Effect of Secondary Air Injection in Redesigned Exhaust Pipe of Two-Stroke Internal Combustion Engine

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ABSTRACT

The emission produced by two-stroke internal combustion engine is not under the limits of vehicle emission norms mentioned by pollution department. An experimental study was performed for more fundamental understanding of effect of secondary air injection on exhaust emissions of two-stroke cycle engine during cold starting period by redesigning the exhaust pipe. The pressurized secondary air is injected in the newly designed exhaust pipe near the exhaust port with the help of separate single cylinder two-stage compressor and nozzle. The effects of different operating conditions were investigated. The amount of HC, CO and CO_2 measured with the help of exhaust gas analyzer. The study found that significant reduction in exhaust unburnt HC and CO due to injection of pressurized atmospheric air in redesigned exhaust pipe. The change in design of exhaust pipe with secondary air injection reduced HC, CO and CO_2 emissions by 62.77%, 39.285% and 17.129% respectively in idling condition. In full acceleration condition, HC, CO and CO_2 emissions reduced by 70.12%, 72.17% and 9.52%, respectively.

Keywords: emission control, redesigned exhaust pipe, secondary air injection, two-stroke engine

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INTRODUCTION

The two stroke engines are banned because of its high exhaust emissions. Two-stroke engine exhaust has high amount of unburnt HC and CO due to incomplete combustion but two stroke engines have certain advantages. They produce more power and more compact than four stroke engines. Also, they are lightweight and economical. Internal combustion engine needs rich air-fuel mixture during cold starting. As a result, high amount of CO and HC produced during cold starting period. The vehicle emission norms are getting stricter to control the pollution from vehicle exhaust emissions. In internal combustion engines, secondary air injection is proven method of reducing harmful substances during cold starting. Ambient air containing oxygen is injected into exhaust pipe. The available methods for implementation of secondary air injection are pumped air injection and aspirated air injection. Pumped air injection system uses a pump called air pump turned either by electric motor or by engine, aspirated air injection system takes advantage of negative pressure pulses in the exhaust system of engine idle. The exhaust pipe redesigned for the proper space and time required for efficient burning of the unburnt charge. The pressurized air reacts with the outgoing exhaust gases and converts the unburnt HC, CO into H_2O and CO_2 efficiently [1].

BACKGROUND

In 1970, the US congress passed the clean air act, which called for first tailpipe emission standards. The environmental protection agency established a federal test procedure (FTP) in which emissions were measured using a constant volume sampling system. The FTP cycle was conducted on engine dynamometer and included measurement from the automobile during cold working and hot working period. Both the tests were taken out at the same speed and acceleration. The only difference between two tests was that, first began with cold start and second began with warm start. However, the cold start phase generated several times as much HC and CO as warm start phase [1]. The study by Michel e. crane on rapid exhaust post oxidation on FTP-75 with ford escort equipped with 1.9l SI engine showed mass emission measurements acquired during the first 70 sec of FTP-75 revealed total HC and CO reduction of 68% and 50%, respectively [2]. The paper published by Coffin showed the timed secondary air injection system reduced emission levels roughly by factor of 2 under no typical fast idle no load conditions [3]. In the beginning, passive secondary air system was used with the airflow driven by the pressure pulsation in exhaust system. Since 1990, for most application active secondary air system is employed [4]. In early 90s, pierburg was one of the first original equipment manufacturer suppliers to develop a secondary air pump [5]. Pritchard and Cheng studied the effect of secondary air on the exhaust oxidation of particulate matter in direct injection spark ignition engine under fuel rich fast idle condition (1200 rpm, 2 bar NIMEP). The results showed substantial oxidation of unburned feed gas species (HC & CO) and significant reduction of both number upto 80% and volume upto 90% [6]. The first system injected air very close to the engine either in cylinder head exhaust port or in exhaust manifold. As emission strategies grow more sophisticated, rather than being a primary emission control device the secondary air injection system was adopted to support effective function of catalytic convertor [7]. Borland and Zhao. Study showed the proper design and optimization of secondary air injection system can significantly reduce HC emissions [8].

MODIFIED EXHAUST PIPE

Figure 1 gives the details about the dimension of modified exhaust pipe. The air nozzle brazed to diverging section of modified exhaust pipe with an angle of 25 degree with the horizontal. The muffler welded to the outlet of exhaust pipe to control noise and vibration. The actual modified exhaust pipe is shown in Figure 2.

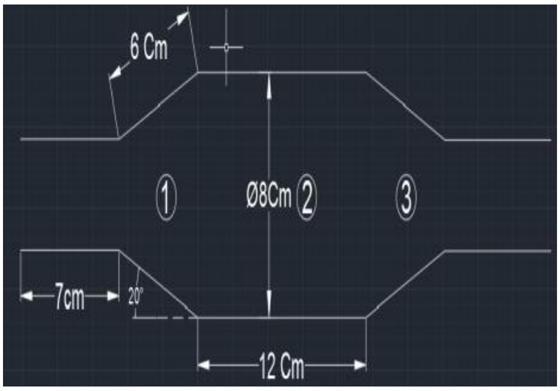

Fig. 1. *Dimensions of modified exhaust pipe.*

The main purpose to modify the exhaust pipe is to control the emissions from the engine by providing sufficient space and time for the reaction between exhaust unburnt gases and secondary air. It is made up of Steel sheet because of its good formability and good thermal conductivity. The modified exhaust pipe's first part has gradually increasing diameter, which helps in creating pressure in exhaust pipe. It results in decrease in velocity of exhaust gases coming out from engine. The intermediate part of exhaust pipe has constant diameter and sufficient length, which helps in proper reaction between secondary air and unburnt exhaust. The third section has gradually decreasing diameter, which increases the velocity of exhaust gases. It helps in easy escaping of exhaust gases.

METHODOLOGY

The first test carried out with original exhaust system of engine without secondary air injection. The second test was taken by replacing the conventional exhaust system with modified one. Engine operating conditions were same in both tests. The technical specifications of the two-stroke engine are given in Table 1.

***Table 1.** Technical specifications of two-stroke spark ignition engine.*

Engine displacement	98.00cc
Engine type	Two stroke/petrol
Maximum power	7.7 bhp @5600 rpm
Maximum torque	1.0 kg @ 5000 rpm

Exhaust gas emissions were recorded with the help of exhaust gas analyzer in both conditions. Separate single cylinder two stage air compressor used to compress the atmospheric air. Figure 3 shows the setup for experiment. The compressed air with pressure of 5 bar was injected by nozzle inside modified exhaust pipe with the help of air gun. Secondary air was injected as soon as the start of engine. The oxygen present in pressurized air reacts with outgoing exhaust gases and converts unburnt HC, CO into H_2O and CO_2.

$H_2 + 0.5\ O_2 = H_2O$

$CO + 0.5\ O_2 = CO_2$

***Fig. 2.** Modified exhaust pipe.*

***Fig. 3.** Experimental setup.*

RESULTS

The result in Figures 4 and 5 shows the comparison between original system and modified system. The emitted content in the exhaust emission CO, CO_2 (%) and HC (PPM) according to engine accelerating conditions [9–11].

Idling Condition

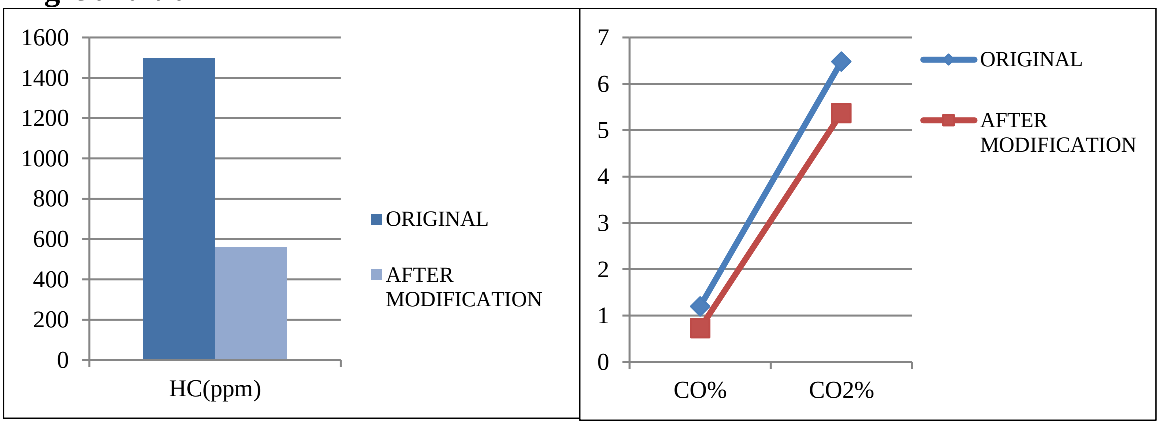

***Fig. 4.** Experimental results at idling condition.*

Full Acceleration Condition

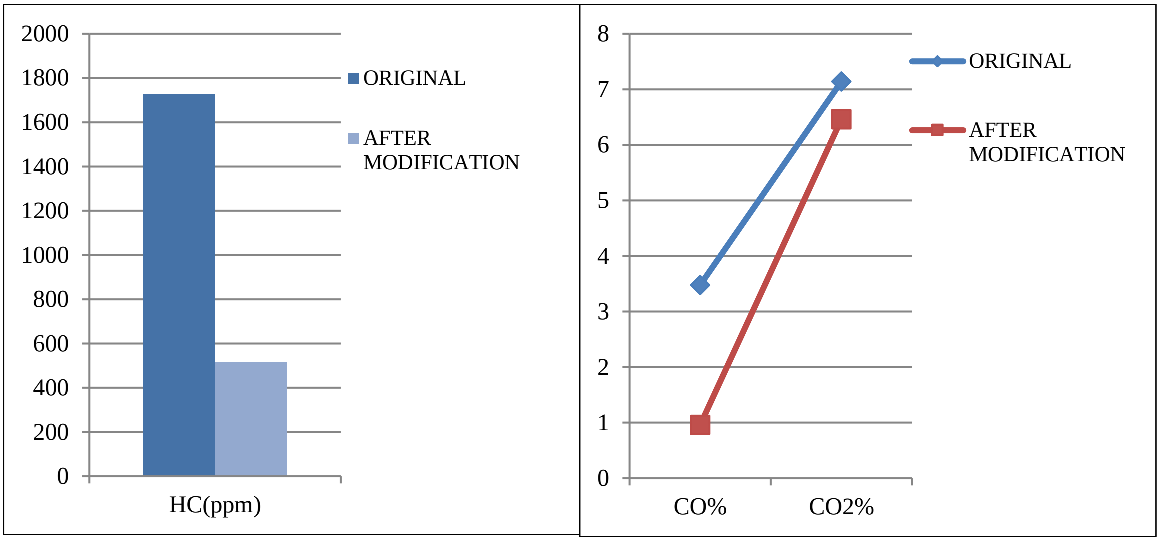

Fig. 5. *Experimental results at full accleration condition.*

CONCLUSION

After analyzing all results of experiment and relevant data for modified exhaust pipe air injection system, conclusion comes as overall pollution of vehicle reduced drastically. In addition, it is cost effective and easy to implement in existing vehicles. Percentage reductions in pollution after implementing the system are as below.

In idling condition – CO – 39.285%, CO_2 – 17.129% and HC – 62.77%

In full acceleration condition – CO – 72.17%, CO_2 – 9.52% and HC – 70.12%

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REFERENCES

[1] D. Lee, J. Heywood. Effects of secondary air injection during cold start of SI engines, *SAE Int J Engines*. 2010; 3(2): 182–96p.

[2] M. Crane, R. Thring, D. Podnar, L. Dodge. Reduced cold-start emissions using rapid exhaust port oxidation (REPO) in a spark-ignition engine, *SAE Technical Paper 970264*. 1997.

[3] K.P. Coffin. Effect of timed secondary-air injection on automotive emissions, *NASA Technical Memorandum NASA TM X-2737*. 1973.

[4] M. Kochs, M. Kloda, G. van de Venne, J. Golden. Innovative secondary air injection systems, *SAE Tech Paper*. 2001-01-0658

[5] PIERBURG [SI 0106] MS Motor service international Gmbh-0510 EN.

[6] J. Pritchard, W.K. Cheng. Effects of secondary air on the exhaust oxidation of particulate matters, *SAE Technical Paper*. 2015-01-0886.

[7] J. Kedaria, S.B. Bhatt. Experiment investigation on pollution control by air injection system to catalyst for oxidation process, *Int J Adv Eng Technol*. 2013, 39–40p. E-ISSN 0976-3945.

[8] M. Borland, F. Zhao. Application of secondary air injection for simultaneously reducing converter-in emissions and improving catalyst

light-off performance, *SAE Technical Paper 2002-01-2803*. 2002.

[9] K. Nishizawa, T. Yamada, Y. Ishizuka, T. Inoue. Technologies for reducing cold-start emissions of V6 ULEV's, *SAE Technical Paper 971022*. 1997.

[10] R.B. Poola, R. Sekar. Study of using oxygen-enriched combustion air for locomotive diesel engines, *CONF-961017-7 ANL/ES/CP-90529*. 1996.

[11] H. Watson, E. Milkins, G. Rigby. A new look at oxygen enrichment 1) the diesel engine, *SAE Technical Paper 900344.* 1990.

