International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 10‖ October 2013 ‖ PP.39-47

Analysis of Exhaust Emissions on Diesel-Biodiesel Blends with Ethyl Hexyl Nitrate Additive and Exhaust Gas Recirculation

K. Srinivasa Rao[1], M. Rajesh[2], K. Venkateswarlu[3]
[1]*(M.Tech Student, Thermal Engineering, Mechanical Engineering Department, V.R.Siddhardha Engineering College, India)*
[2]*(Assistant Professor, Mechanical Engineering Department, V.R.Siddhardha Engineering College, India)*
[3]*(Associate Professor, Mechanical Engineering Department, M.I.C.College of Engineering, India)*

ABSTRACT: *Direct injection (DI) diesel engine is well designed today as a main power train solution for transportation due to its several advantages. However, at the same time emission legislation, mainly for oxides of nitrogen (NOX) and particulate matter (PM) becomes more obvious, reducing their limit to extremely low usage as transport vehicles. One efficient method to control NO_X in order to achieve the future emission limit are the rather exhaust gas recirculation (EGR). EGR is one of the most effective means of reducing NO_X emissions from compression ignition (CI) engines and is widely used in order to meet the emission standards. In the present work experimental investigators are carried out on a single cylinder direct injection diesel engine using diesel-biodiesel blends with cetane improver Ethyl Hexyl Nitrate as an additive under different Exhaust Gas Recirculation conditions. The combined effect of EGR and Ethyl Hexyl Nitrate on the reduction of NO_X emissions. The combined effect of EGR and Ethyl Hexyl Nitrate on Exhaust emissions is studied. With increase in EGR percentage CO_2, CO emissions increases while HC, NO_X emissions decreases.*

KEYWORDS : *CO_2 Emissions, CO Emissions, Exhaust Gas Recirculation, Ethyl Hexyl Nitrate, HC Emissions, NO_x Emissions, Palm Stearin Oil*

I. INTRODUCTION

In the face of escalating oil prices and depleting oil reserves, the search for alternative sources of fuels has been intensified more than ever before in the history of mankind. Aside energy security concerns, issues of climate change as a result of the emission of carbon dioxide (CO_2), Nitrogen emissions (NO_X), carbon monoxide (CO) and other harmful compounds associated with the use of fossil fuel have also been one of the driving forces in the search for alternative sources which are environmentally friendly and sustainable. The use of bio-diesel in diesel engines dates back to 1892 when Rudolf Diesel demonstrated his new invention (diesel engine) using peanut (groundnut) oil as the fuel. Aside economies of scale which favored petroleum derived fuels subsequently, other factors have also hampered the use of bio-diesel in diesel engines. Of great concern are the relatively high viscosities and the low volatilities of most of the bio-diesels and carbon deposits on the piston during the running of the engine. All these factors have been observed to have a negative impact on the performance of the engine. A possible remedy proposed by many authors is the blending of the bio-diesel and diesel in some proportions. This is expected to cut down on cost, improve the fuel properties to make it suitable for use in engines and also reduce the quantity of greenhouse gases being emitted into the atmosphere and also global warming can be reduced. The other possible remedy is to modify car engines to run purely on B100 (100% bio-diesel). This could be expensive but one that may provide a long-term solution barring any conflict with food production. The main commodity sources of biodiesel in India are non-edible oils obtained from plant species such as Jatropha, Pongamia, pinnata, karanja etc. Also, the use of biodiesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons (HC), carbon monoxide (CO) and participate matters. But uses of biodiesel slightly increase nitrogen oxide (NO_X) which can be reduced by incorporating EGR system.

NO_X formation in diesel engines is predominant when the temperature in the combustion chamber is high since at higher temperatures the tendency of nitrogen to react with oxygen causes NO_X to increase. Many authors reported that biodiesel has oxygen content which allows for better combustion and reduces emissions of engine exhaust, except NO_X emissions [1-5]. This problem can be overcome by using NO_X reduction techniques like Exhaust Gas Recirculation (EGR). EGR is recirculation of a part of the exhaust gas which helps in reducing the NO_X [6] which however is accompanied by increased paniculate and unburned hydrocarbon (UHC) emissions [7].

EGR Is applied in diesel engines both with diesel and biodiesel as fuels separately. Especially Jatropha biodiesel (JBD) produced higher NO_X in diesel engines when compared to other Biodiesel fuels. JBD combined with EGR operation in diesel engines reduced NO_X emissions considerably [8, 9]. Sunflower methyl ester biodiesel blend B20 combined with EGR 15% produced 25% less NOx emissions compared to diesel fuel for the same level of smoke emissions which also increases brake thermal efficiency and BSFC [10]. Emission standards like EURO-V need to be incorporated in diesel engines to maintain higher EGR levels for cleaner emissions [11]. EGR, with proper injection timing, and injection pressure can reduce the NO_X emission with a trade-off on smoke and efficiency. Retarded injection timing without EGR with 220-230 bar injection pressure is the optimum combination for controlling the NO_X emission with lesser effect on smoke density and efficiency [12]. However Higher EGR levels are responsible for the development of gaseous emissions like hydrocarbons and for increased particle density and size in the exhaust [13, 14]. Biodiesel-is a viable alternative to petroleum diesel which improves the performance of diesel engines and reduces the emissions except NO_X [15]. Diesel-biodiesel blends require additives for improving the lubricity, ignition and better mixing. In that oxygenates are the candidates for reducing particulates since they contain oxygen content which helps in better combustion and lower exhaust emissions[16-21]. The addition of Di Methyl Carbonate (DMC) to diesel fuel increases efficiency marginally with reduction in NO_X emissions while PM and soot emissions were reduced considerably [22, 23]. However low cetane number and high latent heat of vaporization while low viscosity and insufficient lubricity of Di Methyl Ether (DME) are the limiting factors of DMC as an additive [24]. Additives like Diethylene Glycol Dimethyl Ether and liquid cerium showed significant improvements in BSEC and exhaust emissions [25]. Coated engines with Additives exhibited improved efficiency, in addition to the increase in cylinder pressure, reduction in NO_X and reduction in maximum heat release rate. Thermal Barrier Coated (TBC) DI diesel engine with fuel additives (di iso propyl ether) reduced the smoke density and NO_X emission of the engine exhaust [26]. 1-4 dioxane, an ether derived from alcohol as an additive to the diesel fuel reduced smoke density with slight increase in NO_X and drop in fuel economy. Brake thermal efficiency is improved marginally and smoke reduced significantly with the blends when compared to neat diesel for TBC engines [27]. Cetane improvers reduce the ignition delay [28] which allows better cold starting, reduced NO_X emissions, and smoother engine operation [29]. Ignition delay in engines plays an important role in combustion performance and reducing all regulated and unregulated emissions including NO_X emissions [31]. Cetane improver with oxygenate such as glycol ether reduced particulate, HC, and CO emissions [32]. Ethanol-diesel blends with EHN as additive increased BTE and reduced significantly the emissions like CO,THC, smoke, and particulates in CRDI diesel engine and also decrease cylinder pressure, ignition delay, the maximum rate of pressure rise, and the combustion noise[33]. While Ethanol-diesel blends with cetane improver with advanced fuel injection angle shows a large decrease in exhaust smoke concentration and a small decrease in exhaust NO_X concentration [34].

The main objective of the paper is to ascertain which of the locally available bio-diesel is most suitable to replace diesel in CI engines. The paper sought to establish the best blends that give

1. Highest thermal efficiency.
2. Minimum brake specific fuel consumption of the engine
3. Minimum smoke density
4. Lower Emissions

To achieve these objectives, a four stroke single cylinder CI engine constant speed with Exhaust Gas Recirculation is been considered with the blends of Palm Stearin biodiesel and diesel and the following parameters were observed:

1. Fuel consumption rate
2. Thermal efficiency
3. Smoke density
4. Exhaust gas temperature
5. Emissions from the engine

To perform this experiment smoothly, several objective arc aimed. The objectives of this experiment are: To analyze the significance of exhaust gas recirculation (EGR) system in reducing nitrogen oxide in the exhaust gas emissions. To study the combined effects of the EGR system and DTBP towards the performance of the engine and exhaust gas emissions. To compare the effects of using biodiesel and diesel fuel to the performance and emissions of a diesel engine. Palm stearin oil was obtained from the open market. Blend of palm stearin oil and diesel were prepared such that the following B30 and B100; on volume basis were obtained. Fuel specifications and parameters were determined at the university Laboratory. The calorific value, viscosity, Flash and Fire point of each blend were determined at Italab Private Limited, Industrial Testing & Analytical Laboratories, Chennai.

II. METHODOLOGY

Exhaust Gas Recirculation is an efficient method to reduce NO_X emissions from the engine. It works by recirculating a quantity of exhaust gas back to the engine cylinders. Intermixing the recirculated gas with incoming air reduces the amount of available O2 to the combustion and lowers the peak temperature of combustion. Recirculation is usually achieved by piping a route from the exhaust manifold to the intake manifold. A control valve within the circuit regulates and times the gas flow. The same factors that cause diesel engines to run more efficiently than gasoline engines also cause them to run at a higher temperature. This leads to a pollution problem, the creation of nitrogen oxides (NO_X). You see, fuel in any engine is burned with extra air, which helps eliminate unburned fuel from the exhaust. This air is approximately 79% nitrogen and 21% oxygen. When air is compressed inside the cylinder of the diesel engine, the temperature of the air is increased enough to ignite diesel fuel after it is ignited in the cylinder. When the diesel fuel ignites, the temperature of the air increases to more than 1500°F and the air expands pushing the piston down and rotating the crankshaft. Some of the oxygen is used to burn the fuel, but the extra is supposed to just pass through the engine unreacted. The nitrogen, since it does not participate in the combustion reaction, also passes unchanged through the engine. When the peak temperatures are high enough for long periods of time, the nitrogen and oxygen in the air combines to form new compounds, primarily NO and NO_2. These are normally collectively referred to as "NO_X".

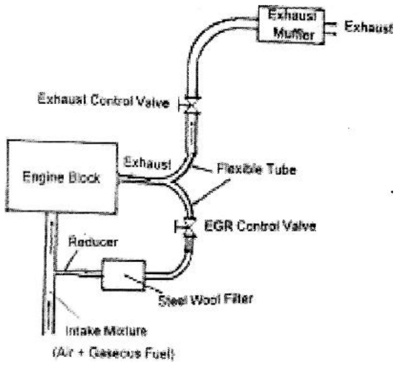

Fig. 1 EGR System

Nitrogen oxides are one of the main pollutants emitted by vehicle engines. Once they enter into the atmosphere, they are spread over a large area by the wind. When it rains, water then combines with the nitrogen oxides to form acid rain. This has been known to damage buildings and have an adverse effect on ecological systems. Too much NO_X in the atmosphere also contributes to the production of SMOG. When the sunrays hit these pollutants SMOG is formed. NO_X also causes breathing illness to the human lungs. Since higher cylinder temperatures cause NO_X, So it can be reduced by lowering cylinder temperatures. Charge air coolers are already commonly used for this reason. Reduced cylinder temperatures can be achieved in three ways.

- Enriching the air fuel (A/F) mixture.
- Lowering the compression ratio and retarding ignition timing.
- Reducing the amount of Oxygen in the cylinder

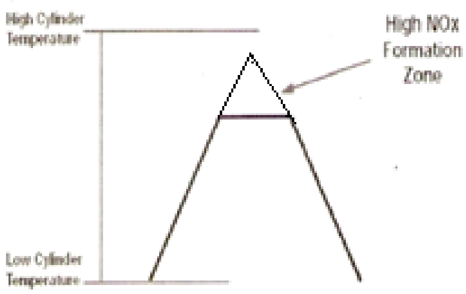

Fig. 2 NO_X formation zone

Enriching the air fuel (A/F) mixture to reduce combustion temperatures. However, this increases HC and carbon monoxide (CO) emissions. Also Lowering the compression ratio and Retarded Ignition Timing make the combustion process start at a less than the optimum point and reduces the efficiency of combustion. These techniques lower the cylinder temperature, reducing NO_X. But it also reduces fuel economy and performance, and creates excess soot, which results in more frequent oil changes. So, the best way is to limit the amount of Oxygen in the cylinder. Reduced oxygen results in lower cylinder temperatures. This is done by circulating some exhaust gas and mixing it into the engine inlet air. This process is known as Exhaust Gas Recirculation.

III. RESULTS AND DISCUSSIONS

In this paper exhaust emission analysis of biodiesel is investigated. Most vehicle fuels (gasoline, diesel, natural gas, ethanol, etc) are mixtures of hydrocarbons, compounds that contain hydrogen and carbon atoms. In a perfect engine, oxygen in the air would convert all of the hydrogen in fuel to water and all of the carbon in the fuel to carbon dioxide (carbon mixed with oxygen). Nitrogen in the air would remain unaffected. In reality, the combustion process is not perfect, and automotive engines emit several types of pollutants. The emission analysis graphs of HC, NO_X, CO and CO_2 are shown in Fig. from 3 to 18

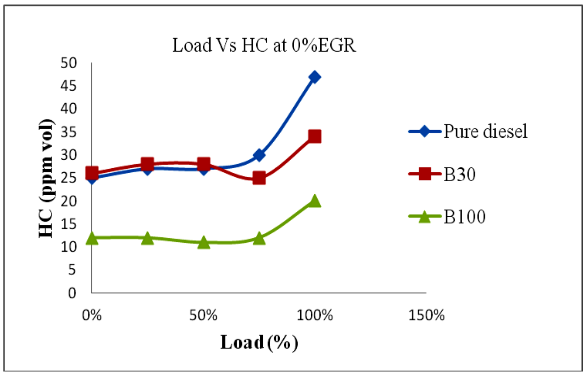

Fig. 3 HC Emissions of Varying Load with 0% EGR

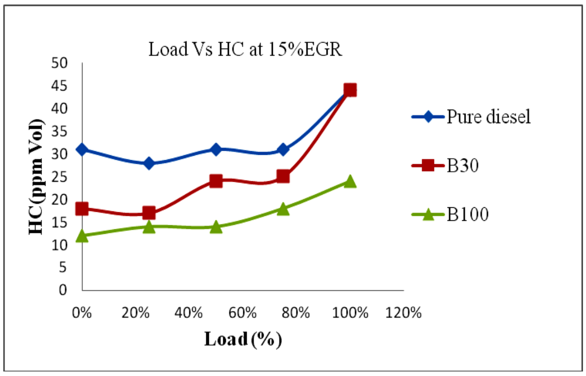

Fig. 4 HC Emissions of Varying Load with 15% EGR

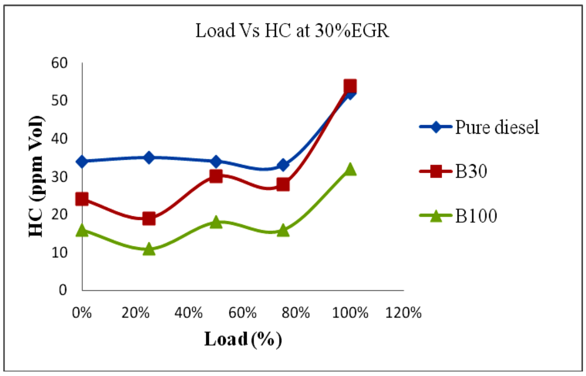

Fig. 5 HC Emissions of Varying Load with 30% EGR

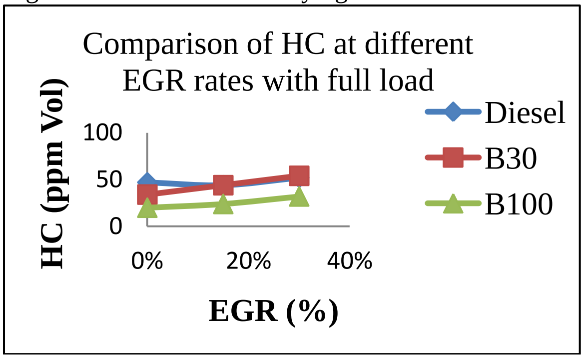

Fig. 6 Variation of HC Emissions with EGR mass fraction at Full Load

From Fig. 3 to 6 it can be seen that HC emissions decrease with biodiesel percentage at all loads. It can also be seen that HC emissions increase with increase in EGR rate.

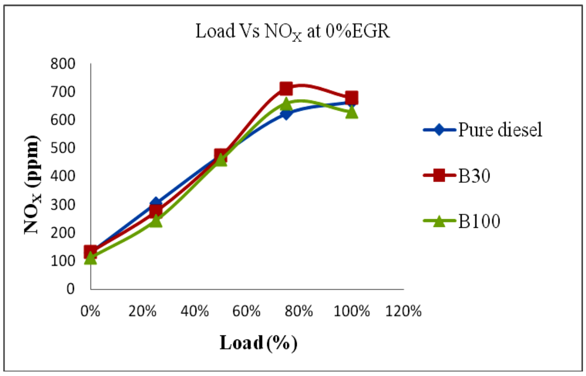

Fig. 7 NO_X Emissions of Varying Load with 0% EGR

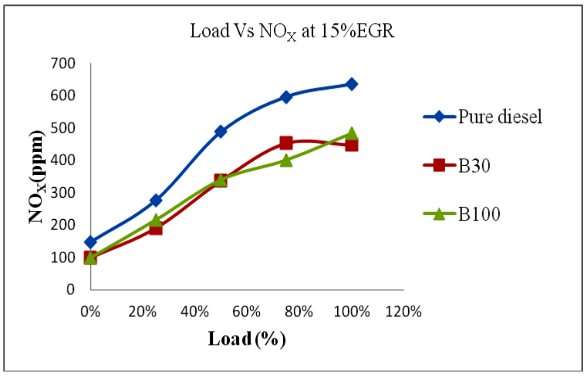

Fig. 8 NO_X Emissions of Varying Load with 0% EGR

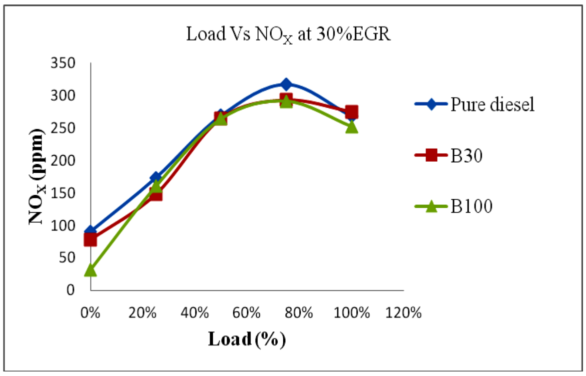

Fig. 9 NO_X Emissions of Varying Load with 30% EGR

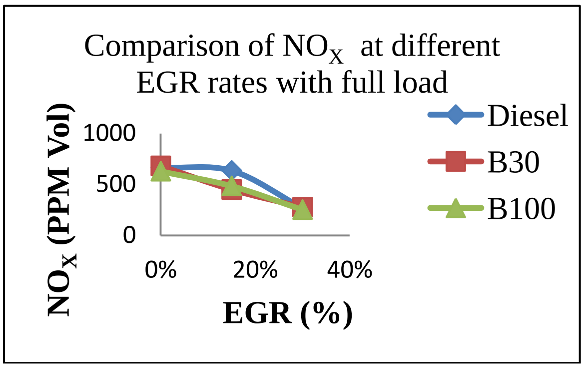

Fig. 10 Variation of NO_X Emissions with EGR mass fraction at Full Load

From Fig. 7 to 10 NO_X emissions increase with increase in biodiesel percentage. However with increase in EGR rate NO_X decrease significantly.

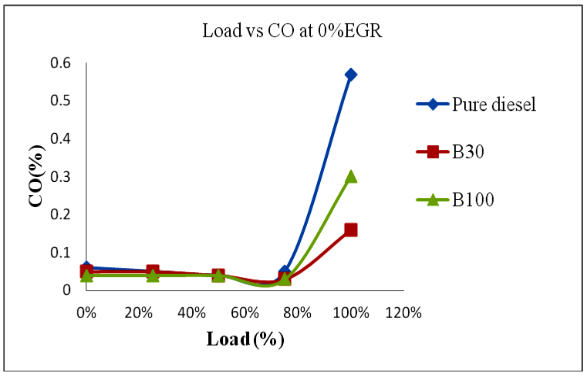

Fig. 11 CO Emissions of Varying Load with 0% EGR

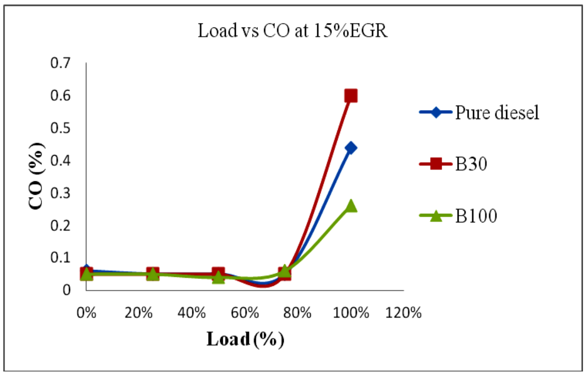

Fig. 12 CO Emissions of Varying Load with 15% EGR

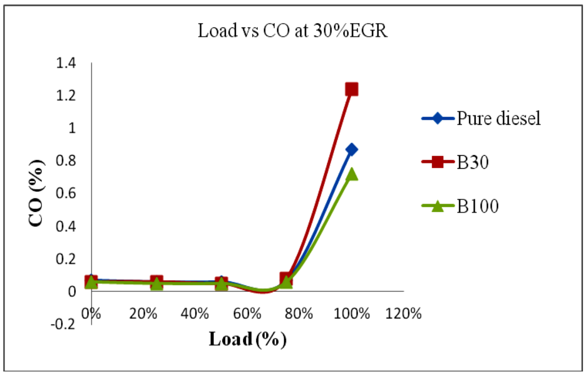

Fig. 13 CO Emissions of Varying Load with 30% EGR

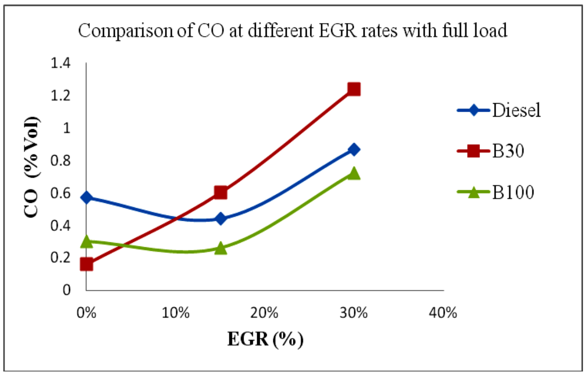

Fig. 14 Variation of CO Emissions with EGR mass fraction at Full Load

From Fig. 11 to 14 it can be seen that CO emissions decrease with biodiesel percentage at all loads. It also decreases with increase in EGR rate.

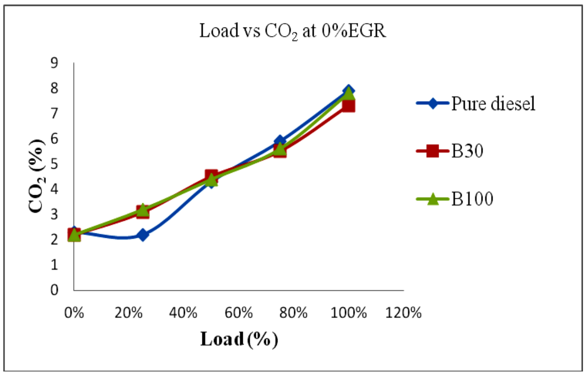

Fig. 15 CO_2 Emissions of Varying Load with 0% EGR

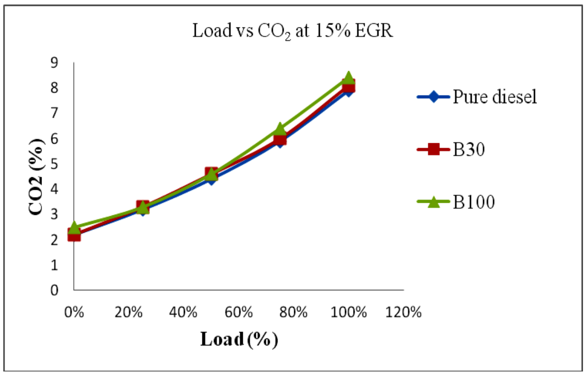

Fig. 16 CO_2 Emissions of Varying Load with 15% EGR

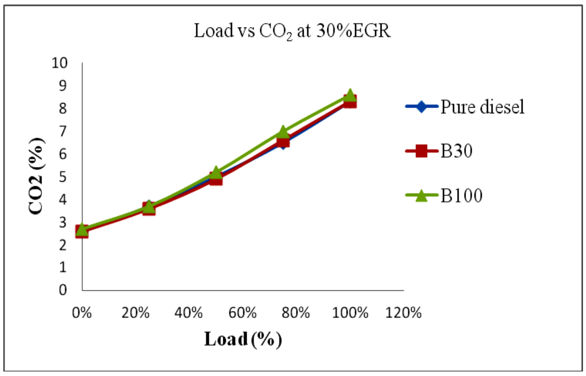

Fig. 17 CO_2 Emissions of Varying Load with 30% EGR

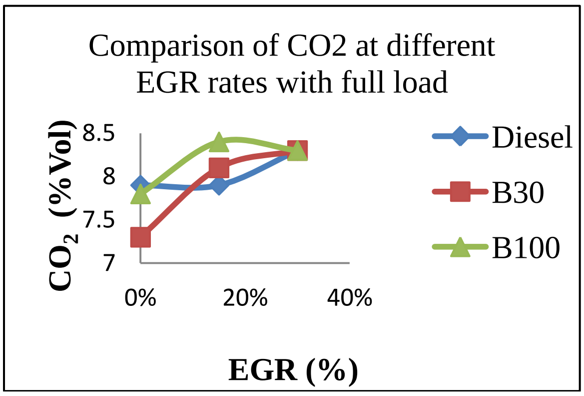

Fig. 18 Variation of CO_2 Emissions with EGR mass fraction at Full Load

CO_2 emissions decrease with increase in EGR rate as we can observe in Fig. from 15 to 18.

IV. CONCLUSION

In this paper, the emission analysis of HC, NO_X, CO and CO_2 are carried out for palm stearin biodiesel. It was observed that HC emissions decrease with biodiesel percentage at all loads. It can also be seen that HC emissions increase with increase in EGR rate. NO_X emissions increase with increase in biodiesel percentage. However with increase in EGR rate NO_X decrease significantly. It can be seen that CO emissions decrease with biodiesel percentage at all loads. It also decreases with increase in EGR rate. CO_2 emissions decrease with increase in EGR rate.

REFERENCES

[1] S. Oberweis, and T.T A1-Shemmeri, Effect of Biodiesel blending on emissions and efficiency in a stationary diesel engine, International Conference on Renewable Energies and Power Quality (ICREPQ' 10), Granada (Spain), 2010.

[2] Y.X. Li, N.B. McLaughlin, B.S. Patterson, and S.D. Burtt, Fuel efficiency and exhaust emissions for biodiesel in an agricultural tractor, Canadian Biosystems Engineering, 48, 2006.

[3] R.M Alagu, and E.G. Sundaram, Nitrogen oxide emission in biodiesel fuelled CI engines – A review, Frontiers in Automobile and Mechanical Engineering (FAME), 2010.

[4] Venkanna Krishnamurthy Belagur, and Venkataramana Reddy Chitimini, Effect of injector opening pressures on the performance, emission and combustion characteristics of di diesel engine running on honne oil and diesel fuel blend, Thermal Science, 14(4), 1051-1061, 2010.

[5] Murari Mohon Roy, Performance and Emissions of a diesel engine fueled by diesel-biodiesel blends with special attention to exhaust odor, Canadian Journal on Mechanical Sciences and Engineering, 2(1), 2011.

[6] N. Ladommatos, S.M. Adelhalim, and Z. Hu, The effects of carbondioxide in exhaust gas recirculation on diesel engine emissions, Proceedings of the Institution of Mechanical Engineers Part D: Journal of Automobile Engineering, 212(1), 25-42, 1998.

[7] Hitoshi Yokomura, Susumu Kohketsu, and Koji Mori, EGR System in a turbocharged and intercooled heavy-duty diesel engine-expansion of EGR area with venture EGR System, Engine Research Dept., Research & Dev. Office, MFTBC, Technical Review, 15, 2003.

[8] M. Gomma, A.J. Alimin, and K.A. Kamarudin, The effect of EGR rates on NO_X and smoke emissions of an IDI diesel engine fuelled with Jatropha biodiesel blends, International Journal of Energy and environment.2(3), 477-490, 2011.

[9] V. Pradeep, and R. P. Sharma, Use of HOT EGR for NO_X control in a compression ignition engine fuelled with bio-diesel from Jatrophaoil, Renewable Energy, 32, 1136- 1154, 2007.

[10] K. Rajana, and K. R. Senthilkumar, Effect of Exhaust Gas Recirculation (EGR) on the Performance and Emission Characteristics of Diesel Engine with Sunflower Oil Methyl Ester, Jordan Journal of Mechanical and Industrial Engineering (JJMIE). 3(4), 306 - 311, 2009.

[11] Vinicius Peixoto, Celso Argachoy, Ivan Trindade, and Marcelo Airoldi, Combustion Optimization of Diesel Engine with EGR system using ID and 3D simulation tools, Department of Engine Design Engineering, MWM International Diesel Engines of South America Ltd. Sao Paulo, Brazil.

[12] Subramani Saravanan, Govindan Nagarajan, Radhakrishnan Ramanujam, and Santhanam Sampath, Controlling NO_X Emission of Crude Rice Bran Oil Blend for Sustainable Environment, CLEAN – Soil, Air, Water, 39(6), 515-521, 2011.

[13] M. Robert Wagner, B. Johney Green, jr. M. John Storey, and C. Stuart Daw, Extending Exhaust Gas Recirculation Lilits in Diesel Engines, Oak Ridge National Laboratory.

[14] Mohamed Y.E. Selim, Effect of exhaust gas recirculation on some combustion characteristics of duel fuel engine, Energy Conversion and Management, 44, 707-721, 2003.

[15] N. Ladommatosa, S. abdelhalima, and H Zhao, Control of oxides of nitrogen from diesel engines using diluents while minimizing the impact on particulate pollutants, Applied Thermal Engineering, 18(11), 963-980, 1998.

[16] Avinash Kumar Agarwal, Shrawan Kumar Singh, Shailendra Sinha, and Mritunjay Kumar Shukla, Effect of EGR on the exhaust gas temperature and exhaust opacity in compression ignition engines, Sadhana, 29, 275-284, 2004.

[17] Syed Yousufuddin, K . Venkateswarlu, and Naseeb Khan, A computational study to investigate the effects of insulation and EGR in a diesel engine, International journal of Energy and Environment, 3(2), 247-266, 2012.

[18] X. G Wang, B Zheng, Z.H Huang, N.Zhang, Y. J Zhang, and E.J Hu.2010, performance and emissions of a turbocharged, high-pressure common rail diesel engine operating on biodiesel/diesel blends, proc.IMechE,part D:J.Automobile Engineering, 225, 2010.
[19] G.D. Zhang, H. Liu, X.X Xia, W.G. Zhang, and J.H. Fang, Effects of dimethyl carbonate fuel additive on diesel engine performances, Proc IMechE,Part D:J Automobile Engineering, 219, 2005.
[20] T. Nibin, A.P. Sathiyagnanam, S.Sivaprakasam, and C.G.Saravanan, Investigation on Emission Characteristics of a Diesel Engine using Oxygenated Fuel Additive, IE(I)journal, 86,2005.
[21] Md. Nurun nabi, and Md. Wahid chowdhury, Improvement of engine performance using Diethylene Glycol di Methyl ether(DGM)as additive, Jurnal teknologi, 44(a), 1-12, 2006.
[22] Ni Zhang, Zuohua Huang, Xiangang Wang, and Bin Zheng, A Comparative Study of two kinds of Biodiesels and Biodiesel-DEE Blends in a Common Rail Diesel Engine, SAE international, 2011-01-0640.
[23] Murat Karabektas, and Murat Hosoz, Performance and emission characteristics of a diesel engine using isobutanol-diesel fuel blends, Renewable Energy, 34, 1554-1559, 2009.
[24] C. Sundar Raj, S. Sendivelan, and S. Arul, Performance of a Thermally Insulated Constant Speed Diesel Engine with Dioxane Blended Fuels, Global Journal of Researches in Engineering, 10(2) ,2010.
[25] A.P. Sathiyagnanam, C.G. Saravanan, and S. Dhandapani, Effect of Thermal-Barrier Coating plus Fuel Additive for Reducing Emission from Di Diesel Engine, Proceedings of the world Congress on Engineering 2010,Vol II, WCE 2010, London, U.K. June 30-July 2, 2010.
[26] K. Manish Nandi, The Performance of Ditertiary-Butyl Peroxide as Cetane Improver in Diesel Fuels, ARCO Chemical Company, Newtown Square, PA 19073.
[27] G.J. Suppes, K. Bockwinkel, M.H. Mason, J.B. Botts, and J.A. Heppert, Multi functional diesel treatment additive from vegetable oils, Department of chemical and petroleum Engineering, The University of Kansas.4006 Learned, Lawrence, KS 66045-2223, (785)864-3864.
[28] S. Kobori, T. Kamimoto, and A.A. Aradi, A study of ignition delayof diesel fuel sprays, International journal of Engine Research, 1(1), 29-39, 2000.
[29] Yukio Akasaka, Effects of Oxygenated Fuel and Cetane Improver on Exhaust Emission from Heavy-Duty DI Diesel Engines, SAE Technical paper.No 942023, 1994.
[30] Hawnam Kin, Byungchul Choi, Seangho Park, and Yong-Kill Kim, Engine Performance and Emission Charactristics of CRDI Diesel Engine Equipped With WCC and DOC Using Ethanol Blended Diesel Fuel, Automobile Research Centre, Chonnam National University, Gwangju, Korea.
[31] W. Li, Y. Ren, X. B Wang. H Miao, D. M jiang, and Z.H Huang, Combustion characteristics of a compression ignition engine fuelled with diesel-ethanol blends, Proceedings of the Institution of Mechanical Engineers, Part D: Journal Of Automobile Engineering, 22(2), 265-274, 2008.
[32] Wu YU, Gen CHEN, and Zuohua Huang, Influence of cetane number improver on performance and emissions of a common-rail diesel engine fueled with biodiesel-Methanol blend, Front. Energy. 5(4), 412-418, 2011.
[33] Y. Ren, Z. H Huang, D.M jiang, W. Li, B. Liu, and X.B Wang, Effects of the addition of ethanol and cetane number improver on the combustion and emission characteristics of a compression ignition engine, Proc.IMechE, Part D:J. Automobile Engineering, 222, 2008.
[34] Michael Boot, Peter Frijters, Carlo Luijten, Bart Somers, Rik Baert, Arjan Donkerbroek, J. H. Robert, Klein-Douwel, Nico Dam, Cyclic Oxygenates: A New Class of Second-Generation Biofuels for Diesel Engines, Energy & Fuels, 23,1808-1817,2009.