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"Experimental Investigation and CFD analysis of Exhaust Back Pressure (EBP) of CI Engine"

[1] Mr. Prashant D. Dabhade [2] Prof. P. R .Kulkarni [3] Prof. R. S. Powar
[1] PG research student, M.E.(Heat power Engg.), Dr.J. J. Magdum College of Engg. Jaysingpur
[2]Associate Professor & Head, Department of Mechanical Engg., Dr.J. J. Magdum College of Engg., Jaysingpur
[3]Dean Academics, Dr. J. J. Magdum College Of Engg., Jaysingpur

Abstract:- **Compression Ignition (CI) Engines fueled with diesel emits high amount of oxides of nitrogen (NOx) and particulate matter (PM). Exhaust gas recirculation (EGR), Catalytic converter, diesel particulate filter (DFP) are few of the effective techniques to reduce emissions in diesel engine. Now-a-days very emerging techniques are upcoming in tail pipe emissions reductions. However, these are resource of producing Exhaust Gas Backpressure (EBP) on CI engine. The objective of current work is to investigate the performance of diesel engine by employing EBP by controlling gate valve. The tests are conducted at the valve closing of 0%, 25%, 50% and 75% respectively. EBP was measured with pressure gauge. The loads were varied from 0 to full load in step of 25% at constant speed. Also, CFD analysis was done with Fluent 6.2.23 for 50% & 75% valve close. Engine operating parameters (start of injection (SOI), injection opening pressure (IOP), nozzle holes geometry and CR) were maintained at standard operating conditions for diesel engine.**

The experimental results showed that, For long rote (location) of EBP has no significant effect of EBP. It was noted that only 0.02 kg/cm2 gauge pressure or 1 kg/cm2 absolute pressure was applied. Very less penalty in BTHE and BSFC at most 6% was observed with 50% valve closing. Further, penalty of about 50% in all emissions and more than 16% in performance of 75% valve closing (1.155 kg/ cm2) is inferior and not affordable. It should be noted that for 50% valve closings and 1.05 to 1.08 kg/cm2 emissions were almost closer to 25% valve closing. In addition 3 to 5% penalty of emissions can be observed. In additions, CFD Fluent results of velocity, pressure and temperature- counters, XY Plot and vector have showed significant comparative analysis between optimum pressure 50% valve closing (1.08 kg/cm2) and 75% valve closing (1.155 kg/cm2) at peak power of 3.21 kW. It should be crucial to noted that 50% valve closing (1.05 to 1.08 kg/cm2 EBP) can be applied effectively in tailpipe emissions reducing devices.

Keywords:-- **Operating parameter, COME, EGR, emissions, performance.**

I. INTRODUCTION

CI Engines are well known as better power source due to high thermal efficiency, fuel economy, higher compression ratio, lean air-fuel mixture operation, good reliability, higher performance, and fuel economy compared to Spark Ignition (SI) Engine. Due to these merits, CI Engines are predominantly used to drive tractors, heavy Lorries, trucks, buses, moving machinery etc. Also, CI Engines are quality governed engines. Owing to low fuel consumption, CI Engines have become increasingly attractive for small Lorries, various agriculture machines and passenger cars [1-3]. Recently, many researchers are trying to work out key technology to meet forth-coming emission norms. This advancements in CI Engine comprises of direct injection (DI), turbo-charging, air-to-air-inter cooling, multi-valve cylinder head, advanced high pressure injection system (split injection or rate shaping), electronic management system, lube oil consumption control and combustion optimization with and without swirl support, etc [5]. However, after treatments are effective techniques to reduce emissions [4]. Furthermore, it produces exhaust back pressure to engine. It should be noted that, through investigation and analysis of exhaust back pressure is crucial. Backpressure usually refers to the pressure exerted on a moving fluid by obstruction against its direction of flow. The average pressure in the exhaust pipe during the exhaust stroke is called the mean exhaust pressure and the atmospheric pressure is called the ambient pressure. The difference between these two pressures is defined as exhaust backpressure [5-7, 12, 13]. Particulate matter and other exhaust product adhere with flow passage of exhaust systems, causing reduction in flow passage while resulting in increased backpressure up on the engine [8].

Agrawal A. K., et al. [4] worked out an experimental investigation to observe effect of EGR on exhaust gas temperature and exhaust opacity in CI Engines. It was observed that, as EGR rate increases exhaust gas temperature decreases significantly. However, this result surely concludes that NOx can be decreased by increasing

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EGR rate. On other hand, BSFC and brake thermal efficiency were unaffected at part load and EGR rate of 15%. Peter Hield [7] examined the effect of increased back pressure on a turbocharged diesel engine using the Ricardo Wave engine modeling software, to gain understanding of the problem and provide a good base for future work on methods of improving engine performance. As the back pressure increases, the engine must work harder to pump the gases out of the cylinder against the higher pressure. The pressure ratios across the turbocharger compressor and turbine decrease, reducing the mass flow of air through these components and thus the air available to the engine. At the same time, the fuel flow must increase to provide the extra power necessary to overcome the increased pumping losses while maintaining a constant brake power output. Murari Mohon Roy, et al., [8] their study had investigated the effect of engine backpressure on the performance and emissions of a CI engine under different speed and load conditions. A 4-stroke single cylinder naturally aspirated direct injection (DI) diesel engine was used for the investigation with the backpressure of 0, 40, 60 and 80 mm of Hg at engine speed of 600, 950 and 1200 rpm. Domkundwar V.M., [9] Backpressure usually refers to the pressure exerted on a moving fluid by obstructions against its direction of flow. The average pressure in the exhaust pipe during the exhaust stroke is called the mean exhaust pressure and the atmospheric pressure is called the ambient pressure. The difference between these two pressures is defined as backpressure. Mohammad Joardder, et al., (2011) [12] investigated the effect of engine backpressure on the performance and emissions of a CI engine under different speed and load conditions. A single cylinder, 4-stroke, naturally aspirated, direct injection (DI) diesel engine was used. The backpressure of 0, 40, 60 and 80 mm of Hg were operated at engine speed of 600, 950 and 1200 rpm.

II. EXPERIMENTAL SET-UP & METHODOLOGY

Table: 1 Specifications of Engine

Make and Model	Kirloskar, TV1
No. of Cylinders	One
Orientation	Vertical
Cycle	4 Stroke
Ignition System	Compression Ignition
Bore X Stroke	87.5 mm X 110 mm
Displacement Volume	660 cc
Compression Ration	17.5 : 1
Arrangement of valves	Overhead
Combustion Chamber	Open Chamber (Direct Injection)
Rated Power	5.2 kW (7 HP) @1500 rpm
Cooling Medium	Water cooled

The engine selected for conducting tests is Kirloskar TV1, four-stroke, single-cylinder, water-cooled, naturally aspirated, DI (open chamber), diesel engine. The exhaust line was modified to apply back pressure by operating manual control valve. The back pressure was operated with this manual control gate valve opening. Engine operating conditions were kept constant as standard operating condition requirements of CI engine.

Fig. 1. Overall view of engine set-up with EBP

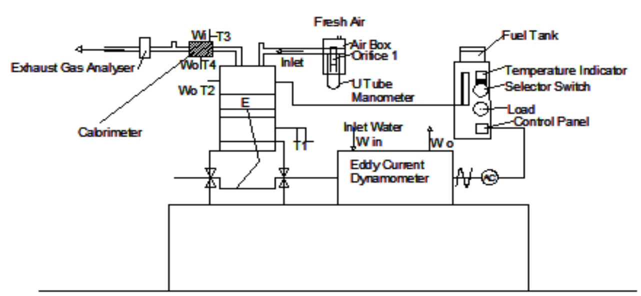

Fig. 2. Schematic of engine set-up fitted with EBP system

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III. METHODOLOGY

Set of tests were conducted on computerized single-cylinder, four-strokes engine fitted with short loop, and long route cooled EBP system to evaluate performance-emissions characteristics of EBP system. Initially, engine was tested at manufactures specified parameters with diesel fuel at SOI 23 deg. bTDC, IOP 205 bar, CR: 17.5, nozzle hole Ø = 0.3 mm. During each set of experimentations gate valve openings were varied from full open to 25%, 50% and 75% open respectively. It should be noted that full closed or zero open is not possible. The loads were varied from zero to full load in step of 25%. Speed was tried to be maintained constant. The operating parameters, test conditions

Table: 2 Operating-Measuring parameters & test conditions

Sr.	Parameter	Specification
1	CR & Speed	17.5:1 @ 1500 rpm.
2	SOI	23^0 bTDC (Diesel)
3	IOP	205 bar Diesel
4	Nozzle hole & dia.	4 hole nozzle (100% COME), 3 hole nozzle (20% COME & Diesel); Ø = 0.3 mm (all nozzles)
5	Fuel studied	Diesel
6	EBP	25%, 50% 75% valve open & Full valve open
7	Load	Zero to full load (0 to 12.6 kg) in steps of 25%
8	Measuring Parameter	Temperatures, time for 25 cc fuel consumption, EBP, Emissions
9	Experimental Investigation by calculations	B.P., mass flow rate of fuel, BSFC, BTHE, mechanical efficiency, volumetric efficiency, EGT, emissions

IV. RESULT AND DISCUSSIONS

The results with elaborative discussions are presented in two sections. The first section consists of effect of engine back pressure on characteristics of CI engine. However, next section is CFD analysis of exhaust line due to engine back pressure. As discussed in earlier chapter experimentations are done at four operating conditions of EBP. Also, at each operating conditions (25%, 50%, 75% valve openings & full open 100%,) loads were varied from no load to full load in step of 25%. It is assumed that all readings are taken at steady state conditions. Assume: The rated power of CI Engine we studied was 5.2 kW. However, we could not reach to it (rated power) because as per manufacturers specification & guidance for safety operation of engine. Hence, we considered next lower 3.7 kW as 100% power @ 12.6 kg loading to engine. Moreover, please note power & loading variation in step of 20% with respect to assumed data.

a. Exhaust Back Pressure

Fig. 3 sheds light on effect of EBP with varying in power for different valve closing. It was observed that, EBP increase with increase in power. Maximum of 1.155 kg/cm^2 absolute pressure was observed at 75% valve closing and full power. This was due to at higher power, more exhaust may be produced. However, more valve closing produces more obstacles in passage of exhaust resulting higher EBP. While less EBP was observed at lower valve closing and lower power. The 25% valve closing shows almost similar to no EBP at lower loads. Further, at higher power and 25% valve closing it was observed significant raise in EBP to 1.03 kg/cm^2. This raise in EBP for low power to peak power at all valve positions is in the rage of 5% to 17.5% and is significant. The 75% valve closing shows higher EBP 1.03 kg/cm^2 at low power to 1.55 kg/cm^2 at full load or power. Also, 0 % valve closing can be assumed at No EBP hence, it is exposed to atmospheric pressure of 0.98 kg/cm^2.

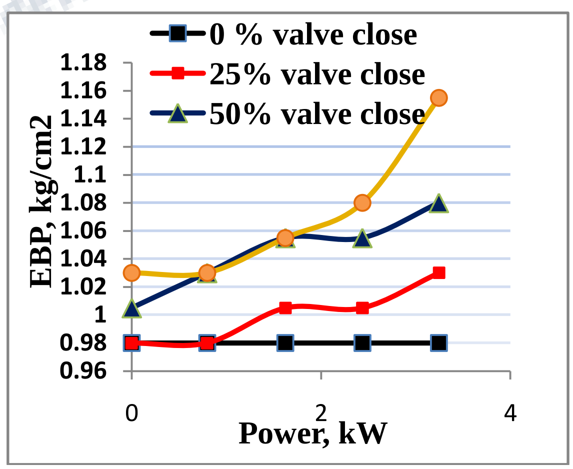

Fig. 3 Effect of valve closing on EBP

b. Brake specific fuel consumptions

The BSFC among valve closing (EBP) was found to be higher for 75% closing. This may be due to raise in EBP might not meeting respective power hence more consumption of fuel. Also, excess fuel present in engine was slightly showing detonation. This was resulting in poor performance. BSFC 0.349 kg/ kW hr at part load or power

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(75% load, 9 kg) was observed less at 0% valve closing

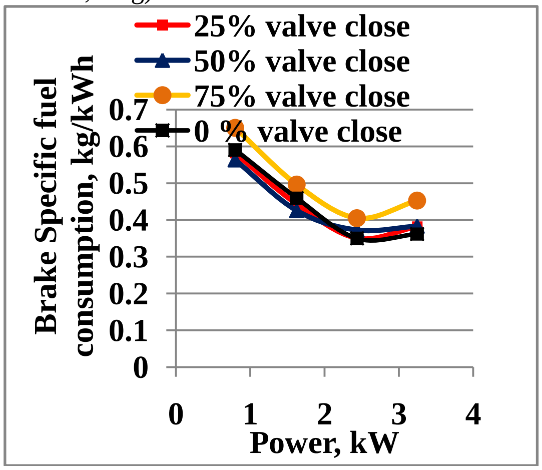

Fig. 4. Effect of BSFC on valve closing

4.3 Effect of BTHE on valve closing (EBP)

Effect of BTHE can be observed from Fig. 5 that it increases with increase in output power consumptions for all EBP. BTHE for 75% load (2.4 kW power) was found to be higher. For zero closing or no EBP, BTHE was highest 24.51% compared to 21.17% BTHE of 75% valve closing or 1.155 kg/cm^2 EBP. This may be due to no loss of power or fuel penalty during without EBP.

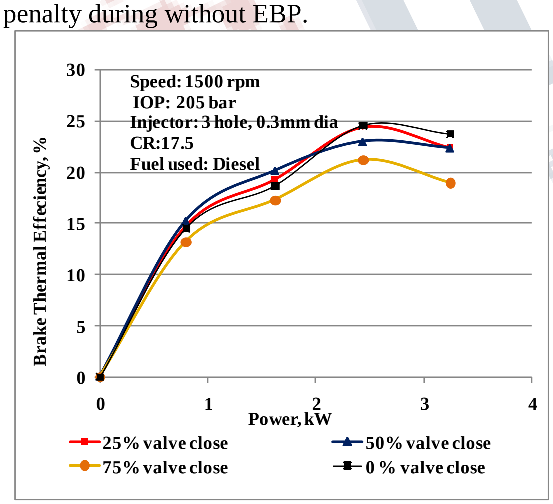

Fig. 5. Effect of BTHE on valve closing

The difference between these two BTHE is 13%. However, BTHE for 50% valve closing was closer to 25% and 0% valve closing. The BTHE was 6% inferior to no EBP condition.

4.4 NO Emissions

The effect of NO emissions with EBP at increase in power can be seen from Fig. 6. It was observed as expected that, NO emission was increasing with increase in load or output power. This may be due to higher combustions are producing higher peak cylinder temperature. Moreover, at higher in-cylinder temperature more NO are formed. The NO emission 658 ppm was highest at 756% valve closing and 3.21 kW power requirements. At 0% valve close (No EBP) NO emissions were least at part load while NO emissions were least for 50% valve close at full load (power) demand.

4.5 HC Emissions

It should be noted that HC emissions are significance of UHC. More the HC or CO emissions more will be fuel penalty. It was found to be at all load (power) demand HC emissions were higher for 75% valve closing. This may be due to lack of oxygen present for proper combustion. It was observed 88 ppm of HC with 75% valve closing which is about 55% inferior to NO EBP and cant be tolerated. However, HC emissions for 50% valve closings were lesser compared to other valve closing. The Fig. 7 sheds light on characteristics of HC emissions.

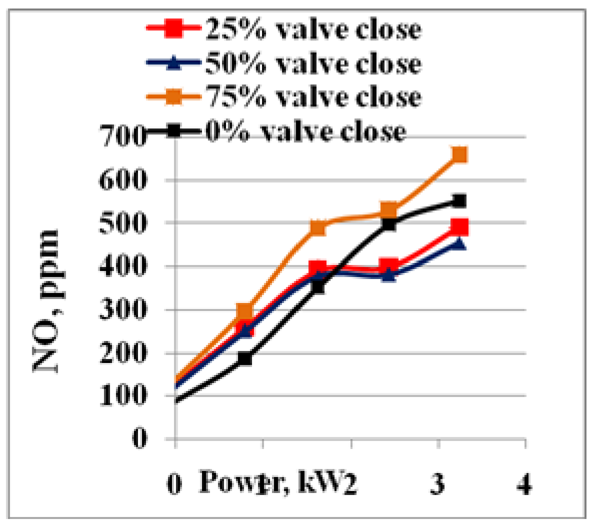

Fig 6 Effect of No emission on valve closing

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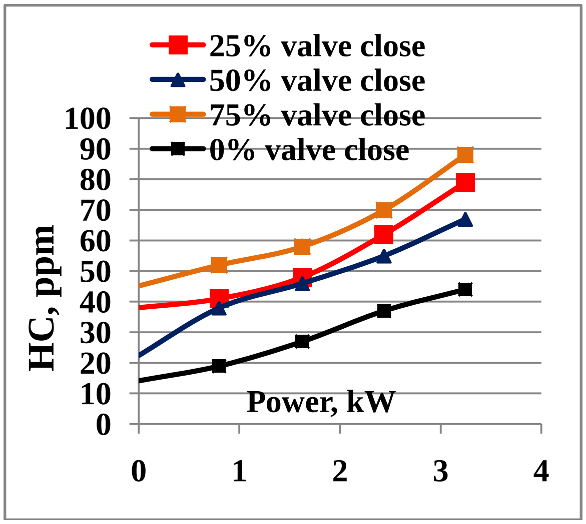

Fig. 7. Effect of HC emissions on valve closing

V. CFD RESULTS DISCUSSIONS

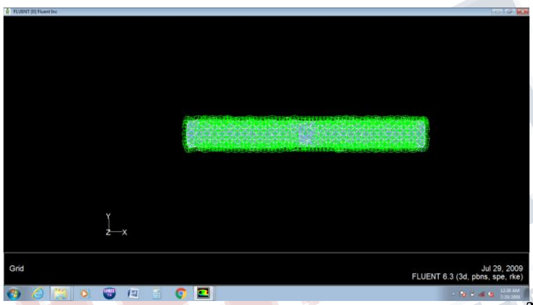

Fig. 8. Grids for 75% valve closing (1.155 kg/cm^2)

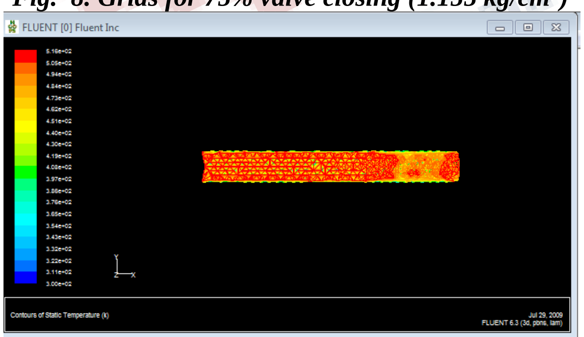

Fig. 9. Temperature contours for 50% Valve closing or 1.08 kg/cm^2 EBP

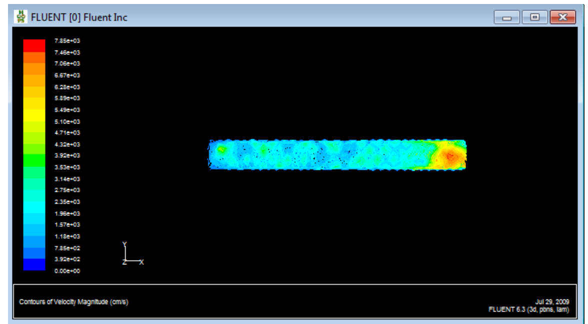

Fig. 10. Velocity contours for 50% Valve closing or 1.08 kg/cm^2 EBP

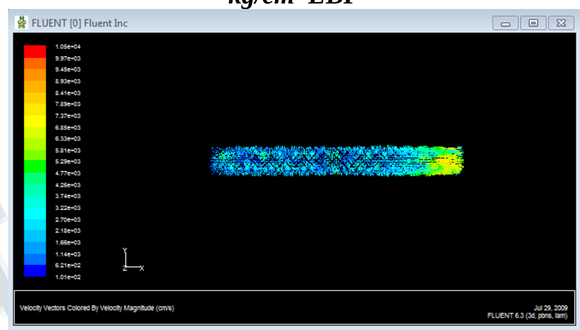

Fig. 11 Velocity vectors for 50% Valve closing or 1.08 kg/cm^2 EBP

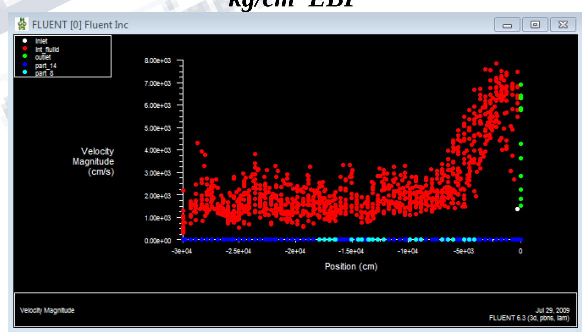

Fig. 12. XY Plot of velocity magnitude for 50% Valve closing or 1.08 kg/cm^2 EBP

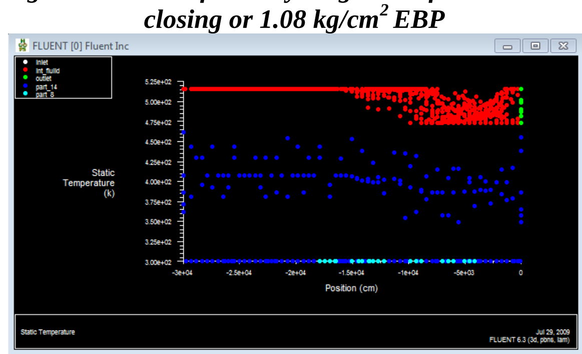

Fig. 13. Plot of Static Temperature magnitude for 50% Valve closing or 1.08 kg/cm^2 EBP

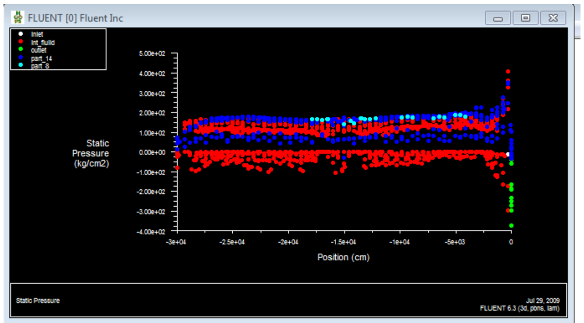

Fig. 14. Plot of pressure magnitude for 50% Valve closing or 1.08 kg/cm^2 EBP

VI. SUMMARY

It should be noted that for 50% valve closings and 1.05 to 1.08 kg/cm^2 emissions were almost closer to 25% valve closing. In addition 3 to 5% penalty of emissions can be observed. However, very less penalty in BTHE and BSFC about 6% was observed with 50% valve closing. Further, penalty of about 50% in all emissions and more than 16% in performance of 75% valve closing (1.155 kg/ cm^2) is inferior and not affordable. It should be crucial to note that 50% valve closing (1.05 to 1.08 kg/cm^2 EBP) can be applied effectively in tailpipe emissions reducing devices.

VII. CONCLUSIONS

- For long rote (location) of EBP has no significant effect of EBP. It was noted that only 0.02 kg/cm^2 gauge pressure or 1 kg/cm^2 absolute pressure was applied.
- Very less penalty in BTHE and BSFC at most 6% was observed with 50% valve closing. Further, penalty of about 50% in all emissions and more than 16% in performance of 75% valve closing (1.155 kg/ cm^2) is inferior and not affordable
- It should be noted that for 50% valve closings and 1.05 to 1.08 kg/cm^2 emissions were almost closer to 25% valve closing. In addition 3 to 5% penalty of emissions can be observed.
- In additions, CFD Fluent results of velocity, pressure and temperature- counters, XY Plot and vector have showed significant comparative analysis between optimum pressure 50% valve closing (1.08 kg/cm^2) and 75% valve closing (1.155 kg/cm^2) at peak power of 3.21 kW.
- It should be crucial to noted that 50% valve closing (1.05 to 1.08 kg/cm^2 EBP) can be applied effectively in tailpipe emissions reducing devices.

REFERENCE

1. Mathur M. L., Sharma R. P., “A course in internal combustion engines” Dhanpat-Rai publications, ND, 15th ed., (2005), pg. 3-9, 252-254.
2. Ganesan V., Engine emission and their control, “Internal combustion engines”, McGraw Hill, ND, 3rd ed., (2008), pg. 471-500.
3. Heywood J. B. “Fundamental of Internal Combustion Engines” McGraw Hill International Editions, Automotive Technology series, (1988) 87-1525.
4. Agrawal A. K., Singh S. K., Sinha S., Shukla M. K., “Effect of EGR on exhaust gas temperature and exhaust opacity in CI engines”, Sadhana vol. 29, part 3, (2004), pg. 275-284.
5. http://www.dieselnet.com/tech/diesel_exh_pres.php
6. Mayer, A., 2004. “Number-based Emission Limits, VERT-DPF-Verification Procedure and Experience with 8,000 Retrofits”, VERT, Switzerland, pg.367-374.
7. Peter Hield et al., “The effect of back pressure on the operation of a diesel engine”, Defence Science & Technology Organization, DSTO- TR-2011, Feb. 2011.
8. Murari Mohon Roy, et al., “Effect of Engine Backpressure on the Performance and Emissions of a CI Engine”, The 7th Jordanian International Mechanical Engineering Conference (JIMEC’7) (2010), 27 – 29.
9. Domkundwar, V.M., “A Course in Internal Combustion Engine, Dhanpat Rai and CO. (P) Ltd.”, 2000. Pg NO. edition etc.
10. Rabia S. M., and M. Abd-El-Halim., “Effect of valve timing and exhaust back pressure on the performance of gasoline engine”, Journal of Engineering Sciences, Assiut University, Vol. 38, No. 3, (2010) 685-696.
11. https://www.google.co.in/webhp?ie=UTF8&rct=j#q=Exhaust+Pressure+Valve+Removal
12. Mohammad Joardder, Md. Shazib Uddin and Murari Mohon Roy., “Effect of engine backpressure on the performance and emissions of a ci engine”, Proceedings of the International Conference on Mechanical Engineering, Dhaka, Bangladesh, ICME11-TH-013 (ICME2011),18-20.