Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 1, Number 2; October-December, 2014 pp. 94-97

http://www.krishisanskriti.org/jmsme.html

Study of Automobile Exhaust Emissions

Kshitij Aggarwal[1] and Mridul Garg[2]

[1,2]B.Tech (Delhi Technological University)
E-mail: [1]kshitijagg@hotmail.com, [2]mridulgarg11@gmail.com

Abstract: *On account of more stringent regulations being imposed on the automotive industry to mitigate exhaust emissions to curb the problem of pollution and global warming worldwide, extensive research is being conducted to study the effect of various combustion parameters on exhaust emission gases. This paper deals with a comprehensive study of the various factors that affect exhaust emissions. The effect of compression ratio, ignition timing, exhaust gas recovery (EGR) and engine load is studied on the major exhaust emission gases, namely NOx, CO, CO2 and Hydrocarbons (HC). Extensive studies have been carried out by reviewing the work of other scholars and analyzing their observations to come up with a general trend on how exhaust emissions are affected. It is observed that increase in compression ratio leads to an increase in amount of NOx and HC emissions whereas the amount of CO and CO2 emissions increase till the best compression ratio after which they gradually decrease. Advancing ignition timing has no effect on CO and CO2 emissions but leads to an increase in NOx levels and installing EGR leads to reduction in NOx and CO2 levels but an increase in CO levels on account of lower charge temperature and greater availability of O2. Also increasing the load leads to increased levels for almost all the exhaust emissions on account of higher combustion rates.*

1. EMISSIONS

NOx

Experiments carried out on a PCCI engine running on diesel demonstrated that under premixed combustion, NOx emissions were only mildly reduced when compression ratio was reduced from 18.4:1 to 16.0:1 within the SOI timing range of 5°BTDC to 3°ATDC. The reductions in NOx can be explained by the retardation in Injection Delay which leads to a reduction in the gas temperature at TDC of the compression stroke and more complete mixing of air and fuel mixture.

Fig. 1 shows the variation of NOx with the compression ratios for diesel and WCO blends [1] at best injection timing. In general NOx emission increases with the increase in load and also for higher compression ratios the NOx emission was increased because of increased operating temperature. NOx emissions for the biodiesel operation are higher than the neat diesel, since the biodiesel contained the inbuilt oxygen in their molecular structure.

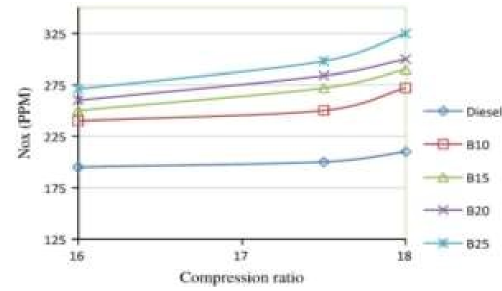

Fig. 1: Variation of NOx with the compression ratios for diesel and biodiesel blends at best injection timing (27°).

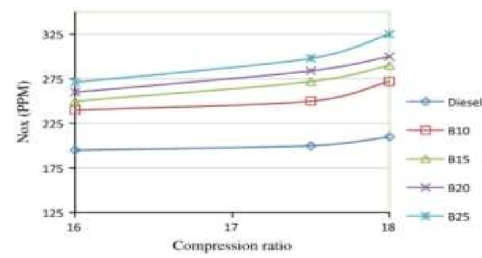

Fig. 2 shows the variation of NOx with the injection timings [2] at full load condition for best compression ratio for different diesel and biodiesel blends. For the retarded injection timings NOx emissions were found to be less whereas for advanced injection timings it increased.Fig. 2. Variation of NOx with injection timing for diesel and biodiesel blends best compression ratio (18°).

EGR effects on combustion and NOx formation Exhaust Gas Recirculation (EGR) is effective in reducing NOx formation since it lowers the peak flame temperature attained during the combustion process. Several effects may contribute to this result when the intake charge is diluted with exhaust gases. These effects are listed below hereafter:

- The dilution or oxygen displacement effect, i.e. the reduction in the oxygen mass fraction due to the displacement of some of the oxygen in the fresh intake air charge by inert gases, which causes a reduction in the local flame temperature because of the spatial broadening of the flame due to the reduction in the oxygen molar fraction.

- The thermal effect, due to the increase in the average specific heat capacity of the gases in the combustion zone, since re-circulated exhaust contains CO_2 and H_2O with higher specific heat than that of air.
- The chemical effect, i.e. the reduction in the combustion temperature due to endothermic chemical reactions, such as the dissociation of CO_2 and H_2O.

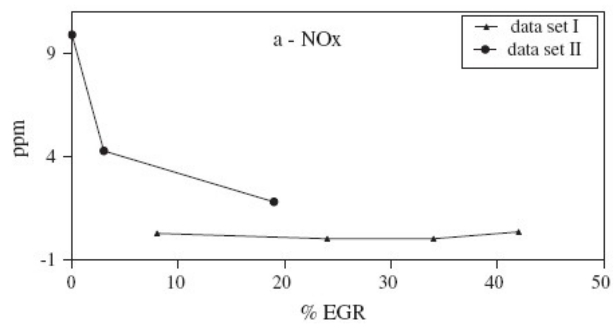

Fig. 3 The influence of EGR on emission characteristics of NOx.

The influence of EGR on exhaust emissions of n-heptane/natural gas fueled HCCI engines [3] and found the same results.

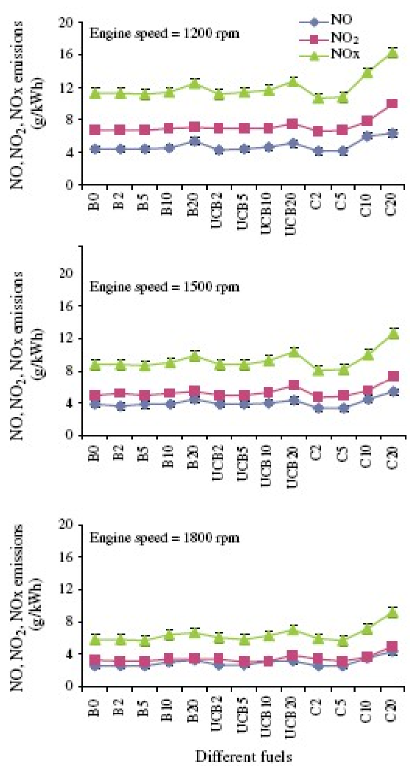

Fig. 4 NOx emissions at different engine speeds for various fuels: (a) with engine speed of 1200 rpm, (b) 1500 rpm, and (c) 1800 rpm.

CO

The results showed that the CO emissions increased drastically at lower loads and decreased slightly at higher loads for the blends compared to diesel fuel. The drastic increase in the CO percentage at low load for blend is due to decrease in the cylinder gas temperature and delayed combustion process. The lower temperature and delayedcombustion would have suppressed the oxidation process even though enough oxygen was available for combustion. Slight reduction in CO emissions is noticed for blends at high load and that would be due to inbuilt fuel oxygen and improved combustion process due to better mixing.

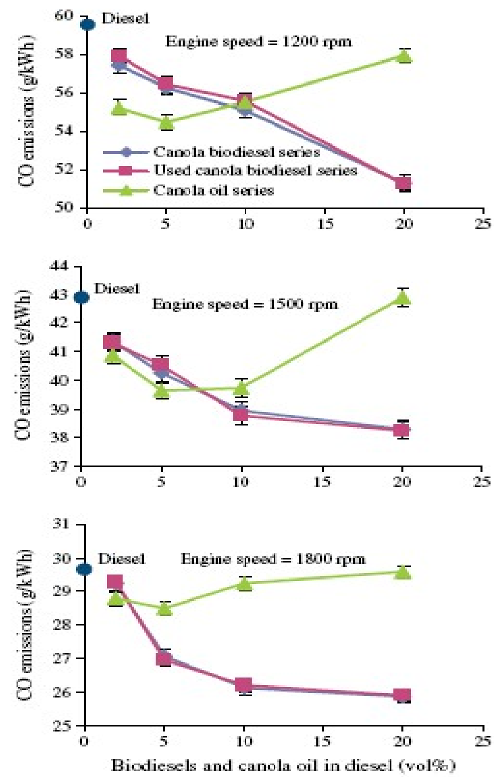

Fig. 5. CO emissions at different engine speeds for various fuels: (a) with engine speed of 1200 rpm, (b) 1500 rpm, and (c) 1800 rpm.

The CO emission remains unchanged with respect to injection timing for blends as well diesel fuel at both speeds. The advanced injection timing should have produced a higher cylinder temperature to increase in the chemical reaction speed of combustion region. Also, the advanced injection timing should have increased the oxidation process between carbon and oxygen molecules to reduce CO emissions as noticed. However the variation of CO emissions with respect to injection timing in this study is curious and may be air fuel ratio would have played a major role compared to the combustion temperature to keep CO emissions unchanged with respect to injection timing.

Fig. 6 shows the variation of carbon monoxide emission of the biodiesel blends (WCO methyl ester) and diesel [4] with v arious compression ratios. The CO emission of the blend B40 is close to the standard diesel and it is found to be higher for compression ratio 21:1. The other blends B20, B60 and B80 have slightly lesser CO emission for compression ratio 21:1. The percentage of CO increases due to rising temperature in the combustion chamber, physical and chemical properties of the fuel, air–fuel ratio, shortage of oxygen at high speed, and lesser amount of time available for complete combustion. The effects of fuel viscosity on fuel spray quality would be expected to make some CO increase with vegetable oil fuels.

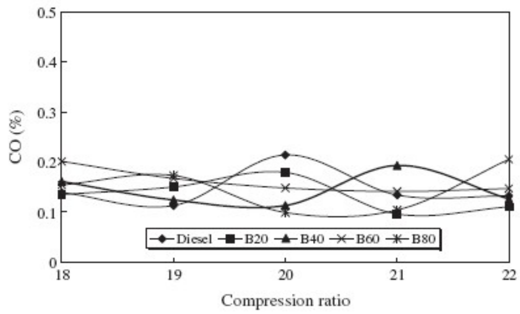

Fig. 6: Variation of carbon monoxide with compression ratio for different biodiesel blends.

CO emissions increase with increased amount of EGR [5] in an n-heptane/natural gas HCCI engine due to lower charge temperature and available O2, which leads to incomplete combustion and as a result high CO formation.

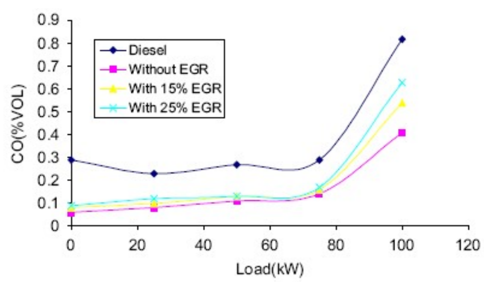

Fig. 7: The influence of EGR on emission characteristics of CO.

CO_2

The variation of carbon dioxide emission with different compression ratios are shown in Fig. 8. The WCO methyl ester biodiesel blend [6] emits higher percentage of CO_2 than diesel at lower compression ratios and vice versa. More amount of CO_2 is an indication of complete combustion of fuel in the combustion chamber. It also relates to the exhaust gas temperature. CO_2 emission of the blend B40 for compression ratio 21:1 is lesser due to incomplete combustion and inadequate supply of oxygen.

The variation of carbon dioxide with brake power [7] of the engine for different values of hydrogen enrichment without EGR, with 15% EGR and 25% EGR is shown in Fig. 9. The Fig. reveals that the formation of carbon dioxide is 14.7% by volume for neat diesel operation, while it is 12.3% by volume with EGR of 15% and 25%, without EGR it is 11.1% by volume. The reduction in carbon dioxide emission is due to the absence of carbon in hydrogen fuel.

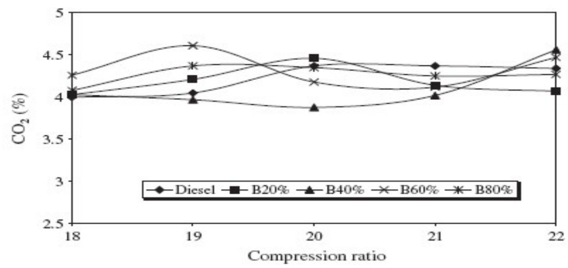

Fig. 8: Variation of CO_2 with compression ratio for different blends.

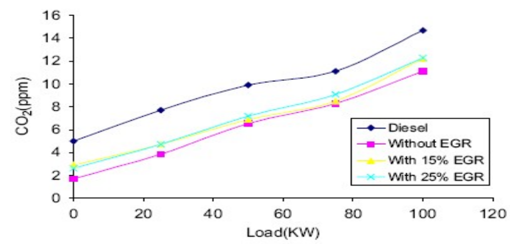

Fig. 9. Variation of $CO_2$with load.

HC

The variation of hydrocarbon emission with different compression ratios for different WCO biodiesel blends [8] is given in Fig. 10. It shows that the hydrocarbon emission of various blends is higher at higher compression ratios. The effects of fuel viscosity, on the fuel spray quality, are expected to produce some HC increase with vegetable oil fuels. It is show that the increase in compression ratio increases the HC emission for Blend B40. The other blends B20, B60 and B80 produce lesser hydrocarbon emissions at higher compression ratio than the standard diesel. Due to the longer ignition delay, the accumulation of fuel in the combustion chamber may cause the higher hydro carbon emission.

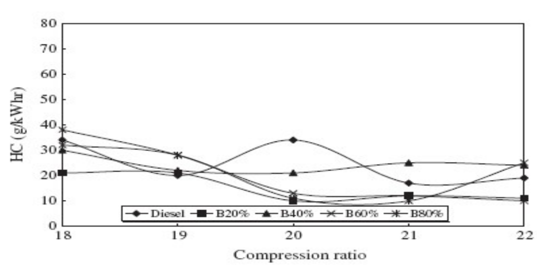

Fig. 10: Variation of HC emission with compression ratio for different blends.Fig. 11. HC emissions at different engine speeds for various fuels: (a) with engine speed of 1200 rpm, (b) 1500 rpm, and (c) 1800 rpm

Fig. 11 demonstrates HC emissions at different engine speeds [9] for canola oil biodiesel fuels. At 1200 rpm, diesel fuel produces 2.98 g/kW h of HC; it decreases gradually with biodiesel–diesel blends and becomes 22% lower for UCB20 and 20% lower for B20. No significant change is observed for canola oil–diesel series. At 1500 rpm, diesel fuel produces 2.5 g/kW h HC, and then decreases to 1.92 g/kW h for UCB20 (about 23% reduction) and to 1.97 g/kW h for B20, which is about 21% reduction. Again there is no significant change with canola oil–diesel series. At 1800 rpm, diesel fuel produces 1.88 g/kW h of HC; UCB20 and B20 show 23% and 21% reduction, respectively. At this speed, canola oil–diesel series shows approximately 6% increase than that of diesel.

2. ACKNOWLEDGEMENTS

We are really thankful to our Project Guide Dr. Bhupendra Singh Chauhan, Assistant Professor, Department of Mechanical & Automotive Engineering, Delhi Technological University, New Delhi, for his invaluable guidance and assistance, without which the accomplishment of the task would have never been possible. We hope to continue our upcoming projects in the following year on the same line.

We would like to express our sincere & heartfelt obligation towards all the personages who have helped us in this endeavor. Without their active guidance, help, cooperation & encouragement, we would not have made headway in the project.

Any omission in this brief acknowledgement does not mean lack of gratitude.

REFERENCES

[1] Shivakumar, P. Srinivasa Pai, B.R. Shrinivasa Rao, "Radial-Basis-Function-Network-Based Prediction of Performance and Emission Characteristics in a Bio Diesel Engine Run on WCO Ester", *Advances in Artificial Intelligence*, Volume 2012 (2012), pp. 1-7.

[2] Mustafa Canakci, Ahmet Necati Ozseze, Erol Arcaklioglu, Ahmet Erdil, "Performance and exhaust emissions of a biodiesel engine", *Applied Energy*, 2006.

[3] Morteza Fathi, R. Khoshbakhti Saray, 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*, Volume 88, December 2011.

[4] T. Korakianitis, A.M. Namasivayam, R.J. Crookes "Natural-gas fueled spark-ignition (SI) and compression-ignition (CI) engine performance and emissions", *Progress in Energy and Combustion Science*, 2009.

[5] Haiqiao Wei, Tianyu Zhu, Gequn Shu , Linlin Tan, Yuesen "Wang Gasoline engine exhaust gas recirculation – A review", *Applied Energy*, 2011,

[6] S. Imran, D.R. Emberson , D.S. Wena, A. Diez , R.J. Crookes , T. Korakianitis, "Performance and specific emissions contours of a diesel and RME fueled compression-ignition engine throughout its operating speed and power range", *Applied Energy*, 2012.

[7] Avinash Kumar Agarwal, "Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines", *Progress in Energy and Combustion Science*, 2006.[8] K. Muralidharan, D. Vasudevan, "Performance, emission and combustion characteristics of a variable compression ratio engine using methyl esters of waste cooking oil and diesel blends", *Applied Energy*, 2010.

[8] Shivakumar, P. Srinivasa Pai , B.R. Shrinivasa Rao, "Artificial Neural Network based prediction of performance and emission characteristics of a variable compression ratio CI engine using WCO as a biodiesel at different injection timings", *Applied Energy*, 2010.

[9] Fig. 1-2. Shivakumar, P. Srinivasa Pai, B.R. Shrinivasa Rao, "Radial-Basis-Function-Network-Based Prediction of Performance and Emission Characteristics in a Bio Diesel Engine Run on WCO Ester", *Advances in Artificial Intelligence*, Volume 2012 (2012), pp 1-7.

[10] Fig. 3. Morteza Fathi, R. Khoshbakhti Saray, 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*, Volume 88, December 2011.

[11] Fig. 4. S. Imran, D.R. Emberson, D.S. Wena, A. Diez, R.J. Crookes, T. Korakianitis, School of Engineering and Materials Science, Queen Mary University of London, Mile End Road, London E1 4NS, UK; Parks College of Engineering, Aviation and Technology, Saint Louis University, St. Louis, MO 63103, USA.

[12] Fig. 5-Murari Mohon Roy, Wilson Wang, Justin Bujold, Department of Mechanical Engineering, 955 Oliver Road, Lakehead University, Thunder Bay, Ontario, Canada P7B 5E1.

[13] Fig. 6-K. Muralidharan, D. Vasudevan, Department of Mechanical Engineering, PSNA College of Engineering & Technology, Dindigul 624 622, India.

[14] Fig. 7-Morteza Fathi, R. Khoshbakhti Saray, M. David Checkel, Iran Heavy Duty Diesel Engine Mfg. Co. (DESA), Tehran, Iran; Faculty of Mechanical Engineering, Sahand University of Technology, Tabriz, Iran; Mechanical Engineering Department, University of Alberta, Edmonton, AB, Canada T6G 2G8.

[15] Fig. 8-K. Muralidharan, D. Vasudevan, Department of Mechanical Engineering, PSNA College of Engineering & Technology, Dindigul 624 622, India.

[16] Fig. 9-N. Saravanan, G. Nagarajan, K.M. Kalaiselvan, C. Dhanasekaran, Internal Combustion Engineering Division, Department of Mechanical Engineering, College of Engineering, Guindy, Anna University, Chennai 600025, India.

[17] Fig. 10-K. Muralidharan, D. Vasudevan, Department of Mechanical Engineering, PSNA College of Engineering & Technology, Dindigul 624 622, India.

[18] Fig. 11-Murari Mohon Roy, Wilson Wang, Justin Bujold, Department of Mechanical Engineering, 955 Oliver Road, Lakehead University, Thunder Bay, Ontario, Canada P7B 5E1.