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Comparison of Part and Full load Emissions of CI and HCCI Engine with Exhaust Gas Recirculation

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Abstract:The present study is experimentation, not only on CI engine but also conducting experiment on CI engine running on HCCI mode operation without using exhaust gas recirculation and with using exhaust gas recirculation and comparing the emissions of both such as the Oxide of Nitrogen (NO_X), Oxides of carbon (CO), carbon dioxide (CO_2), Un-burnt hydro-carbons (HC)etc., These values are measured and compared under various conditions and plotted for easy understanding of effect of EGR on engine emissions. This paper focused on part load and full load emission comparisons for CI and HCCI mode operations with and without using exhaust gas recirculation. So separate experiments conducted and readings are recorded.

Keywords: *CI, EGR-CI, HCCI, EGR-HCCI, CO, NOx*

1. Introduction

As we know engine emissions are the important parameter to evaluate the running conditions of the engine, not only in environmental point of view but also on human health. The emissions indicate how well the combustion process and it exhaust concentrations from combustion and also how good working condition of the engine. The present study is conducting experimentation, not only on CI engine but also CI engine running on HCCI mode of operation and comparing the emissions of both such as the Oxide of Nitrogen (NO_X), Oxides of carbon (CO), carbon dioxide (CO_2), Un-burnt hydro-carbons (HC). These values are measured and compared under various conditions and plotted graphs for easy understanding of engine emissions. It is my small effort to know emission comparisons for CI and HCCI mode operations using exhaust gas recirculation.

2. Measurement of Exhaust gas emissions

Table-1 specifications of Multigas analyser

MEASURMENT	RANGE	RESOLUTION
CO	0 -9.99%vol	0.001%vol
HC	0-15000PPM	1PPM
CO_2	0-20%vol	0.01%vol
O_2	0-25%vol	0.1%vol
NOx	0-5000PPM	1PPM vol
Engine RPM	500-6000RPM	1RPM
Oil Temperature	0-150^{0}C	1^0

Lambda(λ)	0.200-2.000%	0.001

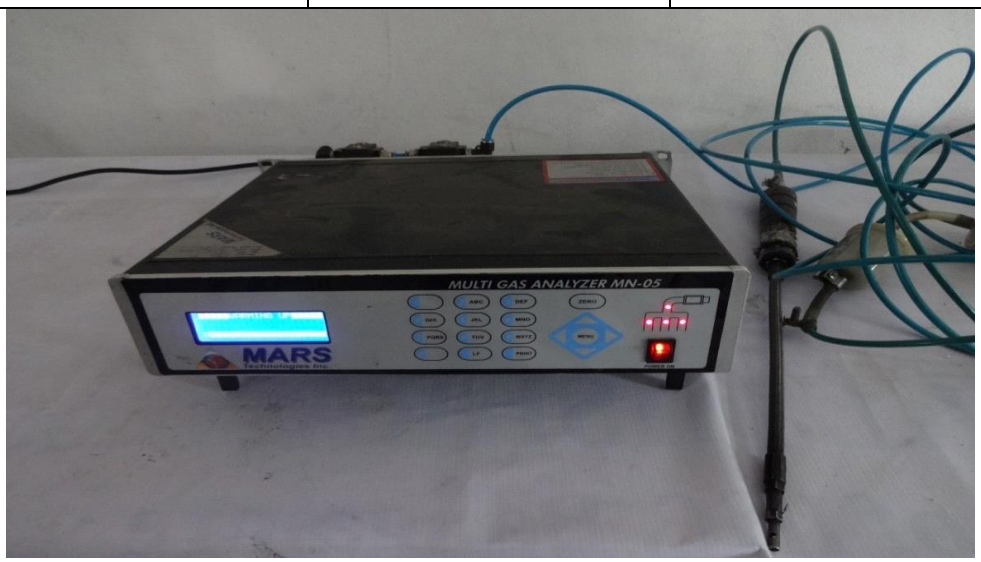


Figure1. Exhaust gas analyzer

Exhaust gas analyzer type NM-05 of five gas version is used in this experiment which will analyze the emissions of NOx, CO,CO_2 ,HC and O_2 gases. This is a multi gas analyser of MARS make which can analyze five gases and it works based on infrared spectroscopy technology with signal inputs from an electrochemical cell. It is a Non-dispersive infrared measurement technique with signal inputs from an electrochemical cell which uses for measurement of CO, CO_2 and HC gases. The following are the specifications of Mars make Multi-gas analyser MN-05

3. Comparison of emissions under part load and full load using EGR

3.1 Nitrogen oxide (NO_X):

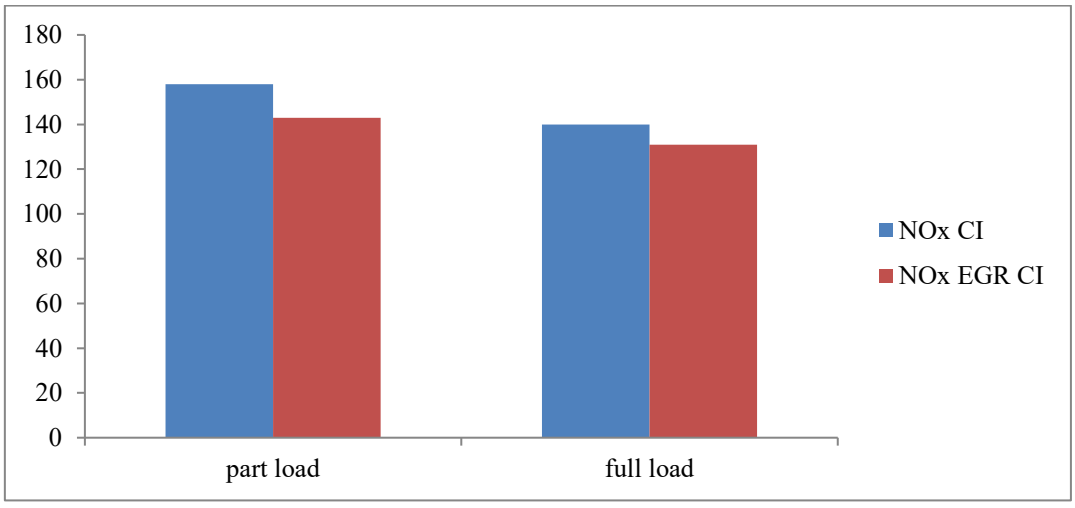
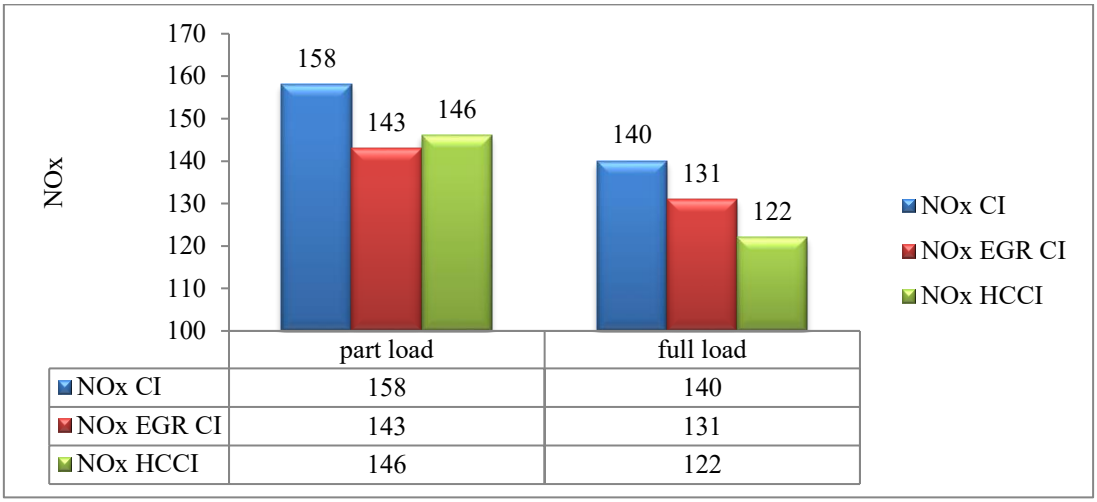


Figure2: NO_x Vs BP at CI & EGR CI

NOx emissions are lower than the normal CI condition using exhaust gas recirculation for both condition of CI and EGR-CI. Using exhaust gas recirculation NOx emissions are reduced at full load when compared with part load.

The following figure shows the comparison of NOx for three test conditions, it shows with increasing brake power the emission of NOx is decreasing for all three test conditions of normal CI, EGR-CI and HCCI.



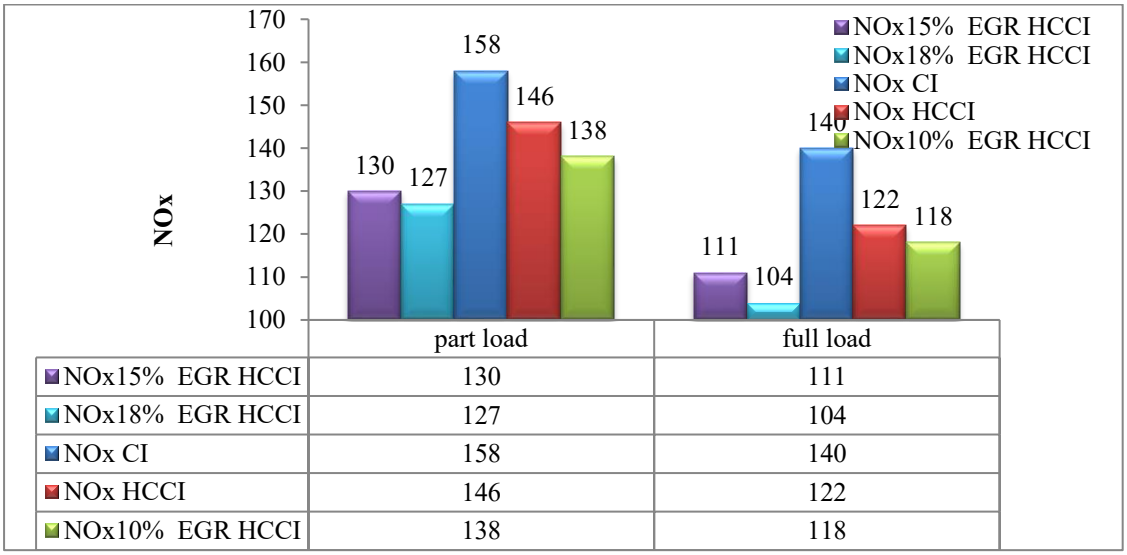
	part load	full load
NOx CI	158	140
NOx EGR CI	143	131
NOx HCCI	146	122

Figure3: NO_x Vs BP at CI, EGR-CI& HCCI

4. Nitrogen oxide (NO_X) with EGR

Figure4.0 gives the picture of the NO_X emissions at part load and full load conditions at all the test conditions. Test one is emissions of NOx under normal CI condition at full load and part load. Test two is emission of NOx under the running condition of normal CI engine using exhaust gas recirculation at part load and full load and third condition is running of modified CI engine in the mode of HCCI condition at part load and full load.

. It was observed for all three test conditions CI,EGR-CI and HCCI the NOx emissions at full load is lower than the part load condition and also the emission of NOx is lower than CI and HCCI at part load using exhaust gas recirculation.

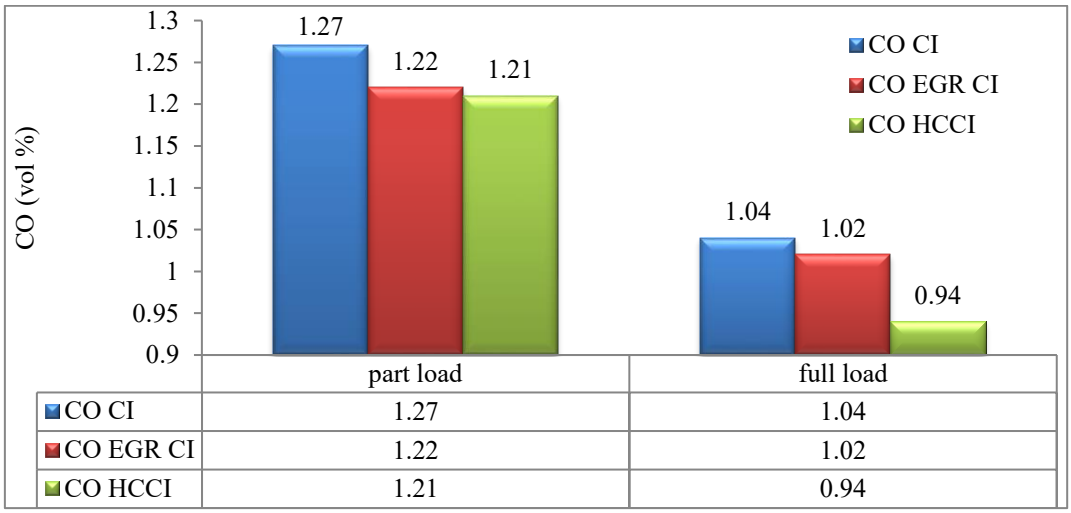


	part load	full load
NOx15% EGR HCCI	130	111
NOx18% EGR HCCI	127	104
NOx CI	158	140
NOx HCCI	146	122
NOx10% EGR HCCI	138	118

Figure4: NOx Vs BP at CI & EGR HCCI

Comparison of NOx emissions under three test conditions of CI, HCCI and EGR-HCCI is for Part load is 50% load on the engine and full load is 100% load on the engine. The NOx emissions are expressed in parts per million. NOx emissions at part load is higher for CI mode running.It shows the NOx emissions for HCCI condition at part load is higher than full load condition. The emissions of at full load condition shows NOx emissions are decreasing with the increased substitution of exhaust gas recirculation and also emissions of NOx at all substitution of exhaust gas recirculation is higher at part load

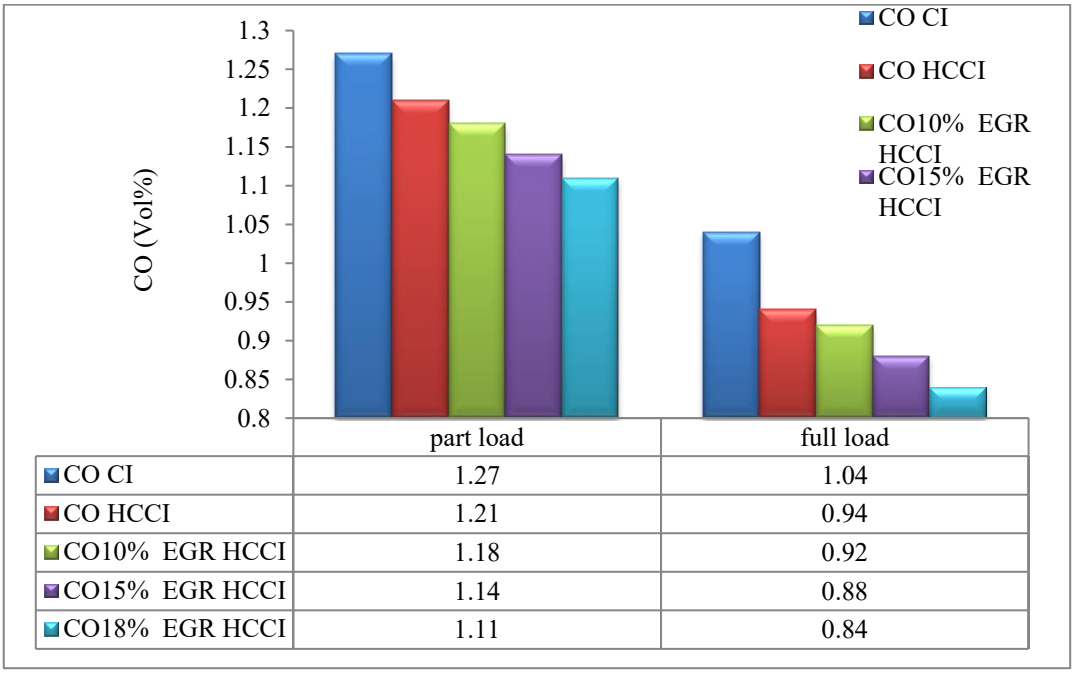
4.1 Carbon monoxide (co):



	part load	full load
CO CI	1.27	1.04
CO EGR CI	1.22	1.02
CO HCCI	1.21	0.94

Figure5: CO at CI, EGR CI and HCCI

For all test conditions the emissions are higher at part load copared to for full load conditions.

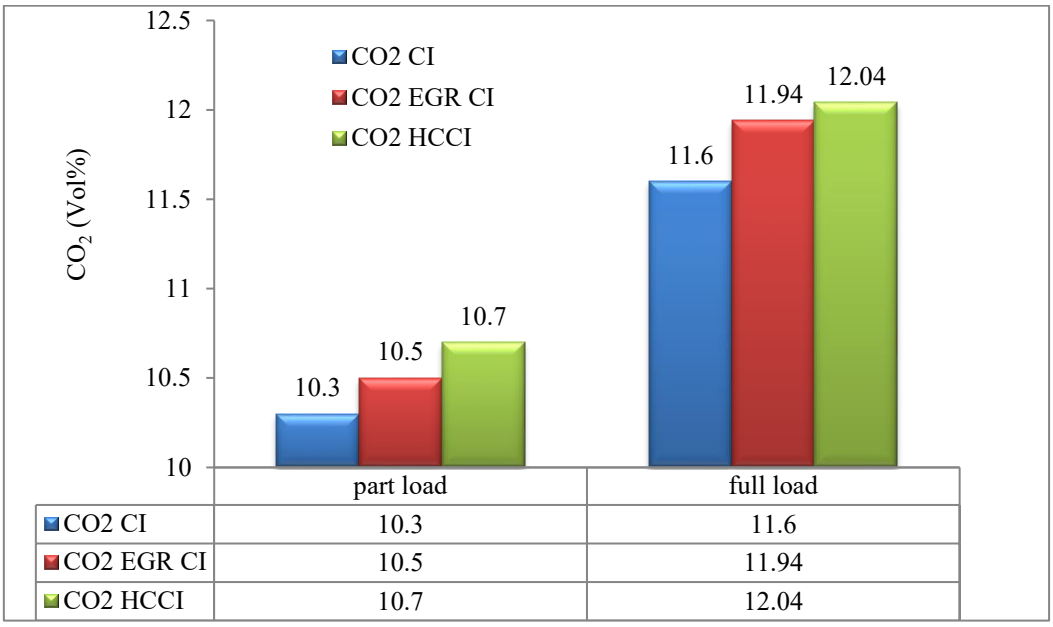


	part load	full load
CO CI	1.27	1.04
CO HCCI	1.21	0.94
CO10% EGR HCCI	1.18	0.92
CO15% EGR HCCI	1.14	0.88
CO18% EGR HCCI	1.11	0.84

Figure 6: CO at CI and EGR HCCI

At all the test condition the CO emissions are higher at part load when compared with full load condition. At part and full load conditions CI engine emissions are higher than emission of HCCI and emissions are decreasing with the increase of exhaust gas recirculation.

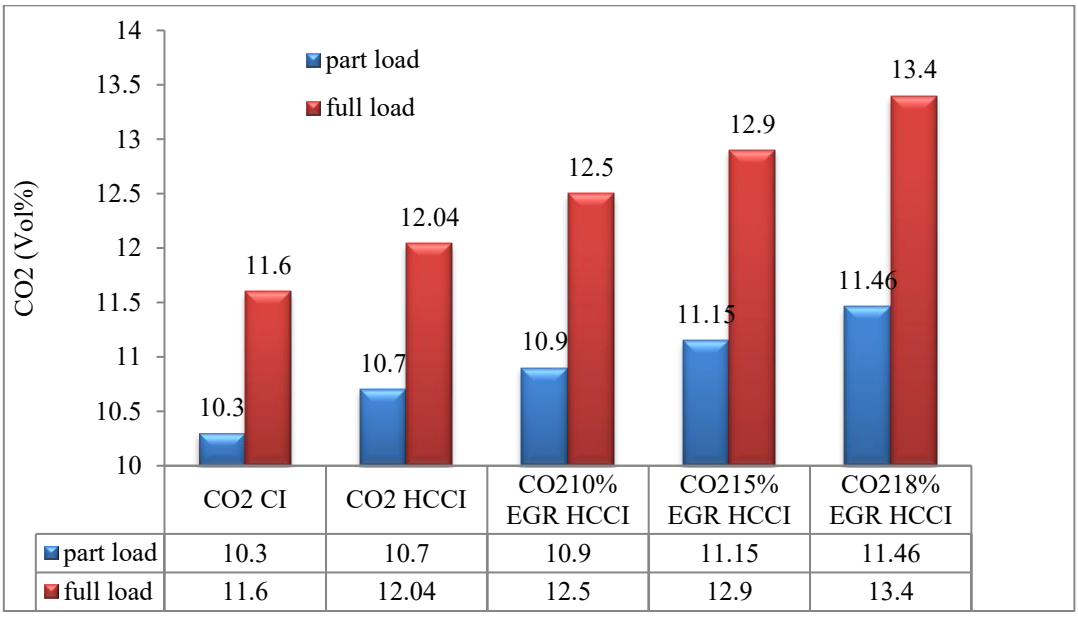
4.2 Carbondioxide (CO_2)



	part load	full load
CO2 CI	10.3	11.6
CO2 EGR CI	10.5	11.94
CO2 HCCI	10.7	12.04

Figure7: CO_2 at CI, EGR CI and HCCI

CO_2 emissions are higher at full load for normal CI condition. it is also showing CO_2 emissions are higher at full load of EGR-CI condition and the third is CO_2 emissions of HCCI test condition also at full load is higher than part load for HCCI condition. on these three test trail, emissions of CO_2 is higher at full load then the part load.

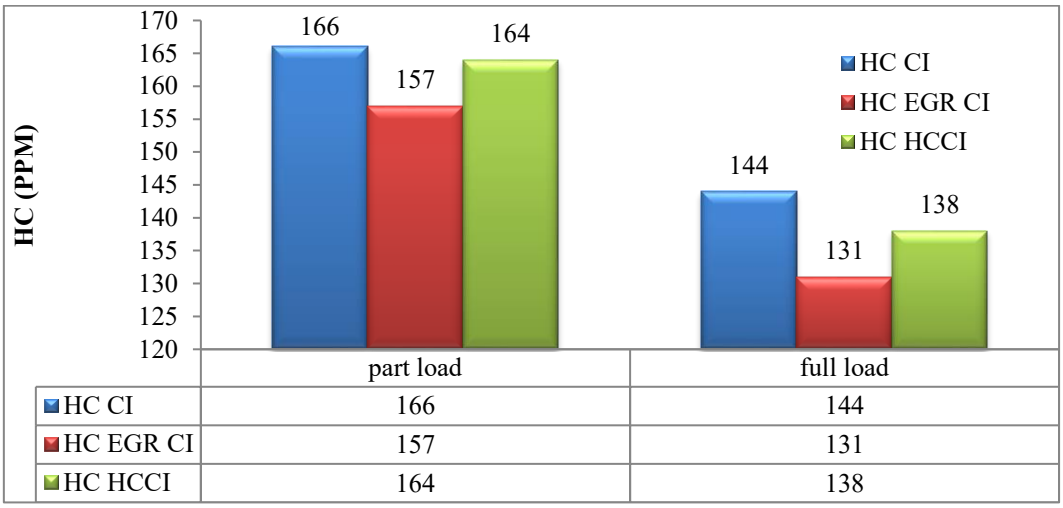


	CO2 CI	CO2 HCCI	CO210% EGR HCCI	CO215% EGR HCCI	CO218% EGR HCCI
part load	10.3	10.7	10.9	11.15	11.46
full load	11.6	12.04	12.5	12.9	13.4

Figure8: CO_2 Vs BP at CI and EGR HCCI

In all above cases the emissions of CO_2 is higher at full load than part load and also CO_2 emissions are increasing with the increased flow rate of exhaust gas recirculation which is higher at 18% of EGR on HCCI test condition with full load and lower for CI engine test condition at part load.

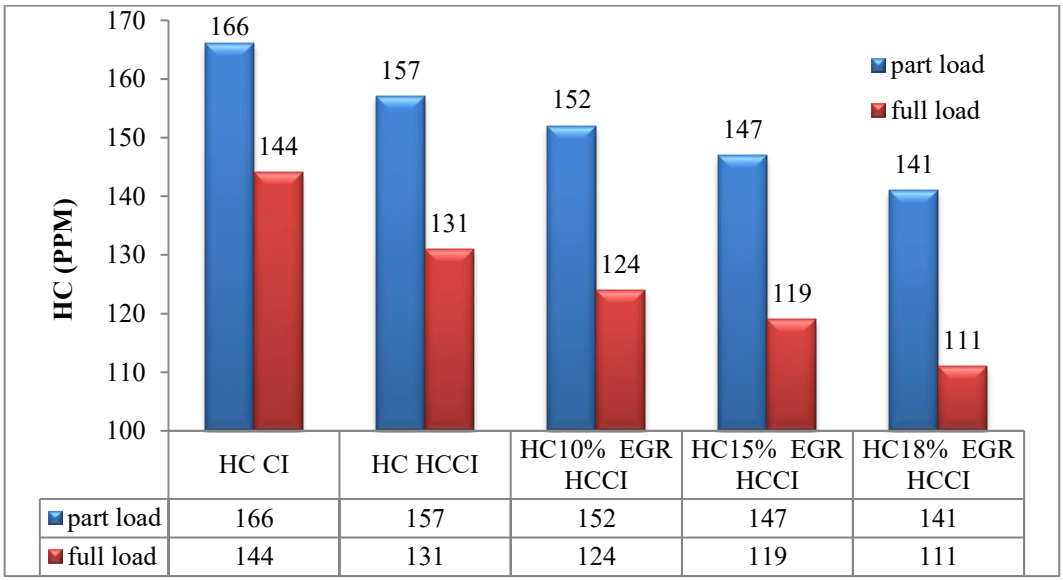
4.3 Hydro carbons (Hc):



	part load	full load
HC CI	166	144
HC EGR CI	157	131
HC HCCI	164	138

Figure9: HC at CI and HCCI

At Part and full load EGR-CI engine hydrocarbon emission with exhaust gas recirculation is lower than the emission of normal CI and HCCI without using exhaust gas recirculation. In all three cases the emissions at full load condition is lesser then part load condition.



	HC CI	HC HCCI	HC10% EGR HCCI	HC15% EGR HCCI	HC18% EGR HCCI
part load	166	157	152	147	141
full load	144	131	124	119	111

Figure10: HC at CI and EGR HCCI

HC emission for CI test condition is higher at part load and for full load test condition and for EGR-HCCI condition at part load with exhaust gas recirculation emissions are higher than full load the with exhaust gas recirculation. for all these conditions the emissions of HC is higher at part load and also shows with increased rate of exhaust gas recirculation the emission of hydro carbons are decreasing.

5. Comparison of HCCI Engine results with and without EGR

The NOx emissions of normal CI are higher than HCCI condition. NOx emissions of HCCI condition is 8% lower by median value and it is nearer to EGR-CI condition. With 18% EGR on HCCI condition NOx emissions are much lower(9%) than normal CI and EGR-CI condition

Up to 66% of brake power CO emissions of HCCI condition is 11% lower by median value than normal CI condition, there after it will increase with increase of BP. With the substitution of 18% EGR on HCCI condition at part load there is a drop of 10% CO emissions and it is increasing at higher loads.

CO_2 emissions are higher when CO emissions are lower for both CI and HCCI condition. CO_2 emissions of HCCI is higher than EGR-CI condition. At higher load using 18% of exhaust gas recirculation on EGR-HCCI there is a drop of 10% CO_2 emissions ,it indicate increasing of carbon monoxide.

HC emissions of HCCI condition is 8% lower than normal CI condition at lower load. With the use of 18% EGR on EGR-HCCI engine there is a drop of 7% HC emissions and increasing marginally at peak load.

6. Conclusions

- The NOx emissions decreases with the use of EGR, at 18% EGR on HCCI mode, NOx emissions are much lower than normal CI and EGR-CI modes.
- At part load of HCCI mode CO emissions are lower by median value than normal CI condition. With the substitution of 18% EGR on HCCI condition at part load there is a drop of 10% CO emissions.
- CO_2 emissions are higher, when CO emissions are lower for both CI and HCCI modes. An emission of CO_2 for HCCI is higher than EGR-CI mode. At higher load using 18% of exhaust gas recirculation on EGR-HCCI there is a drop of 10% CO_2 emissions, which indicate increasing of carbon monoxide.
- When CO_2 emissions are higher, it appears CO emissions are lower for CI and HCCI engines. At higher load using 18% of exhaust gas recirculation on EGR-HCCI there is a drop of 10% CO_2 emissions ,it indicate increasing of carbon monoxide and less efficient combustion.
- HC emissions of HCCI mode are lower than normal CI condition at lower load. But with the use of 18% EGR on HCCI engine there is a drop of 7% HC emissions and after it is increasing marginally at peak load.

REFERENCES

[1] P.margard, F.mauss, M.kraf,; “homogenous charge compression engine simulation study on the effects of in homogeneities” Journal of engineering for gas turbines and power, Vol.125,April 2003 by ASME, page 466-471, www.asme.org

[2] Nidal H. Abu-Hamdeh,;"Effect of cooling the recirculated exhaust gases on diesel engine emissions", Energy Conversion and Management, Volume 44, Issue 19, November 2003, Pages 3113–3124.

[3] D.S. Kim, C.S. Lee, “Improved emission characteristics of HCCI engine by various premixed fuels and cooled EGR”, Fuel 85 pp 695–704, 2006.

[4] Keeler, B., and Shayler, P. J., 2008, “Constraints on Fuel Injection and EGR Strategies for Diesel PCCI-Type Combustion,” SAE Paper No. 2008-01-1327

[5] D.T. Hountalasa, G.C. Mavropoulosa, K.B. Binderb,; “Effect of exhaust gas recirculation (EGR) temperature for various EGR rates on heavy duty DI diesel engine performance and emissions”, Energy, Volume 33, Issue 2, February 2008, Pages 272–283.

[6] Maiboom, A., Tauzia, X., and Hétet, J., "Experimental Study of Various Effects of Exhaust Gas Recirculation (EGR) on Combustion and Emissions of an Automotive Direct Injection Diesel Engine," Energy, 33 (1), pp. 22–34. 2008,

[7] M. Ghazikhani, M. R. Kalateh, Y. K. Toroghi, and M. Dehnavi ,;"An Experimental Study on the Effect of EGR and Engine Speed on CO and HC Emissions of Dual Fuel HCCI Engine" Engineering and Technology, International Journal of Mechanical, Aerospace, Industrial, Mechatronics and Manufacturing Engineering Vol: 3, No: 4, 2009, World Academy of Science.

[8] Yuh-Yih Wu, Ching-Tzan Jang, Bo-Liang Chen,; "Combustion Characteristics of HCCI in Motorcycle Engine" Journal of Engineering for Gas Turbines and Power by ASME, APRIL 2010, Vol. 132 / 044501-1

[9] Deepak Agarwala, Shrawan Kumar Singha.C, Avinash Kumar Agarwalb,;" Effect of Exhaust Gas Recirculation (EGR) on performance, emissions, deposits and durability of a constant speed compression ignition engine" Applied Energy, Volume 88, Issue 8, August 2011, Pages 2900–2907.

[10] Morteza Fathi, R. Khoshbakhti Saray and M. David Checkel,; " The influence of Exhaust Gas Recirculation (EGR) on combustion and emissions of n-heptane/natural gas fueled Homogeneous Charge Compression Ignition (HCCI) engines" Applied Energy, 2011, vol. 88, issue 12, pages 4719-4724.

[11] Harilal S. Sorathia, Dr. Pravin P. Rahhod and Arvind S. Sorathiya,; "Effect Of Exhaust Gas Recirculation (EGR) On NOx emission From C.I. Engine" - A Review Study" International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974 IJAERS/Vol. I/ Issue III/April-June, 2012.

[12] P. M. Diaz,N. Austin, K. Maniysundar, D. S. Manoj Abraham, and K. Palanikumar,; "Simulation Analysis of Combustion Parameters and Emission Characteristics of CNG Fueled HCCI Engine" - Hindawi Publishing Corporation Advances in Mechanical Engineering, Article ID 541249, 10 pages, November 2013

[13] Rahul Chandra, Abhishek Jha, A.V.Laxmi,; "Performance Of Diesel Engine Using Exhaust Gas Recirculation", ISSN 2278-3091 ,International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.1, Pages : 433 – 436 (2013)

[14] Elahehneshat, Rahim Khoshbaknti Saray,; "Effect of different heat transfer modes on HCCI engine simulation" Energy conversion and management 88(2014)Page 1 to 14 www.elsevier.com

[15] M. Bidarvatan, M. Shahbakhti,; "Gray-Box Modeling for Performance Control of an HCCI Engine With Blended Fuels" Journal of Engineering for Gas Turbines and Power by ASME, October 2014, Vol. 136 / 101510-1

[16] T. Karthikeya Sharma, G. Ambaprasad Rao, K. Mahu murthy,; Department of Mechanical Engineering NIT- Warangal "Effective reduction of incylinder peak pressures in HCCI engine – A computational study" Alexandria Engineering Journal 54- Elsevier (2015) 373-382

[17] Bang- Quan He, Mao-Binliu, Hua Zhao,; "Comparison of combustion character tics of n-butanol / ethanol – gasoline blends in a HCCI engine" Energy conversion and management 95 (2015) 101-109,www.elsevier.com

[18] Amin Yousefi , Ayatallah Gharehghani, Madjid Birouk,; "comparison study on combustion characteristics and emissions of HCCI Engine with and without pre combustion chamber –Energy conversion and management 100(2015) 232-241

[19] Samad Jafarmadar, Peyman Nemati, Rana Khodaie,; "Multi dimensional modeling of the effect of EGR on energy terms in an HCCI engine fueled with a mixture of natural gas and diesel"- Energy conversion and management 105 (2015) 498-508,www.elsevier.com

[20] Usman Asad, Ming Zheng, David S.-K. Ting, Jimi Tjong,; "Implementation Challenges and Solutions for Homogeneous Charge Compression Ignition Combustion in Diesel Engines" Journal of Engineering for Gas Turbines and Power by ASME, OCTOBER 2015, Vol. 137 / 101505-1

[21] Jose Marime Lujan, Carlos Guardiola, Benjamin pla, Pan Bares,; " Estimation of trapped mass by in cylinder pressure resonance in HCCI engines" Mechanical Systems and signal processing 66-67 (2016) 862-874,www.elsevier.com