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Emission and Combustion Characteristics of Multifuel Engine with Biofuel Blends: A Review

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Abstract:- **Everlasting demand for energy, depletion of fossil fuels due to over exploitation, rising concern over harmful emissions and its detrimental impact on nature while burning fossil fuels etc. have led to wide scale researches on developing alternative fuel resources .The major research works on this area is focused upon biofuels which are considered to be clean in emissions and having competent performance characteristics as that of conventional diesel fuel. During the last two decades many new promising sources of biofuels have been developed and experimented for analyzing its emission and combustion characteristics. Blending of biodiesel with pure diesel in different proportions have enabled us to use the engine without any modifications at all. Various blend proportions have have been tried for analyzing its emission and combustion characteristics were lower proportions proved to have better compatibility in existing engines. This paper is a literature review on the performances and emissions of biodiesels from Jatropha, mustard oil and used cooking oil when blended with diesel.**

Keywords:- Brake thermal efficiency, Brake specific fuel consumption, Emissions, Blending ratio

1. INTRODUCTION

Energy demand over the globe is rising steeply due to the increased industrial activities and vehicle population in developed and developing countries. The world is currently over dependent on fossil fuels like petroleum, natural gas or coal for its various energy demands. A country like India which holds a mass population is one among the largest consumers of energy. There has been a drastic increase in the energy consumption since the last two decades with 80 percent of it met by burning coal and other fossil fuels. As the consumption of fossil fuels increases the harmful emissions from it like carbon monoxide, hydrocarbon, nitrous oxides or smoke also rises into an alarming amount. These harmful gases are responsible for various environmental issues like acid rain, photochemical smog, global warming etc. Major cities like Delhi are ailing due to air pollution and has been in the news headlines for its climate issues recently. Several species of flora and fauna are already facing extinction threat due to the loss of natural habitat and unfavorable living conditions as the environment pollution increases drastically. World organizations like UN are stressing on its member countries in various climate summits for implementing zero emission strategies and achieving the target by 2050. COP26 held at Glasgow was mainly aimed at bringing the World leaders under a roof to join hands together to restrict the temperature rises and nullify climatic changes by controlling the greenhouse gas emissions.

The health issues caused by inhalation and exposure to polluted environment is yet another severe consequence of harmful emissions. Numerous diseases like chronic asthma, bronchitis and lung cancer have been reported extensively from polluted cities all over the world.

Air Quality Index abbreviated as AQI is a standard used by the government agencies to convey the public on the quality of environment in which they are living. According to the National Air Quality Index of India an index number of 401 or above is considered to be very hazardous and can deteriorate the lung health of healthy people also .Many cities in India like Delhi have recorded a very poor quality index this year compared to previous years.

Alternative fuels can reduce the dependence on fossil fuels. It will be socially and environmentally beneficial to us in many ways. One of the major alternative fuels used nowadays is the biodiesel which can be obtained from vegetable oils or animal fats. The major advantage of the biodiesel is that it can be manufactured locally with minimum investment. It is beneficial economically as it can generate a lot of employment opportunities in the rural areas as well as can utilize the waste lands effectively for cultivating biofuel crops. In many parts of the world the biodiesel so obtained from sources like waste cooking oil is been directly used in the agricultural equipments without blending with diesel. This reduces the agricultural expenses of farmers thereby multiply their income.

One of the major debates regarding the production of biodiesel is the food vs. fuel feud. There are existing arguments that when biodiesel is been manufactured from edible sources that may lead to food shortage especially in poor countries. An alternative to this argument is the cultivation of biofuel crops like Jatropha which is non edible. It is proven that Jatropha oil has excellent fuel properties than any other species which is almost comparable to that of pure diesel. Major advantage of Jatropha plant is that it is suitable to grow in many of the climatic conditions thereby opening an opportunity to convert the waste lands into profitable and economically beneficial.

Reducing the foreign oil dependence is essential for promoting national security. While we depend on fossil fuels to a large extend it has got adverse effects on the national income. Wealth of a nation will flow to oil producing countries thereby increasing the national debt. Domestic production of oil with meagre investments will increase the energy security.

Biodiesel is manufactured by the transesterification process. In this process vegetable oils or animal fats are treated with an alcohol to forms esters and glycerol as by product. It can be manufactured from various oils like soybean, rape seed,

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mustard oil, sunflower oil, karanja oil, jatropha or even used cooking oil. The chemical term for biodiesel so obtained from such renewable resources are known as Fatty Acid Methyl Esters (FAME).The biodiesels so obtained can be assured of its quality by FAME analysis procedure. The quality of fatty acids present in the FAME determines its overall properties.

2. PROPERTIES AND BLENDING

Usually biodiesel is applicable to all kinds of diesel engine by blending it with petroleum diesel. Blends with biodiesel percentage 20 %(B20) or less can be used directly without any engine modifications. Biodiesels can be even used in its pure form (B100) but may need certain engine modifications to avoid maintenance issues.B20 is the most commonly used blend as it is good at cold weather performance, cost efficient and gives less emissions without compromising the overall efficiency and fuel consumption.[2]

After manufacturing the biodiesel it has to be checked for various properties like calorific value, viscosity, density etc. so as to assure its quality before running in engines. An inferior product may lead to clogging and finally ending up at catastrophic failure of engine.

There are standard values for all the specifications available. Some of them are shown in Table 1.

Table 1
Properties of biodiesels of different oils

	Cetane Number	Calorific Value (kJ/kg)	Density (kg/m^3	Viscosity (mm^2/s)
Jatropha	57	39425	870.7	4.4
Mustard	53	36688	885	4.87
Used Cooking Oil	55	37780	878.6	4.78
Diesel	48	43388	834	2.9

From Table 1 it can be concluded that the properties biodiesel are very close to that of petroleum diesel. This enables it to be used as a powerful alternative to conventional fuel. The biofuels are again attractive with its good lubricating properties, negligible sulphur content, biodegradability, clean emissions and high cetane number. The biodiesels so derived from different vegetable oils have more oxygen content which supports combustion. More efficient combustion will lead to lesser release of unburnt hydrocarbons (UHC). While scrutinizing existing data the overall diesel consumption of our nation during 2008 – 2009 was close to 52 million tons and almost 160 million tons of CO2 is expected to be emitted by burning of fossil fuels [1] [9]

The readiness to ignition or ignitability of fuel is represented by its cetane number. From the table it is evident that biodiesel having high cetane number reduces the ignition delay period. A reduced ignition delay will enhance the cold weather performance. With higher cetane number the capacity for auto ignition increases which in turn leads to lower emission of nitrous oxides.

Having long fatty acid ester chains biofuels are obviously denser as compared to conventional petroleum diesel. From table 1 it is evident that maximum density is observed for mustard oil. If the fuel is denser then mass of fuel entering will be more since fuel is inserted volumetrically. From reviews of many experimental works it can concluded this will affect the air fuel ratio and thereby gas temperatures. Since incylinder temperatures have direct impact on NOx emissions fuel with maximum density is expected to have higher engine emissions. Inadequate cooling can further increase the NOx emissions.

Calorific value of a fuel is the energy liberated when unit mass of the fuel undergoes complete combustion. So higher calorific value implies to better efficiency .From the table 1 it is evident that the calorific value of biofuels are lesser than that of normal diesel. Jatropha is experimentally proved to have the highest calorific value among most of the available sources of biofuels making it highly preferred. As the oxygen content in the fuel is more subsequently the energy density will decrease. So to maintain the same power output more quantity of fuel has to be consumed and thereby decrease the fuel efficiency.

Viscosity of biofuels is higher than that of fossil fuels. Viscosity of a fuel is so important since it has direct impact on fuel injection equipments. Generally cold weather performance of an equipment is greatly affected by this property. From table 1, in the fuels considered diesel fuel has the minimum viscosity whereas mustard biodiesel has the maximum. Due to which the chances of poor functioning of the injectors is highly probable in second case. When injectors are malfunctioning it directly affects the atomization of fuels. Engine is required to work harder since the movement of fuels through the moving parts are not so rapid. This will lead to higher consumption of fuels.

Flash point of biodiesels are generally higher than that of pure diesel. It is inversely related to the fuels volatility. So the storage of biofuels is comfortable when compared to pure diesel.[1] [7] [8]

3. EXPERIMENTAL WORKS

Scientists and engineers are frequently trying to find new sources of biofuels which are more efficient in calorific value and other desirable fuel properties. New methods have been adopted to check whether the cost of production can be reduced.

Researchers are testing the biodiesels in various engines to check for its performance and emission characteristics in different ways. The tests have been done for same fuel in different compression ratios, blending with diesel in different proportions or by adding additives for performance enhancing etc.

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4. PERFORMANCE AND EMISSIONS

Jatropha Curcas is considered as an excellent source of biodiesel with good fuel properties as compared to other sources of biofuels. Studies have been conducted to compare the performance, emission and combustion characteristics from this non edible oil. Jatropha oil have been tested in its various blend ratios to compare the performance with that of pure diesel.

The study with various blend ratios of jatropha 5%, 10%, 20%, 30% and 100% are undergone to compare the results with that of pure diesel. Majorities of the studies claims that ignition of fuel starts earlier for biodiesel. It also suggests that peak incylinder pressure achieved by biofuel blends are usually lower when compared to that of pure diesel. Maximum cylinder is an indicator of the ability of any fuel to merge well with hot air to undergo combustion.[2] [4]

Brake thermal efficiency: Majority of the studies proved that the brake thermal efficiency also increases with increase in brake power. It was the same for both diesel and biofuel blends. At the same time it was observed that brake thermal efficiency for biofuel blends were lesser compared to pure diesel during the whole running process. The reason for this is suggested that calorific value of biofuel blends are lesser and so the specific fuel consumption is also more.

Brake Specific fuel consumption is always found to be more for biodiesel blends .This occurs mainly due to the high viscosity and density of biofuel blends leading to high heating value. Low calorific value of biofuel blends is another reason .More fuel has to be consumed for maintaining the same engine output.

The exhaust gas temperature is another aspect compared. All studies claims that exhaust gas temperatures increase with brake power. Poor combustion characteristics of biofuel blends leads to low exhaust gas temperature whereas it is recorded high for pure diesel. [9][10]

The most interesting factor to be considered is the variations in exhaust gas emissions. Considering the CO2 emission it was found that there is a uniform increase in the carbon dioxide emission with increase in brake power. This is because as the brake power increases combustion occurs more effectively. The carbon dioxide emissions are found to be higher for biodiesel blends when compared to that of pure diesel. The reason for this is the excessive oxygen content in biofuels when compared to pure diesel which lead to complete combustion of CO to CO2.

Conversely it was observed that carbon monoxide emissions were more for pure diesel. But a few other studies also claims that emission of carbon monoxide decreases with increase in brake power as better combustion occurs at higher levels. From various graphs it was evident that as the biofuel percentage increases the emission of carbon dioxide increases with it. Likewise CO emissions increases as the biofuel percentage in the blend decreases.[17][19] [8]

Another crucial emission factor is the hydrocarbon emission (HC).Evidently from most of the studies it's proven that the hydrocarbon emissions are lesser for biofuel blends. But a general trend observed from the graphs is that at partial loads hydrocarbon emissions will be less compared to that of full loads. This is common for both diesel and biodiesel blends. Insufficient oxygen which lead to more HC emissions is the reason for it.[7][8][9]

NOx emissions are next into consideration. At higher loads better combustion temperature can be achieved which lead to more emissions of nitrous oxides. It's concluded that the release of NOx is depended upon the air fuel mixture as well as the combustion temperature. Throughout the experimental process it was found that the NOx emissions were more biodiesel blends compared to that of pure diesel. The reason is supposed as the higher incylinder pressure and temperature achieved due to low ignition delay in case of biodiesels. Moreover the flame temperature of the fuel is another factor which depends mainly on the incylinder pressure and temperature. When combustion occurs swiftly it gets less time to cool the cylinder which is a favorable factor for NOx formation. As the biodiesel percentage reduces the NOx emission also decreases which is evident from many experimental results.[11] [12]

Many studies tend to prove that smoke opacity decrease with increasing amount of biofuel percentage. At lower loads smoke opacity is almost same for all the blends whereas the smoke opacity decreases with increase of biodiesel percentage at higher loads. Higher cetane value of biofuels which leads to good combustion might be the reason for this reduction in smoke opacity for biofuel.

CONCLUSION

1. Due to more effective combustion the emission of CO2 increases in case of biofuel blends. There are some counter arguments in some journals as carbon to hydrocarbon ratio is lower for biodiesel.
2. Hydrocarbon emissions were observed higher for diesel when compared to that of biofuel blends owing to lesser oxygen content in it compared to biofuels.
3. As the heating value of biodiesel is lesser compared to that of pure diesel there is loss in engine brake power.
4. NOx emissions were observed to be higher in case of biofuels due to its excessive oxygen content. High cetane number of biofuels is yet another justification for it.
5. Due to high viscosity and low heating value the specific fuel consumption is more for biofuels when compared to that of pure diesel.

The experimental results proved that the engine performance with biodiesel and its various blend proportions are comparable with that of pure diesel.

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