Reduction of Nitric Oxide Emissions from a Direct Injection Diesel Engine Run on Non-Petroleum Fuel Blend using Natural Antioxidant

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ABSTRACT

Small and medium sized industry and other manufacturing units in the India have vital contributed to the growth of our country. However, to run these units and for transportation of products more of petroleum fuels have been consumed. To replace the petroleum fuels many researches have been done and biodiesel derived from Jatropha oil has been found one of the suitable candidates. In this study fuel obtained by the pyrolysis of waste tire is blended with jatropha biodiesel and used as test fuel. The fuel B20 (80% Jatropha biodiesel+20% tire pyrolysis oil) has higher viscosity then diesel which restrict its good performance. The one of the major obstacles of using this as diesel engine fuel is its long-term storage issues. It is well known fact that to improve the oxidation stability we need to add some antioxidant. The TPO has some natural antioxidant itself. Further some synthetic antioxidants were added in B20 and oxidation stability was checked. Also, test have been done with B20 in two different conditions i.e. with and without antioxidant. The synthetic antioxidants tert-butyl hydroquinone (TBHQ), pyrogallol (PY) and propyl gallate (PG) has been chosen for this study. The test was conducted in a single cylinder diesel engine of model TAF1. The various performance and emission studies have been conducted, analyzed and presented in this research paper.

KEYWORDS: *Biodiesel; Antioxidants; Tire pyrolysis oil; Diesel Engine*

***How to cite this paper*:** Danish Siddiqui | Akhlesh Shakya "Reduction of Nitric Oxide Emissions from a Direct Injection Diesel Engine Run on Non-Petroleum Fuel Blend using Natural Antioxidant" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-2, February 2020, pp.613-619, URL: www.ijtsrd.com/papers/ijtsrd30082.pdf

IJTSRD30082

1. INRODUCTION

Worldwide, the demand for energy is increasing exponentially with the increase in the population and improvement in living standards [1]. The source of energy for almost in all the sectors including domestic, transportation etc. is still fossil fuels. The excess consumption of the fossil fuels is major cause for the global greenhouse gas (GHG) emissions which cause an adverse effect on the public health and climate change. Internal combustion (IC) engines used in transportation, power generation, and commercial sector are one of the significant contributors to the air pollution. The GHG emission noticed from different resources is illustrated in Fig.1. To reduce these emissions, we need to move towards fuel derived from other resources.

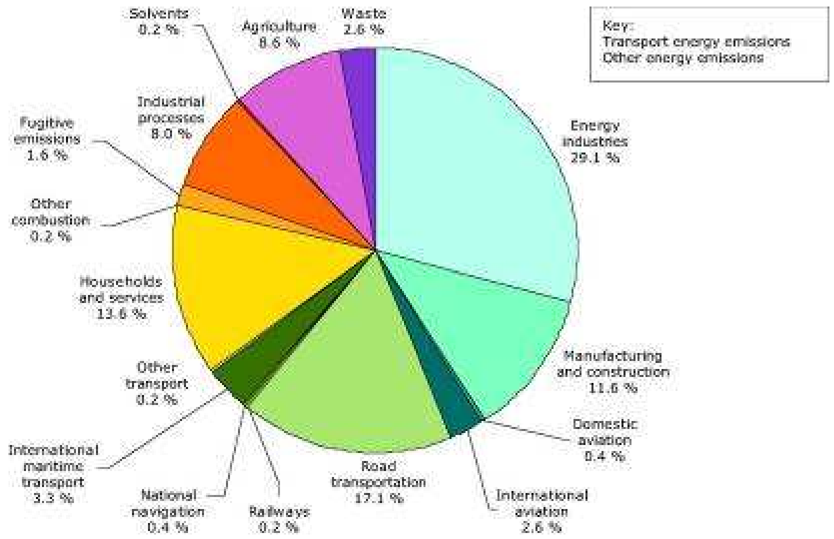

Fig. 1 Annual greenhouse gas emissions [1]

The prime research's done is related about CI engine modifications required for fruitful run of bioliquid fuels in conventional compression ignition. Almost every modern CI engines would run on biodiesel quite happily provided that the biodiesel has enough high quality, moreover biodiesel required much less engine modification but for low class engines there were some basic problems such as failure of rubber seal, cold starting, fuel injector failure due to high viscosity, poor atomization, less lubrication, etc. [2-3]. The alternative fuel can be majorly classified as first generation biofuels, second generation biofuels and third generation biofuels. The details are given in Fig. 2.

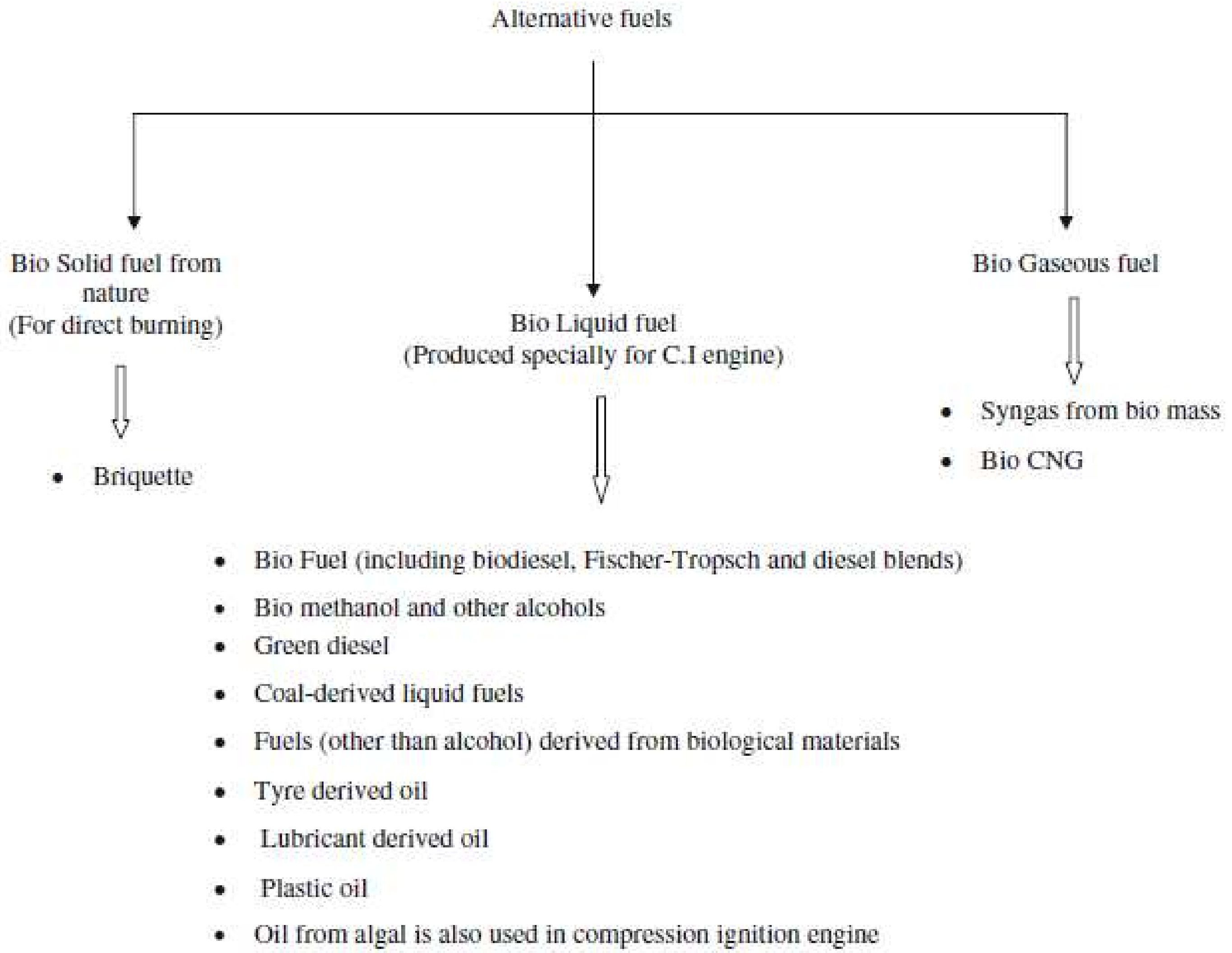

Fig. 2 Major alternative fuels for energy production

Based on the literature it was noticed that many studies have been done on the usage of antioxidant to improve the long-term storage ability of biodiesel [4-5]. In this study fuel obtained by the pyrolysis of waste tire is blended with jatropha biodiesel and used as test fuel. The fuel B20 (80% Jatropha biodiesel+20% tire pyrolysis oil) has higher viscosity then diesel which restrict its good performance. The one of the major obstacles of using this as diesel engine fuel is its long-term storage issues. It is well known fact that to improve the oxidation stability we need to add some antioxidant. The TPO has some natural antioxidant itself. Further some synthetic antioxidants were added in B20 and oxidation stability was checked. Also, test have been done with B20 in two different conditions i.e. with and without antioxidant. The synthetic antioxidants tert-butyl hydroquinone (TBHQ), pyrogallol (PY) and propyl gallate (PG) has been chosen for this study. The test was conducted in a single cylinder diesel engine of model TAF1. The various performance and emission studies have been conducted, analyzed and presented in this research paper.

2. Experimentation

The test was conducted in a diesel engine which gives power out put of 4.4 kW at rated rpm of 1500 rpm. The schematic diagram of the set up is given in the figure 3. The important parameters such as brake thermal efficiency, nitric oxide emission, hydrocarbon emission, smoke opacity etc. were recorded and analyzed and compared with diesel operation.

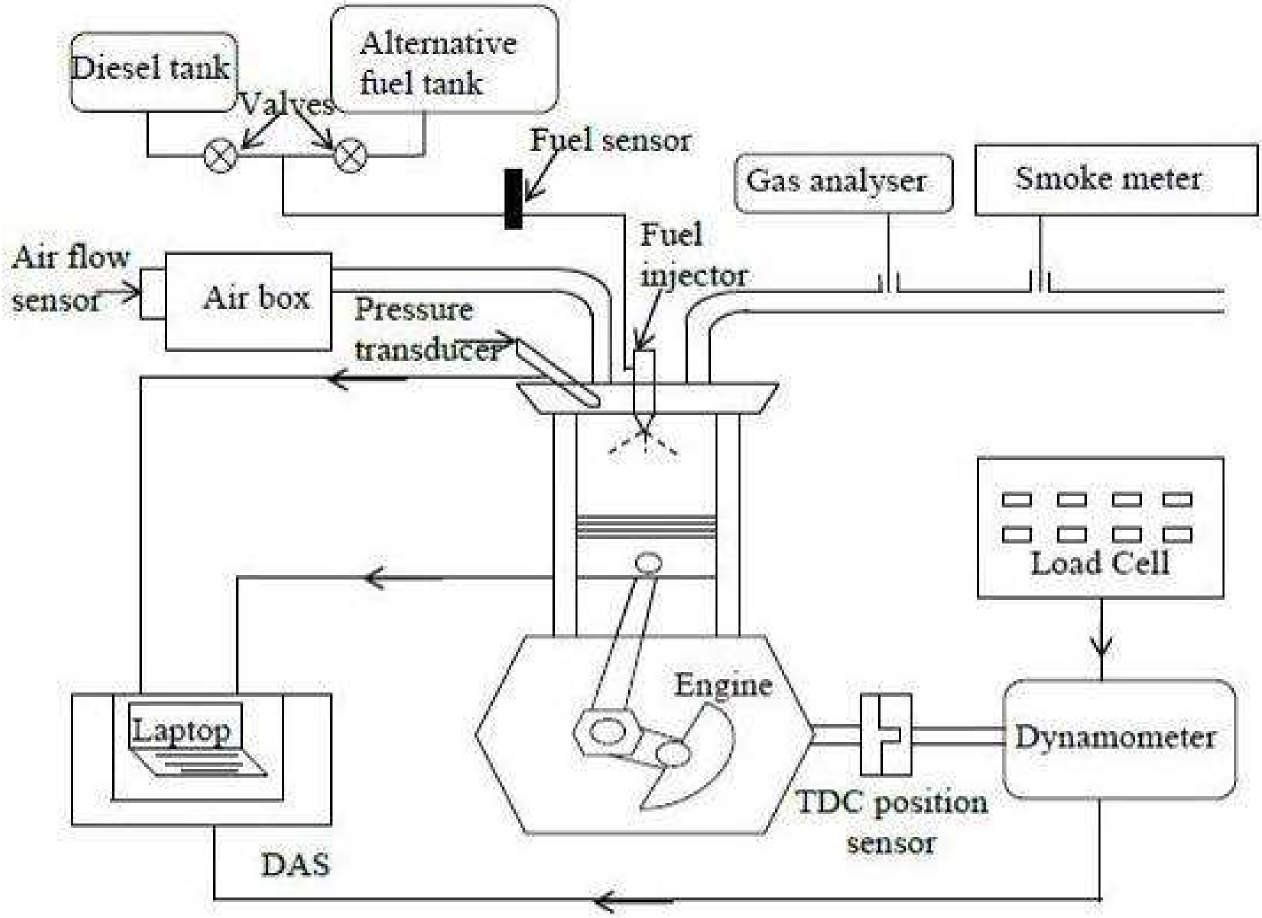

Fig.3 Schematic diagram of the set up

3. Oxidation Stability

The oxidation stability of B20 was check by the help of Rancimat apparatus. Three different type of phenolic antioxidants with an amount of 200 ppm were mixed with the B20 blend and the results of the oxidation stability were determined and compared with the B80 blend when the same antioxidants were used with a concentration of 400 ppm. So it was noticed that adding the antioxidants oxidation stability improves.

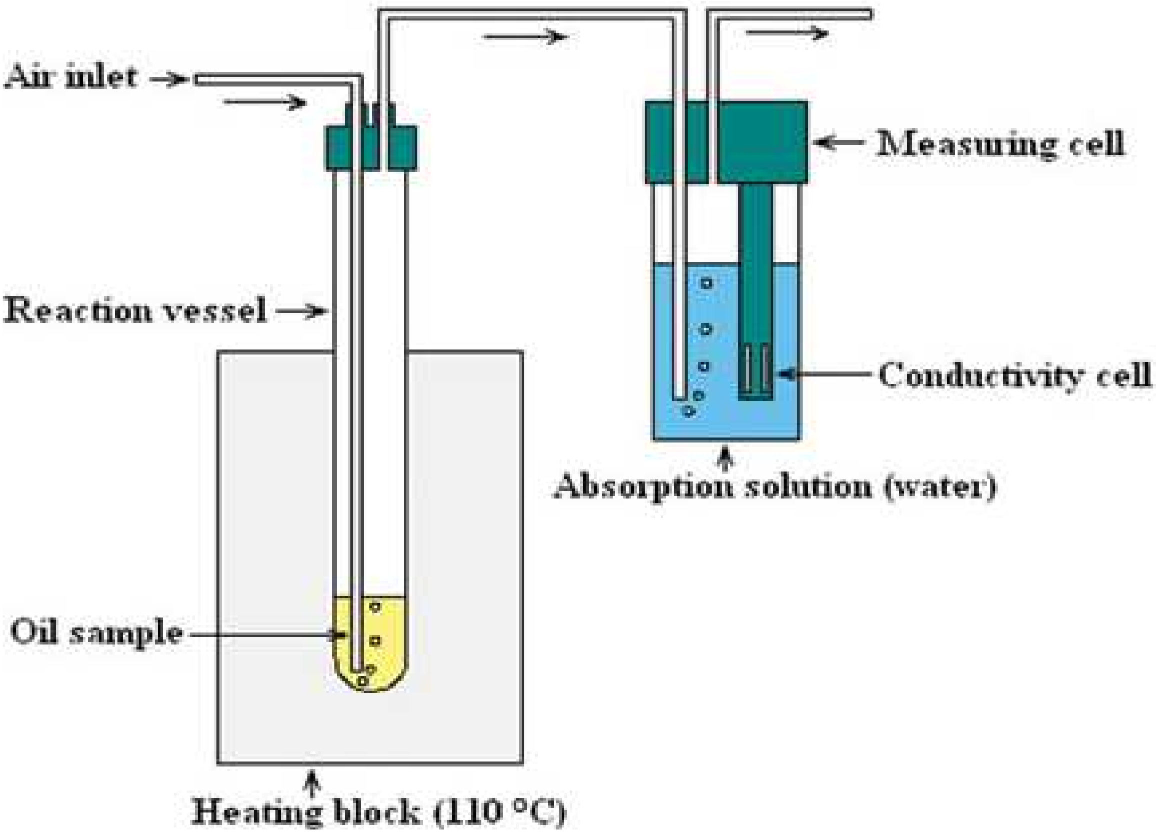

Fig.4 Schematic diagram of Rancimat method

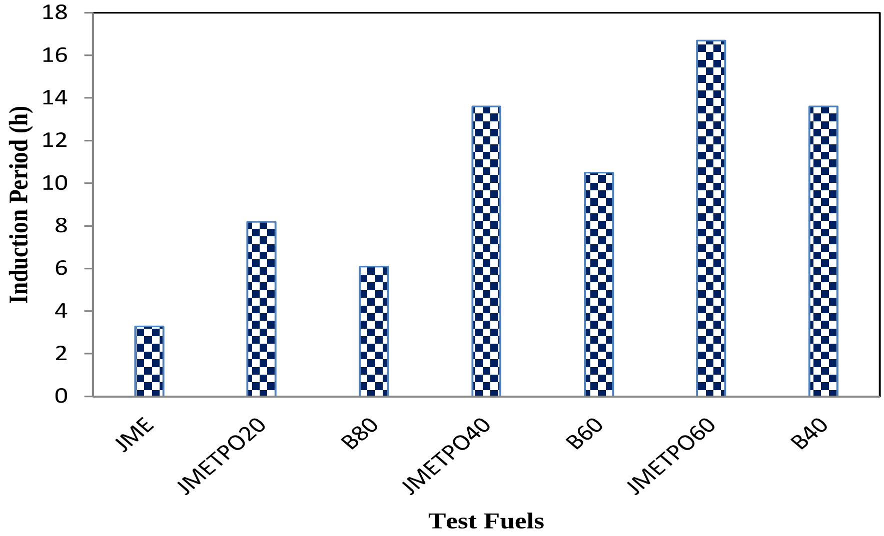

Fig. 5 Oxidation stability of test fuels

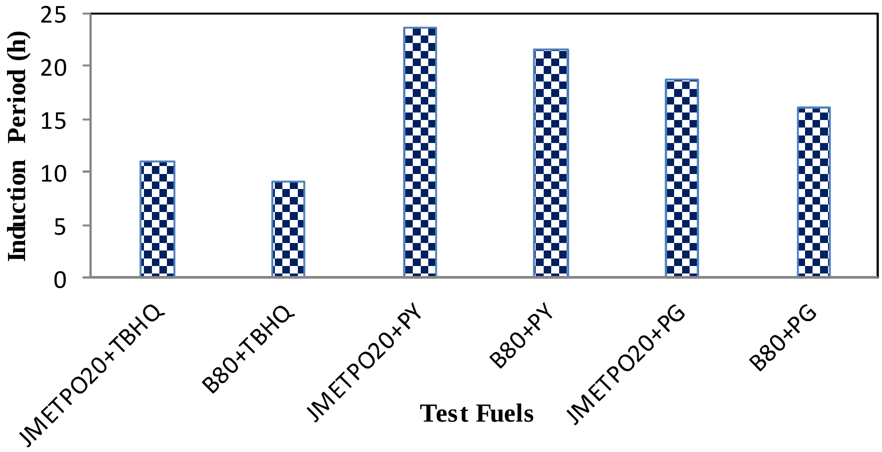

Fig. 6 Effect of antioxidants on the oxidation stability

4. Brake Specific Energy Consumption (BSEC)

Brake Specific Energy Consumption is an important parameter for CI engine, it means how much fuel is consumed to provide thermal energy of fuel input was converted into shaft output [6]. Figure 7 shows the comparison of BSEC for CI engine without preheating and with preheating for B20 fuel in a unmodified engine. The engine requires more fuel with the blend than with diesel, to produce the equal power output, owing to the lower calorific value, higher density of the blend and combustion attributes. It is found that the addition of antioxidants TBHQ, PY and PG to the JMETPO20 blend resulted mean reduction in BSEC by about 2.3%, 7% and 5.4% respectively at full load compared to that of JMETPO20 blend without antioxidant. Further, the antioxidants PY is found to be the most effective antioxidant for reducing BSEC [7-8]. The findings and trends are supported by literature available data

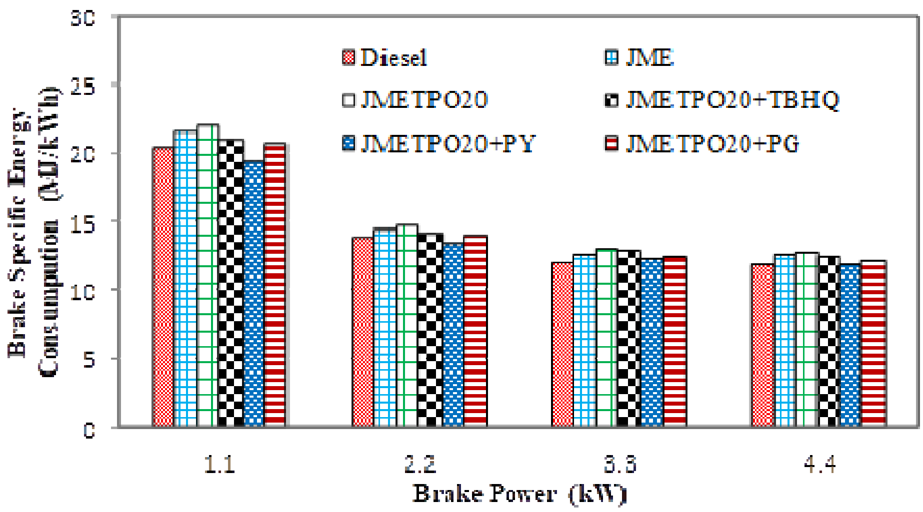

Fig. 7 Load Vs BSEC

5. Nitric Oxide (NO)

Automobiles significantly contaminate the environment by emissions of pollutants like carbon monoxide (CO), carbon dioxide (CO_2), nitric oxides (NOx), sulphur dioxide (SO_2), unburnt or partially burnt hydrocarbons, and particulates [9].

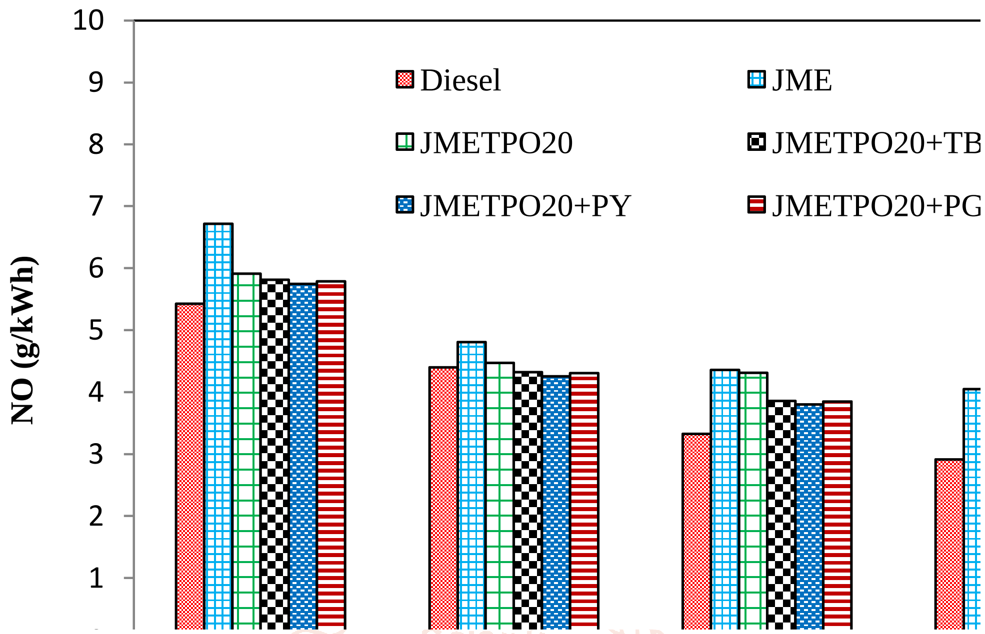

Fig. 5 Load Vs NO

We can see that with the addition of antioxidant NO emission decreases due to drop in double bond molecule. These findings are supported by some researchers [10-12]. It should also be noted that most vegetable oils contain small quantities of nitrogen containing proteins. This small amount of nitrogen in addition to atmospheric nitrogen releases extra NOx emissions through combustion. This might be a contributing factor for vegetable oils to have higher NO emissions than diesel fuel. The antioxidants are effective in reducing the formation of NO from the combustion of the JMETPO20 blend. The optimum reduction is found with the PY antioxidant when tested with the JMETPO20 blend and this is due to decrease in the prompt NO_x formation by reducing free radicals during combustion process.

6. Hydrocarbon Emission (HC)

Unburned hydrocarbon is produced due to the incomplete combustion in the combustion phase because it is the unburned part of fuel which was exhausted in atmosphere during exhaust stroke of CI engine [13]. The unburnt hydrocarbon emissions for the B20 blend was lower as due to complete combustion happed in preheating condition. It can be further noticed from the figure that adding antioxidant to the JMETPO20 blend leads to a marginal rise in the HC emission at all loads. This increase in the HC emission may be due to decrease in oxidative free radical formed by the antioxidants

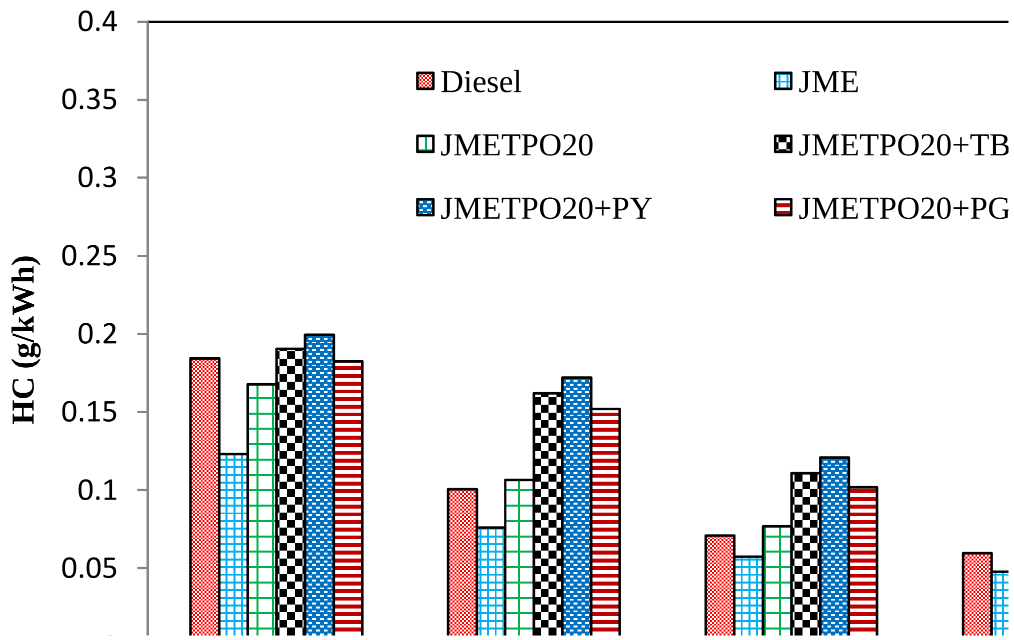

Fig.6 Load Vs HC

7. Smoke Opacity

The graph between smoke emission with power output is shown in Fig. 7. With B20 blend smoke emission is decreased particularly at higher loads due to better atomization of the fuel [14-17]. Smoke level at the maximum power output of 3:7 kW is 51% in case of pure JB and 65% in case of B20 blend. The smoke level with diesel is at maximum power. However, there is a drastic reduction of smoke emission in dual fuel operation with methanol induction. The smoke opacity at full load for diesel, JME and the JMETPO20 blend are recorded as 86.3%, 52.2%, and 63.1% respectively. Smoke opacity is lower for the JME and the JMETPO20 blend compared to that for diesel. This is due to the presence of oxygen in the JME which may help to break the aromatic content of the TPO. Addition of antioxidant to the JMETPO20 blend marginally increases the smoke opacity of engine operated at all loads. For the TBHQ, PY and PG added to the JMETPO20 blend, the values of smoke opacity are 65.1%, 68% and 66.8% respectively, at full load.

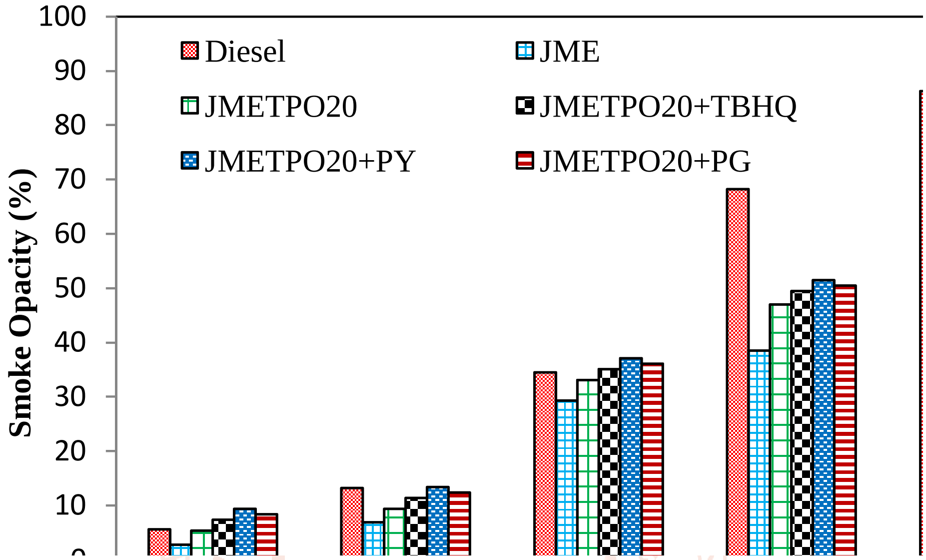

Fig. 7 Load Vs Smoke Opacity

8. Conclusion

From the above fuel modification, it is concluded that the use of B20 blend with different types of antioxidants makes its lon-term storage property longer. The OS of the any biodiesel is poor than diesel. When the fuel derived from waste tire was blended by about 20% a volume basis with the JME, the blend had a composition of efficient and improved oxidation stability. The JME has a poor oxidation stability; on the other hand, the TPO contains some phenolic compounds which give a positive effect on improvement of oxidation stability while blended with the JME. Also, it can be summarized that it is possible to improve the oxidation stability as per the EN 14112 and IS-15607 specification of the JMETPO20 blend by blending 20% TPO in 80% JME and by adding only 200 ppm of PY antioxidant. It was also noticed that the antioxidant dosage could be reduced by about 50% in the above case in comparison when 20% diesel is blended in 80% JME.

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