A comprehensive review on performance, combustion and emission characteristics of diesel/biodiesel/alcohols and their blends

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Abstract. In the current scenario as governments are facing the issue of environmental depletion. The main cause of this depletion is emission by the transport sector. The heavy-duty vehicles mainly depend on diesel (a hydrocarbon fuel). This review paper shares information regarding the alternative sources of diesel for a compression ignition engine. For reduction in emission content researchers made great efforts but proportionally the number of vehicles continuously increases. In this field the binary and ternary fuel are gratefully used in such engine. The alcohols family help to make such blends where considerably results being achieved. The binary fuels have its own impacts on environment during the combustion inside the engine. It found that the less number of works done in field of quaternary blends. Some special features being required to accept such blends. These factors include viscosity, lubricity, and stability and material compatibility. Further work is required in acceptable blended fuel characteristics to ensure the long term effects on engine workability.

Key words: Emission, CI Engine, Performance, higher and lower alcohol

1. Introduction

Gradually retardation of fossil fuels an alarming sound for all humanity. As the use of petroleum products are majorly used in transport sector. Diesel is one of the most used fuels by this sector. Due to the better mileage capacity, durability, diesel is the backbone of this transport sector[1]. The reports on energy stated that all we are on the verge of energy crises. Mahmud et al.[2] stated that the 1.1% globally energy consumption demand increased by the transport sector only because of vehicle industry Although the growth of number of vehicles responsible for harmful emission content. About 22% of GHG being produced by this transport sector. Although so many data shared the information on GHG emission. It is estimated that between the tenure of 1990 to 2020 emission of carbon dioxide increased by 92% from transport sector. As reported by United State Energy Information Administration that by year of 2040 there will increase the trend of using renewable energy sources[3]. Today, the major share of energy consumed is derived from fossil fuel. Fossil fuel consumption leads to both health and environmental degradation[4]. The renewable energy sources are those types of energy sources which are naturally available and having a less of impact on environment as compared to conventional source of energy. As previous research was showing that the demand is increased in such a way that remaining expected fuel is not sufficient for next 100 years. Biodiesel would be feasible alternative fuel for the diesel[5]. Currently the biodiesel extracted from animal fats and biodegradable material. In the presence of appropriate catalyst and fer,biodiesel can be synthesised by reaction between alcohol and feed stock

As so many resources treated as waste. The edible and non-edible oil are the two more prominent resources to produce the biodiesel. It is discovered that there are around 300 assortments of oil seeds
however just 10–15 assortments have been investigated up until now, among which Kusum, the nauseating vegetable oils can be considered as a potential alternative fuel. In India, Kusum seeds are treated as waste which in turn makes it economical substitute of expensive fossil fuel\cite{6}. The biodiesel from the oil (edible or non-edible) could be achieved by two-step chemical reaction esterification and transesterification\cite{7}. The rigorous chemical treatments used for generation of biodiesel. At present the due to its unique characteristics conventionally biodiesel is blended with diesel to achieve the reduce emission although enhance the performance (degree of workability) and combustion characteristics of the engine \cite{8}. Conventionally the proportion of treated biodiesel is varying 5% or more. It can be used in an unmodified diesel engine\cite{9}qi. Although if neat biodiesel used in CI engine there will some engine modification is essentially required. So there is a solution if fossil fuels vanish then make some modification in the engine the neat biodiesel can be used. Conclusively the biodiesel would be an alternate source of fuel for the petro-diesel (CI) engine. When the produced biodiesel blend with petroleum diesel it has some special nomenclature. Such as B5, B10 and many more till certain designated value. The nomenclature B5 represented that 5% biodiesel contained with 95% of diesel. After ongoing research on CI engine with different proportions of biodiesel with diesel, it found second-generation biodiesel need not required any edible material as raw material. 

Basically, due to mixing any bio fuel it is very essential to save fossil fuel (diesel). On the basis of the period of generation they categorized majorly in 3 parts. However the 4th generation biodiesel still under research phase. The 4th generation biodiesel considered as advanced biodiesel \cite{3}. Most economical biodiesel is second-generation type biodiesel as it does not require any crop material which being used by human being as a food source material \cite{10}. During the complicated research on biodiesel with petroleum diesel it found that these type blends of diesel/biodiesel have low emission. The reduce emission achieved due to better combustion because it has oxygen-rich content although rich sulfur content. A full load test conducted on DI (Direct Injection) diesel engine however it was found the CO emission is decreased almost 50% \cite{11–14}.

In the initial phase biodiesel formation and it was achieved its Physico-chemical properties were similar to fossil diesel fuel Jatropha and Karanja blends fuel provided the lowered value of NOx and CO emission. Although the BSEC increased \cite{15}. The review of this article provides a glimpse of binary blends, ternary blends. Afterward it helps to understand about quaternary blends. In the whole study all the test conducting on unmodified diesel engine.

2. Binary blends of diesel

Qian et al.\cite{16} Investigated the physicochemical properties of diesel with soybean biodiesel. They prepared the blends of different proportions of biodiesel such as B5, B15, B25, and B50. Although observed that viscosity is gradually increased with biodiesel enrichment. On the other side biodiesel volatilization decreased in binary blend.

Zhang et al. \cite{17} performed their investigation on binary blends of diesel with butanol/pentanol. Both the blends were effectively reduced the emission of elemental carbon (EC). Also found the marginal reduction in total counts of solid particle and volatile particles. Although it was observed during investigation that decreases the trend of organic carbon (OC).

Kumar et al.\cite{18} conducted research on blends of diesel with higher alcohol (n-butanol) with the variation of alcohol 0 to 30%. After the evaluation of achieved data from experiment, it was concluded that heat release rate (HRR) got increased this output shown by its peaks of in-cylinder pressure. However, the substantial reduction observed in reduction in BSFC when increased the percentage
fraction n-butanol. Smoke opacity decreased with increasing the percentage of n-butanol. Although, oxides of nitrogen and CO emission decreased on enhanced the percentage of n-butanol.

Kumar and Saravanan [19] conducted their research on n-pentanol and diesel to observed the emission and performance under exhaust gas recirculation (EGR). It was found in the investigation that upto till 45 % of higher alcohol can be used in a CI engine without any changes.41% NOx emission was recorded at medium load by increase EGR rate and 33.7% at high load.

Yerrenngoudaru et al. [20] found the emission characteristics of the binary blend of diesel with methyl ester of mango seeds in presence of three antioxidants DEA (Di-ethyl Amine), PHC(Pyridoxine Hydro Chloride) and TBHQ (Tert Butyl Hydro Quinone) respectively. Investigation conducted on a single-cylinder CI engine to evaluate the performance and emission characteristics. The different proportions (100, 250, 500, 1000 ppm) of antioxidants were used in this study. It was found that PHC exhibited maximum NOx reducing activity as compared to other two.

Yang et al. [21] gave the broad numerical examination of a diesel motor fuelled with lamp fuel and its mixing with diesel. In this recreation, they utilized the KIVA4 code combined with CHEMKIN. During this examination, they totally filled the motor, later on, blended in with diesel in various extents. Thought of fuel mix proportion and fuel infusion point were two central point variables to inspect the presentation of the motor. In this exploration there were three examples made flawless diesel (D100), D50K50 (half diesel and half lamp fuel), K100 (100% lamp fuel). This reproduction proposed that fuel with a more prominent level of lamp oil appears to give the greatest power yield, decreased CO discharge. Yang et al. Inferred that the D50K50 with 47.5CAD of infusion edge.

Yusri et al. [22] Prepared the blends of diesel with butanol in different proportions. The three proportion were D95Bu5 (95% diesel, 5% Butanol), D10Bu90 (90% diesel, 10% Butanol), D85Bu15 (85% diesel, 15% Butanol) respectively. The investigation showed that ignition delay and combustion duration was higher for butanol blends as compared to D100 (neat diesel). Due to blending with butanol found that lower in-cylinder pressure, rate of heat release and rate of pressure rise. Higher engine cyclic variation shown when increases the blending ratio with butanol. For D85Bu15 possessed higher cyclic variation.

Atmanli and Yilmaz [23] found in their investigations that binary blends of diesel with n-butanol and 1-pentanol had better stability. However, investigation performed for both binary blends separately. The mixing ratios were 5 - 35% alcohol by volume. All the blends made to perform on single-cylinder diesel engine at loads of 0, 3, 6, 9 kW at a constant speed of 1800 rpm. The BTE reduced by 7.36%, BSFC increased by 14.02%. However EGT increased 48%. The positive side of the investigation it was observed that the average NOx emission reduced by 14.27%. Both the alcohol with diesel revealed lower combustion efficiency, slightly higher CO and HC emission. Although they concluded that n-butanol and 1-pentanol were chemically stable and could be used in an unmodified diesel engine.

Bari and Hossain [24] used the palm oil diesel (POD) as biodiesel and mixed with diesel. After observation it was found that BSFC little higher than diesel-run engine. This was due to LCV of POD. Although oxygen-rich content POD the thermal efficiency closed to diesel engine which operated on neat diesel. Emission analysis has shown that HC and CO emission very closed to the values of the diesel-run engine. However no starting problem was found even knocking sound was not observed.
Capuano et al. [25] utilized the waste vegetable oil (WVO) straightforwardly in the inner ignition motor and saw that because of the lower warming estimation of WVO accomplished the decreased warmth discharge rate when contrasted with the perfect diesel-run motor. Higher BSFC can be constrained by cutting edge infusion timing in spite of the fact that by expanded bay fuel temperature. In any case, these amendments improved the proficiency of the motor.

Pali et al. [26] performed the research study on single-cylinder water-cooled CI engine. During the experiment prepared the blends of Diesel/Kusum Biodiesel. In different proportions blends were prepared. All the blends were available with increased concentration of Kusum biodiesel such as D100, KB10, KB20, KB30, KB40, where D represents diesel and KB for Kusum Biodiesel. For understanding the blends notation KB10, Diesel was 90% and Kusum Biodiesel was 10%. It was concluded that CO emission decreased with enriched concentration of Kusum Biodiesel. BTE somehow decreased with increased proportions of Kusum Biodiesel. However the BSE (Brake specific energy) increased with improved composition of Kusum Biodiesel. For D100 the highest in-cylinder pressure was 67.51 bar at full load. It was observed that peak in-cylinder pressure decreased as the increase the proportion of Kusum Biodiesel, for KB40 which was 63.53 bar. In this research study it was concluded that Kusum Biodiesel would be better alternative green fuel for diesel engine.

Ozener et al. [27] worked on a single cylinder CI engine. The investigation tried to found another alternate source for CI engine. After obtaining the biodiesel from soya bean mixed with the diesel. Those blends were used to carry out the experiments on the CI engine. They used B10, B20, B50 blends for the investigation. It was observed that BSFC increased about 2-10% due to lower heating value, slightly increased the CO emission from 1.46-5.03%, but oxides of nitrogen (NOx) were found reduced. This investigation concluded that soya bean may be a good option as an alternative fuel for CI engine.

3. Ternary blends of diesel

Ternary blends which are formed by mixing of diesel, biodiesel, and alcohol. A number of researches conducted to provide more sustainable alternative fuels for diesel engine. Basically the transport sector (heavy-duty transport) based on CI engine. Basically during blends formation alcohols had two types of family. First is lower alcohol and second is higher alcohol. Behind the selection of any types of alcohols a complicated research study involved. There were so many factors played role for selection such are viscosity, density, flash point, pour point, solubility with diesel and biodiesel. The number of researches has been conducted for ternary blends of diesel to achieve the optimize output with controlled emission.

Yerrennaoudaru et al. [28] used the twin-cylinder diesel engine for their experiment. The blends of diesel/vegetable oil /alcohol (ethanol) were used in this experimentation. Although Prepared blends of ethanol with palm oil, cotton seeds oil, apricot oil and Pogamia oil with diesel to observe the performance and emission characteristics of diesel engine. It was found in observation that BTE of neat diesel-run engine was higher as compared to blends of ethanol and vegetable. Among all the blends of Apricot oil and ethanol exhibit higher BTE. The trend of HC emission was similar in all prepared blends. CO2 emission reduced by 17% when using the blends of vegetable oil. It was observed that CO emission in diesel-run was 14.7 ppm. Least value of CO emission found in Apricot and Pogamia vegetable oil blend i.e 7 ppm at full load. Slightly reduction of NOx found in apricot vegetable oil blend. It was approximately 720 ppm when engine ran on neat diesel and 600 ppm when engine operated on vegetable oil blends. 20% of opacity was observed on the diesel-run engine. However it was 35% for vegetable oil blends.
Yerrennaoudaru et al. [20] observed the performance, emission, and combustion of ethanol blended with palm oil, canola oil, and soya bean oil in a CI engine. In this investigation, the parameters evaluated such as emission of CO, CO2, HC, NOx, aldehydes, and smoke. Their work compared between the conventional and modified piston of a twin-cylinder diesel engine. BSEC was greater for full load modified piston of CI engine fuelled with 50% ethanol and 50% soya bean oil. Maximum BTE for modified piston diesel engine at full load 45% and least for ethanol blended with canola oil. 200ppm HC observed in conventional piston CI engine. Maximum CO2 26% emitted by conventional piston CI engine at full load. Conclusively explained that the ethanol blended with vegetable oil was more feasible as compared to conventional CI engine.

Bhurat et al. [29] focussed on the performance and emission characteristics of a single-cylinder water-cooled diesel engine. Prepared Blends were D100, E10D90, E15D85, E10B10D80, and E15B10D75. Where E represent ethanol, B for biodiesel and D is diesel. During investigation thermal efficiency and NOx were decreased when using the blends of ethanol as compared to neat diesel. Somehow the unwanted trends were found in Co and HC emissions. The full load was 10 kg during experiment. BMEP was highest when engine was fuelled with E15B10D75. 2.9 kW BP was found in E10D90. BSFC found increase due to higher ignition delay of ethanol. 39% of thermal efficiency observed at load of 8 kg in E10B10D80. Inadequate oxyden led to increased value of CO emission in ethanol blends.

Caligiuri et al. [30] utilized the ternary mixes of diesel-biodiesel-bioethanol in 3.5 kW single-chamber water-cooled diesel motor. By utilizing the RSM (reaction surface strategy) framed a condition by disposal the term individually. Play out the examination of fluctuation (ANOVA) planned for proving the parameters of impact (factors) on the above-demonstrated degree (reaction), a consequent utility of the Response Surface Methodology (RSM) permitted to figure the relapse trademark coefficients that portray the consequences of the measurably huge unbiased factors on the reaction. The RSM, generally from various numerical hardware, for example, engineered neural systems.

Paul et al. [31] evaluated the performance, exergy, analysis of blends of Diesel-ethanol and Pongamia piñata methyl ester (PPME) on a 4 stroke single cylinder water-cooled compression ignition engine. During the whit ole investigation the fraction of PPME was fixed at 50%. The fraction part of ethanol gradually increased at difference of 5%. 21.17% enhanced in BTE when ethanol kept at 15% although 4.61% decreased in BSEC. It was observed that unburnt HC slightly increased with 15% ethanol. It was observed that exergetic efficiency increased by 25.7% although exergy destruction rate decreased by 22.02%. D35E15B50 shown the falling trend for exergy generation.

Atmanli [32] explained the concept that how to utilize higher alcohol with diesel and biodiesel. Due to enhanced properties of higher cetane number, higher heating value (calorific value), greater stability with blends of diesel/biodiesel. During the engine run found that blended higher alcohol i.e. the mixture of diesel-biodiesel-propanol/n-butano/1-pentanol found that increased value of cloud point and CFPP. On the other hand reducing trend observed in density, viscosity, LHV and cetane number. Emission of oxides of nitrogen found decreased in all higher alcohol blend with diesel and biodiesel.

Kumar et al. [33] conducted research on the ternary blends of Pongamia-WCO biodiesel-diesel. Ternary blend had cloud point of 7°C and 6.2°C was pour point that were higher than petro diesel. Moreover as compared to ternary higher amount BSFC found in WCB and Pongamia oil biodiesel.
4. Conclusion
From the exhaustive review it can be concluded that BSEC were found to increase by substantial rate, still the controlled emission of NOx not achieved. Still researchers made to rigorous effort to replace the conventional fuel as diesel from the transport sectors but stake holders can’t depend on the biodiesel. There are several needs of modification in CI engine. There is possibility to find the material which can enhance the rate of combustion which will lead to complete combustion.

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