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Study on Alternative Fuels for Compression Ignition Engines

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ABSTRACT

This review paper studies potential alternative fuels for automobile engine application for compression ignition (CI) engines. Diesel engines are favorable for use due to its fuel consumption and higher torque. Nowadays, we are facing the difficulties of crisis of fossil fuels due to rapid increase in demand of it in automobiles and industries. The use of fossil fuels further leads to environmental degradation by polluting the air. Hence, in the present era, more importance is given on alternative source of energy for running the engines. The representative alternative fuels for CI engines include biodiesel, di-methyl ether (DME), and jet propellent-8 (JP-8). Naphtha can be also used as an alternative fuel for advanced combustion in premixed charge compression ignition. The production methods, storage characteristics, and the supply chain of each alternative fuel are discussed, and are followed by concentrating the attention on the main research topics for the mentioned alternative fuels. Literature survey investigates on relative advantages and disadvantages of alternative fuels for application to engine combustion. The engine combustion study consists of the combustion process from spray development, air–fuel mixing characteristics, to the final combustion product formation, which are studied for each alternative fuel. An overview is obtained for alternative fuels together with summaries of engine combustion characteristics for each fuel, in addition to its current status and future scopes.

Keyword: *Compression ignition engine, Alternative fuels, Biodiesel*

1. INTRODUCTION

Internal combustion engines (ICEs) are prime movers that convert the heat produced from combustion of fuels into mechanical energy. The most popular fuels used in internal combustion engines are fossil fuels such as gasoline and diesel .Gasoline fuel works on a spark ignition engine and diesel fuel is used in compression ignition engine. The spark ignition and compression ignition engine differ in the main aspect of method of ignition. The combustion of gasoline fuel is initiated by a spark event igniting the homogeneous air–fuel mixture in SI engines, while the combustion of diesel fuel takes place when the fuel is exposed to high temperature gas, heated by compression in CI engines. Nowadays compression ignition engines, which uses diesel, are gaining more popularity due to their high efficiency and high torque output. Dieselis one of the most efficient and energetic fuels available today. Because it has more calorific value and usable energy than gasoline, it delivers better fuel economy. The major problems of using fossil fuels in IC engines are production of greenhouse gases, global warming, depletion of ozone layer and acid rain. The population explosion and the increase in living standards of human beings over last few centuries have made the use of automobiles and engines widespread .Thus the widespread use of fossil fuels causes the problem of pollution as well as resource depletion. Due to these disadvantages of fossil fuel the researches take interest in developing alternative fuels for IC Engine

1.2 Alternative fuels and their importance

Alternative fuels are known as non-conventional fuels. Any fuel which can replace the conventionally used fuels like petrol and diesel can be called Alternative fuels. Some well-known alternative fuels include biodiesel, bio alcohol, hydrogen, Liquefied petroleum gas, Ethanol, Propane etc. Alternative fuels are derived from sources other than petroleum. Most are produced domestically, reducing our dependence on imported oil, and some are derived from renewable sources. Often, they produce less pollution than gasoline or diesel. The advantage of Alternative fuels is that they produce less harmful pollutants as compared to conventional fuels. The finite availability of fossil fuels, specifically diesel, and the harmful emissions due to the combustion of these fuels leads to the need to focus on alternative fuels. Diesel emissions include pollutants that can cause adverse health and environmental effects. Most of these pollutants are formed due to the processes during combustion, such as incomplete combustion of fuel, reactions between mixture components under large temperatures and high pressures, accidental combustion of lubricating oil and oil additives as well as combustion of non-hydrocarbon components of diesel fuel, such as sulphur compounds and fuel additives. Common pollutants include unburned hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx) or particulate matter (PM).

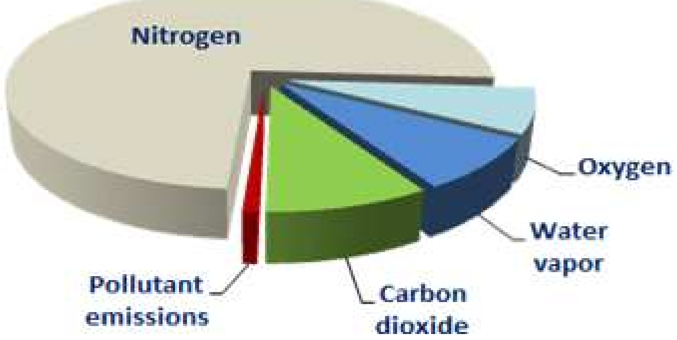

Figure1. Relative concentration of pollutant emissions in diesel exhausts gas

As seen in the figure1, the diesel engine emissions contain a considerable amount of carbon dioxide which is a greenhouse gas. Abundant Carbon dioxide emissions lead to global warming and other hazardous effects. This fact also highlights on the need to focus on Alternative Fuels. The global demand for energy in the transportation sector is expected to grow continuously at a rate between 1.2% to 1.4% per annum. The availability of diesel, which is a fossil fuel will decrease over the current decades. So in order to maintain the balance between increasing demand and resource requirements, the field of alternative fuels has to be studied

2. MAJOR ALTERNATIVE FUELS FOR CI ENGINES

2.1 Biodiesel

Biodiesel is an alternative fuel produced from bio-originated feedstock. A variety of oils have the potential to be processed into fuels. The sources of biodiesel include vegetable oil, animal fat, and waste cooking oil. The most commonly used raw materials for biodiesel fuel are Rapeseed and soybean oils. The waste cooking oil can be reutilized for the production of biodiesel which gives an added benefit of solution to the disposal issues. Sources for biodiesel production differ in different countries, based on production cost, environmental impact, and agricultural methods. The second generation biodiesel production at the first stage is based on agricultural residues. Successful sustainable commercial biodiesel production from residues is in practice in developed countries such as the U.S. and Europe [1].Another prominent and promising method for the production of biodiesel is through the use of micro algae. The biodiesel produced through this method was found to be more efficient. But this method is not widely implemented because the production processes are more costly [1]. Biodiesel or biodiesel blends are made mandatory in some parts of the world. Biodiesel-diesel blends does not demands any modification in the engine structure in most cases as there is no much differences between the both.

2.1.1 Fuel properties of biodiesel

The heating value of biodiesel is not as much as that of regular diesel fuel [1], while it by and large has a higher cetane number [8]. and transportation security. Biodiesel has higher cloud and pour guides looked at toward ordinary diesel, because of the higher part of immersed unsaturated fats. Cloud and pour points demonstrate the least temperatures, at which a fuel can be Biodiesel likewise shows a higher flash point contrasted with customary diesel [9], which is favorable for fuel stockpiling pumped, before transforming into a wax of crystals [10]. Higher cloud and pour focuses mean inconveniences in case of cold start, and speak to an impediment to the utilization of mixes with huge biodiesel parcels. Biodiesel is denser and thicker, and has higher surface strain, contrasted with customary diesel. The thickness of the biodiesel backed off the needle speed, and diminished the stream execution of the injector amid the transient injection behavior. It impeded the beginning of shutting transient, and brought about longer aggregate injection duration. The computed Reynolds number (Re) of WCO biodiesel was generally a large portion of that of diesel, because of its multiplied thickness. The higher consistency of biodiesel prompted a littler spray angle, and in this way poor air entrainment.

Macroscopic spray pictures of waste cooking oil (WCO) biodiesel and palm biodiesel in a steady volume chamber uncovered that the biodiesels had longer injection delay and fluid length, while the spray angle, territory and volume were littler than those of ordinary diesel [1]. The fluid length expanded and spray angle diminished with the expansion in blending proportion of biodiesels [1]. The U.S. EPA created a survey of distributed biodiesel outflows information for heavy duty engines. Figure 2 outlines the general outcomes for CO, HC, NO x and PM discharges [11]. As the biodiesel proportion in diesel expanded, a reasonable pattern of lessened CO and HC outflows was seen which implies higher ignition effectiveness. These outcomes were expected due to the oxygenated idea of biodiesel, where more oxygen was accessible for consuming, and for lessening the discharges in the fumes [1]. It additionally advanced steady and complete burning by conveying oxygen to the pyrolysis zone. The oxygen substance can decrease locally over-rich regions and leads to confinement of essential molecule development. Further, the motor work of Westbrook et al. demonstrated that the solid oxygen and carbon bond stayed unblemished, keeping it from getting to be accessible for soot generation [1] . The C particles with fortified O in fuel atoms couldn't add to ash generation. Figure 3shows the correlation of essential molecule estimate from WCO biodiesel and diesel sediment. The residue particles from the biodiesel were made out of littler essential particles than those from regular diesel. One powerful clarification is the increased fire temperature with biodiesel, caused by a decrease in the heat transferred through radiation as an outcome of the lower measure of ash transmitted [1]. There is no huge contrast in the figured stoichiometric adiabatic fire temperature among biodiesel and diesel [12] Be that as it may, the genuine fire temperatures can be influenced by ash outflows, since radiation from hot PM as a predominant source of warmth move from the in-cylinder gases, and this can be in charge of huge cooling of soot jet flames [13]. It was found that, the radioactive cooling by PM lessened fire temperature by 25– 50 K, relating to an expected NO x decrease of 12%– 25% [1]. In this way, the ignition of biodiesel could be kept up at hoisted in cylinder temperature, because of the lower PM emanations, lastly, higher NO x discharges.

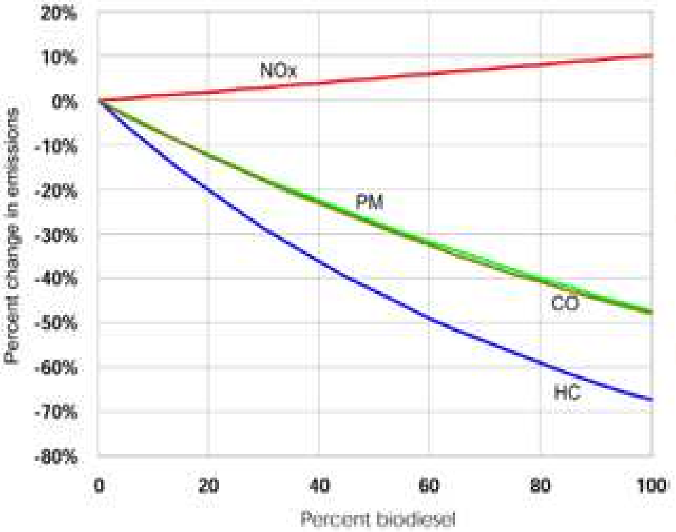

Figure 2: Average emissions when various proportions of biodiesel are used in compression ignition engines

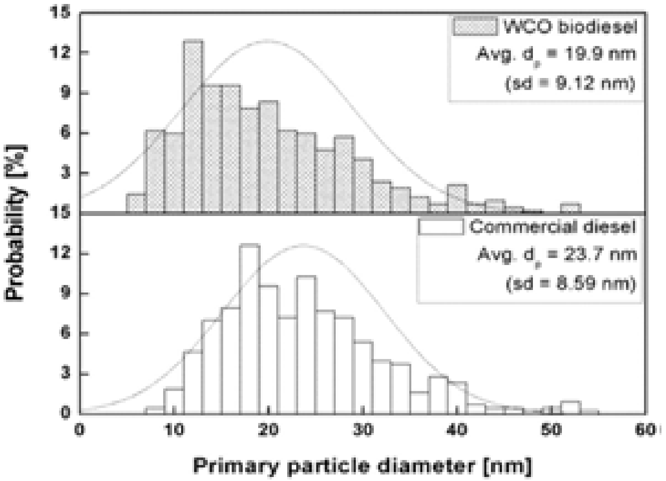

Figure 3: comparison of primary particle size between WCO biodiesel and diesel

2.2 Di methyl Ether

Dimethyl ether is an odorless and colorless organic compound belonging to the group of ethers. Under typical ambient conditions (pressure 0.1 MPa and temperature25°C) it remains in the volatile phase. In a closed space under pressure of its own vapour it changes into liquid.DME has been utilized for quite a long time as an aerosol propellant in the industry. It has picked up consideration as a perfect elective fuel to LPG, diesel and gas, with physical properties fundamentally the same as those of LPG [1]. It offers surprising potential as a car fuel, as well as for electric power age, and in residential applications, for example, warming and cooking. DME can be gotten from numerous sources, including non-renewable energy sources (flammable gas and coal) and sustainable materials (biomass, squander and farming items). Two strategies exist for creating DME as a fuel in extensive amount with generally minimal effort. The strategies incorporate (1) a two-advance process (indirect method) of adding a dehydration step advance to the last piece of mechanical methanol preparing, and (2) a one-advance process (direct method) of orchestrating DME specifically from combination gas (H 2, CO). Some ongoing improvements in the combination strategies for DME, customary procedures and creative advances in reactor outline, and utilized catalysts permitted the effective generation of DME [1]. In general, the generation sum is little; at around 150,000 tons overall [1].The fuelling of a diesel engine with dimethylether is possible without any substantial modifications. Yet, due its low boiling temperature of 25°C, it is necessary to store ether in an airtight container. The pressure generated byoi its vapor converts ether into a liquid under temperatures of 20–30°C , which allows the application of the already existing LPG solutions for its storage (fuel tank) .

2.2.1 Fuel Properties

DME is in gas stage at standard temperature and weight. But, it changes to fluid when subjected to humble weight (> 6 MPa) or cooling. This simple liquefaction makes DME simple to trans-port and store. This and different properties, including high oxygen substance, and absence of sulfur or different harmful mixes, make DME an adaptable and promising arrangement in the blend of clean sustainable and low-carbon powers under thought around the world. The cetane number of DME is higher than that of diesel, which makes it a promising elective fuel for CI motors. The density of volatile dimethyl ether is greater than that of air. Carbon has the greatest mass share of 52.2% in a DME molecule. The share of hydrogen in the molecule mass is estimated at 13%. It is noteworthy that DME has better Carbon to hydrogen ratio than diesel fuel (C/H). This result in a lesser amount of CO2 and greater amount of H2O generated following full combustion, which is the effect of the Combustion of hydrogen. A DME molecule does not have direct bonds among the atoms of carbon this facilitates full combustion, thus reducing the amount of carbon monoxide and particulate matter. Full combustion is also facilitated by a reduction of local oxygen deficits through the presence of this element in the molecule. Oxygen constitutes34.8% of the molecule mass, which makes the calorific value of DME 40% lower compared to other fuels. The mass modulus of versatility for commonplace hydrocarbon fuel is 2– 6 times more prominent than that for DME. This shows more noteworthy pressure work for DME is required. The spray structure of DME was classified as for three different pressure conditions, to be specific below saturated vapor pressure of DME (or at atmospheric condition), beyond critical pressure of DME and lastly, in the middle of these weight ranges [1]. Underneath the saturated vapor pressure, at around 0.6 MPa, the showers displayed the flash boiling phenomenon. At the point when the fuel is infused at ambient pressure in the middle of the saturated vapor pressure and critical pressure(5.37 MPa), the conduct of the DME shower is like that of diesel in terms of general shape (with marginally expanded spray angle). The splash at long last transforms into a miscible turbulent jet when the surrounding pressure is past the critical pressure. The progress from ordinary spray to miscible turbulent stream might be experienced amid spray advancement. The in-chamber weight of present day diesel motors exists in the scope of 4– 6 MPa before the burning. It is expected that the splash of DME in motors would be presented to conditions in the region of its critical pressure .Majority of published research results on exhaust emissions from diesel engines fuelled with dimethyl ether indicates a significantly better emission performance compared to diesel fuel. The comparison of smoke opacity tests performed on an engine fuelled with different fuels has shown lower PM emissions when DME is used. Scarce emission of PM observed during DME combustion is most likely the result of combustion of the lubricating oil or the fuel lubricants. The reduced emission of particulate matter is mainly a result of the low boiling temperature that causes better evaporation of the fuel and its better mixing with air, simple composition of the molecule, presence of oxygen in the molecule and no direct Bonds between the atoms of carbon. Figure 4 presents the results of hydrocarbon and carbon monoxide tests performed on a diesel engine fuelled with diesel fuel and DME [5]. It is noteworthy that, in terms of mass, the engine fuelled with DME generates much less hydrocarbons compared with diesel fuel but in terms of number the differences for both fuels are smaller an depend on the engine speed.

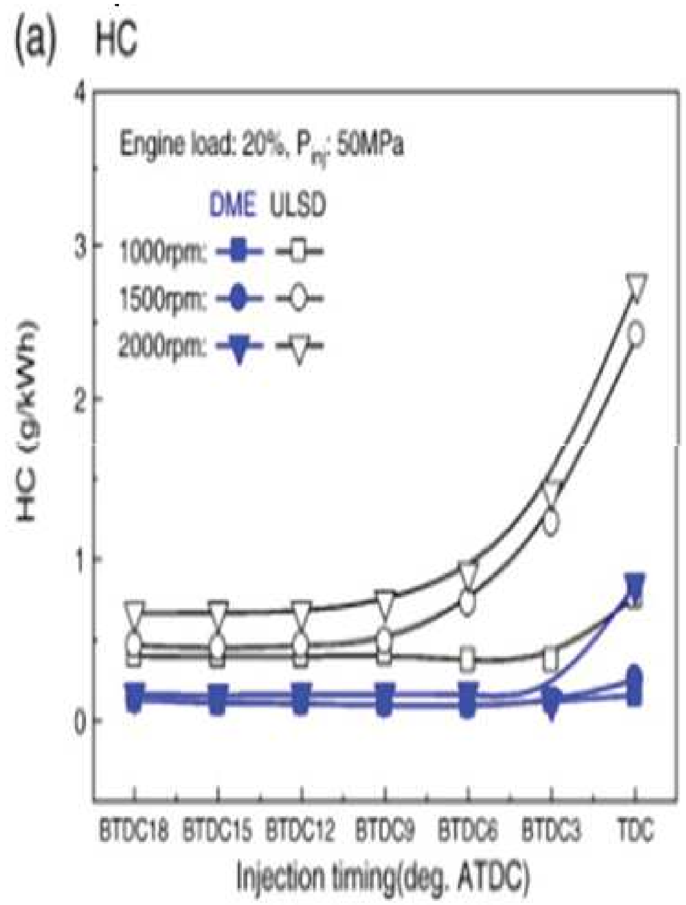

Figure 4 a. Comparison of the emission of HC for combustion of DME and diesel fuel

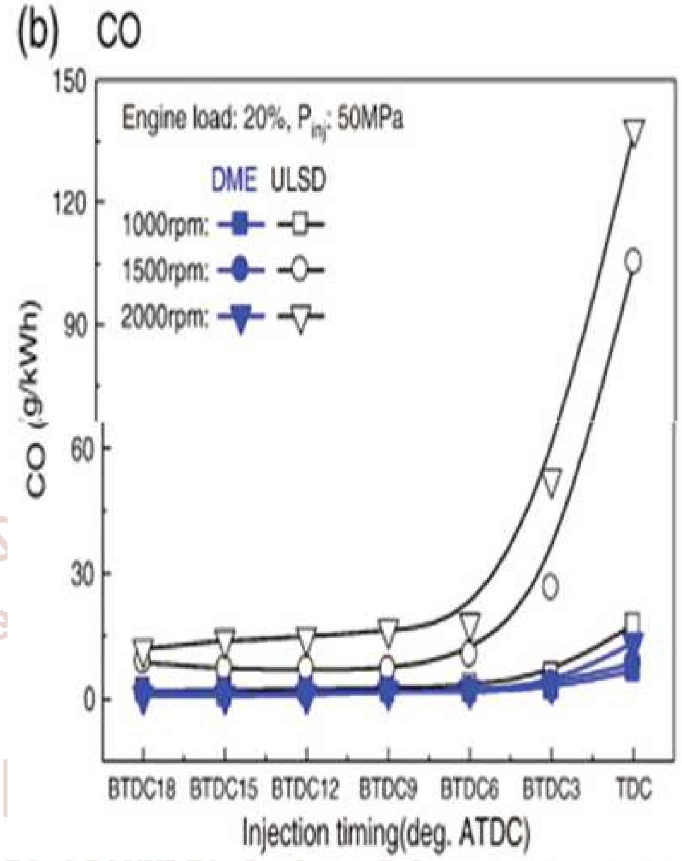

Figure.4 b. Comparison of the emission of CO for combustion of DME And diesel fuel

The investigations of the exhaust emissions have shown that the quantity distribution of the generated hydrocarbons depends on the moment of fuel injection into the combustion chamber. An increase in the injection delay results in greater HC emission. This relation is particularly conspicuous for higher engine speeds. Compared to diesel fuel, the combustion of dimethyl ether in a compression ignition engine is characterized by a lower emission of hydrocarbons for the entire range of injection time. An increased emission is visible only for much delayed injection and higher engine speeds. The main reason for such a low emission of HC is the composition of the molecule, the presence of oxygen as well as rapid and full evaporation of the injected fuel.[5

Thanks to its chemical properties such as high cetane number, low boiling and ignition temperatures, dimethyl ether turns out to be a very good fuel for compression ignition engines. Dimethyl ether mixes with air well and is easily ignited even under sub-zero temperatures. Its lower density, viscosity and lubricity compared to conventional fuels are potential downsides but may be cost-effectively eliminated by adapting of the injection systems and introducing fuel lubricity additives [5].The potential of DME application in compression ignition engines have its environment related implications. Dimethyl ether has a very good carbon to hydrogen ratio, which generates more water vapour during combustion. Through no direct bond between the carbon atoms, formation of particulate matter is limited so that high exhaust gas recirculation rate is possible in order to reduce NOx, which renders the application of any additional after treatment systems unnecessary. Because of good evaporation rate and the presence of oxygen atom in the molecule, the emission of carbon monoxide and hydrocarbons is also reduced, compared to diesel fuel. Besides, the adverse ecological impact of this fuel is reduced by a good CO2 balance [5]. DME may be manufactured from renewable materials such as wood chips, biomass or waste. Other than exhaust emissions the DME's environmental characteristics also include: no toxic, carcinogenic, erotogenic and mutagenic impact on the living organisms, safe decay products (water and carbon dioxide), short half-life in the troposphere and no impact on the stratosphere. Proper adaptation of the infrastructure consisting in partial adapting of the existing solutions used in the LPG distribution may result in this fuel becoming increasingly popular and the group comprising Sweden, Denmark, USA, Japan, Korea and China, where DME road tests are in progress, will eventually expand

2.3 Jet Propellent-8.

Jet Propellant-8 (JP-8) is a kerosene type jet fuel (8–16 carbon particles for every atom) that incorporates four added substances: a static dissipate added substance, corrosion inhibitor, grease property improver, and fuel framework icing inhibitor. JP-8 is created in a raw petroleum refining process, which is ordinary oil refining. Its boiling point lies between that of gas fuel and diesel fuel [3]. The cost of JP-8 is less expensive than that of diesel fuel, in light of the fact that JP-8 does not require any procedures to improve its cetane number. JP-8 is accepted as the common fuel for military vehicles by the NATO (North Atlantic Treaty Organization). The use of JP-8 Independently in compression ignition engines is not popular in automobiles but they can give better emissions and efficiency when used along with biodiesel blends. Notwithstanding its utilization for controlling air ship, JP-8 is utilized as a fuel for radiators, stoves, tanks, by the U.S. military and its NATO partners as a swap for diesel fuel in the motors of about all strategic ground vehicles and electrical generators, and as a coolant in motors and some other air ship segments. Current diesel motors are intended for both military and business applications; however their construct adjustments are based with respect to the utilization of diesel fuel, not military fuel. Henceforth, working standard motors with JP-8 accompanies non-ideal execution [2].

2.3.1 Fuel Properties of JP-8

Thecetane number of JP-8 territories from 39 to 45, contingent upon the generation locale, which is by and large lower than that of diesel fuel. The ignition delay of JP-8 (cetane number of 38) estimated in a steady volume vessel was 25%– 50% higher contrasted with diesel fuel (cetane number of 46), in spite of the fact that JP-8 has a more prominent part of vaporized fuel. The ignition delay of JP-8 estimated in a heavy duty diesel engine or a traveler auto diesel engine was likewise longer than that of diesel. The chemical delay of the JP-8 fuel particle was more overwhelming over its physical deferral. Nonetheless, the ignition delay was never again larger for JP-8 if the measured cetane number is in a comparative range to that of diesel, which brought about the contrary outcome. This is likely because of the physical start delay being predominant over the chemical delay, when the cetane numbers are in a comparative range. In diesel motors, fuel is typically infused into the burning chamber utilizing a volume-based framework [2]. The JP-8 has a notably lower density than diesel. Lower thickness will result in lower engine power, and will in this manner influence particular fuel utilization. The NO x outflow qualities changed, depending on the engine working conditions. JP-8 produced lower NO x contrasted with diesel fuel, because of lower fragrant substance and fire temperature. JP-8 indicated higher NO x levels as the engine load expanded to mid-load range, because of the more flammable blend of close stoichiometric condition caused by prolonged ignition delay and better evaporation. The smoke discharge demonstrated a steady pattern. The burning with JP-8 for the most part produced lower smoke than with diesel fuel. The quicker evaporation rate of JP-8 created a lesser fuel-rich area, which could advance the air– fuel blending procedure, and lower the nearby equivalence ratio. The outcomes acquired through two-colour strategy uncovered that the JP-8 showed more uniform blend dispersion inside the chamber. The distinction in the aromatic content segment between the two energizes could likewise influence the smoke emission. The fuel with higher aromatic contents substance delivered more polycyclic HCs, known as the antecedent of smoke, in this manner discharging more PM.

Figure 5 demonstrates heat discharge bends for diesel and JP-8, worked with various pulse widths. Results relate to the 1200 r/min and low load condition. The pinnacle of the premixed spike with JP-8 is higher than that of the diesel-fuelled engine.[1] This can plainly be ascribed to an expanded ignition delay and amassing of fuel in the ignition chamber preceding ignition. The heat discharge profiles demonstrate an expanded premixed burn fraction with JP-8.

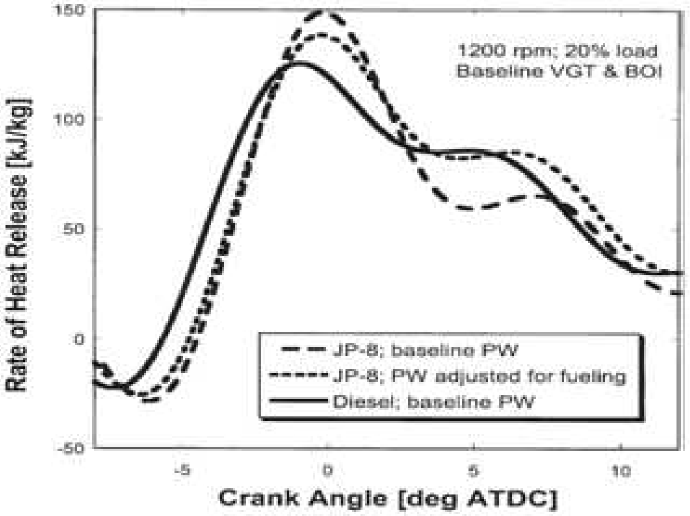

Figure5 .Effect of JP-8 on heat release profiles with JP-8 at 1200 r/min and 20 per cent load

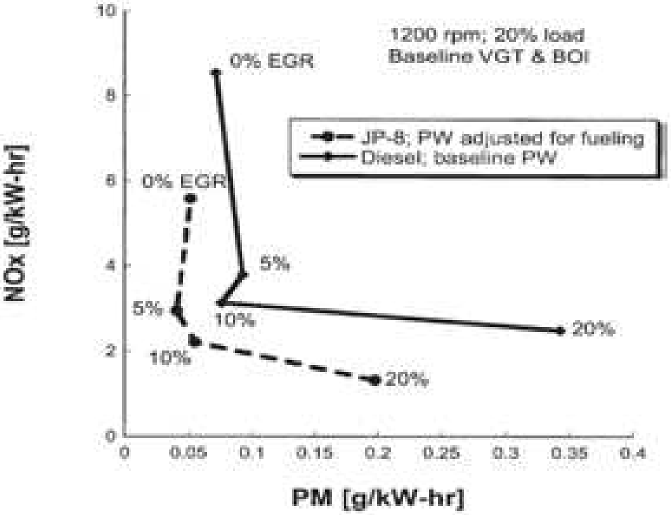

Figure6 .Comparison of the NO*x*–PM emissions of the JP-8 and Diesel at 1200 r/min and 20 per cent load

Figure 6 demonstrates a regular NOx– PM exchange off bend for the EGR sweep performed at steady injection timing (BOI).[2] The NOx– PM bend for JP-8 fuel is moved essentially to the lower left of the chart when contrasted with diesel because of the simultaneous decrease of NOx and PM discharges isn't as conspicuous at the higher load setting. As clarified before, the lower PM outflows are ascribed chiefly to higher fuel volatility and lower sulfur content, while the lower NOx is basically because of the lower aromatic content. The NOx decrease isn't as prominent at the higher load setting. In any case, this is joined by an amazing decrease of PM. Tests with JP-8 indicated better particulate issue and NOx outflows under different conditions. In particular, the ash development is drastically diminished on account of helpful effects of higher volatility of fuel and the extended ignition delayon mixing. The helpful effect of EGR on transmission tradeoffs is for the most part unaltered with JP-8. The general patterns got with the NOx– PM trade off curves are pushed toward the lower ideal, with a strong inclination towards cut down proportions of PM.

JP-8 cannot become a direct replacement for diesel fuel due to its lower density and lower mass of fuel injected for same injection duration. This factor leads to performance reduction of the engine. The lower cetane number of JP-8 prompts expanded ignition delay, hindered beginning of ignition, and expanded portion of premixed burning. In any case, advancing of the injection timing is not prescribed, since expanded portion of premixed burning adjusts for impeded start of ignition, in this manner saving wanted burning phase [3].

CONCLUSION

The major part (up to 90%) of propulsion for transportation will in any case depend on the internal combustion engines(ICE), even up to 2040 [6]. Without a doubt, the worldwide interest for transportation fuels is relied upon to develop constantly at somewhere in the range of 1.2% and 1.4% for every annum [7]. Talks on the present state and the eventual fate of transportation fuel are vital. An early talk on future choices for elective fuels as of now occurred amid the 1980s [1]. These endeavors were made not exclusively to look for elective answers for vitality security and supportability, yet additionally to look for advantages that elective fuels can give to engine productivity change and emission decrease. Steady entrance of low-carbon fuels, for example, bio fuels and petroleum gas, is relied upon to contribute to bringing down ozone harming substance (GHG) discharge in the long haul.[4] Cutting edge innovations in the assembling procedure of befouls can possibly diminish GHG outflow contrasted with regular powers on a well-to-wheel (WTW) basis. GHG outflow is expected to expand here and now, because of the expanded interest for fuel utilization. Be that as it may, it very well may be diminished again when escalated utilization of biofuels and engine efficiency changes can be implemented. The particular properties of alternative fuels can extend the potential for extra productivity change of engine, where traditional fuels would some way or another has confronted restrictions. Different obstructions block the development of elective powers, including specialized and social issues; and in the following couple of decades, they can't supplant traditional powers to any generous degree [7]. Be that as it may, endeavors can be made to understand the upsides of particular powers in an alternate way when joined with conventional fuels. Expanding the segment of the oxygenated energizes, for example, biodiesel or DME, may bring about enduring a bigger measure of EGR for NO x decrease, without falling apart the eco-friendliness or smoke outflow. Despite the fact that alternate fuels are not profitable in every perspective, advantageous qualities can give direction on what the collaboration between fuel properties and combustion may be like in the future. The future patterns of engine improvements cannot remain against the advancement of the fuel business, nor do they contradict it. Car producers and the refinery business should confront the test together for more effective and clean ignition engines later on. The expanding vitality request of oil based fluid fuel and elective energizes, in addition to the imbalance of interest among different fills would in the long run yield well disposed collaboration between the car and refinery ventures.

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