ISSN:2348-2079

Volume-6 Issue-1

International Journal of Intellectual Advancements and Research in Engineering Computations

Experimental analysis of secondary air injection in lower CC engine

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Abstract - The effect of secondary air injection (SAI) on exhaust hydrocarbon (HC) and carbon monoxide (CO) emission has been investigated in a spark- ignition (SI) single cylinder engine operating at steady–state condition. An experimental study was performed to develop a more fundamental understanding of the effects of SAI on exhaust gas emissions and catalyst light-off characteristics in a modern SI engine. The effects of several design and operating parameters of secondary air injection (SAI) such as secondary air flow rate and air injection location were investigated to understand the mixing and heat loss. Time-resolved HC and CO concentrations were tracked from the cylinder head exhaust to the catalytic converter outlet. Oxidation characteristics of HC and CO are monitored with a Fast response CO and HC emission analyzer and exhaust gas temperatures with thermocouples. Effects of exhaust air-fuel ratio (A/F), location of SAI, and engine-A/F have been investigated. Results prove that HC and CO reduction worth increases as the location of SAI is closer to the exhaust.

Index words - Secondary air injection (SAI), Emission, Hydrocarbon, Carbon monoxide.

I.INTRODUCTION

Atpresent, automobiles are considered as one the major source of emissions of various pollutants such as hydrocarbon (HC), carbon monoxide (CO) and nitrous oxide (NOx). Unburned gases from combustion chamber produce these kinds of toxic pollutants. To control these emissions, government implements stringent emission control strategies. In order to achieve the emission norms, a vast research is going on in automobile industries trying out of new techniques to achieve the emission norms. Secondary air injection (SAI) system is one of the best methodsto burn the unburned gases such as hydrocarbon (HC) and carbon monoxide (CO).

II. LITERATURESURVEY

1. Georgina Santos et al [7]analyzed that carbon monoxide, carbon dioxide, hydrocarbon, particulate matters are the major things which cause emission severe. In-Cylinder solutions some are recommended to reduce emissions. Such as Secondary Air Injection (SAI), Exhaust Gas Recirculation (EGR), Low Temperature Combustion (LTC), Homogeneous Charge Compression Ignition (HCCI), Premixed Charge Compression Ignition (PCCI).

2. Hyun Sung Simet al[10] investigated about the effect of Secondary air injection (SAI) on exhaust hydrocarbon (HC) emission in SI engine. Characteristics of pollutants observed with FID analyzer and exhaust gas temperature with thermocouples. The results what they found shows that HC reduction rate increases as the location of SAI is closer to exhaust valve for both Synchronized and continuous SAI's.

3. Kenneth P. Coffin et al [15]took a single cylinder of an automotive V-8 engine was fitted with an electronically timed system for the pulsed injection of secondary air. A straight- tube exhaust minimized any mixing other than that produced by secondary-air pulsing. The device was operated over a range of engine loads and speeds. Effects attributable to secondary-air pulsing were found increased.

4. Pritchard et al [20]discussed that the effects of secondary air on the exhaust oxidation of particulate matters (PM) have been assessed in a direct-injection-spark-ignition engine under fuel rich fast idle condition (1200 rpm; 2 bar NIMEP). Substantial oxidation of the unburned feed gas species (CO and HC) and they found that there is a significant reduction of both the particulate number (up to ~80%) and volume (up to ~90%) has been observed.

5. P. Brijesh et al [21]reviewed that CO2, CO, HC, NOx, SO2 and PM comes out as harmful products during incomplete combustion from internal combustion (IC) engines. It is required to modify existing engine technologies and to develop a better after-treatment system to achieve the upcoming emission norms. Since Exhaust gas recirculation (EGR) technology has been utilized previously to reduce NOx. Even though it is quite successful for small engines, problem persists with large bore engines and with high rate of EGR. Modern combustion techniques such as low temperature combustion (LTC), secondary air injection (SAI), homogeneous charge compression ignition (HCCI),

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premixed charge compression ignition (PCCI) etc. would be helpful for reducing the exhaust emissions and improving the engine performance.

III. DESIGN AND ANALYSIS

Position of secondary air injection (SAI) plays a major role in reducing the emissions. A detailed study made to freeze the position and profile of secondary air injection at engine cylinder block (Fig.1). L-Section profile has been chosen to reduce pressure and increase velocity of air after certain point of time.Pressure and velocity of air flow hasbeen simulated through CFD software tool for the respective profile. Results are plotted in Fig.2.

Technical specification of the engine isprovided in below table (Table.1)

Table.1. Technical specification of the engine

DESCRIPTION	SPECIFICATION
Engine type	Single cylinder Air cooled Engine
Fuel type	Petrol
Displacement (CC)	110CC
Bore	53.5mm
Stroke	48.8mm
Maximum Power	9.5bhp
Maximum Torque	9.4Nm

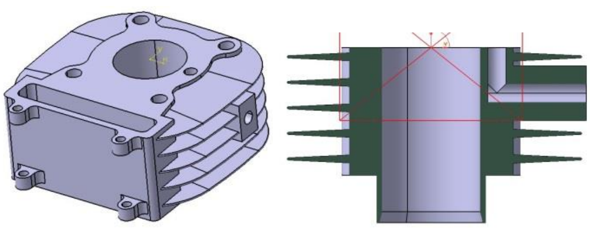
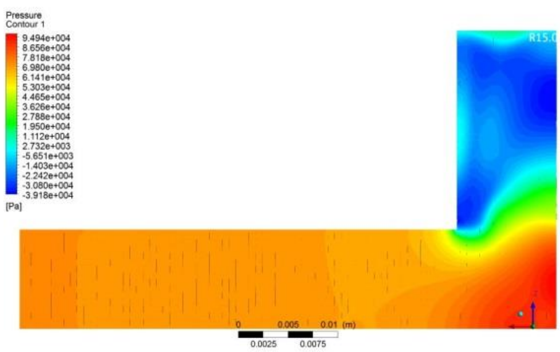


Fig.1: 3D Model of SAI profile in cylinder block



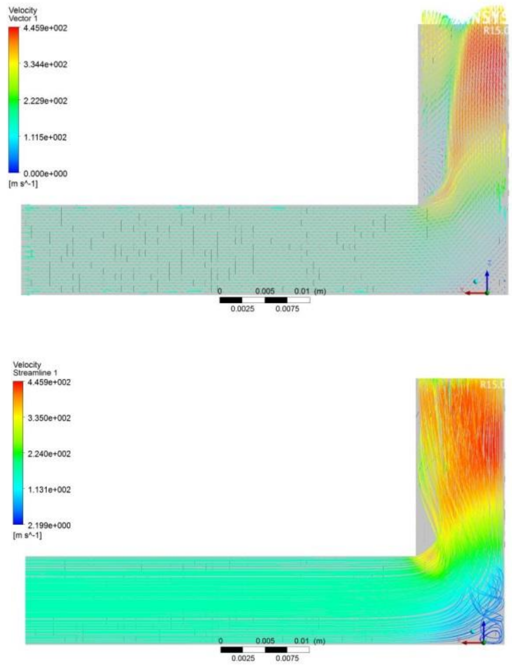


Fig.2: CFD results of SAI profile

CFD results clearly explains that the air flow decreases in pressure and increases in velocity at profile outlet.

IV. EXPERIMENTAL SETUP

A modern air cooled petrol engine of 110CC used in this work. This experimental setup includes the following parameters i) Engine (with Secondary Air Injection setup) and dynamometer, ii) Exhaust system setup,iii)Engine subsystem and instrumentation, iv) Engine control system, v) Data acquisition system, vi) In Cylinder pressure measurement, vii) Fast response CO and HC emission analyzer.

Fig.3. explains about the block diagram of secondary air injection system used in this experiment.

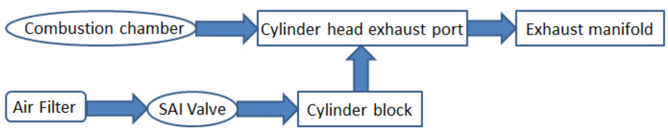


Fig.3: Block diagram of SAI system

Considering the above stated design and proven CFD results, prototype of cylinder block made and testing has been carried out. Prototype of cylinder block is shown in Fig.4.

Fig.4: Cylinder block prototype with SAI

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To burn the unburned gases from the combustion chamber, fresh secondary air is passed into the cylinder head exhaust port through a separate path from air filter. SAI valve has been used to control the pressure of air to be induced into cylinder block.Once the fresh air at ideal air speed enters into the cylinder head exhaust port, the unburned gases from combustion chamber such as hydrocarbon (HC) and carbon monoxide (CO) reacts with oxygen (O_2) to form water (H_2O) and carbondioxide (CO_2) respectively.

Balancing equation for the same has been shown below.

Hydrocarbon reacts with Oxygen:

$$4\ HC + 5\ O_2 = 4\ CO_2 + 2\ H_2O$$

Carbon monoxide reacts with Oxygen:

$$2\ CO(g) + O_2(g) = 2\ CO_2(g)$$

Hence by using Secondary air injection system in enigne exhaust system, there would be a significant reduction in Carbon monoxide and hydrocarbons.

V. RESULTS AND DISCUSSION

Exhaust emission such as hydrocarbon (HC), carbon monoxide (CO) and nitrous oxide (NOx) have been measured at two various conditions. One is without secondary airinjection system and the second is with secondary air injection. Comparisons have been made between both results to evaluate the reduction of HC, CO and NOx emissions. Fig.5 shows the HC emission results of both with and with secondary air injection system.

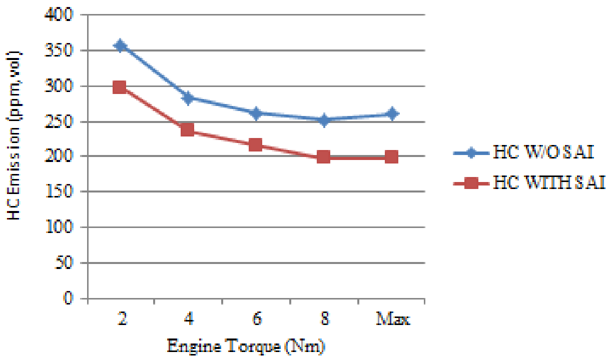

Fig.5. HC Emission result plot

Table.2. HC Emission result (ppm,vol)

Engine Torque (Nm)	HC W/O SAI	HC With SAI
2	358	298
4	283	237
6	262	216
8	252	198
Max	260	198

Fig.5 explains that the values of HC gases decreased by introducing secondary air injection system in engine exhaust. HC emission drops approximately 20% fromexisting emission. Dilution of HC gases decreased by increasing secondary air injection air flow into the exhaustmanifold. Table.2. shows the values obtained in HC emission tests of with and without SAI.

Fig.6 shows the CO emission results of both with and with secondary air injection system.

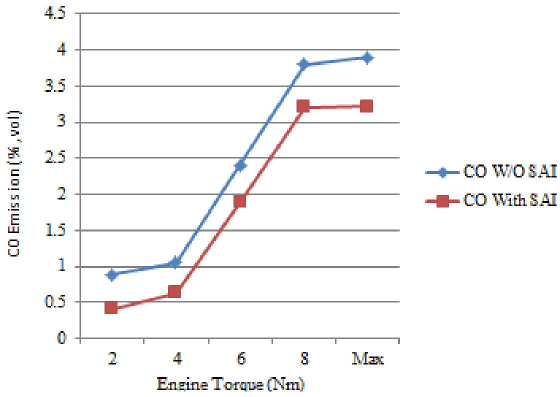

Fig.6. CO Emission result plot

Table.3. CO Emission result (%,vol)

Engine Torque (Nm)	CO W/O SAI	CO With SAI
2	0.88	0.41
4	1.05	0.63
6	2.4	1.88
8	3.8	3.2
Max	3.9	3.22

Fig.6 explains that the values of CO gases decreases by approximately 50% of emission at lower engine torque. Gradually by increasing engine torque CO emission also increases. Since secondary air injection controls around 30% of CO emission from the existing emission values at maximum torque.Table.3. shows the values obtained in CO emission tests of with and without SAI.

Fig.7 shows the NOx emission results of both with and with secondary air injection system.

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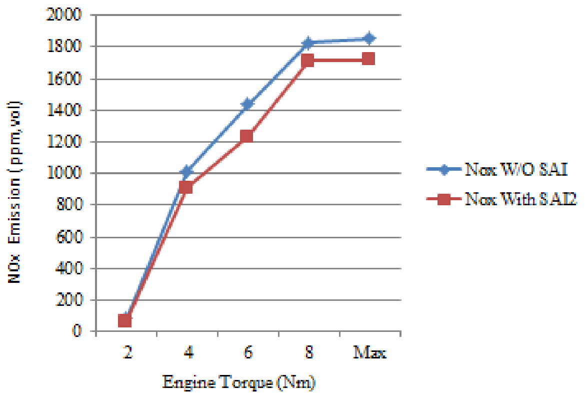

Fig.7. NOx Emission result plot

Table.4. Nox Emission result (ppm,vol)

Engine Torque (Nm)	NOx W/O SAI	NOx With SAI
2	84	66
4	1015	912
6	1435	1232
8	1826	1715
Max	1856	1720

NOx gases increases by increasing engine torque shown in Fig.7. NOx gases produced due to excess heat generated in combustion chamber. Since secondary air injection mainly controls HC and CO emission gases. Eventhough secondary air injection system controls around 10% of NOx gases by reducing the heat generation from combustion chamber. Table.4. shows the values obtained in NOx emission tests of with and without SAI.

VI. CONCLUSION

This experiment clearly explains about the impact of secondary air injection system which is a major factor in reducing and controlling HC, CO and NOx gases. The secondary air injection system was set up on single cylinder air cooled 4 stroke 110CC engine. The results states that the pollutant emissions got decreased drastically after introducing secondary air injection system. The average reduction of HC, CO and NOx after using secondary air injection system with ideal air speed is around 20%, 25% and 10% respectively.

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