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Current Trends in Reducing Emission and Fuel Consumption in Diesel Engines

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Abstract: Diesel engines are used around the globe in many transportation and power production activities. These engines consume large amounts of fuel and produce many dangerous pollutants. If we add to this all, the coming day for the depletion of oil, all these things together require consideration of alternatives to reduce the consumption of diesel oil and its pollutants. In this study, we navigate through the scientific research space and review the latest findings of science in this regard. There are substitutes for diesel, including fully compensated, or mixing with it to reduce pollutants. All these alternatives have their positives and negatives. To this day, diesel fuel is still dominating the ignition engines and has not yet achieved a competitive advantage in terms of combustion efficiency.

Keywords: diesel, alternatives, alcohol, biodiesels, water-diesel emulsion.

INTRODUCTION

Transport can be considered an essential element in the economy, development and human well-being. However, despite its importance, many problems have been associated with increasing transport activities, perhaps the most serious of which is air pollution and full dependence on oil [1]. These two risks have a particularly direct impact on the economies of the developing world [2]. Addressing the damage of environmental and health air pollution means putting huge budgets that these states cannot offer to its citizens [3]. The fluctuation of oil prices has directly harmed producers, exporters and consumers [4].

Diesel fuel can be considered the best available fossil fuel. Compared with gasoline, the CO and HC emissions emitted are less [5]. The NOx and PM pollutants produced are more than gasoline. The risk of nitrous oxide is that it causes serious diseases in the body, is absorbed through the lungs and directly combines with hemoglobin, raises the level of carboxylic in the blood and lowers the level of oxygen that reaches the organs of the body, which disrupts its work and may cause poisoning of the body or serious diseases [6].

Environmental issues are increasingly affecting the manufacture of diesel engines, due to the emission of nitrogen oxides and particulate matter [7]. Reducing the amounts released from these substances into the atmosphere is the most important objective of environmentalists, industrialists and legislators. Therefore, we find that most of the environmental protection institutions in the world put special conditions on cars that operate in diesel, and have developed determinants of pollutants emitted and these limits are tightened strictly periodically [8].

Diesel engines fill the world and move various forms of cars, trucks, trains, and ships. The resulting pollutants can be counted in billions of tons a day if we add these generate from the electricity generators, whether the large ones with hundreds of megawatts or small ones with capacities of less than one megawatt [9]. In addition, diesel fuel is cheaper than gasoline. Diesel is characterized by more energy than gasoline. Each cubic meter of diesel produces energy of 9800 kilowatts, while the same amount of gasoline generates only 8,860 kilowatts. This means diesel is more economical than gasoline, and diesel engines need less fuel than gasoline to cut the same distance [10].

The second advantage of diesel is the low cost, because it is extracted from crude oil through partial distillation and can be produced in large quantities in oil refineries, which makes it less expensive compared to gasoline or kerosene [11]. In addition, diesel needs a higher evaporation temperature than gasoline, which makes it harder to burn than gasoline. This makes it safer because it is less likely to ignite than other types of gasoline that respond to flammability at high speed, but requires special technology and larger engines to burn fuel at higher pressure than gasoline engines [12].

Several recent studies have shown that the concentration of hundreds of diesel generators causes concentrations of many pollutants that harm the occupants [9]. In the same manner, the concentration of pollutants emitted from trucks and cars in the crowded highways in cities such as Baghdad-Iraq causes pollution concentrations that can cause many diseases [13]. Not to mention cities with high population density, such as Hong Kong, Delhi and New York. The disadvantages that affect the diesel engine and limit its use in many applications are the high cost of construction and weight, and large size Perhaps the biggest disadvantage that prevents the use in many applications is the high noise that results from it [14]. To date, with the experience of many diesel alternatives, no one alternative has been obtained that has the same thermal value as diesel or burns with the same specifications [15]. Many excellent alternatives to diesel have a lower thermal value, which means consuming more fuel or emitting more dangerous pollutants [16]. So the researchers went on to add some substances to diesel, such as additives, alcohols, water, and other types of gaseous fuels such as natural gas, liquefied petroleum gas, and hydrogen [17 & 18].

Several modifications have been made to the diesel engine to reduce the exhaust emissions from it and to reduce fuel discharges. These modifications include increased injection pressure, use of valve timing variation, and the use of different types of engines such as HCCI, PCCI, and RCCI. To date, none of these engines and fuels is widespread and still in research and development, and diesel fuel remains the most widely used fuel around the world [19]. In recent years, automotive companies have begun to equip their production with many additives as filters and catalysis in all models of their vehicles to reduce emissions. However, it cannot completely eliminate diesel emissions despite significant technological advances, and can only reduce about 95% of the emitted pollutants [20].

This paper aims to review the last modifications in fuel type and engine design used to enhance the diesel engine operation and reduce the dependence on the fossil diesel fuel. Although the work in this area is old and began to focus on it since the seventies of the last century, the focus of this article will be the latest publications and the latest research studies in the field of research and development.

Adding Alcohols to diesel fuel

Alcohols are chemical substances, which mean that in their chemical composition there are oxygen atoms that are necessary for combustion. So, running the engine with alcohols or adding them to the original fuel, whether diesel or gasoline, improves the quality of the combustion through the added amount of oxygen [21]. From here, many researchers studied the operation of a diesel engine with alcohol or by adding alcohol to diesel fuel. The specifications of the combustion of alcohols is closer to the gasoline than diesel, as they have high octane numbers and low cetane numbers, which makes its work as fuel for diesel engine difficult. From here they were added in different ratios to diesel [22].

Ref. [23] studied the addition of ethanol to diesel in variable fractions and the effect of these blends on the performance and emissions of a diesel engine. The experiments were performed using a four-cylinder engine with a total engine speed of 1500 rpm. The results showed that diesel-ethanol mixtures caused a decrease in CO pollutants, unburnt hydrocarbons (HC), and Nitrogen (NOx). The ethanol mixture also causes a 13.8% increase in the specific fuel consumption o because of its low heating value. The results show that ethanol can be added to diesel fuel and used in diesel engines without any engine modifications.

Ref. [24] checked the performance and contaminants emitted from blends consisted of biodiesel - butanol - micro algae and compare them to diesel fuel. The blends mixtures produced higher fuel consumption and thermal efficiency than conventional diesel. All diesel mixtures used in the study showed a decrease in PM varying between 0.5% to 60.4%. Carbon dioxide emissions increased by 1.72 to 2.94% compared to diesel fuel, which means better combustion. The increase in butanol fraction by 20% resulted in an increase in the emitted HC emission by 18%.

Ref. [25] compared the engine performance and emitted pollutants when fueled by diesel and diesel – methanol blends. The study was conducted using a four-cylinder, direct injection diesel engine operated at full load. The results showed that the diesel-methanol mixtures caused a marked decrease in CO and HC pollutants, and a limited NOx increase. The results also showed a clear reduction in noise by increasing the ratio of methanol to the mixture.

Ref. [26] tried to take advantage of direct injection of a mixture of diesel fuel with alcohol additives (ethanol, butanol, isopropyl alcohol) in volume proportions of 100: 0, 90:10, 85:15, 80:20, 75:25, and 70:30. The addition of alcohols to diesel increases fuel consumption slightly and reduces carbon dioxide emissions. The smoke opacity was reduced by diesel-alcohol mixtures from 42.24% to 68.2%. Nitrogen oxides also decreased by 6.62% to 11.62% compared to diesel.

Ref. [27] studied the performance of a single-cylinder engine feeding with a different mix of diesel-ethanol. The results showed that the fuel consumption at high loads is less than the diesel engine. Fuel consumption increases for low and medium loads by increasing ethanol in the mixture. The thermal efficiency of a diesel engine is higher than that of a dual fuel engine for low and medium loads, and less than the high loads.

Ref. [28] tried increasing combustion efficiency and reducing exhaust emissions by adding n-propanol at different volume rates such as 2%, 4%, 6%, 8% and 10% to diesel. The results showed that thermal efficiency at full load increased by 11.78% when n-propanol was added by 10% to diesel. CO2 and NOx emissions decreased by 44.12% and 9.33%, respectively, Ref. [29] tried increasing combustion efficiency and reducing exhaust emissions by adding n-propanol at different volume rates such as 2%, 4%, 6%, 8% and 10% to diesel. The results showed that thermal efficiency at full load increased by 11.78% when n-propanol was added by 10% to diesel. CO2 and NOx emissions decreased by 44.12% and 9.33%, respectively at full engine load.

Ref. [30] investigated the effect of adding methanol and ethanol to diesel on the combustion properties of a diesel engine while changing injection timing when using five different fuel mixtures. The experimental results showed that the maximum pressure inside the cylinder and the maximum heat release rate were obtained by advancing the fuel injection timing for all types of fuel studied. Flammability was increased at the original and advanced injection timings for ethanol/diesel and methanol /diesel blends compared to diesel. Increasing the amount of methanol or ethanol in the mixture caused an increase in the delay period and a decrease in total combustion duration for all injection timings.

Ref. [31] analyzed the fuel consumption and pollutants of a multi-cylinder diesel engine that uses biofuels (90% Jatropa oil + 10% ethanol) and compared with normal diesel available in the market. The study showed that the biofuels used represent a good alternative fuel with closer to diesel performance and better emission characteristics than diesel.

Ref. [32] has burned of a mixture of butanol-diesel (B5, B10 and B20) in a turbocharged direct-injection diesel engine. The results showed that thermal efficiency is higher and fuel consumption is better than that of other studies. The addition of a small volume of butanol to diesel in a turbocharged diesel engine resulted in better performance than using ethanol or methanol with diesel, the researchers conclude.

Ref. [33] used four four-cylinder compression ignition engines to conduct tests with 10% ethanol or 10% methanol mixed with diesel fuel using EGR technology. The study focused on the mutual relationship between NOx and PM. The results showed that PM concentration decreases with the addition of alcohol to diesel regardless of type, and decreases with the increase in the amount of oxygen in the blend. PM concentrations emitted from the diesel engine increase when supplied with pure diesel fuel and equipped with EGR technology. The operation of the engine with diesel-alcohol blends caused a significant reduction in the concentrations of NOx-PM trade off.

Ref. [34] evaluated the performance and emissions of mixtures of methanol and propanol (20% by volume) and diesel when the diesel engine is operated by direct injection under full load conditions. The results showed that the brake power was less and the fuel consumption was higher when using the alcoholic mixtures compared to diesel. Nitrogen oxides emissions have also fallen compared to diesel.

Ref. [35] simulated the performance characteristics and pollutants of diesel engine when operated with a mixture of diesel and ethanol added by 20%, diesel and added jatropha by 20%, and added 20% ethanol and 20% jatropha to diesel and compared between them. The results showed that the use of JB20 reduced thermal efficiency compared to pure diesel, but when adding ethanol, the efficiency increased slightly. Diesel fuel operation caused the lower fuel consumption than the other blends studied. The use of JB20 resulted in an increase in nitrogen oxides concentrations compared to E20, while JBE20 resulted in reduced NOx emissions compared to diesel. Carbon dioxide emissions follow the trend followed by nitrogen oxides emissions. Diesel showed the highest PM emission at full load.

Ref. [36] added biodiesel - alcohol to diesel to form ternary fuel blend and used it in a diesel engine having no major modifications. The main results of the study showed that the use of this mixture caused the reduction of pollutants emitted while maintaining the same performance of diesel fuel alone.

Dual mode (gaseous fuel-diesel) engine

Gaseous fuels such as natural gas (NG), liquefied petroleum gas (LPG), and hydrogen are suitable for gasoline engines, as these fuels resist engine knock more than conventional liquid gasoline. It also emits fewer pollutants if mixed and burned with the appropriate conditions for each fuel [37]. Some researchers have suggested that the use of gaseous fuel in diesel engines through the concept of dual fuel is more economical and less environmental pollution [38]. There are several publications on the use of dual fuel engines to introduce gas to the cylinder. The use of natural gas in dual fuel engines has been studied from the combustion duration and ignition point [39], and from the point of view of performance and emissions [40, 41]. The combustion, thermal loading and temperature distribution of the double motors were also studied [42]. The use of neat methane in dual fuel engines was investigated from the point of view of the laminar flame spread limits [43]. Besides, the performance and emission of a dual fuel engine was evaluated by [44].

Ref. [45] conducted an experimental study on the possibility of improving the performance of the diesel engine by inserting volumetric fractions of gaseous hydrogen into the cylinder using a single cylinder engine. Experiments were performed using the higher useful compression ratio and engine speed of 1500 rpm to study the effect of variables such as the equivalent ratio and timing of injection. The results showed that the higher useful compression ratio of the diesel used in the study was (17.7: 1), and this percentage was increased when using a mixture of diesel and hydrogen. The results also showed the possibility of operating the engine at very low equivalence ratios when using hydrogen. The addition of hydrogen with elevated volume fractions increased the thermal efficiency of the dual-engine compared to diesel and reduced the fuel consumption.

Ref. [46] modified a single-cylinder diesel engine for the use of liquefied petroleum gas (LPG) in the study of performance, emission and combustion characteristics in a duel fuel mode. The results showed that NOx and smoke were reduced for the dual-fuel engine in the total load range. However, this engine suffered from the problem of poor thermal efficiency and high emissions of HC and CO, especially in low loads due to poor ignition. To address this situation, a glow plug was introduced into the combustion chamber, improving thermal efficiency, and resulted in low concentrations of hydrocarbons, carbon monoxide and smoke emissions.

Ref. [47] converted a heavy diesel engine for truck applications on the highway to a dual fuel engine (diesel + natural gas) and studied the effect of this conversion on PM and CO2 emissions. The results showed that this type of engines caused a significant reduction in PM and in CO2 emissions. In contrast, there is a small reduction in the brake power during transit operation. The results also showed an increase in HC in the exhaust gases of this type of motors.

Ref. [48] examined the performance characteristics and contaminants of a single cylinder diesel engine when adding natural gas to diesel (in dual fuel mode). The results showed that the bulk of the released energy resulted from the combustion of gaseous fuel. The use of a small amount of diesel was to provide a source of ignition. The following variables were examined: the equivalent ratio, engine speed, and the effect of changing the diesel fuel injection timing on fuel consumption and emitted pollutants. The use of dual fuels has significantly reduced nitrogen oxide emissions, but at very low equivalence ratios and low loads CO and HC emissions were increased compared to diesel.

Ref. [49] tried to reduce the emissions of polycyclic aromatic hydrocarbons (PHS), HC, CO, CO2, PM, and NOx when the engine was run in low-load case using different amounts of H2/O2 added to premium diesel fuel (PDF). The results showed that the dual fuel used reduced the fuel consumption by 12.6% compared with PDF. At the same time, the emissions decreased by 32.3% for PHSs, 9.5% for HC, 7.2 % for CO, 4.4% for CO2, 19.3% for PM, but NOx levels increased by 9.9%.

Ref. [50] conducted a numerical study of the pre-combustion chamber effect on combustion performance of dual fuel/natural gas engine emissions. The study was performed using direct injection system (DI) and indirect injection (IDI). The researchers used the same numerical model of the dual fuel engine with a similar compression ratio, the boundary layers, and the initial conditions of the DI comparison with the IDI combustion system for the dual fuel engine. It was also determined that the size of each combustion chamber should be constant to obtain the same compression ratio as 17.2. The thermal efficiency of the dual fuel engine with the IDI system was increased by 28.1%. The dual fuel engine with the DI system gets malfunction when the injection timing is delayed to 4-12 °BTDC. NOx levels for the IDI dual fuel engine are about 80% lower than DI engine for all the injection timing tested. CO2 and PM levels are less also by average of 30.9% and 96.2%, respectively.

Ref. [51] added hydrogen to diesel in the dual fuel engine and studied the effect of the coolant EGR addition on the engine performance and the pollutants emitted from it. The variables studied were: air-to-fuel ratio, injection timing, and engine speed. The results show that the engine performance and emissions were affected by air/fuel ratio and the injection timing, and the use of cooled EGR is highly detrimental to them. The results showed that there is a trade-off relationship between hydrogen and EGR. Adding hydrogen increased the concentration of nitrogen oxides and reduced the PM concentrations. However, when cooled EGR was added the nitrogen oxides concentrations were lowered and the PM levels were increased. The resulted concentrations of NOx and PM depended on either of these additives are more effective.

Ref. [52] studied experimentally the combustion of LPG in a dual fuel engine to understand the effect of the liquid fuel properties when injected directly, using rapeseed methyl ester (RME) and gas to liquid (GTL) fuels. The results showed that 60% of liquid fuel can be replaced with liquefied petroleum gas (LPG) while maintaining stable combustion of the engine, resulting in a clear reduction in soot and NOx. Also, the results showed that RME-LPG dual fuel could be a good alternative to diesel-LPG dual fuel, as it gave better engine performance and lower HC, CO and soot compared to other liquid fuels. This result could be returned to the oxygen content of the fuel. Nitrogen oxides levels have increased with RME-LPG dual fuel operation.

Ref. [53] tried to adjust a diesel engine to use high potential renewable fuel mixtures. The experimental study conducted using a diesel engine that was run in a dual fuel mode, and was fueled with esters of Honne (EHNO), Honge oil (EHO) and hydrogen addition. The study showed that the thermal efficiency increased by 20%. With hydrogen addition and then decreased with increasing the hydrogen fraction. Emissions such as HC, CO, and smoke decreased with hydrogen addition while NOx levels were increased.

Ref. [54] devoted his study on the effect of adding hydrogen to diesel in the duel fuel engine on the emitted particulate matter (PM). The variables studied were: engine load, speed, equivalent ratio, diesel injection timing, and the rate of addition of hydrogen on the emitted PM. The experiments were performed using a 4-cylinder engine. Hydrogen was introduced into the engine with three volume ratios of 30, 50 and 70%. The addition of hydrogen caused a significant change in the emitted particles. The studied variables also had a significant impact on the output PM.

Ref. [55] studied the effect of many operational variables such as diesel injection pressure, injection timing, diesel fuel mass, and the ratio of gas substitution ratio. In addition, the authors studied the effect of the engine load and its speed on the efficiency and exhaust pollutants of diesel engine operated on dual diesel/natural gas mode. The study results indicated that the increase in injection pressure led to an increase in the indicated thermal efficiency. However, without appropriate control of combustion duration a decrease in the indicated thermal efficiency and an increase in HC and CO levels can occur.

Ref. [56] studied the performance and emissions characteristics of turbocharged diesel engine operated with natural gas as the primary fuel and diesel as the ignition source. The results showed that NOx emissions decreased at low loads, while CO and HC levels rose, as well as the brake specific fuel consumption was higher compared to those of the corresponding diesel engine.

Ref. [57] added hydrogen to the suction manifold of a diesel engine fueled by biodiesel fuel. The engine was also powered by a heavy EGR ratio. The EGR system used to achieve a high level of control over the exhaust gas flow rate and temperature. The added hydrogen has increased NOx concentrations in the exhaust gases, and the high EGR rates have reduced the thermal efficiency of the engine. The ratio of NOx emitted by the engine depends on the amount of added hydrogen and EGR. Adding hydrogen with large amounts of EGR significantly reduced CO, HC, and PM. The use of hydrogen and biodiesel increases engine noise, which was decreased with EGR addition.

Biodiesel Fuels

Biodiesel is an oxygenated fuel that is similar to alcohol because its chemical composition has a high proportion of oxygen. This feature makes biodiesel a desirable alternative to fossil diesel as oxygen in its composition improves the quality of combustion and reduces CO2, CO, HC, and PM pollutants [58, 59]. Biodiesel has a low heating value compared to diesel, which makes it consume more fuel to cut a specific distance. Also, containing dissolved waxy materials that may accumulate in the filters and cause its clogging [60].

Ref. [61] examined the emissions and the distribution of the nanoparticles PM size emitted from diesel engines fueled with diesel fuel mixed with biodiesel by 20% (20BD). The emission studied were HC, CO, NOx and nano-size PM in accordance with engine operating conditions with and without exhaust gas recycling (EGR). The study results showed that under high load conditions, the maximum torque achievable with a mixture of diesel-biodiesel is slightly less than that achievable with diesel fuel. Smoke also fell by more than 20% for all the operating conditions. The number and mass of the particles also decreased in fuel about 43% when not using EGR. When EGR was added to the engine, the number and mass of the particles decreased for the D100 and BD20 by 24% and 16%, respectively.

Ref. [62] reviewed how to prepare biodiesel fuel, and the types of catalysts used to produce this fuel. The reference also studied the effect of free fatty acids on its production, the different use of monohydric alcohol in the preparation of biodiesel and the effect of biodiesel composition on the properties of fuels. The authors also studied the effect of mixing biodiesel with other fuels on fuel and the characteristics of the engine performance and the resulting emissions. The study focused in particular on the use of alternative substrates in the production of biodiesel. Finally, the future challenges and prospects for biodiesel.

Ref. [63] tested experimentally the performance and the emission characteristics of a direct-injection diesel engine when using biodiesel derived from inedible oil such as Jatropha oil and mixed with diesel in volume ratios of (JB5), 10% (JB10), 15% (JB15), and 20% (JB20). The researchers did not make any adjustments to the engine. Exhaust gas emissions have declined for HC, CO, CO2 for all types of fuel blends studied. Engine noise for biodiesel-diesel blends decreased compared to diesel engines.

Ref. [64] investigated the impact of the addition of biodiesel manufactured from plant waste to diesel fuel on engine performance and emissions. The researchers used two different blends of manufactured biodiesel by adding 80% diesel to 20% biofuels and 100% bio-diesel. The use of biodiesel provides a significant reduction in carbon monoxide, HC and PM, but has increased NOx by 7 and 11% for B20 and B100, respectively.

Ref. [65] used the biodiesel produced from cooking waste oil in a four-cylinder, direct injection turbo diesel engine. The engine is equipped for comparison purposes with pure diesel fuel and three diesel/biodiesel mixtures (B25, B50 and B75). The results showed that the use of biodiesel resulted in the production of less conventional smoke compared to that produced by diesel fuel due to better combustion efficiency. The use of biodiesel also reduced total hydrocarbon and carbon emissions and increased emissions of nitrogen oxides. The study found that emissions of diesel/biodiesel mixtures are lower than diesel fuel, which means that its use improves air quality.

Ref. [66] studied the use of Iraqi sunflower oil as a raw material for the production of biodiesel by transistrifection process. The researchers used the multi-cylinder diesel engine to test the performance and emissions of biodiesel alone, and when mixed with pure diesel. The experimental results show that CO and HC pollutants are reduced when the engine is made with Biodiesel (B100) clearly. The resulting exhaust gases are very low, and the noise level is lower than that of a diesel engine. When the engine is powered by biofuel, it has the largest fuel consumption and the highest nitrogen oxides concentrations. Increasing engine speed will increase the temperature of the exhaust gas, CO2 emissions, fuel consumption, and nitrogen oxides concentrations.

Ref. [67] reviewed the effect of ignition delay, combustion and emissions specifications of a diesel engine equipped with biodiesel. Review studies have agreed that the specification for the burning of the biodiesel is slightly different from diesel. The biodiesel has an early start of combustion and ignition period of less than 1-5° and 0.25-1°, respectively.

Ref. [68] studied the effect of fueling a diesel engine with Jatropha oil separately, and blended it with ethanol and butanol. The study found that 80% Jatropha oil + 20% butanol mixture was the most appropriate alternative, since its properties were closest to fossil diesel fuel. The combustion process of diesel and biofuel mixture improved when the mixture temperature increased. The CO2 emissions for both diesel and biofuels have increased as the temperature increased. Fuel consumption decreased with increasing temperature andit was higher on average when using biofuels.

Ref. [69] investigated the exhaust emissions of a diesel engine fueled by diesel fuel mixed with ester of olive oil extracted from wastes. The results showed that the use of biodiesel reduced CO2 emissions by 58.9%, carbon monoxide by 8.6%, NO by 37.5% and SO2 by 57.7%, with an increase in NO2 emissions up to 81%. Biodiesel provided a slight increase in brake fuel consumption (less than 8.5%), which can be tolerated due to the benefits of exhaust emissions.

Ref. [70] prepared biodiesel from Iraqi corn oil and used it separately, as well as mixing it with different ratios of diesel to operate a direct injection 4-cylinders engine. Engine variables such as load, velocity and injection timing impacts were studied on the particulate matters emitted. The results showed a significant reduction in PM (between 15%

and 52%). The study concluded that PM concentrations could be further reduced if the sulfur content in Iraqi diesel fuel was significantly reduced.

Ref. [71] evaluated the performance exhaust emissions of bio-diesel fuel derived from soybean oil and added to fossil fuels with low sulfur content. The researchers studied the use of blends of diesel and four biodiesels that included 5%, 20%, 50% and 100% soybean oil. The results of experiments showed that the use of various mixtures of bio-soybeans increases fuel consumption while increasing the proportion of biofuels in the mixtures. The addition of biodiesel to diesel reduced emitted pollutants (i.e. nitrogen oxides and carbon monoxide), and the decrease rate was enlarged by increasing biodiesel in the mix.

Water –diesel emulsions

The most dangerous pollutants emitted from diesel engines are nitrogen oxides and particulates (BEM). The mechanism of forming these two polluters in the combustion chamber of the diesel engine is contradictory and the technique of simultaneously reducing them is very difficult [72]. In general, techniques used to reduce NOx cause an increase in particle emissions and vice versa [73].

The use of diesel water emulsion can be considered one of the promising ways to achieve economic reduction in these polluters. The use of diesel water emulsions as fuel for engines can control nitrogen oxides and smoke emissions together [74]. The use of this type of fuel causes lower NOx emissions due to lower gas temperature and increased concentration of OH radicals [75]. It also causes low PM emission due to the small explosion of water and increased concentration of OH radical [76]. Studies have also shown an improvement in brake thermal efficiency under certain operating conditions [77].

Ref. [78] enabled the reduction of nitrogen oxides using a water-diesel emulsion, which causes local temperature reduction and low reaction rate. It also benefited from the abundance of oxygen and hydrogen by providing better mixing and improved combustion, which reduced BM.

Ref. [79] reviewed the effect of the use of diesel-water emulsion on emissions and combustion efficiency. The study showed that there was a reduction in NOx emissions and particulate matter, but there was an increase in emissions of HC and CO when water content in the emulsion was increased. The efficiency of combustion improved with the use of water-diesel emulsion.

Ref. [80] used water- diesel emulsion to determine effective ways to reduce diesel engine emissions. The researcher added the water to diesel at different rates and conducted the study at a fixed engine speed and variable engine load. The results showed a decrease in NOx, HC, CO, CO2, and PM with an increase in water emulsion to 20%, accompanied by a reduction in the brake fuel consumption.

Ref. [81] used diesel-water emulsions in diesel engine and investigated the performance, combustion and emissions. The water was added to other types of fuel (diesel, biodiesel, jet fuel) to form emulsions. The researchers used for these purposes emulsifiers (70:30 fuels to water) produced using carboxymethylated wood lignin as a stabilizing agent. The combustion experiments were performed at a constant engine speed of 2000 rpm and using three loads (0, 1.26 and 3.26). The use of emulsifiers has increased the mechanical efficiency of the engine except for jet fuel emulsion. Fuel consumption also decreased and thermal efficiency of the engine increased. The emulsions studied resulted in lower peak pressure within the cylinder and decreased heat release. The results showed that there was a significant reduction in NOx emissions with a significant increase in carbon monoxide (CO). Emulsifier engines produce lower carbon dioxide emissions.

Ref. [82] used nano-Al2O3 after mixing it with water on a weight basis to form a suspension with a weight ratio of 1, 3, 5, 7, and 10%. A fixed volume ratio of the suspended product (10%) was added to the diesel and mixed together completely. The results showed that the suspension used increased thermal efficiency by 5.5% and reduced fuel consumption about 3.94%, compared to diesel. The emissions of CO, HC, NOx, PM and noise were lower than diesel while CO2 emissions increased.

Ref. [83] studied the effect of the emulsion type, the microexplosion phenomenon, the stability of the emulsion, the improvement of the physicochemical properties, and the effect of the water content on combustion and engine emissions. Also, the authors reviewed the effect of the fuel injection pump and shape and arrange of the spray nozzle.

The study concluded that the effect of these components in microexplosion in any emulsion should be concentrated and needed to be studied further.

CONCLUSIONS

To date, no fuel is available with combustion characteristics and exhaust pollutants that make it the best alternative to diesel fuel in both transport and stationary engines. The driving force of increased interest in finding alternatives to diesel is a practical response to the restricted limitations on this fuel exhaust pollutants. Working to reduce all contaminants, whether CO2, HC, CO, NOx, PM, and noise at the same time did not lead to the identification of a viable alternative fuel. All types of alternatives studied, whether alcohols, biodiesel, or diesel-water emulsions have many advantages in reducing some pollutants, but cause some increase or increased fuel consumption. The conclusion of the study, after reviewing several literatures, is that the continued research into a suitable alternative to diesel that can reduce the consumption of fuel and the pollutants emitted from combustion at the same time is an urgent need.

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