International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-2, Issue-11, November 2014

Investigation on performance characteristics of single cylinder four stroke DI Diesel engine operating with varying cooled EGR (Exhaust Gas Recirculation) system.

Pratik G. Sapre, Kunal A. Bhagat, Prof.A.M.Wankhade, Prof.V.W.Khond

***Abstract*— This paper addresses the effective application of EGR(Exhaust Gas Recirculation) for reduction of NOx as well as its effect on engine performance from naturally aspirated direct injection stationary diesel engine. In same paper static single cylinder model is presented and experimentally validated to demonstrate the use of cooled exhaust gas recirculation (EGR) to alleviate the tradeoff between performance parameters & harmful engine emission. EGR is effective method to reduce NOx but its thermal throttling reduces thermal power efficiency can be validated from performance graph. The test were conducted on different load & constant speed i.e. 1530 rpm resulted 65% drop in NOx & also lower thermal efficiency that we don't deserve further work will vanish these effect., further presented static model may be considered as further study to optimized performance & emission characteristics. looking toward running & future oriented emission norms' compel engine manufactures to incorporate technology to reduce engine combustion temperature so that main reason behind NOx reduction is explain on the basis of actual test conduction in department lab and prediction by surveying emission papers. In this paper other emissions like HC,CO,CO2 were measured with cold EGR equipped with partially cold Heat exchanger in rout system**

***Index Terms*— Diesel Engine, NOx, Cooled EGR, Heat Exchanger.**

I. INTRODUCTION

Diesel Engines are typically more efficient due to higher compression ratio and also find significant used in heavy duty transportation sector, irrigation sector, small electric power generation and captive power plant engines because of its higher thermal efficiency and lower fuel consumption but it emits higher NOx which is one of most undesirable pollutant & so looking towards economical factor EGR (Exhaust Gas Recirculation) is most effective method to reduce NOx. The effect of EGR temperature on emission as well as performance parameter. However technology like Exhaust Gas Recirculation is essential to cater to the challenge posed by increasingly stringent environmental emission legislation. The overall role of exhaust gases in a the complete combustion process is well understood & test conducted on same engine[1].Pratik G sapre et al performed test on same engine & have emission variation on plane diesel fuel for different loading condition, he obtained tremendous decrement in NOx from exhaust and upto 65% reduction occurred.[2].Avinash Wankhade et al, Pratik G Sapre et al carried their first work on static diesel engine to learn effect of EGR on performance as well as on emission, these was about of hot EGR working and its effect on exhaust temperature and emission parameters[3].after carried experiment on it cooled EGR had modified performance graph than before work done. Deepak Agarwal et al.,[4] investigate the effect of EGR on soot deposited,& wear of vital engine parts, especially piston rings etc. Avinash kumar.et.al [8] studied the effect of EGR on exhaust gas temperature and exhaust opacity in CI engines. They found that that the exhaust gas temperatures reduce drastically by employing EGR. Thermal efficiency and brake specific fuel consumption are not affected significantly by EGR. However particulate matter emission in the exhaust increases, as evident from smoke opacity observations. Shahadat.et.al [15] studied the combined effect of EGR and inlet air preheating on engine performance in diesel engine. They found that at medium load conditions, oxides of nitrogen(NOx), carbon monoxide (CO), engine noise, and brake specific fuel consumption decreased when inlet air preheating and EGR were applied together as compared to those during normal operations of the engine. Ghazikhani.et.al [16] studied the effect of EGR and engine speed on CO and HC emissions of dual fuel HCCI engine. They observe that increasing engine speed at a constant EGR rate leads to increase in CO and UHC emissions due to the incomplete combustion caused by shorter combustion duration and less homogeneous mixture. Results also show that increasing EGR reduces the amount of oxygen and leads to incomplete combustion and therefore increases CO emission due to lower combustion temperature. HC emission also increases as a result of lower combustion temperatures. Selim [17] studied the Effect of exhaust gas recirculation on combustion characteristics of dual fuel engine. He found that the combustion noise and thermal efficiency of the dual fuel engine are affected when EGR is used in the dual fuel engine.

Manuscript received November 01, 2014.
Pratik G. Sapre, Department of Mechanical Engineering, M.Tech student at G.H.Raisoni College of Engineering,Nagpur
Kunal A. Bhagat, Department of Mechanical Engineering, M.Tech student at G.H.Raisoni College of Engineering,Nagpur
Prof.A.M.Wankhade, Associate Prof.B.N.C.O.E.Pusad
Prof.V.W.Khond, Asst.Prof.G.H.R.C.O.E.Nagpur.

II. EXPERIMENTAL SETUP & METHODOLOGY

A single cylinder, naturally aspirated four strokes, vertical air cooled engine is taken. Various parameters are measure by electric alternator type dynamometer used to measure brake power, tachometer to find rpm of engine, thermocouple to measure temperature, AVL five gas analyzer to measure various emissions like NOx,CO,HC etc.

Fig:-1 Experimental set of Cooled EGR

2.1.SPECIFICATION OF THE DIESEL ENGINE

Diesel engine used for this test is naturally aspirated water cooled single cylinder four stroke CI engine.

Engine Specification:-

4 Stroke single Cylinder air cooled self start CI engine.	Make:-Kirloskar
Rated Power:-7.5kw (10 HP)	Bore Dia.:-80mm
Stoke Length:-110mm	Connecting Rod Length:-234mm
Swept Volume:-562cc	Compression Ratio:-17.5:1
Rated Speed:-rpm	Rated Torque:-4.6kg-m
Arm Length:-150mm	

2.2.EGR TECHNIQUE

It is a well known to reduce NOx emission in which a part of exhaust gas is recirculation. It acts as diluents to the combustion mixture. Introduction of EGR is to reduce oxygen concentration. Increase specific heat of incoming charge which ultimately reduces peak combustion temperature. Resupply of unburnt hydrocarbon (opportunity to reburn)

EGR ratio is calculated as;

EGR %=Megr/Mi*100

C. MODEL CALCULATION

2.3Amount of exhaust gas taken from tail pipe

Data from available venturi dimensions & EGR pipe.

D=0.0875 m ⟶(bore dia. of engine)

L=0.11 m ⟶(stroke length)

N=1520 rpm = 25.33(rps)

$Q_s = \frac{\pi}{4} \times d^2 \times L \times H$

$= \frac{\pi}{4} \times 0.0875^2 \times 0.11 \times 25.33$

$Q_s = 0.01675\ m^3/s$

Flow through venturi meter,

d_1=0.0254 m ⟶A1=5.0671×10^{-4} m^2 (Area at inlet)

d_2=0.0127 m ⟶ A2=1.2667×10^{-4} m^2(Area at throat)

(1 inch=2.54 cm)

$$Q_{act} = 0.98 \times \frac{A1.A2}{\sqrt{A1^2 - A2^2}} \times \sqrt{2gh}$$

(Actual Discharged from Venturi)

To find h, from U-tube manometer reading,

It is taken 4 cm at full opening of Venturi valve when EGR is active mode.

x =4 cm = 0.04 m

$S_l = \frac{\rho ehhaust}{\rho air} = \frac{0.995}{1.24}$ =0.8024

S_h =1;

$\therefore h = x \times \left[\frac{Sh}{Sl} - \right] = 4 \times [\frac{1}{0.8024} - 1]$

=0.985 cm = 0.00985 m.

$\therefore$ Qact

$$0.98 \times \frac{(5.0671 \times 10-4) \times (1.2667 \times 10-4)}{\sqrt{(5.0671 \times 10-4)^2 - (1.2667 \times 10-4)^2}} \times \sqrt{2 \times 9.81 \times 0.00985}$$

$= 1.282983 \times 10^{-4} \times \sqrt{2 \times 9.81 \times 0.00985}$

Qact =5.64×10^{-5} m^3/s ⟶ z

Qatm= 0.01669 m3/s ⟶ y

Qventuri = 0.01675 ⟶ x

$$\therefore x - y = z$$

Qact/Qventuri ⟶ $\frac{0.0000564}{0.01675}$

=0.0033 m^3/s

0.00336 m^3/s amount of exhaust taken from EGR 1 inch pipe so, we have to find out how much % of exhaust taken from venturi can be calculated as,

$$\frac{0.00336}{0.01669} = 20.13\%$$

So, 20.13 % of exhaust gas is taken from exhaust tail passing from venturi modes and regulated by venturi EGR valve. Equations

Fig 2.Convergant –Divergent Nozzle

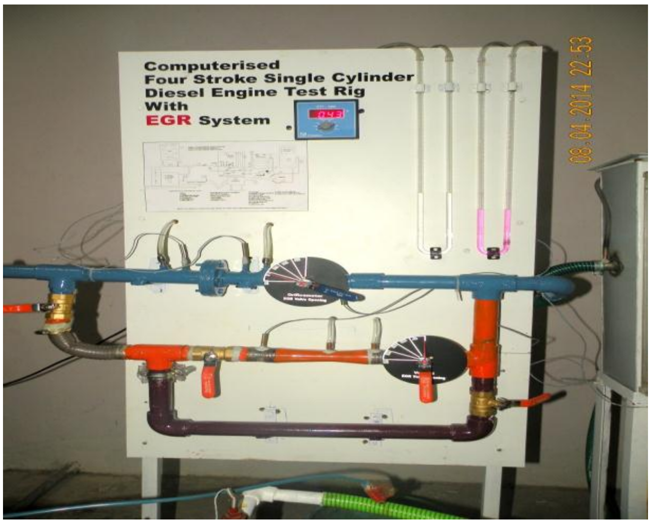

Fig 3.Schematic Test Rig with EGR system

The objective of developing this experiment test set up is to investigate and demonstrate the effect of various EGR rates on engine performance and emission.

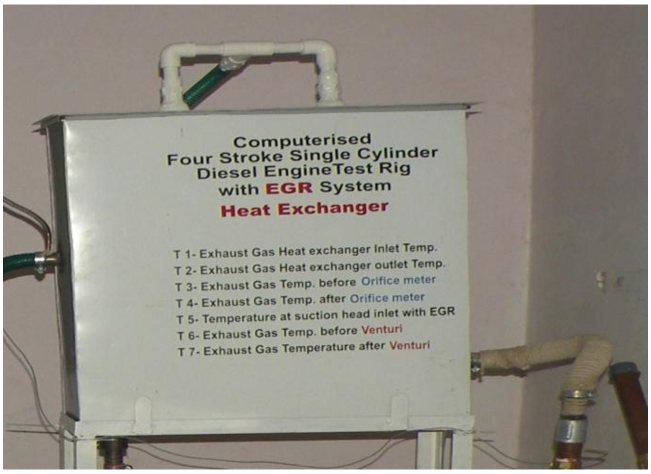

Fig 4.Indirect type partially cold Heat Exchanger

The water inlet for Stainless Steel pipe is given outlet source. In order to get the heat transferred from the exhaust gas to the water. It must be continuously supplied for maintaining the temperature of exhaust gas nearly equal to atmospheric temperature.

III. Results and Discussion

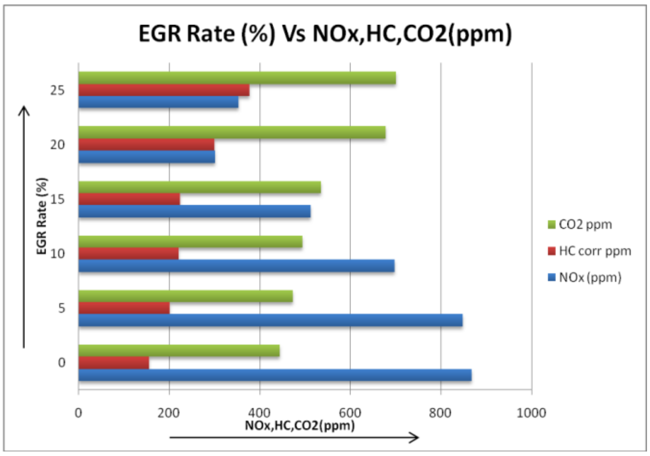

Fig 5:-NOx, HC,CO_2 Vs EGR Rate(%)

Above fig 5 shows combine relation between engine emission parameters with varying EGR rates (%) on 45 N-m Torque. When torque is increased it requires more fuel rate as compare to lower loading condition so in combustion chamber more amount of free air from atmosphere took part in chemical reaction.

A significant effect on NOx emission is obtained. Also combustion is affecting up to certain extent as a result of which HC emission is also getting high as shown but amount of carbon dioxide is increased at higher EGR rate.[1,3,7].

3.1 Brake Specific Fuel Consumption (kg/kWhr) vs. Torque(N-m)

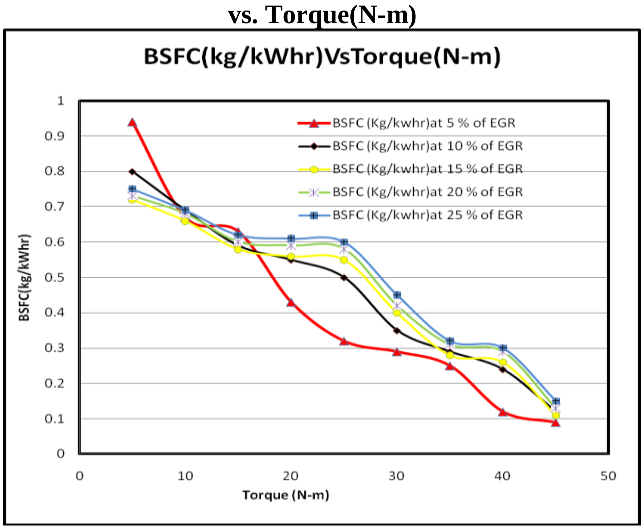

Fig 6 BSFC(kg/kWh)Vs. Torque(N-m)

In above fig BSFC Vs. Torque plotted. It indicates the variations of brake specific fuel consumption with increasing EGR rate. There is remarkable improvement in fuel consumption with increasing EGR. One of the main reason for that effects is due to the reduction of pumping work as the amount of EGR rate is increased(with fuel and air flow rate remains constant),the pump work get reduced and hence the entire inlet charge needing to come passed the throttle. Again due to the reduction in heat loss to the wall of cylinder the significant reduction in burnt gas reduction, improve the fuel consumption trends. The reductions in degree of dissociation in high temperature burn gases also improve brake specific fuel consumption.[6,7,8].

3.2 Mechanical Efficiency vs. Torque(N-m)

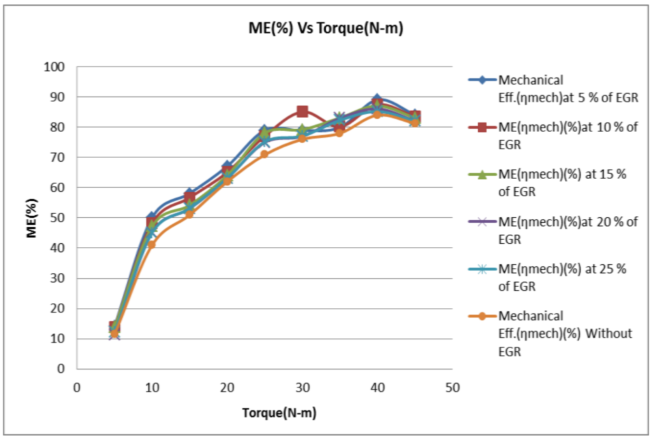

Fig 7 Mechanical Efficiency (%) Vs. Torque (N-m)

Above graph fig 7 is plotted between mechanical efficiency with torque for EGR & without EGR Case. The value of mechanical efficiency for each case is given in result table. Value of mechanical efficiency follows same behavior as Torque increases and decreases after 45 N-m torque. After 40 N-m torque mechanical efficiency is get reduced is due to value of brake power is get reduced. Engine rated torque is 50 N-m so that mechanical efficiency having lower value at high torque condition.[10,11].

3.3 Crank Angle (Degree) Vs. Cylinder pressure (Bar)

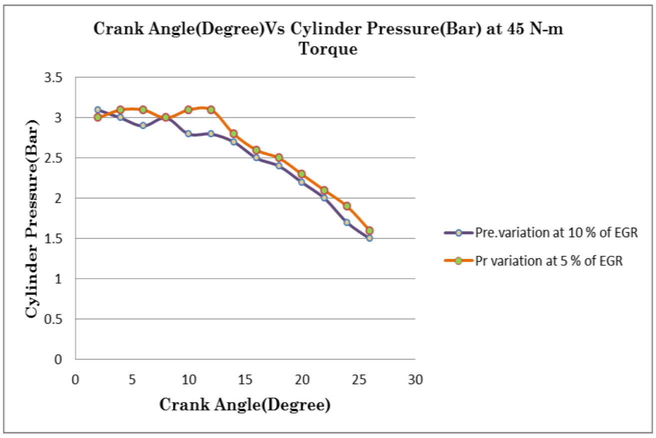

Fig 8 . Cylinder pressure (Bar) Vs Crank Angle in (Degree)

Above graph is plotted between Cylinder pressures Vs Crank angle. Values of crank angle and respective cylinder pressure are taken from performance table. As pressure variation with 5%, 10% of EGR case shows clearly that pressure value is get reduced when 10 % of EGR is supply so it reduce cylinder pressure and also regulates peak temperature value of cylinder in which combustion is taking place, so NOx formation is lower in case of lower cylinder temperature. This means premixed combustion duration for the EGR is lower than that for diesel & reduces the tendency of NOx formation significantly. EGR & without EGR shows similar trends & comparable results in case of cylinder pressure which shows that the mixture formation is good for EGR & the engine operates with same level of maximum pressures.[12]

3.4 Influence of Torque on Air Fuel Ratio

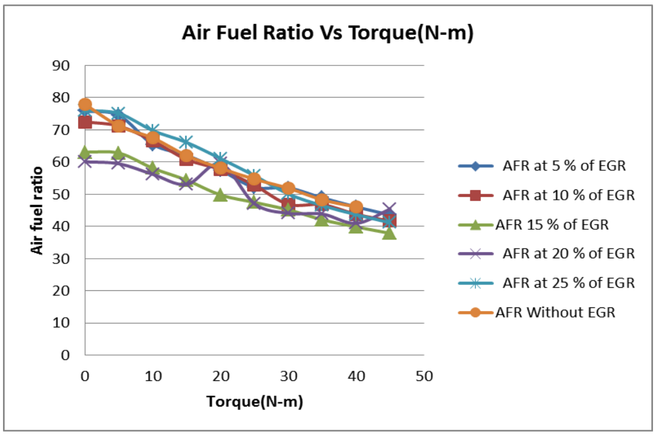

Fig 9 Influence of Torque on Air Fuel Ratio

Above graph shows variation between Air Fuel Ratio and Torque. It can be noted that conventional diesel operation exhibits lower Air Fuel Ratio. This is because diesel combustion process involves utilization of large amount of excess air due to heterogeneous mixture. That is leaner mixture at high load condition. The effect become more visible on above graph as the EGR (%) increased at high load. As a result Air Fuel Ratio higher than that associated with diesel and effects are more apparent with high EGR (%).[9,10,14].

3.5 Influence of Torque on O_2 conc.(%)

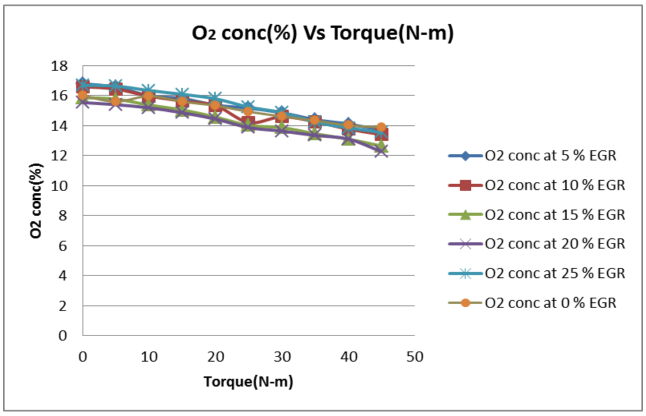

Fig 10.Influence of Oxygen Conc.(%) and Torque(N-m) on NOx emission

In above fig7,line showing amount of oxygen is taking part in chemical process in combustion chamber as EGR is passed simultaneously oxygen conc. By(%) is decreased as shown. When sufficient amount of air is used to burn a certain amount of fuel, while the excess oxygen goes with exhaust as it is in addition the part of air away from the combustion zone does not experienced the combustion process at all. The oxygen conc. available in cylinder is considerably reduced when operating in EGR mode & especially reduced at high EGR ratio at high load so the oxygen conc.(%) subsequently reduced and producing less NOx formation requires higher amount of free molecules of oxygen in combustion chamber.[14]

IV. Conclusion

● an experimental investigation was done on a single cylinder four stroke, water cooled diesel engine. The effect of EGR on Performance & Exhaust emission of the diesel engine was observed & the result of this study may be concluded as follows

● to visualize various effects of the utilization of EGR in single cylinder CI engine, comparative results are given for both with & without EGR case & plotted individually to show its behavior under certain parameter & Torque. Validation results like cylinder pressure versus crank angle shows the interlink effect on emission parameters, reading taken at 9 different torque so as to find out & tolerate in between effects when engine operated under different loading & unloading conditions.

● the cylinder peak pressure of a diesel engine can be reduced by applying the EGR mode strategy. The utilization of EGR further reduces the peak pressure & hence extends the engine life. The effect increases with the increment in EGR percentage.

● Engine operating with cooled EGR was able to reduced NOx up to 65% and reduction in brake thermal efficiency and increases in smoke; CO and UBHC were observed compared to plane diesel.

Acknowledgements

"We wish to express our appreciation to the Mechanical department of B.N.C.O.E.Pusad for supporting financially the project under which current investigation of study has been conducted also we wish to express our grattitude to Prof.V.W.Khond(Prof.From G.H.Raisoni Engg. College) and Prof.A.M.Wankhade for giving idea and domain about this work and the guidelines during the operational investigations."

Fig 11 Computerized DA System to check Performance of Engine

References

[1]Christopher Simoson,John Wagner,''Effects of Cooled EGR on a small Displacement Diesel Engine:A Reduced-Order Dynamic Model & Experimental Study'',ASME,(March 2008,Vol.130/011102-1-11.

[2]Pratik G.Sapre,Kunal Bhagar,''Emission Characteristics for single cylinder DI Diesel engine with Exhaust Gas Recirculation System",IJESRT, [Sapre, 3(9): September, 2014],P.P.315-323.

[3]Avinash Wankhade,Pratik G.Sapre,"Effect of EGR on NOx & Performance Parameters in single cylinder four stroke CI engine",IJERD,vol 10,Issue 6,(June 2014),pp.59-67.

[4]Deepak Agarwal , Shrawan Kumar singh, Avinash Kumar Agarwal; Effect of Exhaust Gas Recirculation (EGR) on performance, emissions, deposits and durability of a constant speed compression ignition engine, Applied Energy 88 (2011) 2900–2907.

[5]Prof. Walke P. V., GHRCE Nagpur, Dr. Deshpande N. V., Professor, V.N.I.T, Nagpur, "Performance and emission characteristics of Diesel Engine using catalyst with exhaust gas recirculation" Proceedings of ASME, Mechanical engineering congress and exposition, November 05-10, 2006, Chicago, Illinois, paper No. IMECE2006-14484.

[6]John B. Heywood "Internal Combustion Engine Fundamentals", 1988, (New York: Mc-Graw Hill), 572 - 590.

[7]Avinash Kumar Agrawal, Shravan Kumar Singh, "Effect of EGR on the exhaust gas temperature and exhaust opacity in CI engine' S¯adhan¯a Vol. 29, Part 3, June 2004, pp. 275 - 284.

[8]M.L.Mathur, R.P. Sharma, 2003 Internal Combustion Engine (New Delhi: Dhanpat Rai Publications) pp 760 - 776.

[9]V Ganeshan, 2007, Internal Combustion Engines Inc.end.(New York: Mc-Graw Hill), pp 480-499.

[10] S.Ghosh,D.Dutta,''Performance & emission parameters analysis of gasoline engine with EGR'',IJERD,vol 4,issue 10,(Nov 2012),pp 8-12.

[11] Prof. Gaurav Rathod, "Combine effect of exhaust Gas Recirculation (EGR) & Varring Inlet air pressure on Performance & emission of CI engine", IOSR-JMCE, Vol. 6, Issue 5(May-jun.2013), pp 26-33.

[12] Alain Maiboom, 2007," Experimental study of various effect of exhaust gas recirculation (EGR) on combustion & emission of an automotive direct injection diesel engine", ELSEVIER, (16-March-2007).

[13] Gurumoorthy S.Hebbar,''Investigation on Performance & Emissions of stationary DI diesel engine with different EGR temperature'',IJAET,(4 April 2014),pp1-9,2013.

[14] M.M.Abdelaal,A.H.Hegab,''Combustion & emission characteristics of a natural gas-fueled diesel engine with EGR'',ELSEVIER,(26 sept 2012),pp 301-312.

[15] Shahadat, M. M. Z., Nabi, M. N., Akhter, M. S.,Tushar, M. S. H. K. 2008. Combined Effect of EGR and Inlet Air Preheating on Engine Performance in DieselEngine. International Energy Journal, 9, 2.

[16] Ghazikhani, M., Kalateh, M. R., Toroghi, Y. K., and Dehnavi, M. 2009. An Experimental Study on the Effect of EGR and Engine Speed on CO and HC Emissions of Dual Fuel HCCI Engine. World Academy of Science, Engineering and Technology.

[17] Selim, M. Y. E. 2003. Effect of exhaust gas recirculation on some combustion characteristics of dual fuel engine. Energy Conversion and Management, 44: 707-721


Pratik G. Sapre obtained his bachelor degree in Mechanical Engineering from Babasaheb Naik College of Engineering, on 2014. Presently he is a Master Degree student (Heat Power specialization) in the Department of Mechanical Engineering,GHRCE, Nagpur,MH,India.


Avinash M Wankhade obtained his Bachelor of Engineering in Mechanical and Master of Engineering degrees in Tribology. Presently, he is working as an Associate Professor in BNCOE at SGBAU Amravati University. He is actively engaged in IC engine research.


Kunal Bhagat obtained his bachelor degree in Mechanical Engineering from Pandav College of Engineering, on 2013. Presently he is a Master Degree student (Heat Power specialization) in the Department of Mechanical Engineering, GHRCE, Nagpur,MH,India


V.W.Khond obtained his Bachelor of Engineering in Mechanical and Master of Engineering degrees in Thermal Engineering. Presently, he is working as an Associate Professor in GHRCE at RTM Nagpur University. His area of interest is in alternate fuel & IC engine.

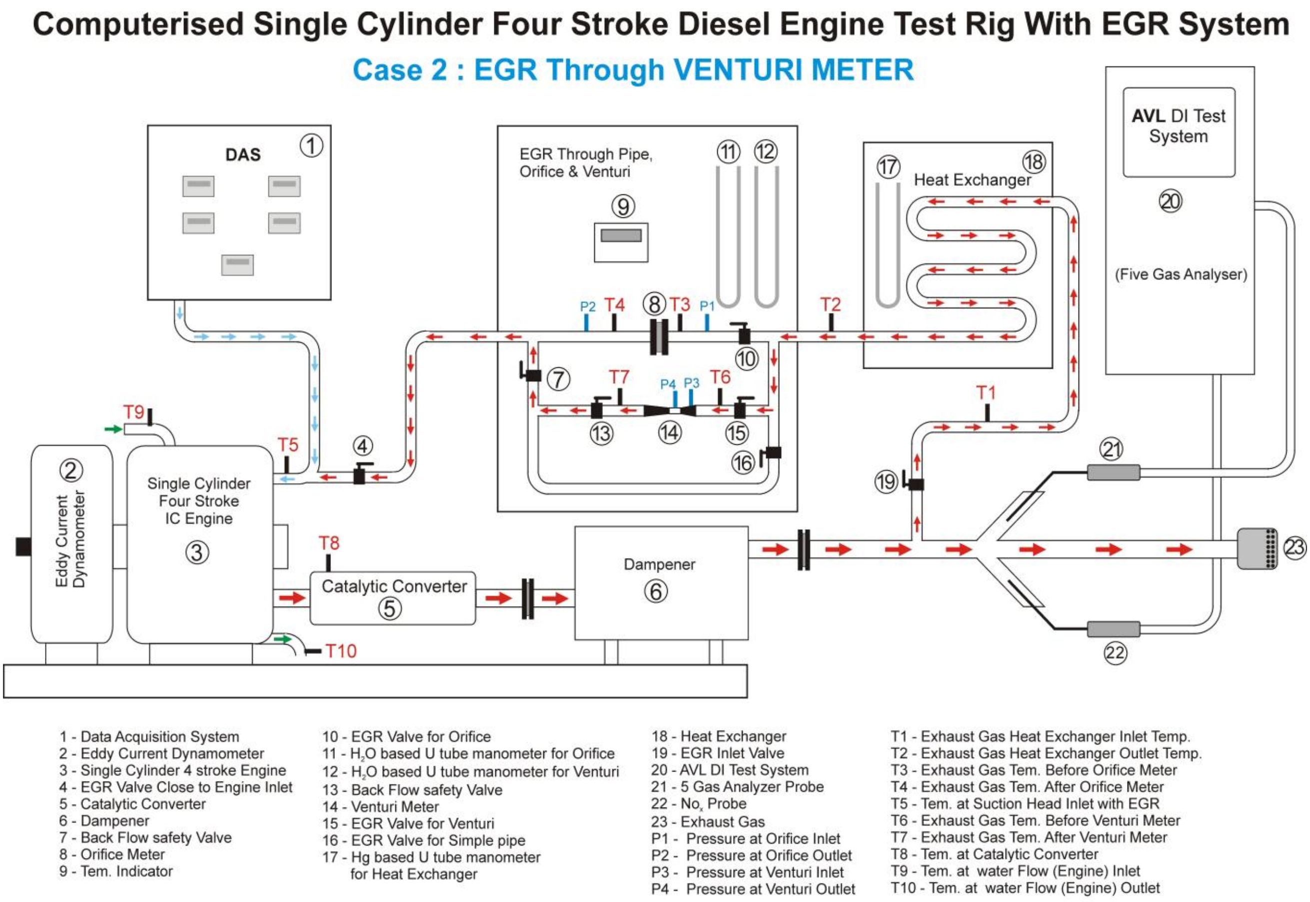

Fig 12 Line diagram of proposed Exhaust Gas Recirculation test rig & flow thought venturi meter.