EMISSION OPTIMIZATION OF 60 HP AGRICULTURAL TRACTOR ENGINE

Prabhanjan Shinde
Rajarambapu Institute of Technology
Islampur, India
prabhanjanshinde11@gmail.com

Sandeep Desai
Rajarambapu Institute of Technology
Islampur, India
sandeep.desai@ritindia.edu

Abstract—In order to meet emission norms, modern diesel engines rely on methods of in-cylinder emission reduction and expensive exhaust after treatment devices. Engine manufacturers across the world are finding difficulty in maintaining balance between customers demand for better fuel consumption and obeying the stringent legislative emission regulations. The main goal of this experimental work is to investigate the effect of optimum combination of variables such as piston bowl diameter with the range of increase up to 1-2 mm precisely matched with engine. Then, the experimental tests were carried out and with the influence of injector configuration, NTP washer size was determined with selected piston bowl using systematic parameter variations. The combustion system under consideration was direct injection diesel engine with inline fuel pump used for off-road applications, used to explore the full potential of the combustion system. The tests were carried out to understand best combination of air and fuel system along with bowl modification related variables to achieve best combustion for emissions. The washer of 2 mm has been used in trial with modification in piston bowl to obtain good emission results.

Keywords— Piston Bowl, NTP, Modification

I. INTRODUCTION

Internal combustion engines are ubiquitous in today's society. Applications for these engines cover a broad spectrum, ranging from passenger transport and goods movement vehicles to specialized vehicles and equipment used in the construction and agriculture industries. While internal combustion engines are integral to today's economy, they have long been recognized as a significant source of pollutant emissions that contribute to poor air quality, negative human health impacts, and climate change. Efforts to mitigate the emissions impact of these sources, such as regulatory control programs, have played a key role in air quality management strategies around the world, and have helped to spur the development of advanced engine and emission control technologies [2]. The overview of various factors that can impact emissions and developments in 2016 related to emissions and efficiency for both diesel and gasoline engines in the automotive and heavy-duty markets. [1]

The in-cylinder air and fuel motion is one of the important factors for controlling the combustion process in compression ignition engine. It improves the air and fuel mixing and burning rate of the fuel. It is essential to achieve a better spatial circulation of the injected fuel throughout the space to obtain a better combustion with reduced emissions [13, 16, 17].

Variation in bowl geometry is effected through a corresponding change in ratio of bowl to piston diameter ratio while maintaining the bowl volume, compression ratio, engine speed and the mass of fuel injected constant [7]. Improve the swirl motion for the proper mixing of fuel and air inside the combustion chamber by making tangential groves on the piston bowl [4].

The influence of piston bowl shape on the performance and emission has been studied widely; observations from these studies help to optimize the piston bowl shape suitable for various applications [9]. In diesel engines, NO_x emission tends to decrease as injection timing is retarded [9, 8, 14]. Retarding injection timing results in less combustion temperatures, which results in less NO_x emission Numerical investigation with optimize bowl geometry and injection nozzle configurations [12]. Various important engine variables are selected for emission optimization [3]. Combustion optimization done with combinations of piston bowl, intake port swirl and injector specifications in off road diesel engine.[6] Different piston bowl concepts have been proposed and implemented over the years for high speed direct injection diesel engines[18].The effects of piston cavities are studied for NO_x, CO, and soot emission.[10]

TABLE I SPECIFICATIONS OF TEST ENGINE

Power Ratings	60 hp 44.7 kW
Application	Agricultural Tractor
No of Cylinders	3
Swept Volume	3.4 liters
Bore	107 mm
Stroke	126 mm
Rated Speed	2200 rpm

Here in this research work, the task was to optimize the existing variable speed, 3.4lit, turbocharged, diesel engine to
meet stringent emission limits. Test is conducted as per ISO 8178-C1 test standard 8- mode test cycle applicable for agricultural tractor application and modification is done with CATIA V5 software for drawing purposes.

II. EXPERIMENTAL SETUP

The Figure 1 shows appropriate measurement equipment its calibration and operational conditions have an important effect on experimental results.

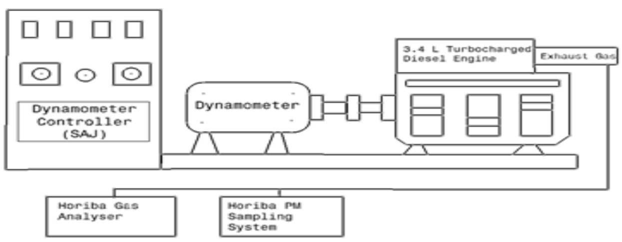

Fig-1: Experimental setup of three cylinder turbocharged engine.

The existing variable speed 3.4 liter, naturally aspirated, water cooled diesel engine was coupled to an SAJ SE/AG 150 eddy current dynamometer by a propeller shaft. Figure 1 shows the experimental set up. The above system consists of Horiba exhaust gas analyzer which measures all the legal pollutants like CO, HC and NO_x. Particulate matter emission was measured using a Horiba sampling system which is smart sampler partial flow particulate measurement device. Testing conditions (intake air, pressure humidity, temperature) were maintained as per ISO 8178-C1 standards. Commercially available diesel fuel is used for experimental study.

III. METHODOLOGY FOR EMISSION OPTIMIZATION

There are two piston bowls for testing; one is original bowl while other is modified one. A modification of bowl parameters is done so as to check effect of modifications on emissions. The following figure shows the original and modified piston geometry.

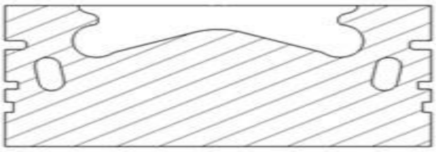

Fig-2: Original piston bowl geometry

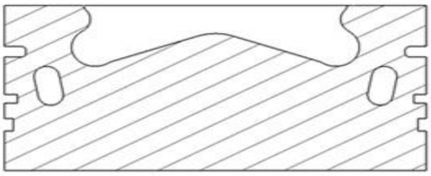

Fig-3: Modified piston bowl geometry

IV. EMISSION TEST CYCLE

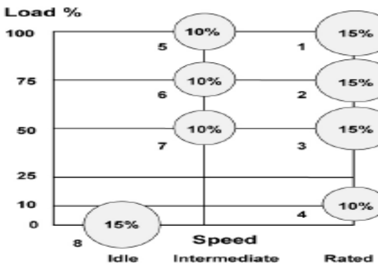

Fig-4: C1 8-Mode Cycle [8]

ISO 8178 C1- 8 mode cycle Figure 4 consists of four modes at the rated speed, three modes at the intermediate speed corresponding to the maximum torque and one at low idle speed. The weightage factor for idle, 1st, 2nd and 3rd mode is 15 % while for 4th, 5th, 6th and 7th mode is 10 % respectively. The influence of rated speed optimization is crucial because it has higher weightage of 55% in the total cycle. Reducing HC emission levels at rated speed 10% load is critical to achieve cycle HC emission.

V. RESULT AND DISCUSSION

In this, work taking number of trials on the original piston bowl geometry and modified piston bowl geometry with different washer thickness and plot the graph for the same. The trial 1, 2 and 3 are taken on the original piston bowl geometry and trial 4, 5 and 6 are taken on modified piston bowl geometry.

A. ORIGINAL PISTON

Trial no. 1: Injector 8x146x825 (per 30 sec) and washer thickness of 3 mm, with turbo charger-45

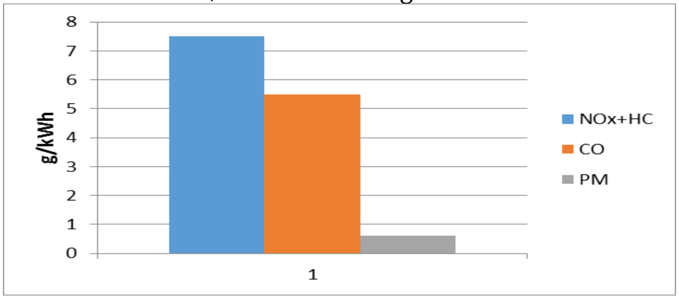

Fig-5: Emission result of original piston bowl geometry with 3 mm washer

In this trial the NOx gas emission is higher at all operating condition than the other gases. PM emission is to the lower side and the CO emission is in between the NOx and PM emission. The maximum NO_x, CO and HC emissions in consists of four modes at the rated speed respectively. In above graph show that the overall NO_x+HC emission is 7.5 g/kWh, CO emission is 5.5 g/kWh and Particulate matter emission is 0.6 g/kWh.

Trial no. 2: Injector 8x146x825(per 30 sec) & washer thickness of 2 mm equipped, with Turbocharger-45

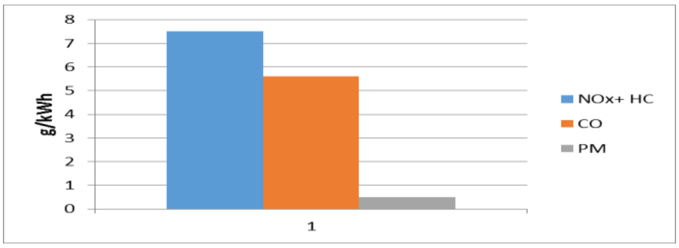

Fig-6: Emission result of original piston bowl geometry with 2 mm washer

The trial shows that the result of 2 mm washer thickness equipped with turbocharger 45. The overall NO_x+HC emission is 7.5 g/kWh, CO emission is 5.6 g/kWh and Particulate matter emission is 0.6 g/kWh.

Trial no.3: Injector 8x146x825(per 30 sec) & washer thickness of 1 mm equipped, with Turbocharger-45

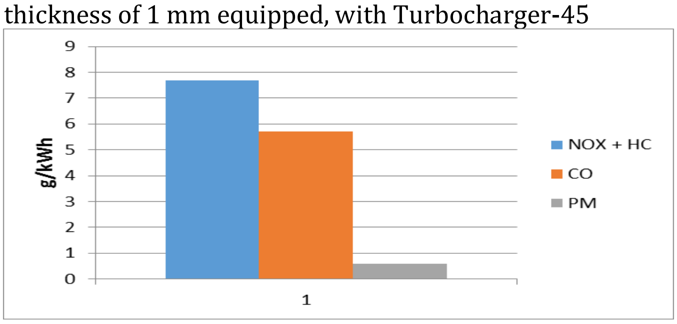

Fig-7: Emission result of original piston bowl geometry with 1 mm washer

The trail is taken on the original piston geometry with 1 mm washer thickness. The increase in rate of CO emission is higher in the 5th mode which shows that oxygen is less and on other hand lower HC emission is high. The above graph show the overall NO_x+HC emission is 7.5g/kWh, CO emission is 5.6 g/kWh and Particulate matter emission is 0.6 g/kWh.

B. MODIFIED PISTON

Trial no. 4: Injector 8x146x825(per 30 sec) &washer thickness of 3 mm, equipped with Turbocharger-45

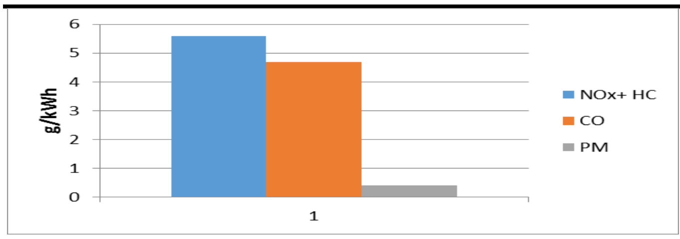

Fig-8: Emission result of modified piston bowl geometry with 3 mm washer

The trial is taken on the modified piston bowl geometry with 3 mm washer thickness. The maximum NO_x, CO and HC emission are in at 6th and 5th mode at intermediate and rated speed respectively. The graph shows that the overall NO_x+HC emission is 5.9 g/kWh, CO emission is 4.7 g/kWh and Particulate matter emission is 0.4 g/kWh.

Trial no.5: Injector 8x146x825(per 30 sec) & washer thickness of 2 mm, equipped with Turbocharger-45

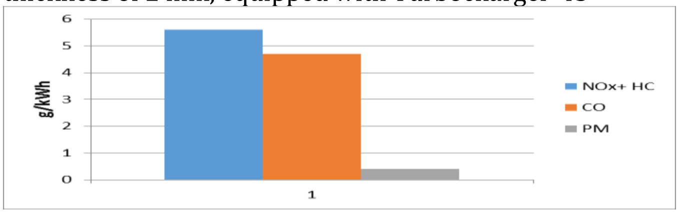

Fig-9: Emission result of modified piston bowl geometry with 2mm washer

The trial is taken on modified piston bowl geometry 2mm washer thickness. The maximum NO_x, CO and HC emissions are at1st mode respectively. From above graph shows that the overall NO_x+HC emission is 5.7 g/kWh, CO emission is 4.7 g/kWh and Particulate matter emission is 0.4 g/kWh.

Trial no.6: Injector 8x146x825(per 30 sec) &washer thickness of 1 mm, equipped with Turbocharger-45.

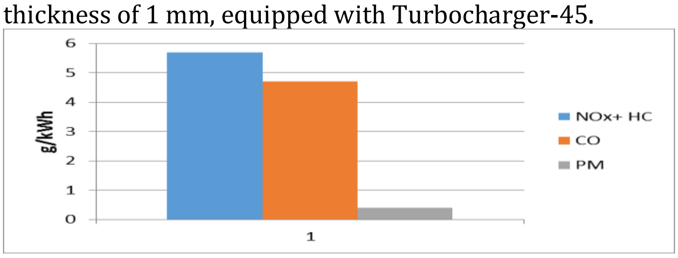

Fig-10: Emission result of modified piston bowl geometry with 1 mm washer

The trial is taken on modified piston bowl geometry with 1mm washer thickness .The maximum NO_x, CO and HC emissions are at 6th, 5th and 4th mode respectively. The over graph demonstrate that the overall NO_x+HC emission is 5.7 g/kWh, CO emission is 4.8 g/kWh and Particulate matter emission is 0.5 g/kWh.

TABLE II

Washer thickness	Original piston geometry			Modified piston geometry		
	NO_x+HC	CO	PM	NO_x+HC	CO	PM
1 mm	7.5	5.6	0.6	5.7	4.8	0.5
2mm	7.5	5.6	0.6	5.7	4.7	0.4
3 mm	7.5	5.5	0.6	5.9	4.7	0.4

The above table shows that emission result of original piston bowl geometry and modified piston bowl geometry. The variation in the emission results are due to,

a) The compression ratio of piston is decreased to 19.5 from 20.

b) The range of increases in piston bowl diameter is 1-2 mm.

VI. Conclusion

From the results obtained, it can be concluded that:

1. According to present study, the best emission result is achieved for 2 mm washer thickness and 8x146x825 nozzle configuration with modified piston option than original piston equipped with turbocharger-45.
2. As discussed in result the percentage improvement with modified piston with standard piston in NOx+HC is 24%,CO is 14%, PM is 33% at same power.

References

[1] Johnson, T. and Joshi, A., 2017. Review of Vehicle Engine Efficiency and Emissions (No. 2017-01-0907). SAE Technical Paper.

[2] Dallmann, T., Shao, Z., Menon, A. and Bandivadekar, A., 2017. Non-Road Engine Technology Pathways and Emissions Projections for the Indian Agricultural and Construction Sectors (No. 2017-26-0230). SAE Technical Paper.

[3] Gupta, S. and Vunnava, G., 2016. Modeling, Analysis and Experimental Validation of Tractor System Architecture for on Field Efficiency Improvement While Conserving Environment (No. 2016-01-8024). SAE Technical Paper.

[4] Subramanian, S., Rathinam, B., Lalvani, J.I.J. and Annamalai, K., 2016. Piston Bowl Optimization for Single Cylinder Diesel Engine Using CFD (No. 2016-28-0107). SAE Technical Paper.

[5] Quazi, M.A., Singh, S.K. and Jadhao, M., 2015. Effect of Piston Bowl Shape, Swirl Ratio and Spray Angle on Combustion and Emission in Off Road Diesel Engine (No. 2015-26-0142). SAE Technical Paper.

[6] Gafoor, C.A. and Gupta, R., 2015. Numerical investigation of piston bowl geometry and swirl ratio on emission from diesel engines. Energy Conversion and Management, 101, pp.541-551.

[7] Balaji, J., Bandaru, B. and Rao, L.N., 2014. In-Cylinder Combustion Control Strategy to Meet Off-Road Emission Norms with Conventional Mechanical Fuel Injection System (No. 2014-01-2648). SAE Technical Paper.

[8] Nimodia, S., Senthilkumar, K., Halbe, V., Ghodke, P. et al., "Simultaneous Reduction of NOx and Soot Using Early Post Injection (No. 2013-26-0055). SAE Technical Paper

[9] Heywood, J. B., "Internal Combustion Engine Fundamentals," McGraw Hill, 2013, ISBN : 978-1-25-900207-6.

[10] Rajamani, V.K., Schoenfeld, S. and Dhongde, A., 2012. Parametric Analysis of Piston Bowl Geometry and Injection Nozzle Configuration using 3D CFD and DOE (No. 2012-01-0700). SAE Technical Paper.

[11] Sheikh, S., Gokhale, N., Thatte, V., Gandhi, N., Deshmukh, B., Aghav, Y., Kumar, M., Nandgaonkar, M. and Babu, M.K., 2011. Efficient Approach for Optimization of Piston Bowl Shape, Compression Ratio and EGR for DI Diesel Engine (No. 2011-24-0013). SAE Technical Paper.

[12] Lijewski, P., Merkisz, J., Fuc, P. and Pielecha, J., 2010. Exhaust emission tests from agricultural machinery under real operating conditions (No. 2010-01-1949). SAE Technical Paper.

[13] Mehdiyev, R., Derbentli, T., Arslan, H., Kutlar, O.A., Ozcan, E., Ogun, K., Gurbuz, T., Babaoglu, O. and Potur, R.A., 2009. Development of a Turbo Diesel Engine by a New Combustion Process for Heavy Duty Vehicles and Tractors (No. 2009-24-0046). SAE Technical Paper.

[14] Karra, P.K., 2009. Parametric study and optimization of diesel engine operation for low emissions using different injectors.

[15] Yub-Yih,et al.," Investigation of realizing SDI with high swirl charge in motor cycle engine" International Journal of Energy, issue2, Volume.3, 2009.

[16] Li, Y., Li, L., Xu, J., Gong, X., Liu, S. and Xu, S., 2000. Effects of combination and orientation of intake ports on swirl motion in four-valve DI diesel engines (No. 2000-01-1823). SAE Technical Paper.

[17] Alkidas, A.C. and Suh, I.S., 1991. The effects of intake-flow configuration on the heat-release and heat-transfer characteristics of a single-cylinder four-valve engine (No. 910296). SAE Technical Paper.

[18] Ikegami, M., Fukuda, M., Yoshihara, Y. and Kaneko, J., 1990. Combustion chamber shape and pressurized injection in high-speed direct-injection diesel engines. SAE transactions, 99, pp.960-974.