Selective Catalytic Reduction:

This technique was developed to overcome shortfall in NSCR that is working in Leaner condition. In Lean combustion amount of oxygen available at exhaust is comparatively high. This reduces effectiveness of NSCR drastically. This issue can be resolved by use of reducing agent like Ammonia or Urea, etc. this can reduce NO_xemission by up to 90%.

Oxidation Catalyst:

This catalyst facilitates oxidation of unburnt HC and CO to greater extent. This technique is mostly used for reducing CO and HC from exhaust gas. This technique can reduce CO emission by up to 98% and HC emission up to 90%.

For this experimental investigation we will use Aqua-Silencer with Two wheeler (Single Cylinder Four Stroke SI Engine). This technique uses perforated tube made up of activated material like (Activated charcoal) and Lime water Solution to reduce Pollutants present in Exhaust. This gives additional benefit of noise suppression to greater extent compared to conventional exhaust system. More over this system can be easily fitted within outer shell of conventional exhaust.

VI. PROPOSED EXPERIMENTAL SETUP

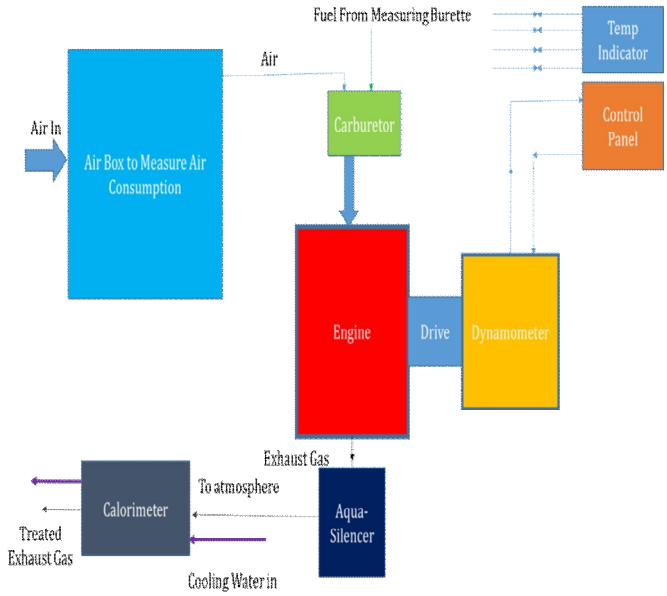

Fig: Proposed Experimental setup for Aqua-silencer

Experimental Set up will be consist of –

- Engine – Selected Engine will be true representative of its class
- Air Box fitted with Manometer – To measure Consumption of Air
- Fuel Burette –To measure Consumption of Fuel
- Dynamometer – To Measure Break Torque and in turn Power Output of Engine
- Aqua-Silencer Unit
- Calorimeter – To calculate Heat lost in Exhaust
- Temperature Indicator – Digital Temperature Indicator to Measure Temperature of Different Engine Parts
- Control Panel – To control working parameters of the engine.

VII. SPECIFICATION OF ENGINE

Table1. Engine Specification

Engine type	Air-cooled 4-stroke
Bore× stroke	56 × 60.7 mm
Displacement	149 CC
Max.Power	14PS (2.1 KW)@8000 rpm
Max Torque	13.4 Nm @ 6000 rpm
Compression ratio	8.5:1
Fuel Induction	Carburetor
Oil capacity	1 lit
Fuel tank capacity	15 liter
Cubic capacity	110CC
Number of cylinder	1

VIII. PROPOSED METHODOLOGY FOR THE INVESTIGATION

Case I: with conventional silencer

Initially Engine will be tested for Exhaust Emissions and Performance. For Exhaust Emission we are taking PUC test of the engine at different operating temperature (Idling, Normal Running, Crussing Range, High Load Condition, etc.) To analyze Performance of Engine We will carry out number of test on the engine such as Speed Test, Load Test, Heat Balance Sheet, PUC Test, Willian's Line test. This data will be useful later for comparison with data using Aqua-silencer setup.

Case II: With Aqua- Silencer

As Previous all required test will be carried out and data will be collected and compared with the data available from previous experimentation with case I. From this comparison we can draw conclusion regarding benefits or limitations of Aqua-silencer.

- **Load test**

Load test is carried out to test behavior of the engine under varying load conditions. During this test speed of the engine is kept constant and load on the engine is varied. We will measure fuel consumption, Exhaust Emissions and Out power. Here we can predict working effectiveness of aqua-silencer at various load conditions if speed is kept constant.

- **Speed Test**

Speed test is carried out to test behavior of the engine under varying Speed conditions. During this test Load on the engine is kept constant and Speed on the engine is varied. We will measure fuel consumption, Exhaust Emissions and Out power. Here we can predict working effectiveness of aqua-silencer at various Speed conditions if Load is kept constant.

- **Heat Balance Sheet**

Heat Energy Supplied during Combustion, Heat dissipated to the surrounding, Heat loss in Exhaust gases, Heat equivalent of Output power. This test will give measure inputs like what is cylinder temperature and exhaust temperature which are playing major role in the formation of Polluting components. At the same time we can get thermal performance of the engine.

- **PUC**

Initially PUC Test of the Engine specified above is carried for idling condition. This test will be core of the experimentation as effectiveness of the system can be directly analyzed from the output data of this test.

- **Willian's Line Test**

With this test we can either calculate friction power or indicated power of the engine. From this data we can calculate Indicated thermal efficiency of the engine.

IX. EXPECTED RESULT

After fitting aqua-silencer setup to the engine

a. Engine Exhaust emission will be clean (free from Pollutants specified earlier)
b. There should not be any variation in Engine Performance or variation if any present, it should be within acceptable range.
c. System will be compatible with other vehicles from same range or class and it will be cost effective.
d. Engine Noise will be suppressed to greater extent compared to conventional exhaust system.

X. VALIDATION OF THE RESULT

According to Capacity and Maximum Vehicle Speed 2 Wheelers are classified under various classes as follows-

Table 2. Class of Two Wheelers

Class	Definition of Class
Class 1	50 cm^3<Engine Capacity < 150 cm^3, Vmax ≤ 50 km/hr or Engine capacity < 150 cm³ and 50 km/h < Vmax < 100 km/h
Class 2.1	Engine capacity < 150 cm³ and 100 km/h <Vmax< 115 km/h or Engine capacity >150 cm³ and Vmax< 115 km/h
Class 2.2	115 km/h < Vmax< 130 km/h
Class 3.1	130 km/h < Vmax< 140 km/h
Class 3.2	Vmax > 140 km/h
Source – ARAI (Indian Emissions Regulations – Limits, Regulation, Measurements of Exhaust Emission and Calculation of Fuel Consumption)	

From this class 1 and 2.1 motorcycles are common in India (Considering current market sell)

We are having emission standard set under BS III , BS IV and BS VI as given bellow. We can compare actual experimental data with standard regulations provided to comment on effectiveness of the system.

Table 3. Emission Regulations for Class 1 or 2.1

Bharat Standard	Pollutants	Specification (mg/km)
BS VI	CO	1000
	HC	100
	NO_x	60
BS IV	CO	1403
	HC	790
	NO_x	390
BS III	CO	1870
	HC	1080 (HC and NO_x combined)
	NO_x	
Source – ARAI (Indian Emissions Regulations – Limits, Regulation, Measurements of Exhaust Emission and Calculation of Fuel Consumption)		

XI. CONCLUSION

Pollution is major issue now a days and steps should be taken in order to reduce the pollution. Transportation is major sector responsible for the pollution. At Lower Temperature Nitrogen will not take part in combustion. High combustion chamber temperature is main reason behind formation of the NO_x. Lean Combustion, cold starting, Low Speed Operation may lead to emission of the Co and Unburnt HC. There are various methods used from last 10 to 15 years to eliminate pollutants after formation in exhaust system. Aqua- silencer can become a better alternative for the costly exhaust systems used now a days. Considering Indian Market, this new system should be cost effective and should fit in current vehicles with minor modification in overall structure of the vehicle.

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