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Performance and Emission Analysis of Waste Cooking Oil and It's Blends with Diesel in a C.I Engine

Ramakrishna Nandam[1], K.Satish prakash[2]

*(Department of mechanical engineering, Amrita Sai institute of science and technology paritala, Andhra Pradesh, India)

** *(Department of mechanical engineering, Amrita Sai institute of science and technology paritala, Andhra Pradesh, India)

Corresponding Author: Ramakrishna Nandam[1]

ABSTRACT: *Now a days increasing in the large number of automobiles in the recent years has results in greater demand for petroleum sources. Due to continuous use of petroleum sources in automobiles causes the depletion of world petroleum reserves estimated to last for few decades, there has been active search for alternate fuels. One of the alternate fuels whose use is rapidly growing is biodiesel. In the present work Bio diesel is produced from waste cooking oil which is obtained from local hotels and restaurants by using transesterification process. Various properties of diesel, waste cooking oil biodiesel and its blends were found. In the present investigation experimental work has been carried out to analyze the performance and emission characteristics of a four stroke single cylinder compression ignition diesel engine fueled with diesel-biodiesel blends (B15, B25, and B35). The performance parameters evaluated were brake thermal efficiency, brake specific fuel consumption, mechanical efficiency, thermal efficiency and the emissions measured were carbon monoxide (CO), hydrocarbon (HC), and oxides of nitrogen (NO_X). The experimental investigation results of diesel-biodiesel blends are compared with that of standard diesel.*

Keywords: *Bio-Diesel, Transesterification, Blends, Performance and emission characteristics, four stroke C.I engine.*

I. INTRODUCTION

Biodiesel is a non-petroleum based diesel fuel which consists of the mono alkyl esters of long chain fatty acids derived from renewable lipid sources. Biodiesel is typically produced through the reaction of a vegetable oil or animal fat with methanol in the presence of a catalyst to yield glycerin and biodiesel (chemically called methyl esters). Biodiesel is a renewable fuel source and also biodegradable because it is part of the family of bio fuels and produced from a biological source such as vegetable oils like corn oil in (Europe), palm oil and coconut oil (Asia), Jathropa oil and karanja oil (India) and soy bean oil (USA).It has similar physical and chemical properties with petro diesel fuel. However, biodiesel properties can sometimes be superior to that of petro-diesel fuel because the former has higher flash point, ultra-low sulphur concentration, and better lubricating efficiency. Biodiesel runs in any conventional diesel engine. No engine modifications are necessary to use biodiesel. Biodiesel dramatically reduces harmful emissions that cause environmental problems such as global warming, acid rain and smog. Biodiesel reduces CO_2 emissions by over 78% compared to petroleum diesel. Even blended with petroleum diesel, biodiesel significantly reduces emissions. Furthermore, the plants used to make biodiesel feedstock absorb more CO_2 as they grow than the biodiesel produces when it is burned

Waste cooking oils are natural substances of plant origin. They are generally liquid, insoluble in water, and have an oily appearance. Fried food items are very popular in the coastal regions of India. Generally cooking oil used for frying are sunflower oil, palm oil, coconut oil etc. as they are easily available, and especially so of the coconut oil which is abundantly available in south India. It is well known fact that, when oils such as these are heated for an extended time, they undergo oxidation and give rise to oxides. Many of these such as hydro peroxides, epoxides and polymeric substances have shown adverse health/biological effects such as growth retardation, increase in liver and kidney size as well as cellular damage to different organs when fed to laboratory animals.

Within the last couple of years Biodiesel has become commercially viable, leading to numerous production plants being established or proposed across Ireland and UK. This is now the accepted disposal method for used cooking oil, although a huge percentage is being exported to mainland Europe, where more favorable tax breaks mean that Biodiesel is more financially viable. In this work, the waste vegetable oil is vegetable oil mixed with diesel at different blends and these blends are further tested. The performance and emissions of bio fuel blends were evaluated using a naturally aspirated single cylinder water cooled direct injection diesel engine and these are plotted on graphs. Ever increasing fuel price, continuous addition of on road vehicles, fast depleting petroleum resources and continuing accumulation greenhouse gases are the main reasons for the development of alternative Fuels.

II. MATERIALS AND METHODS

2.1. Filtration And Heating Of Raw WCO

Non-oil components of the WCO were removed by separation using filter and moisture was removed by heating the oil at about 120^{o}C for 30 to 45 minutes. Heating with electric heater is usually the easiest way to bring the oil up to required temperature.The process will depend on the FFA present on the waste cooking oil. If the FFA is less than 2% then directly Transesterification process can be done. If the FFA is greater than 2% then first Esterification should be done to reduce the FFA content in the WCO then Transesterification should be done.

2.2. Esterification

Esterification is one of process in bio diesel. It works to reduce FFA. If FFA more than 2%. An acid-catalysed transesterification process will eliminate most of the free fatty acids from the waste cooking oil. The Fig.2.1 shows the process of esterification.

1. First 5ml Sulphuric acid (95-98%) is used to mix with methanol (350ml) and stirred until the sulphuric acid is dissolve in the methanol.
2. Add the mixture to the waste cooking oil (1000ml) and stirred to mix the solvents until they become murky.
3. This was then heated to 60^{0}c for 2 hours.
4. A higher temperature or faster stirring rate may push the acidic Esterification to convert free fatty acid to methyl ester.
5. This process is to be continued until the FFA is below 2%.

2.3. Transesterification

Transesterification is a kind of organic reaction where alcoholic group is ester is substituted. In Transesterification, the waste cooking oil contain triglycerides are chemically converted into fatty acid methyl esters are known as biodiesel. The applicability of Transesterification is not restricted to laboratory. Several relevant industrial processes use this reaction to produce different types of compounds. Transesterification reduces the viscosity of cooking oil without affecting the calorific value of the original fuel. Thus, fuel atomization, combustion and exhaust emissions display better results after Transesterification. This process can be done directly if FFA is less than 2%. Potassium hydroxide(KOH) is used as catalyst in this process. The amount of catalyst had an impact in the conversion of esters during the transesterification process. The reaction was carried out using 1% of catalyst concentration. The Fig 2.1 and Fig.2.2 shows the flowchart and chemical reaction of the transesterification process respectively.

1. Potassium hydroxide (6.45grams per 1000ml of waste cooking oil, got by 3.5grams stoichiometric equivalent and 2.95grams for neutralizing FFA) was first mixed with methanol (200ml per liter of oil) together in one container before adding to the waste cooking oil.
2. After add the mixture to the waste cooking oil (1000ml) under constant rate of stirring to mix the solvents until they became murky.
3. This was then heated to about 60^{0}c for 90 minutes.
4. After the transesterification reaction, one must wait for the glycerol to settle to the bottom of the container. This happens because Glycerol is heavier then bio-diesel. The settling will begin immediately, but the mixture should be left for minimum of 12 hours to 24 hours.
5. The settled glycerol should drain out in the general method.
6. Next the raw biodiesel is to be water wash. The purpose of washing is to wash out the remnants of the catalyst and other impurities. Generally water washing is preferred in which lukewarm water (about one third of raw bio-diesel) is added to raw bio-diesel, stirred for a short duration and then impurities are allowed to settle down at bottom with water.

7. The honey colour Biodiesel will float on top while the denser glycerol will have congealed at the middle and the water will be settled to bottom. Separate the three of it with just normal procedure.
8. The honey colour biodiesel should heat for 40 minutes to evaporate the water content in the bio diesel.
9. 750ml of bio diesel is produced from 1000ml of waste cooking oil.

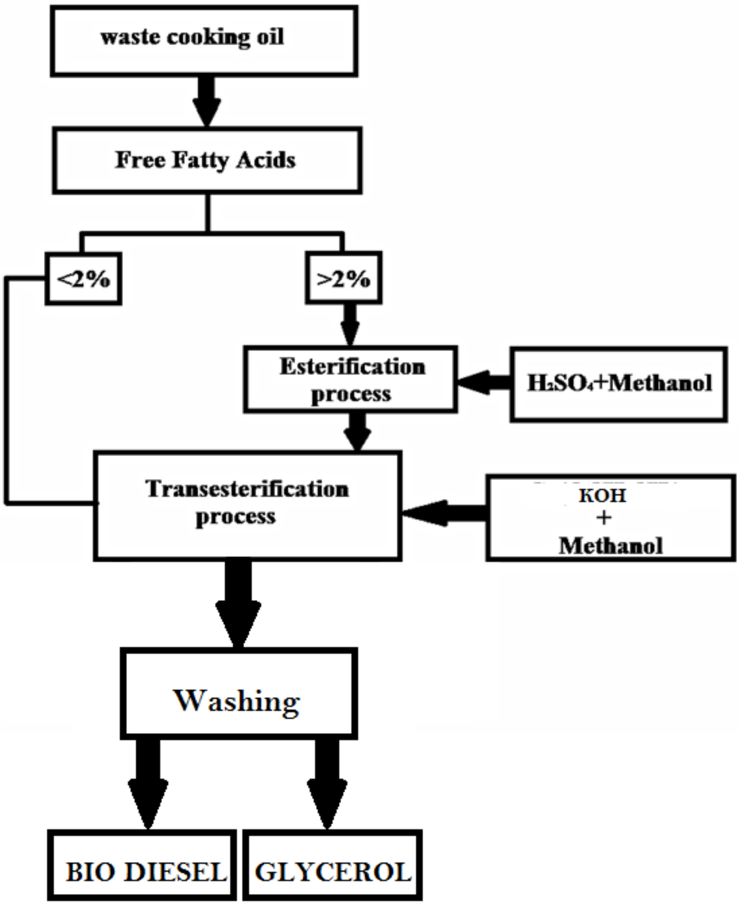

Fig.No.2.1 Flow Chart

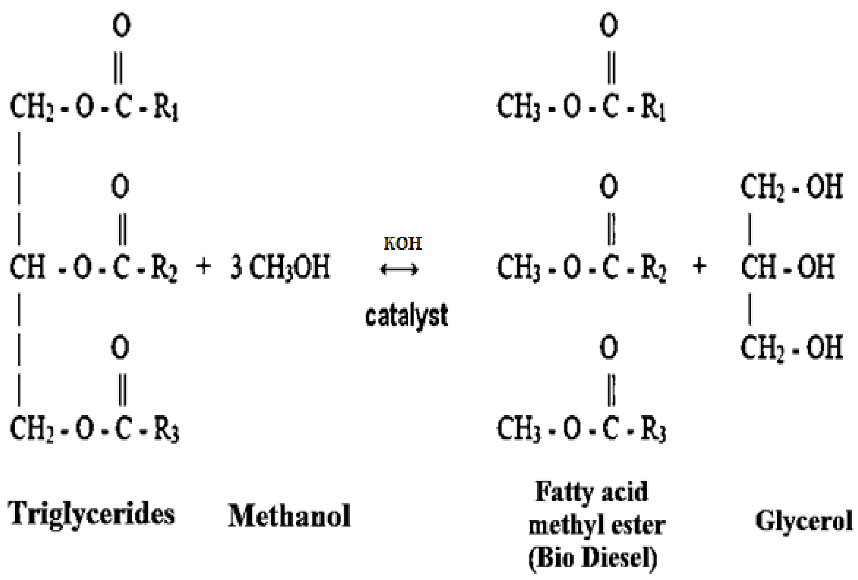

Fig.No.2.2. Chemical Reaction

2.4. Properties of Waste Cooking Oil Biodiesel and Its Blends

The properties of crude waste cooking oil, methyl ester of waste cooking oil and its blends are compared with diesel and given in Table 2.1. It is observed that five oils have the important properties comparable with each other. Density, Viscosity, Flash point, Fire point, and Calorific value of crude waste cooking oil, blends of methyl ester of waste cooking oil and diesel oils are given in Table 2.1.

Table 2.1. Properties of waste cooking oil Biodiesel

Properties	Pure Diesel	WCO	B100	B15	B25	B35
Density at 15^{0}c	0.829	0.92	0.885	0.833	0.845	0.895
Kinematic viscosity at 40^{0}c(cst)	3.54	27.14	5.42	3.72	3.79	4.15
Flash point(^{0}c)	47	145	81	56	63	67
Fire point(^{0}c)	51	152	85	61	69	73
Calorific value(KJ/Kg)	42700	39750	40985	41885	41338	41100

2.5. Experimental Setup

Fig.No.2.3.Test Ring

Table 2.2 specification of tested engine

DESCRIPTION	SPECIFICATION
Name of the Engine	Paro
General details	Single cylinder, four stroke, water cooled, diesel engine
Bhp/KW	6/4.41
Bore diameter	110mm
Stroke length	150mm
Circumference of wheel	190cm
B.S.F.C	209gm/bhp-hr

III. RESULT AND DISCUSSION

3.1. Brake Thermal Efficiency

Fig.3.1 shows the variation in brake thermal efficiency(η_{Bth}) in case of diesel, B15, B25and B35. The effect of mixture strength on BTH as the mixture strength is increasing the value of mass of fuel consumption increases and calorific value decreases. But the increasing mass of fuel consumption is less when compared to the decrease in calorific value. So there will not be much variations in break thermal efficiency. Hence BTH slightly decreases for the blend mixtures. From the graph it is clear that BTH is almost constant up to 36 load and it is more for the blends when load reaches the maximum.

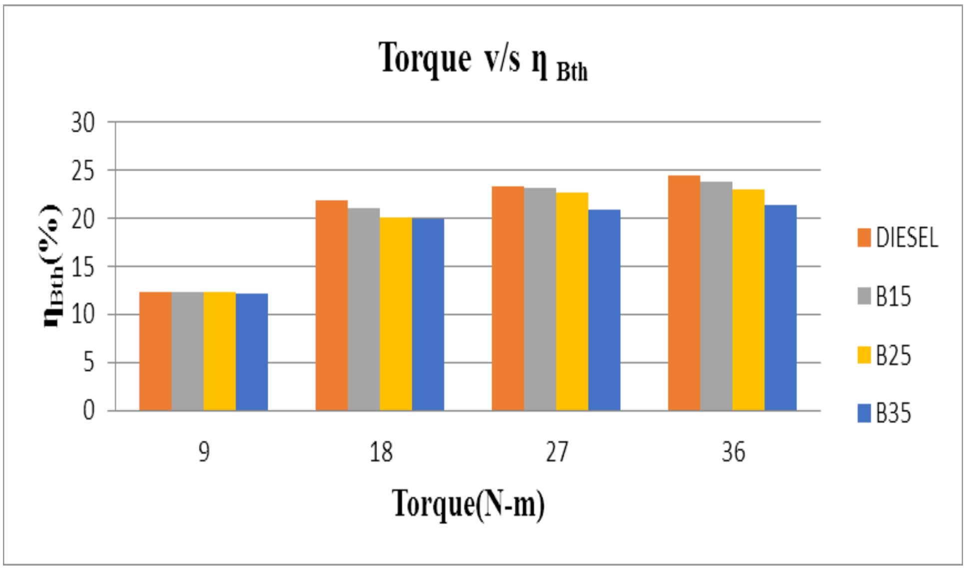

Fig. 3.1 Torque versus Brake Thermal Efficiency

3.2. Mechanical Efficiency

The variation of mechanical efficiency with Torque is shown in Fig. 3.2 From the plot it is observed that there is slight variation of the mechanical efficiency for all the blends of waste vegetable oil compared to the diesel fuel. At full load condition, the mechanical efficiencies are obtained 84.48%, 83%, 74.2%, 69%for fuels of diesel, B15, B25, B35, respectively. Among the three blends of waste vegetable oil the maximum Mechanical efficiency is 83% which is obtained for B15. The mechanical efficiency of waste vegetable oil is decreases as compared with diesel at full load condition.

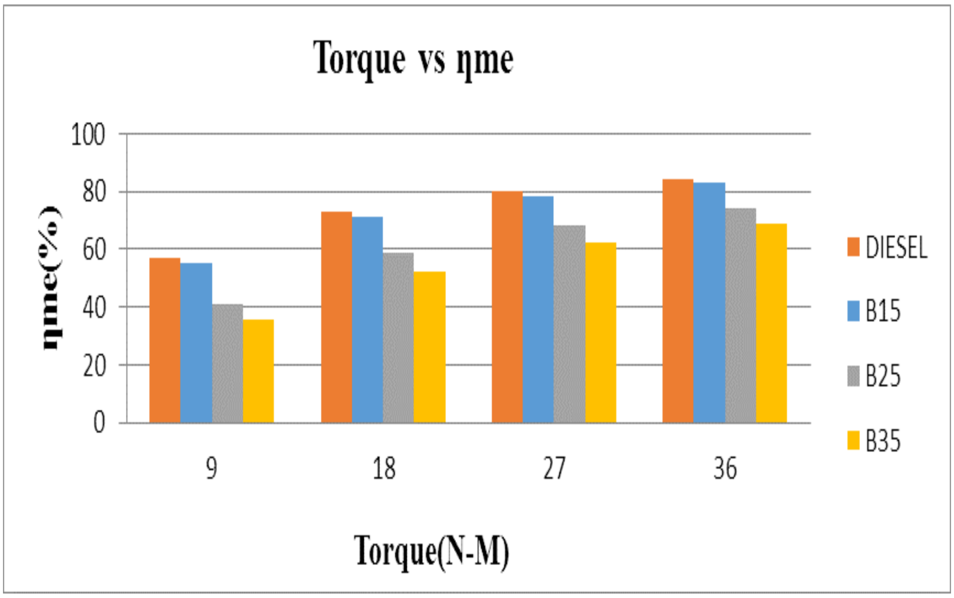

Fig. 3.2 Torque versus Mechanical efficiency

3.3. Thermal Efficiency

The variation of thermal efficiency with Torque is shown in Fig. 3.3 From the plot it is observed that there is slight variation of the thermal efficiency for all the blends of waste vegetable oil compared to the diesel fuel. At full load condition, the thermal efficiencies are obtained 24.31%, 23.47%, 22.79%, 21.26%for fuels of diesel, B15, B25, B35, respectively. Among the three blends of waste vegetable oil the maximum thermal efficiency is 23.47% which is obtained for B15. The thermal efficiency of waste vegetable oil is decreases as compared with diesel at full load condition.

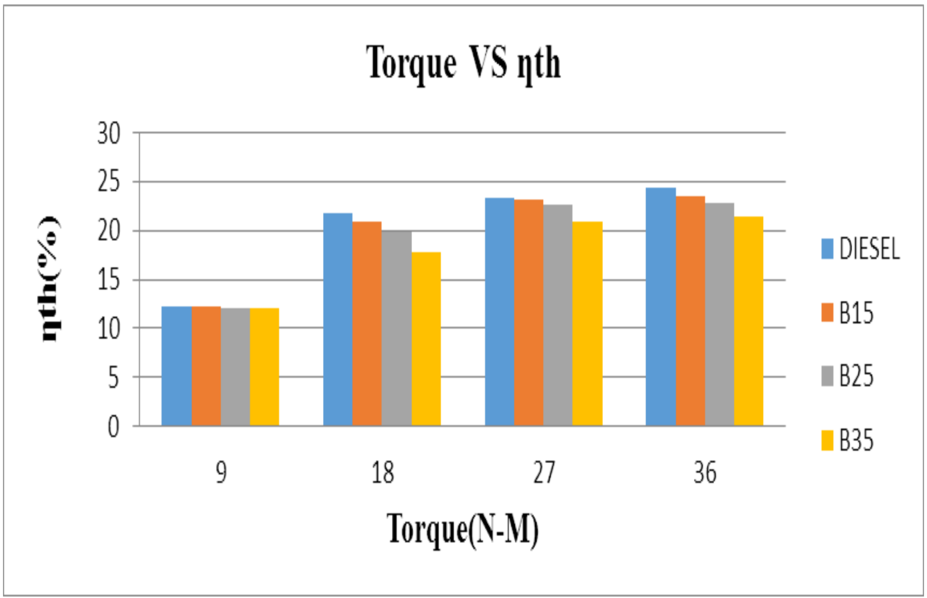

Fig. 3.3 Torque versus Thermal efficiency

3.4. Brake Specific Fuel Consumption

Fig.3.4 shows brake specific fuel consumption of engine against Torques. The plot it is reveals that as the torque increases the fuel consumption increases. The specific fuel consumption is higher in biodiesel ; as compared to diesel .The reason is that fuel has lower calorific value. As a result to produce the same amount of energy, more amount of biodiesel consumed. As the percentage of biodiesel in blend increases the break specific fuel consumptions increases. From figure 6.2.4 it is seen that at low load the BSFC is 0.684 Kg/KW- S for diesel and for B15 blend is 0.69Kg/KW-S. At full load the BSFC is 0.346 Kg/KW-S for diesel and for B15 blend is 0.362 Kg/KW-S. The brake specific fuel consumption of the B15 blend was lower than that of all other blends. This may be due to better combustion and an increase in the energy content of the blend.

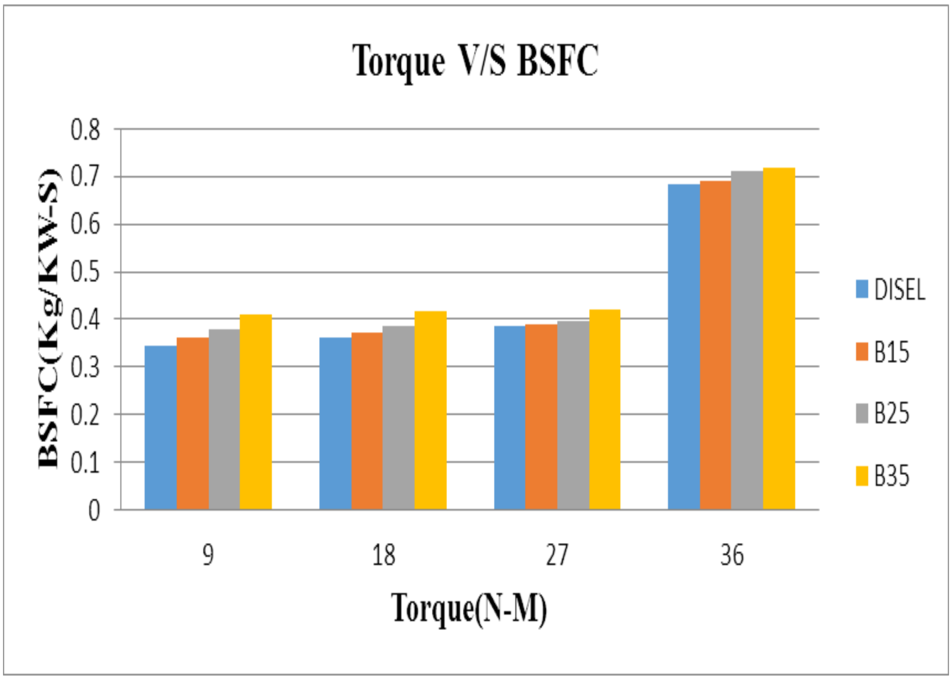

Fig. 3.4 Torque versus Brake Specific Fuel Consumption

3.5. Indicated Power

The variation of indicated power with torque is shown in fig.3.5. The plot it is reveals that as the load increases the indicated power increases. At full load condition the Indicated Power obtained are 2.9kw, 2.95kw, 3.33kw, 3.55kw, for fuels of diesel, B15, B25, B35, respectively.

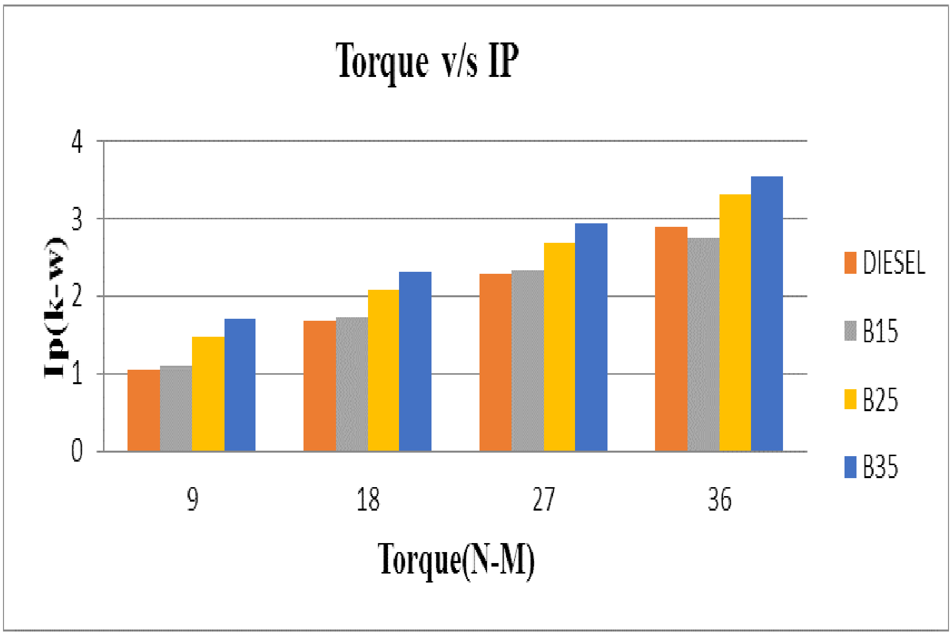

Fig. 3.5 Torque versus Indicated Power

3.6. Carbon Monoxide (CO) Emission

The figure 3.6 shows the CO emission of blends with various torques. The plot it is observed that is interesting to note that the engine emits more CO for diesel as compared to biodiesel blends under all loading conditions. The CO emission of B15 blends decreased significantly at full load. This may be due to the enrichment of oxygen in the waste vegetable oil, in which an increase in the proportion of oxygen promotes further oxidation of CO during the engine exhaust process. At lower waste vegetable oil concentration, the oxygen present in the biodiesel aids for complete combustion. However as the waste vegetable oil concentration increases, the negative effect due to viscosity and small increase in specific gravity suppresses the complete combustion process, which produces small amount of CO. Similarly B15 blend also has low emissions on low load and increasing it by load on an engine. All the blends have low CO emissions at all loads compared to diesel. The value of CO percentage in exhaust gas is nearer to all blends at lower loads and it is much more difference at higher loads.

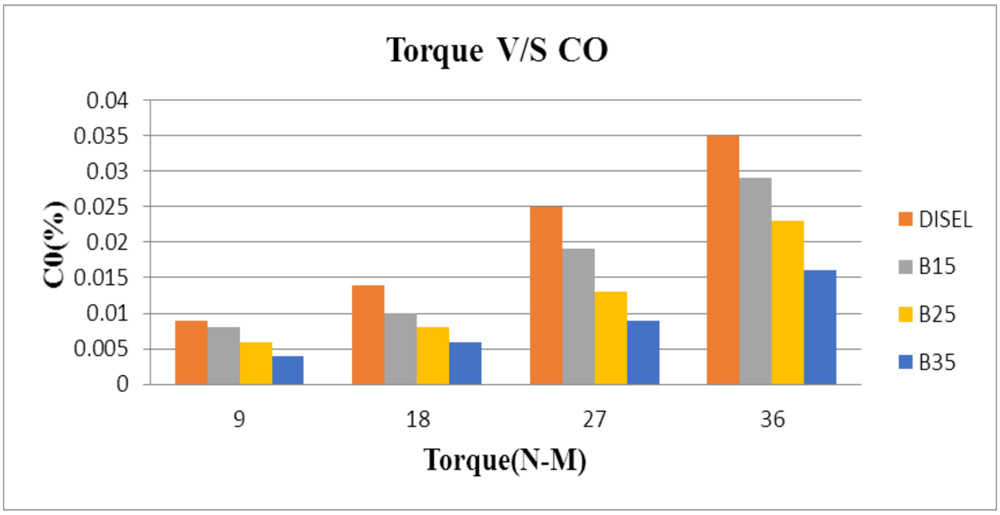

Fig.3.6 Torque versus Carbon Monoxide (CO)

3.7. Hydrocarbon Emission

The Fig. 3.7 shows that the variation of HC emission of Diesel- waste vegetable oil blends fuel under various engine loads. The plot it is observed that the load increases the HC emission increases for diesel as well as blends. For B15 blends, the HC emissions are lower than that of diesel fuel, and this may be due to complete combustion. There are normally some regions within the combustion chamber of an engine fuelled with methyl ester where the mixture is either too rich to ignite the partially decomposed and oxidized fuel in the exhaust. Those un-burnt species are collectively known as un-burnt hydrocarbon emissions. The reduction in HC Emissions is goes on increasing with increase in load from no load to high load. It is better to use 15% waste vegetable oil and 85% diesel blended fuel for reduced emissions of HC.

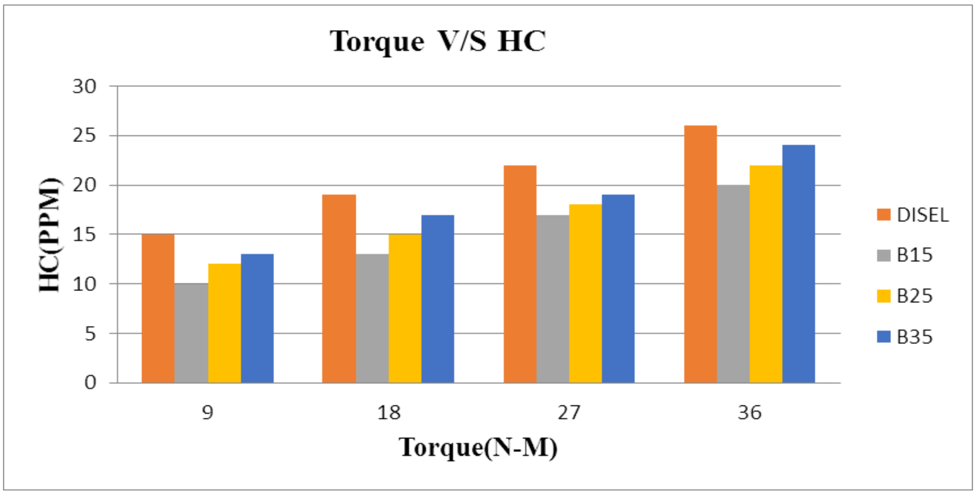

Fig. 3.7. Torque versus Hydro carbons

3.8. Oxides of Nitrogen (NOx) Emissions

Fig.3.8 shows that the variation of NOx emission for Diesel-waste vegetable oil blends and standard diesel for different engine loads. The increase in trend may be due to the presence of oxygen in methyl ester of waste vegetable oil, since the oxygen present in the fuel may provide additional oxygen for NOx formation. Many researchers reported that oxygenate fuel blends can cause an increase in NOx emission. Normally complete combustion causes higher combustion temperature which results in higher NOx formation. Another reason for the increase in NOx emission is the cetane suppressing property of oil. Usually, low cetane fuels offer longer ignition delay and release more heat during the premixed phase of combustion.. Always there was reduction in NOx emissions in B15 blend. The increase in NOx emission is observed in not only waste vegetable oil but also in all vegetable oils due to the presence of oxygen in the oil extracted from vegetable products. From the figure 3.8, it is observed that there is no much more increase in NOx emission at lower loads but greater increase may observe when the load on engine is increasing to maximum value.

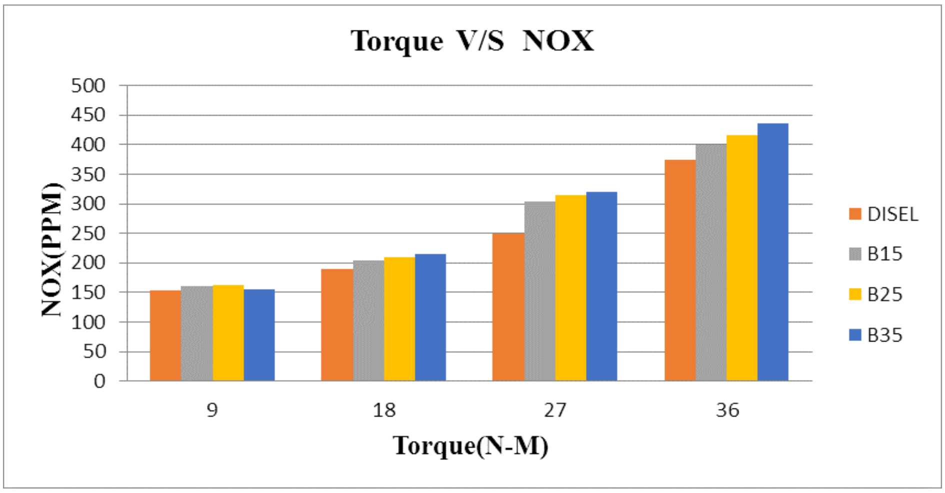

Fig.3.8. Torque versus NOx Emissions

II. CONCLUSION

The conclusions derived from present experimental investigations to evaluate performance and emission characteristics on four stroke single cylinder C.I engine with diesel- waste cooking oil blends are summarized as follows.

1. The BTE of waste cooking oil is decreases as compared with Diesel at full load condition.
2. The Brake specific fuel consumption is increased with the blends when compared to diesel.
3. CO and HC emissions are decreased significantly with the blends when compared with diesel.
4. Comparatively a slighter increment in NOx emission was found while working with all blend at all loads.
5. From the above analysis the blend B15 shows the better performance and emissions compared to other blend (B15, B25, and B35) and diesel. So the B15 blend can be used as an alternative fuel in DI diesel engine.

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