EXPERIMENTAL INVESTIGATION ON SINGLE CYLINDER BSIV DIESEL ENGINE EMISSION IMPROVEMENT

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***Abstract*— In this study experimentation has been carried out on a single cylinder, direct injection, diesel engine for investigating BS-IV emission improvement, specifically on NOx and smoke emissions parameters. To achieve this, some modifications were done on the engine like changes in high pressure pipe (H.P.P), nozzle tip protrusion (NTP), & static injection timing (SIT). The H.P. pipe internal diameter was reduced by 20% with respect to (w.r.t.) its original. In NTP, the distance between nozzle tip to the internal cylinder head surface was changed, firstly by 45.45% decreased & second 23.80% increased w.r.t the original NTP distance. SIT was changed for four different injection timing (Such as 1°, 2° Advanced & 1°, 2° Retard CA BTDC by original SIT). For all modification, tests were conducted and observed the effect on engine performance and emission parameter. In the H.P.P modification the torque and power was improved, whereas the emission of a smoke value was drastically increased and the NOx emission was not significantly decreased. In NTP modification, didn't provide much of a positive result compared to the original NTP in terms of smoke value. In SIT modification, obtained better result, when compared to other two modifications previously carried. In SIT modification in terms of injection timing the test result demonstrated that, with advancing timing NOx emission increases due to improved fuel and oxygen reactions. Advancing the injection timing caused the start of combustion an earlier relative to the TDC. Because of the proper cylinder charge compression and relatively higher temperatures, NOx was increased and smoke shows slightly decreasing. Retarding the engine timing by 1° w.r.t. original SIT, NOx was decreased 5.56 %. This also gives perfect balance between parameters like power, torque, smoke and NOx values which are under the standard norms**.

Keywords*— *High pressure pipe, NTP, SIT, Modification

I. INTRODUCTION

Diesel engine has provided the power units for transportation system and also important fuel economy and durability advantages for large heavy duty trucks, buses, non-road equipment and passengers cars. Diesel engines powered both road and non-road equipment's are the symbols of our modern technological society. While they have many advantages, they also have the disadvantages of emitting significant amount of Particulate Matter (PM) and Oxide of Nitrogen (NO_X) and to the lesser amount hydrocarbon (HC), Carbon monoxide (CO) and toxic air pollutants are one of the main concerning problems still prevailing in developing countries like India, especially in metropolitan cities, like Delhi, Mumbai, Kolkata & Chennai

TABLE I. THREE WHEELER BSIV DIESEL ENGINE EMISSION NORMS

Vehicle	CO g/km	HC+NO_X g/km	PM g/km
3W Diesel engine	0.380	0.380	0.0425

TABLE 2: SPECIFICATION OF EXPERIMENTAL ENGINE

Working Fluid	BS4 Diesel
Number of Cylinder	1
No. of Stroke Per Cycle	4
Engine Name	Single Cylinder Diesel Engine
Bore (mm)	86
Stroke (mm)	75
Dry Weight	52 kg
Intake System	Naturally Aspirated
Metering System	Direct Injection
Compression Ratio	19.5
Displacement (cm^3)	435
Maximum Torque (Nm)	18 Nm @ 2400 rpm
Rated Power	8.5hp @ 3600 rpm

The existing rate of emission (NO_X and PM) BSIV single cylinder DI diesel engine has been marginalised by modifying the existing engine parameters.1.High Pressure Pipe (HP Pipe), 2.Nozzle Tip Protrusion (NTP), 3.Static Injection Timing (SIT) engine as Advanced or Retard.

After introducing the necessary modifications on these parameters (about which has been detailed below), engine is been tested on Full Throttle Performance under the varying speed ranging from 3900 rpm to 1200 rpm, engine has been tested without EGR, The test is conducted by connecting the engine to an eddy current dynamometer that decide the load factor.

The controller software used for this test analysis is called OE-Host DYNO (IASYS DYNO controller).The load at which the engine has to be tested at different load conditions. There are multiple sensors connected to the system to measure the values of rpm, exhaust temperature, oil temperature, exhaust back pressure, air flow meter, load on the engine etc.

II. EXPERIMENTAL SETUP

Engine is mechanical controlled, naturally aspired coupled with eddy current dynamometer. After the modifications, engine will run on 13 mode speeds varying from low idling to high idling speeds (1200 rpm to 3900 rpm).

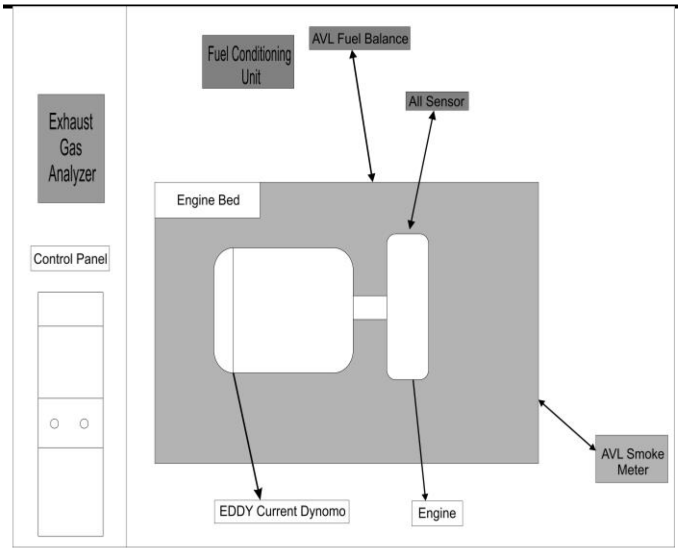

Fig.1: Engine test Bed layout

Fig1 shows the experimental engine test bed layout. Engine was instrumented with the exhaust emissions were measured using a Horiba exhaust gas analyzer capable of measuring all the pollutants like CO, HC and NO_X. Smoke emission was measured using AVL smoke meter 415SE.

III. Result and discussion

A. *High Pressure Pipe Line*

The internal diameter of the HP Pipe line was reduced by 0.25mm (ie.20% reduction) that of original value of HP Pipe. The graphical representation of the result has been shown in below.

Torque

The torque of the engine has improved considerably at regular speed intervals. However the maximum torque obtained by the engine under modified condition is significantly much higher than what it was in the earlier. The graph below shows a clear comparison between the torque values, before and after HP Pipe modification under respective speed intervals. Max torque was increased by 7.06% and rated torque was increased by 2.01%.

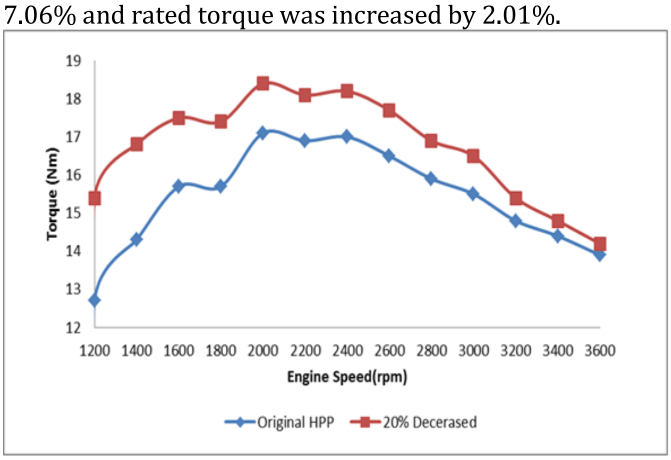

Fig.2: Torque (Nm) V/s Engine Speed (rpm)

Power

On reducing the inner diameter of HP Pipe by 0.25 mm (ie. 20% reduction),it was observed that there is better atomization of fuel droplets with proper mixing of fuel and air inside the cylinder during the the compression stroke thereby improving the power output. We know that Power is directly proportional to Torque. Hence when torque is increased, it can be observed that there is a proportional rise in power too. Max power obtained at rated speed has been improved by 0.3hp to 0.4hp.

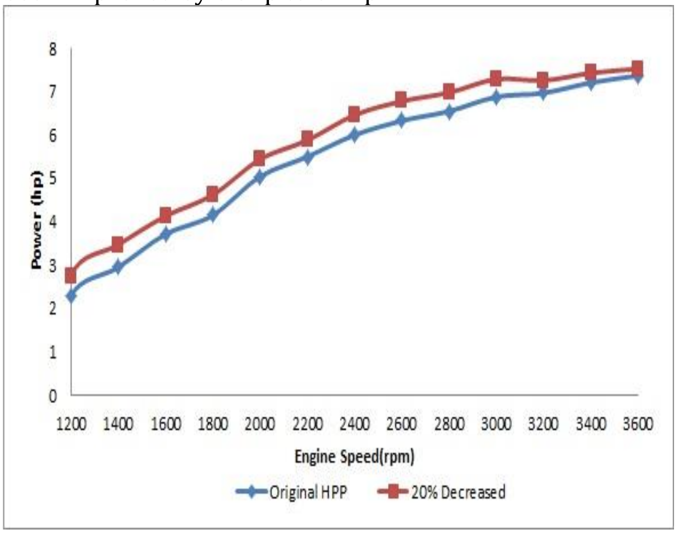

Fig.3: Power (hp) V/s Engine Speed (rpm)

Smoke

Unlike in Torque-Power graph, smoke emission has a slight negative impact on HP Pipe modification. It is observed that a continuous increase in smoke emission is resulted at respective speed intervals.

According to the graph, the smoke emission at rated speed was increased by around 51.28%, whereas at maximum torque the respective smoke emission was increased by 74.02%.

This statistics data implies that smoke emission is maximum at maximum torque value.

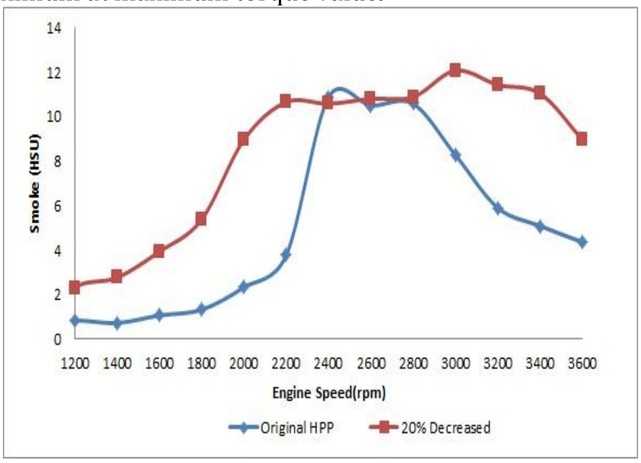

Fig.4: Smoke (HSU) V/s Engine Speed (rpm)

NO_X (Oxide of Nitrogen)

Though the NO_X emission initially showed an increasing trend with constant increase in speed, it started decreasing at a constant rate on regular speed intervals beyond 1800rpm. At rated speed NO_X was decreased by 35.04 % from the original HPP NO_X value and lower side increased by 0.90%.

Hence we can infer that HP Pipe modification had a significant positive impact NO_X emission.

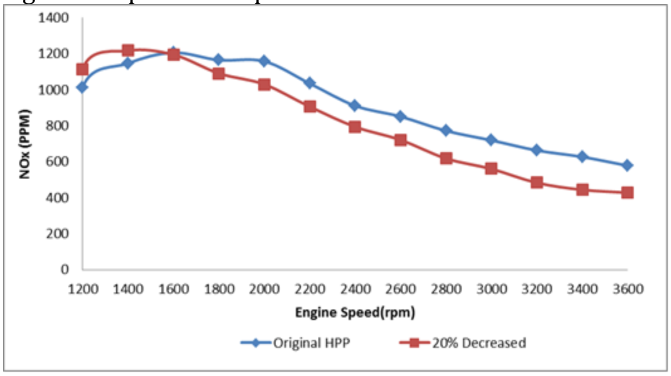

Fig.5: NO_X (PPM) V/s Engine Speed (rpm)

B. *Nozzle Tip Protrusion (NTP)*

Case I: Reducing the in NTP increasing the washer thickness by 1mm that is decreased original distance by 43.4%.

Case II: The increasing the NTP Reducing the washer thickness by 1mm so that the distance increased by 23.80% nozzle tip protrusion inwards (i.e. close to the piston top). Both these cases are compared with original NTP the result of each condition has been explained in details below.

Torque

Case I: In this case when the NTP was decreased by 43.4% the torque was increased. Rated torque by 0.4 Nm and maximum torque speed condition was same.

Case II: In this case the NTP was increased by 0.6 Nm at rated speed and torque was decreased by 0.2 Nm at original maximum torque speed.

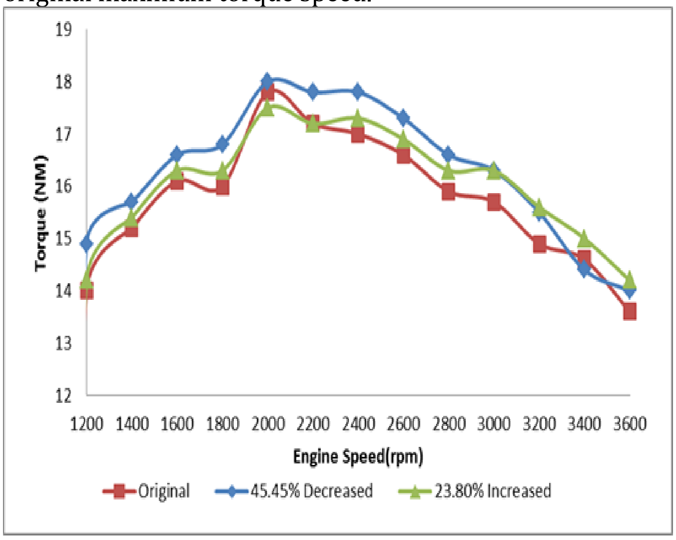

Fig.6: Torque (Nm) V/s Engine Speed (rpm)

Power

The engine output when in all there NTP position has formed to be almost the same. Still a considerable increase in power is obtained when the NTP is reduced by 43.4%.Thus when we compare both torque and power results, we infer that both torque and power output are directly proportional with the same NTP constraints.

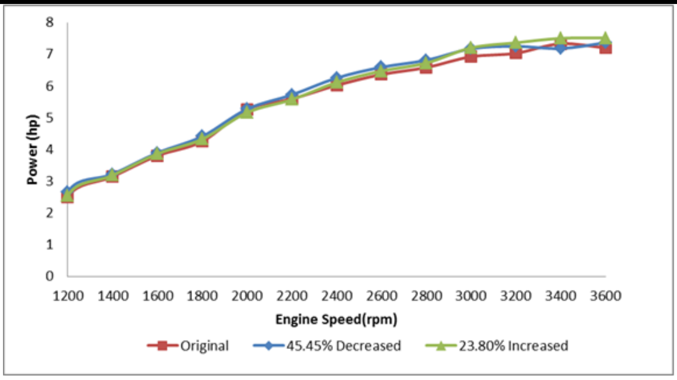

Fig.7: Power (hp) V/s Engine Speed (rpm)

Smoke

Case I (when NTP decreased by 45.5%): In this case the smoke values were decreased by 28.8% at rated speed of the engine. However the smoke was increasing at lower speeds by 71.29%.

Case II (when the NTP increased by 23.80%): In this case the smoke value decreased by 1.70% at rated speed of the engine but was increased by 24% at the lower engine speeds.

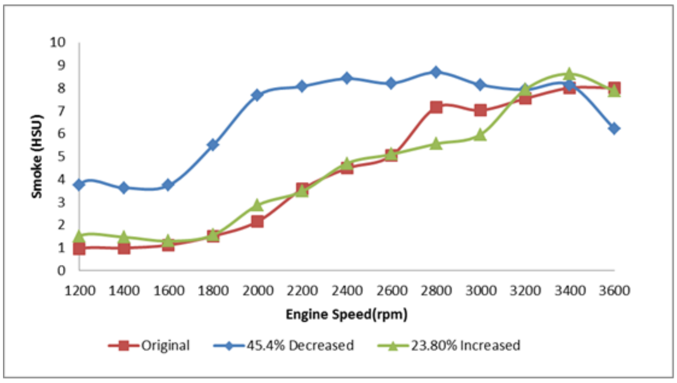

Fig.8: Smoke (HSU) V/s Engine Speed (rpm)

NO_X (Oxide of Nitrogen)

Case I (when NTP was 45.45% reduced by original):Here when the NTP was reduced by 45.45% from the original NTP value, the NO_X was increased by 7.78% at lower engine speed but NO_X was decreased by 7.24% at rated speed.

Case II (when NTP was increased 23.80% by original): In this case NTP was increased by 23.80% of the original NTP value, The NO_X was increased by 4.34% at rated speed and the lower engine speed NO_X was decreased by 5.83%

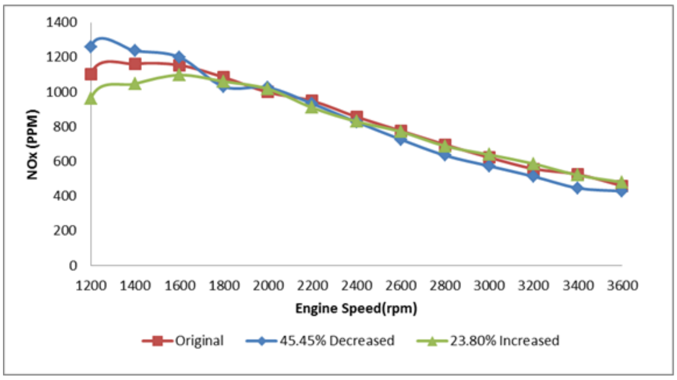

Fig.9: NO_X (PPM) V/s Engine Speed (rpm)

C. Static Injection Timing (SIT)

A new engine was selected to carry out the experimental analysis of static injection timing. In this test, the existing engine injection timing is kept as the benchmark and the injection timing were adjusted with respect to this reference. The injection timing adjusts the thickness of joint under the fuel pump flange. Increase in the thickness of joint retards the injection timing and reduction in thickness of joint advance the injection timing.

For testing the engine performance and exhaust emission we have taken four cases which are:

Case I - Advancing the injection timing by 1°

Case II - Retarding the injection timing by 1° on the removing the shims.

Case III - Advancing the injection timing by 2° on adding shims.

Case IV - Retarding the injection timing by 2° on further adding more shims.

Torque

On testing this engine performance parameters, found that engine torque at different speed intervals varies by almost same rate which is clearly illustrated on torque vs. speed graph.

Case I (When advanced injection timing by 1°): The torque of the engine was increased by 0.2 Nm. at a rated speed and max torque reduced by 0.2 Nm as 1.13% decreased, when the compared to torque at an original SIT.

Case II (Retarding the injection timing by 1° on the removing the shims.): In case II torque of the engine was increased by 1.11%.

Case III (Advancing the injection timing by 2° on adding shims.): Torque was decreased by 2.29%

Case IV (Retarding the injection timing by 2°): Engine torque was decreased by 0.56%.

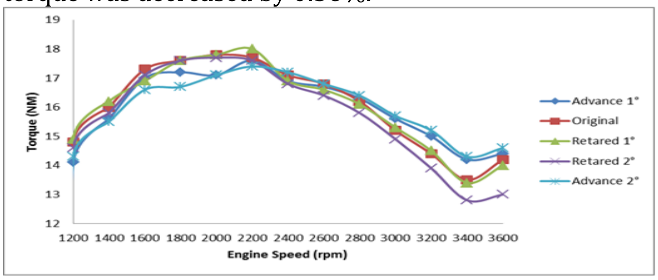

Fig.10: Torque (Nm) V/s Engine Speed (rpm)

Power

The power output of a varying the engine SIT varied almost in the same trend. There is no much of a difference observed in each case of SIT positions.

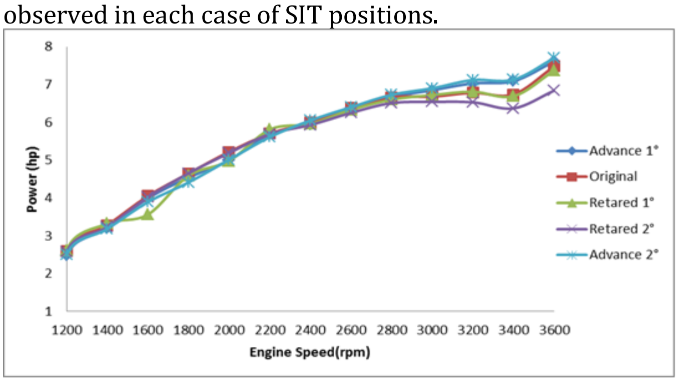

Fig.11: Power (hp) V/s Engine Speed (rpm)

Smoke

On changing the SIT from original position, we can see drastic changes in the smoke values shown in below;

Case I (Advance injection by 1°):While analysing the graph it is observed that in engine advanced by 1° the initial smoke emission is bare minimum whereas the engine speed increase the respective smoke value too rise drastically till rated speed is 36.8% increased by original and lower rpm dropped 10.25% smoke value. While in the case II that is retard by 1°, though the initiated emission is slightly lower than the original case it almost like the original case on conservative increase of engine speed until the engine riches rated speed beyond which it dropped 21.86% which is considerably lower than the original case. In case III engine is advance by 2° smoke values were increased 50% by original SIT. In case IV engine is retard by 2°, even though the maximum smoke emission produced is the highest among all four cases at maximum speed, its conservative smoke emission is the least. Hence it is observed that the case IV has produced the maximum fluctuating smoke emission at various engine speeds.

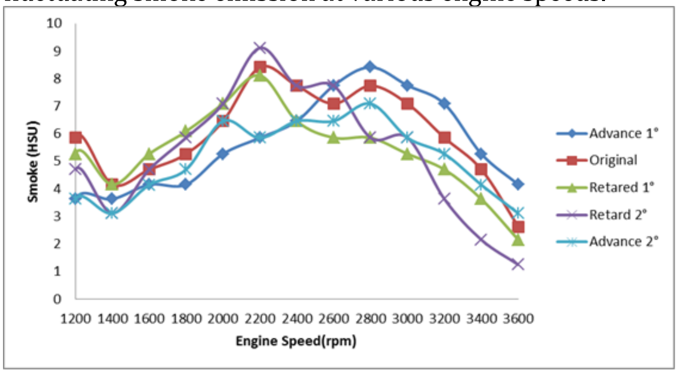

Fig.12: Smoke (HSU) V/s Engine Speed (rpm)

NO_x (Oxide of Nitrogen)

Retarding the injection timing decreases the peak cylinder pressure, which results in lower peak temperatures. As a consequence, the NO_X emissions reduce [1,12]. The NO_X generation of the engine is also majorly affected on the changing the injection timing, we can say that the NO_X is increased and decreased when SIT changes as advance or retarded. The details shown in below the NO_X vs. rpm graph, the NO_X emission has produced the emission minimum at 2° retard SIT and it observed that as the SIT is advanced the resulting NO_X emission has substantially increased so it is inferred that retarding the SIT reduces the NO_X emission whereas a advancing the SIT increases the NO_X emission.

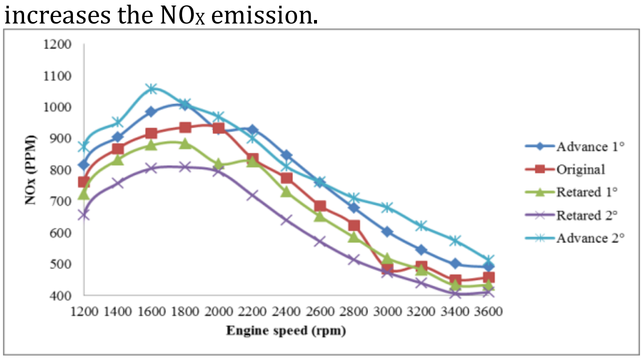

Fig.13: NO_X (PPM) V/s Engine Speed (rpm)

IV. Conclusion

On observing all the statistics resulted in all the modifications it can be concluded that SIT modification has produced one of the desired results in the engine emission compared to High Pressure Pipe modification and Nozzle Tip Protrusion adjustment.

In SIT modification in terms of injection timing the test result demonstrated that the timing was advancing the NO_X emission increased due to fuel and oxygen reaction improved. Advancing the injection timing caused the start of combustion an earlier relative to the TDC. Because of the proper cylinder charge compressed had relatively higher temperatures, NO_X was increased and smoke is slight decreasing. Retarded the engine timing 1° by original SIT NO_X was decreased 5.56 % it can achieve the perfect balance between parameters like power, torque, smoke and NO_X values which were under the standard norms. In case II that is retarded by 1° has produced a satisfactory result compared to other SIT variation cases.

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