A Review on Performance and Emission Characteristic of Oxygen Enriched Combustion of Water Emulsified Bio Diesel

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Abstract— Environment degradation is the major problem in 21st century. Petroleum fuel emission has a major contribution in environmental degradation. Specifically, these review focus on diesel engine which emits HC, CO, NOx, soot emission and PM. These pollutants have a very serious effect on environment. Thus, lots of researches have been done to improve the performance and reduce these harmful emission and to find the alternative of this conventional fuels. One of the alternatives is oxygen enrichment combustion (OEC) and emulsification of bio-diesel. Present, literature review focus on combustion and emission characteristics of compression ignition engine with oxygen enrichment combustion (OEC) and emulsification of bio-diesel.

Key words: Oxygen, HC, CO, NOx

I. INTRODUCTION

The burning of fossil fuels increases as economies grow and the adverse effect of such fuels has prompted a search for fuel alternatives worldwide. Thus, Bio-fuels have become as a substitute for fuel oil, especially for oil-importing countries. The most important advantage of these Bio-fuels is that they are renewable, and are being seen as sustainable sources of energy. Some Researches showed that bio-fuels helps in reducing environmental degradation by reducing harmful pollutants and addressing the problem of the increase in import cost of fuel oil. Diesel engine emits hydrocarbon (HC), oxides of nitrogen, carbon monoxide, soot, and particular matter. All those pollutants have very harmful effect on pollution as well as on human health. Thus, various researches had been done to minimize the amounts of pollutants and to improve performance of IC engine. Therefore it's required to find alternative of this conventional fuels. One of the alternatives of diesel is to use emulsified bio-diesel with oxygen enrichment. Since 1960s, the researches on intake oxygen-enriched combustion (OES) of internal combustion engine have begun, and the intent was to reduce engine-out emissions. Previous preliminary experimental studies showed that oxygen-enriched intake to improve oxygen concentration of combustion chamber by maintaining diesel injection law unchanged, which can accelerate the burning rate, improve combustion temperature, and enhance thermal efficiency to some extent. Diesel fuel in cylinder can also be burnt more thoroughly. Content of CO, HC and PM emissions can be reduced simultaneously because of more complete oxygen-enriched combustion. The power output can also be enhanced by increasing the intake oxygen concentration and fuel mass injected per cycle.

II. LITERATURE REVIEW

A. Oxygen enrichment combustion:

R.B. Poola et al. (2003) [1] did his research on Reduction of Nox and particulate Emission by using oxygen- Enriched combustion air in a locomotive CI Engine. This study discusses operational and emissions results obtained with a locomotive (two- cylinder, EMD 567B) research CI engine when oxygen-enriched combustion air is used. In this research operating condition was identified in which amount of particulates matter and NOx could be reduced simultaneously when the content of intake air oxygen, injection timing and fueling rate were optimized. Using oxygen enrichment, it found that particulates were reduced by approximately 60% and NOx emissions were reduced by 15 – 20% with the optimal operating strategy. Higher gross power, lower brake- specific fuel consumption and lower peak cylinder pressures were also observed. It also found that Gross power was increased by about 15 – 20% at base peak combustion pressure, and gross brake-specific fuel consumption was decreased by 2 – 10% with load.

R.B. Poola et al. (2003) [2] did his research on Study of Using Oxygen-Enriched Combustion Air for Locomotive Diesel Engines. The parasitic power of the air separation membrane required to supply the oxygen-enriched air is also estimated. For a given constraint on peak cylinder pressure, the gross and net power output of an engine operating under different levels of oxygen enrichment are compared with those obtained when a high-boost turbocharged engine is used. A 4 per- cent increase in peak cylinder pressure can result in an increase in net engine power of approximately 10 percent when intake air with an oxygen content of 28 percent by volume is used and fuel injection timing is retarded by 4 degrees. When the engine is turbo- charged to a higher inlet boost, the same increase in peak cylinder pressure can improve power by only 4 percent. If part of the significantly higher exhaust enthalpies available as a result of oxygen enrichment is recovered, the power requirements of the air separator membrane can be met, resulting in substantial net power improvements. Oxygen enrichment with its attendant higher combustion temperatures reduces emissions of particulates and visible smoke but increases NO emissions (by up to three times at 26 percent oxygen content). Therefore, exhaust gas after-treatment and heat recovery would be required if the full potential of oxygen enrichment for improving the performance of locomotive diesel engines is to be realized.

Peter L. Perez et al. (2009) [3] did his research on Performance of a single-cylinder diesel engine using oxygen enriched intake air at simulated high-altitude conditions. He used single-cylinder, naturally aspirated, air-cooled, direct-injected diesel engine to study the effects of oxygen enrichment of intake air on engine performance at simulated high altitude conditions. Altitudes up to17, 000 ft (5200 m) were simulated by using a throttle valve to restrict the mass air flow to the engine and reduce intake pressure to represent the atmospheric pressures observed at high altitudes. This study showed that power output depended mainly on engine load and was not improved by the use of oxygen-enriched air,

and it did not decrease significantly for altitudes up to 8500 ft (2600 m). The use of oxygen-enriched air was effective to prevent the deterioration in brake-specific fuel consumption when increasing simulated altitude, an effect that was observed on fuel conversion efficiency, peak cylinder pressures and maximum rates of heat release. Peak combustion temperatures were affected by simulated altitude and oxygen volume fraction, but the effect of this simulated altitude was of larger magnitude than the effect of oxygen volume.

Youcai Liang et al. (2013) [4] did his research on effect of oxygen enriched combustion and water–diesel emulsion on the performance and emissions of turbocharged diesel engine. It's found that Oxygen enriched combustion (OEC) improve emissions, thermal efficiency and brake power output of diesel engine. The purpose of this paper is to study whether it is feasible to apply water diesel emulsion to mitigate the increasing NOx caused by OEC with comparable BSFC and power output. In this paper effect of OEC on particle size and number concentration was also analyzed. Oxygen and concentration of intake air and water concentration varied from 21% to 24% and 0%, 10%, 20%, and 30% by volume respectively. The result showed that lower BSFC, higher cylinder pressure and shorter ignition delay were observed when OEC was applied, while opposite trends were found when using WDE. PM and NOx are reduce simultaneously by applying OE combined with WDE. According to this study, Optimal operating condition was realized when water concentration in emulsion was below 20% along with low oxygen enrichment.

Wei Zhang et al. (2013)[5] did his research on Influence of water emulsified diesel & oxygen-enriched air on diesel engine NO-smoke emissions and combustion characteristics. Oxygen-enriched combustion of C.I engine can reduce smoke emission and improve thermal efficiency, but increase of NO emission. In this study, experiments were performed on a turbo-charged direct injection diesel engine under the two conditions of 2000 rpm and 180 Nm equivalent powers (57% of the original max load at 2000 rpm) as well as 100% load of this speed. The combination of intake oxygen enrichment and water emulsified diesel was used to improve the NO- smoke emissions without serious penalty in brake specific fuel consumption (BSFC).The results showed that when engine load was 180 Nm with the conditions of 0% to 20% water emulsion ratio and 21% to 21.5% intake oxygen concentration, as well as under the condition of 100% load with 10% to 15% water emulsion ratio and 21% to 22% intake oxygen concentration, the NO-Smoke emissions were found lower than that of original engine and BSFC was not exceeding 5% of the original engine by optimized combination of water emulsion ratio and oxygen concentration.

Wei Zhang et al. (2013) [6] did his research on Influence of EGR and oxygen-enriched air on diesel engine NO–Smoke emission and combustion characteristic.The oxygen enriched combustion of CI engine can reduce smoke emission and increase engine thermal efficiency; however there are increase the Nox emission. The specific fuel consumption and the power loss were lower than 5% compared to the unmodified engine. Also the effect of oxygen enrichment on the particle size distribution was tested and analyzed. The results revealed that the optimal NO–Smoke emission can be achieved at these conditions: the engine speed is 1600 rpm, full load, EGR rate was 30–40% and 21.5–22.5% of intake oxygen density; engine speed 2200 rpm, full load, EGR rate was 20–45% and 22–24% of intake oxygen density. The result of particle size distribution tests showed that oxygen enriched combustion can effectively suppress the diameter growth of particles and lead to fewer large particles with a diameter larger than 100 nm emissions; however it did lead to an increase of 15 nm small particles.

P. Baskar et al. (2015) [7] did his research on Effects of oxygen enriched combustion on pollution and performance characteristics of a diesel engine. He performed experiment test on a single cylinder direct injection CI engine to study the impact of oxygen enrichment on pollution and performance parameters by increasing the oxygen content of intake air from 21 to 27% by volume. The tests results show that the combustion process was improved. Thermal efficiency is increase from 4 to 8 percent and there is decrease in brake specific fuel consumption of 5 to 12 percent. There is also a substantial decrease in unburned HC, CO and smoke density levels to the maximum of 40, 55 and 60 percent respectively. However, there is a considerable increase in oxides of nitrogen (Nox) emissions due to combustion temperature is increased and extra oxygen available which needs to be addressed.

B. Literature review on emulsified bio diesel:

Qimin Wu et al. (2013) [8] did his research Influence of Micro-emulsified Biodiesel on Combustion and Emission Characteristics of a Turbocharged Diesel Engine. He found out that there are sharply reduction in CO, HC, and smoke emission, while 9% increased NOx emission at large load. In his study, he took two kind of micro-emulsified biodiesel containing of 10% and 5.6% water in it. He noticed that under the full load operating condition and rated speed, maximum pressure rise rate and peak heat release rate are increase. Also combustion duration became shorter while ignition delay was prolonged. Particularly NOx and smoke emission are reducing at lighter and medium load. His studied suggested that use of micro-emulsion of bio diesel have a potential to improve combustion and performance characteristics of diesel engine.

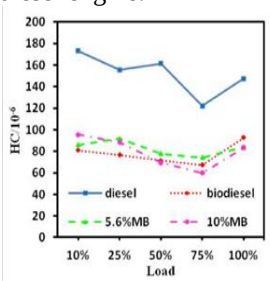

Fig. 1: Emission of HC [8]

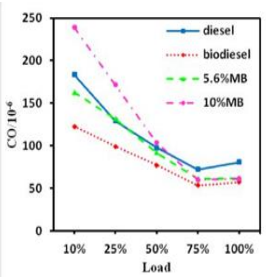

Fig. 2: Emission of CO [8]

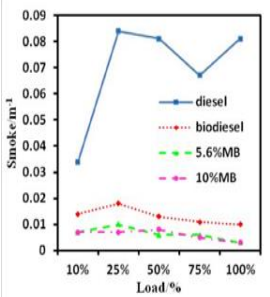

Fig. 3: Emission of Smoke [8]

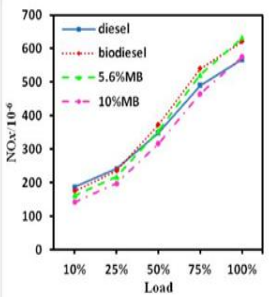

Fig. 4: Emission of NOx[8]

C. Emission characteristics:

HC emissions. As shown in fig 1. There are decrease HC emission for bio diesel and its emulsion. Also there are little higher HC emission at small load and reduced HC emission at larger load for emulsified bio diesel than that of bio diesel.

Co emissions. As shown in fig 2. , there are reduction in CO emissions for diesel, bio-diesel and micro-emulsion bio-diesel under all load conditions.

Smoke opacity. As show in fig 3. About 80% of smoke opacity was reduced for bio-diesel than diesel.

NOx emissions. As show in fig 4. There is increase in NOx emission as the load increase. Though, its show that emission of NOx for micro-emulsified bio-diesel is less compare to bio- diesel and diesel also.

Hifjur Raheman et al. (2014) [9] did his research on Combustion characteristics and emissions of a compression ignition engine using emulsified jatropha bio-diesel blend. He took two kind of combination of bio-diesel blend with water. He studied effect of bio-diesel emulsification with 10% and 15% water by volume in 10% jatropha bio-diesel-blend.

Ignition delay was found to be longer at higher engine loads as increase in water concentration. He also recommended use of emulsified bio-diesel in place of plane bio-diesel because there is reduction in CO2, CO, HC, and NOx with emulsified bio-diesel than 10% jatropha bio-diesel blend.

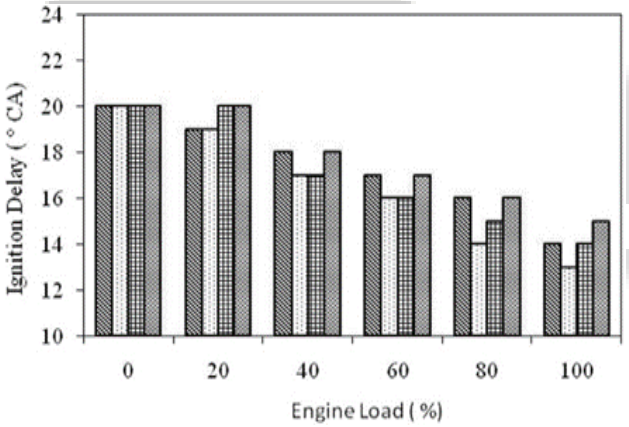

Fig. 5: Delay variation with engine load for diesel, JB10 and emulsified fuel blends

J. Thangaraja et al. (2016) [10] did his research review on Biodiesel NOx penalty and control measures. He noticed that soot emission are significantly reduced with bio-diesel and also suggest the possible ways to reduce NOx from compression ignition engine. he studied effects of bio-diesel fuel composition and properties on NOx emissions and suggests fuel modification and engine tuning for NOx reduction. Fig. 6 shows the effect of cetane number on NOx emissions. Lower the cetane number, longer the delay period. It's found out that bio-diesel has a higher cetane number than diesel, thus shorter the delay period. Bittle et al. [12] found a lower ignition delay of palmolein biodiesel (CN-63.5) with compared to conventional diesel (CN-44) in their engine investigations on a four cylinder turbocharged CRDI engine as show in fig 6. McCormick et al. [13] studied the impact of biodiesel source material and chemical structure on NOx and PM emissions for 14 pure fatty acids and seven biodiesel produced from different feedstock. They found that the molecular structure of biodiesel has a direct impact on cetane number and NOx emissions as shown in fig. 7

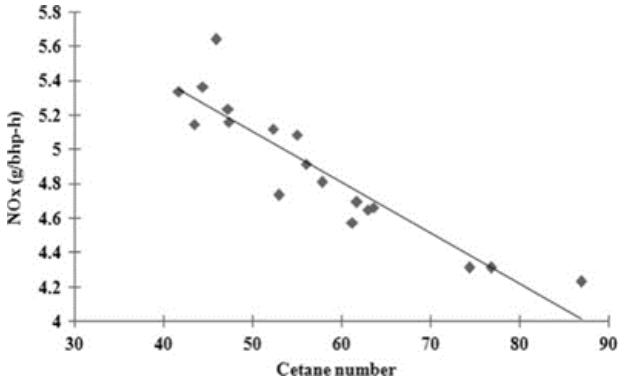

Fig. 6: Biodiesel-NOx variation with cetane number [13]

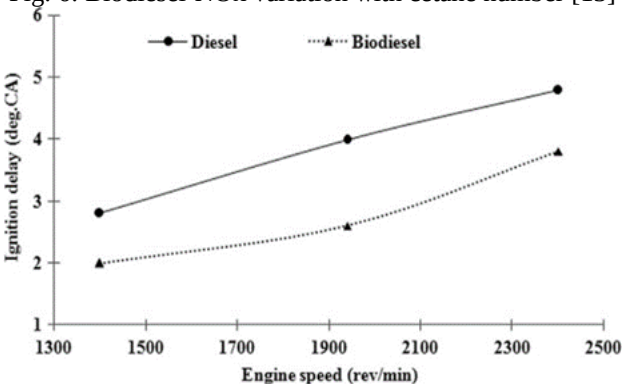

Fig. 7: Comparison of diesel and biodiesel delay period [12]

Biplab K. Debnath et al. [11] did his research on adjusting the operating characteristics to improve the performance of an emulsified palm oil methyl ester run diesel engine. In this paper, debnath et al. [6] took emulsified palm oil methyl ester as a fuel (POME) and tries to investigate the performance, combustion and emission characteristics of emulsified bio-diesel at different compression ratio and injection timing. Two-phase emulsification process [emulsi.] is used to making water in POME emulsified bio-diesel and diesel, POME, water in POME(WIP) were tested on variable compression (VCR) engine at two different condition of CR-18 and IT-20LBTDC and CR = 17.5 and IT = 23LBTDC respectively. There are increases in fuel burning rate due to micro-explosion of emulsified POME. Also water present in emulsification consumes heat that reduces NOx formation as well. BTHEs found 11% higher than diesel and 3% lower than diesel with WIP and POME respectively. At 4.14 bar of BMEP, the maximum BTHEs for WIP is 31.9%, for POME is 27.4% and for diesel is 28.9%. These values are 33.4%, 30.2%, and 29.4% respectively at 4.55 bar of BMEP. Peak pressure is reducing to 15.1% and 1.5% for WIP and POME respectively compare to diesel. Also there are 48% and 34% ignition delay for WIP and POME respectively than diesel. With WIP, CO emission are 43% lesser than POME, CO2 emission are 17% and 16% lesser than POME and diesel respectively and POME has 2% higher CO2 than diesel. WIP reduces 20% NOx than POME and produce 22% higher HC emission than POME.

III. Conclusion

From the above study, it's concluded that

1) Oxygen enrichment into intake of CI engine has a potential to reduce the emission of HC, CO2, CO, and PM due to complete combustion of intake charge. Its lead to rapid combustion of charge, reduce the flame front

path. It's also enhancing the performance characteristic of CI engine. OEC increase gross power and reduce gross specific fuel consumption.

2) Bio-diesel leads to increase NOx. Emulsification of bio-diesel fuel leads to reduce peak temperature will cause decreases formation NOx emissions, smoke opacity and PM. Also its keep lower ignition delay.
3) Thus, there are potential to improve performance and emission characteristics of CI engine with combine effect of both OEC and emulsified bio-diesel.

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