ENHANCEMENT IN EMISSION AND PERFORMANCE CHARACTERISTICS OF DIESEL ENGINE WITH BIO-DIESEL AND ITS BLENDS – AN OVERVIEW

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Abstract

The rapid depletion of petroleum products and its demand with increasing prices led to the search of alternative fuel. Researchers across the globe found that biodiesel with higher cetane number need not any modification in diesel engines. This article reviews about the combustion, performance and emission analysis of diesel engines as the effect of various biodiesel blends with additives. Effect of hydrogen and nano-particles with biodiesel were also covered under the scope of this study.

Effects of Biodiesel blends on emission

Oxides of nitrogen and smoke emissions were main considerations of diesel engine. Many researches are being done since almost a decade for finding an alternate fuel to reduce usage of fossil fuels and reduce pollution. Several alternatives like hydrogen, alcohol fuels, dimethyl ether, biofuels have been analyzed[3].

Ahmet Keskin, Osman Emiroglu, and et. al [1]performed an investigation where n-butanol /biodiesel is used in diesel engine under dual fuel injection. The fraction of n-butanol and the concept of EGR have a combined effect on the process of combustion. Also the dual fuel system decremented the NOx and soot emissions at the same time. The team also investigated the impact of port fuel injection and direct fuel injection on combustion and emissions at various load conditions. It was found that the soot emissions decreased by 90% and the NOx emission decreased by 50%.

Mustafa Atakan Akar, EmineKekilli, and et.al[2]conducted experiments using hydrogen enriched waste oil as biodiesel in CI engine and it was found that using waste oil as biodiesel worsened the performance and emission characteristics. As we know, enriching the test fuels with hydrogen will improvise the combustion and hence gives improved emission characteristics. The nonappearance of carbon atoms in the bonding of hydrogen, CO and CO2 emissions decreased, but it increased NOx emissions.

An experiment conducted by Sara Tayari, Reza Abedi[4]where Chlorella vulgaris methyl ester was used with hydrogen as supplement. The study tells that the usage of this bio fuel had reduced the emissions of CO, HC, and CO_2, but there was considerable increase in NO_X emissions. Even when the bio fuel is fed with hydrogen, CO, CO_2, HC emissions kept decreasing while NO_X emissions kept increasing.

While using Waste vegetable oil or Waste animal oil as biodiesel [5], there was a decrease in CO, HC, smoke emissions when

compared to pure diesel. Other emission like NO_X and CO_2 increased.

Effects of biodiesel blends on Combustion and Performance

Various studies have been carried out all over the world on performance, combustion and emission inspections under various operating conditions. All the literature studies tell us that the stringent NO_X emissions, poor cold flow property and high viscosity are the biggest drawbacks for saleable application of biodiesel.

B.Ashok, et.al [6] investigated with Calophyllum Inophyllum biodiesel along with 30 to 40% of higher alcohols which acts as oxygenated additives. The results conclude that thermal efficiency was close to pure diesel and sometimes higher. On the other hand, the specific fuel consumption was found to be lower with increase in alcohol percentage.

Cuneyt Uysal, Samet Uslu & Mustafa Aydin[8]takes blends of diesel-palm oil biodiesel-diethyl ether and tested under various injection timings in diesel engine. Relative exergy efficiency and relative specific exergy cost of work for the ternary blends were calculated at 25^o and 35^oCA bTDC. It resulted that neat diesel had the best results compared to this particular blend in terms of exergy and exergo economics.

Edwin GeoVaruvel, S. Thiyagarajan and Et.Al[9]conducted research where they used Vegetable oil as the biodiesel and blend it along with hydrogen enhancement. It was found that the initiation of hydrogen advances the engine performance. When compared with plain biodiesel blend, the performance is far better with hydrogen induction. But it is same or inferior when compared to pure diesel.

K.Shojae, et.al[10]concluded based on their investigation that the compression ratio has noteworthy effects on emission and combustion characteristics. The outcome exposed that the cylinder fueled with high viscous biodiesel resulted in poor air-fuel mixture. Being more oxygen atoms in its chemical composition cause higher NO emissions. Also the experiment indicated that the injection angle of 150° with improved fuel consumption rate and 160^o has higher indicated power.

According to the analysis of Ragavendra Gutam, et.al[12],diesel and tallow bio fuel in CI engines, it is found that, the highest cylinder pressure of biodiesel blends B10, B20, B30 and that of diesel fuel at high engine load and 1500 rpm were not varied much. Being high volatile and better missing, the heat release rate of diesel fuel is slightly higher than those of biodiesel blends. Comparison of maximum specific fuel consumption for diesel fuel and biodiesel blends at low loads of the engine shows that diesel having lower fuel consumption. The Brake Thermal efficiency of diesel was found to be superior to biodiesel blends. It decreases as the blending ratio increases. BTE for biodiesel blends was about 5% lesser for biodiesel blends as compared to conventional diesel fuel.

Seyed Reza Mousavi Seyedi, Seyed Mohammad Reza Miri, and Et.al[14] used non-edible rapeseed oil as biodiesel blend and studied the performance characteristics

in the air cooled single cylinder diesel engine. The experiment results disclosed that at 1800 rpm and 2600 rpm, B10D90 blend had the highest torque and power values respectively. It also had the lowermost specific fuel consumption at 1800 rpm. As the biodiesel to diesel ratios increases, power output and torque decreases at 3000 rpm. On the whole, B10D90 blend at full load and at 1800 rpm was selected as the best fuel in terms of the finest performance.

Suleyman Simsek[15] conducted an experiment in an air cooled, single cylinder, four stroke, DI diesel engine with biodiesel consisting of canola, safflower and waste oil mixture obtained by transesterification. Also with biodiesel and diesel fuel mixtures of diverse ratios were used as a fuel. The result proved that increasing biodiesel percentage in the blends with diesel reduces the brake thermal efficiency and on the other hand increases the specific fuel consumption. The emission results of the analysis disclosed that the CO decreased by 34.28%, HC decreased by 17.49%, smoke emission decreased by 50.95% for the given engine load whereas NO_x increased by 80.50% for the given engine load.

Wan Nor Maawa Wan Ghazali and et.al[16] conducted experiment on performance and emissions parameters such as brake power, brake torque, BTE, BSFC, CO, HC, NO_X and smoke concentration in comparison to pure diesel. Outcomes revealed that sources of biodiesel have impact on results to engine performance and emissions. Some of the research generated favorable results towards the biodiesel as compared to pure diesel. The study concluded that, to fulfill the demand of energy and to reduce the pollution biodiesel can be used in CI engine as a standby of diesel fuel. Many researches about optimization, availability and cost-effectiveness of biodiesel needs to be still done to ensure that biofuel fully swap fossil fuel.

Effects of hydrogen with biodiesel blends

E. Elnajjar, S.A.B. Al-Omari, M.Y.E. Selim, S.T.P. Purayil[17] conducted an experiment on E6 Ricardo engine which was 4 stroke and 0.5-litre single cylinder engine. In this experiment the engine speed was varied between 18 to 30 rev/sec. Also, pilot fuel flow rate between 9.92 to 15.79Mlpm, ignition timing between 20 to 45° BTDC. The gaseous fuel (hydrogen) was fed in the rate of 0 to 18.4LPM. The results conveyed that, a variation of 4.15% in thermal efficiency, 64.7% in CO, 76.61% in NOx and 57% opacity was found. For the same biodiesel flow rate, NOx and CO emission dropped with increase in hydrogen content.

A huge range of renewable fuels can be used in Diesel engines. Diesel engines have the capability of supporting this wide range of fuels. One of the potential fuels used is Hydrogen. Mehmet Akcay worked with Hydrogen-Biodiesel with hydrogen flow of 40LPM maximum. This led to noticeable reduction of BSFC up to 12.5% compared to diesel. Mohammad O Hamdan worked with lower hydrogen content and found 4LPM hydrogen enhanced engine efficiency without any knock. With increase in hydrogen content the combustion

temperature increases and thus there is an increment in NOx. Due to many limitations of CI engines the need of a liquid fuel as pilot fuel is there.

Edwin Geo Varuvel, Prabhu Chelladorai, and et.al[18] used grapeseed oil as a alternate fuel which was obtained from bio waste from winery industries. They used the biofuel with Hydrogen in CI engine. On comparison of various performance and emission properties, it is found that, at full load, BTE of engine with hydrogen induction increased from 25.94% to 36.04% for diesel, to 33.97% for grapeseed biodiesel and to 30.95% for neat grapeseed oil. Nitric oxide emission of Grapeseed biodiesel with maximum hydrogen share at full load is higher by 43.61% and smoke emission lower by 19.73% compared to biodiesel operation without hydrogen induction.

Nonedible waste frying oil (WFO)[20]was used as biodiesel and hydrogen gas in diesel engines to reduce reliance on fossil fuels. The research intents to fill the gap in limitations on usage of waste-fired biodiesel and hydrogen gas-powered dual-fuel engines. The results showed that the WFOB70D30 + H10 fuel blend had the highest performance in dual-fuel mode, while the WFOB40D60 blend had the lowest performance in single-fuel mode.

Emissions were also inferior with the dual-fuel mode compared to the single-fuel mode. The study concludes that adding hydrogen gas to biodiesel in dual-fuel mode leads to improved combustion, improved performance, and reduced pollution. The study highlights the potential for anew type of alternative fuel mix pattern and novel modification for diesel engines. The study also highlights the need for further research in this area.

S.Kiran, et.al[21] explored the use of waste lubrication oil as a fuel for diesel engines and obtain a diesel-like fuel with 80% conversion efficiency. Engine experiments with a blend of the fuel and diesel showed reduced emissions and improved performance compared to plain diesel. The authors also studied with gaseous hydrogen to the intake manifold and observed further enhancements in engine performance and emissions reduction. The study proposes that the combination of pyrolyzed waste lubricant and hydrogen is suitable as a fuel for immobile applications such as power backups.

Hydrogen is an important substitute to usual fossil energy. With noteworthy possessions, high calorific value stimulates usage of hydrogen energy like a combined fuel in CI engine. In an experiment the hydrogen was added with B20 fuel for different flow rate namely 4lpm, 8lpm and 12lpm. The examination concluded that exhaust emissions are decremented and performance improved by adding hydrogen fuel. The BTE and NOx increased. The results also showed that the addition of 8lpm H2 with B20 decreased the HC and CO emission compared to B20 and neat diesel fuel. The NOx and exhaust gas temperature are increased for 8lpm H2 addition with B20 fuel.[22]

An experiment conducted by Xiumei Zhang, Rui Yang, Parthiban Anburajan, et.al[23] tells us the outcomes ofusing biodiesel from waste cooking oil blended with

nanoparticles in direct ignition engines, which were further strengthened with hydrogen flow during tests. Various combinations were tested, including pure diesel, diesel-biofuel blends, and blends with nanoparticles and hydrogen. The results disclosed that the accumulation of nanoparticles and hydrogen upgraded the performance parameters such as power, torque, and brake thermal efficiency, while dropping brake specific fuel consumption and emissions of CO, CO2, and other UHC and there was a slight increase in NOx emissions.

Effects of nanoparticles with biodiesel blends

Osama Khan, Mohd Zaheen Khan, et.al[24] explored the biodiesel made from inedible oils as an alternative justifiable fuel to crude oil. They conducted experiments on a diesel engine using biodiesel, Ce_2O_3 nano-particles, and hydrogen blends to optimize performance, vibration, and emission characteristics. The experiments were performed design matrix with five input parameters, including compression ratio, nanoparticle concentration, engine load, ignition pressure and hydrogen blend percentage. The outcomes showed that Water Hyacinth biodiesel in diesel engines resulted in lower environmental impact and enhanced cost-effectiveness.

Lemon peel oil as biodiesel

Ashok Bragadeshwaran et al[26] used Lemon Peel Oil (LPO) as an alternative fuel for diesel engines to reduce NOx emissions without negotiating engine performance. Emulsified fuel samples were prepared using LPO, water, and different surfactants, and their stability was tested. Among all LPOE2 and LPOE4 gave better firmness. The brake thermal efficiency of LPO emulsion reduced compared to pure LPO, while there was a reduction in oxides of nitrogen and smoke emissions. LPO increased HC and CO emissions and lead to lower cylinder pressure and heat release rate diesel fuels.

The growing need for industrialization in transportation has caused a shortage of petroleum-based fuels, making low viscous and low cetane number biofuels a popular alternative. Lemon peel oil is one such biofuel that has been shown to be effective in improving brake thermal efficiency and reducing emissions in diesel engines. A study was conducted to investigate the impact of injection timing and exhaust gas recirculation rates on LPO performance and emissions. The study found that advanced injection timing and EGR implementation can significantly reduce NOx emissions while improving efficiency and reducing smoke, carbon monoxide, and hydrocarbon emissions.[27]

A study by B. Ashok, et al [28] evaluated the performance, emissions, and combustion characteristics of two biofuels derived from waste peels of lemon and orange fruits in a common rail direct injection engine. The research involved variations in injection pressures, split injection quantities, and exhaust gas recirculation. The study found that orange peel oil had higher Brake thermal efficiency than diesel and lemon peel oil at 600 bar with 10% of pilot fuel quantity, while LPO performed better than

diesel, but not as well as OPO. Increasing the quantity of pilot fuel injection resulted in decreased fuel efficiency, and the low viscosity of LPO improved its performance characteristics, while OPO saw a decrement. Both biofuels showed reduced emissions of unburnt hydrocarbon and carbon monoxide emissions under 600 bar and 10% pilot injection, but with increased oxides of nitrogen emission.

According to a study, lemon peel oil (LPO) performs better than diesel fuel in a diesel engine, with increased brake thermal efficiency and reduced smoke, carbon monoxide, and hydrocarbon emissions at standard operating conditions. The study also found that advancing injection timing and exhaust gas recirculation (EGR) can further improve LPO's efficiency and reduce nitrogen oxide (NOx) emissions. For instance, the use of 27° bTDC injection timing with 20% EGR can reduce NOx emissions by 46%. Overall, the study suggests that LPO is a viable biofuel alternative for diesel engines with superior performance and emission output. [29][30]

A study of V. Dhana Raju [31] investigated the potential of using lemon peel oil (LPO) as a sustainable source for biodiesel production by testing different blends of LPO and diesel fuel in a diesel engine. The results showed that the 20% LPO blend had better performance and reduced emissions. Adding 10% diethyl ether (DEE) to the LPO20 blend further improved brake thermal efficiency and reduced emissions. The experimental results were compared to simulation results from DIESEL-RK software, which also showed improved engine performance and reduced emissions with the addition of 10% DEE to LPO20. Overall, the study suggests that LPO20 with 10% DEE has promising engine characteristics.

Camphor oil as biodiesel

Camphor oil is a potential low viscous and low cetane (LVLC) fuel that shows promise as an alternative to fossil fuels. Increasing the concentration of camphor oil in a blend improves brake thermal efficiency while decreasing brake specific fuel consumption. The fuel also demonstrates better emissions with notable reductions in CO and HC, and an increase in CO2. These findings suggest that camphor oil may be a viable alternative fuel or additive to fossil fuels. [33]

The study investigated the impact of blending camphor oil with diesel fuel on soot properties and found that the resulting soot had a smaller fringe length and primary particle diameter but had an increased fringe tortuosity, degree of crystal disorder, and amounts of oxygen functionalities and aliphatic compounds. These changes in soot properties can be used to explain the observed trend of oxidative reactivity. [32]

In experiments conducted by Sanat Kumar et al[34], it was found that a camphor oil blend with diesel at a proportion of 40% yielded the best results in terms of performance and emissions. The addition of multi-wall carbon nanotubes saponified with ethanol to this blend further improved brake thermal efficiency and reduced harmful pollutants in exhaust gases such as NOx and CO. This fuel blend was stable for five days

at room temperature, indicating its potential for use in CI engines without any mechanical changes.

Dimethyl Carbonate as an additive

A study by A. Chandravanshi et al [35] suggests that the addition of dimethyl carbonate (DMC) to biodiesel can improve combustion quality and reduce emissions, resulting in increased thermal efficiency. The optimal blend was found to be 5% DMC in the biodiesel-diesel blend with 10% exhaust gas recirculation (EGR), which showed higher brake thermal efficiency compared to biodiesel alone, but lower than that with diesel. However, higher content of DMC (10% and 15%) led to increased brake specific energy consumption at medium and higher loads, limiting its use in higher content. Lower DMC content (5%) at higher load led to a reduction in carbon monoxide and hydrocarbon emissions, while carbon dioxide emissions increased slightly but remained within safe limits. The emission of oxides of nitrogen (NOx) decreased slightly, and this decrease increased with EGR. The study also noted a significant decrease in smoke emission with DMC as an additive in biodiesel due to improved combustion. However, higher EGR adversely affected the performance and emission characteristics, except for NOx and smoke emissions.

The study conducted by G D Zhang, H Liu, et.al[36] revealed that DMC has the potential to be a promising additive for diesel fuel due to its high oxygen content, suitable boiling point, solubility in diesel fuel, and no carbon-carbon atomic bonds. The experimental results indicated that the use of DMC as an additive in diesel fuel can reduce particulate matter emissions. The combustion analysis showed that the ignition delay of the engine fueled with DMC-diesel blended fuel is longer, but combustion duration is shorter, and thermal efficiency is increased compared to the use of base diesel fuel.

M.A. Mujtaba, Luqman Razzaq, et.al [37] used Biodiesel-DMC blends in an engine and observed that operating the engine at full load between varying speeds of 1100 to 2100 RPM, resulted in an average increase of 1.70%, 1.22%, and 0.95% in Brake Power, average decrease of 1.31%, 2.93%, and 1.08% in Brake Specific Fuel Consumption, average increase of 4.30%, 4.77%, and 4.90% in Brake Thermal Efficiency, average decrease of 2.63%, 2.80%, and 4.54% in Exhaust Gas Temperature. Furthermore, significant reductions of 19.04%, 25%, and 26.47% in CO emissions and average reductions of 12.76%, 19.35%, and 33.33% in HC emissions were observed for B10 + DMC, B20 + DMC, and B30 + DMC compared to biodiesel blends without antioxidant.

The study by T. Ramesh, et.al [38] found that using a DMC enhancer can reduce both HC and CO emissions, but the inclusion of EGR increases these emissions. The B20 + 5 ml DMC @ 20% EGR level resulted in the highest in-cylinder pressure, about 2.38% and 3.88% higher than diesel + 5 ml DMC and B20 blends, but 2.13% lower than diesel fuel. The peak heat release rate was highest for B20, about 10.38% higher than diesel, and smoke emission was reduced by 15.86%, 3.98%, and 6.1% compared to the other test samples when using 5 ml DMC

with 20% EGR. The study also found that brake thermal efficiency increased with increasing concentration of DMC in any blends, indicating that DMC could be a promising additive when blending biofuels with fossil diesel.

Conclusion

Researches discussed so far resulted in following conclusions

1. Bio-diesel and its blends having higher cetane number serves as better alternate in diesel engines with pros and cons
    a. Lower CO and HC emission with increasing NOx
    b. Brake thermal efficiency decreases with biodiesel
2. Cetane rating and combustion properties can be enhanced by using suitable additive with biodiesel blends.
3. Biodiesel with nano-particles resulted in better performance with lesser emission.
4. In search of optimization between emission and performance, a new scope on hydrogen as a blend evolved that seems to be better alternate in future.

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