PERFORMANCE ANALYSIS OF JATROPHA BASED-BASE CATALYSED BIOFUELS ON A DIESEL ENGINE

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ABSTRACT: - Transesterification of oil from non-edible Jatropha curcas L. (Jatropha) seeds is a suitable alternative to produce fatty acid methyl and ethyl esters. The ethyl ester was catalyzed in presence of NaOH and KOH catalysts. Catalyst concentration, molar ratio, reaction temperature, rpm, were kept constant. Jatropha ethyl ester (JEE) and Jatropha methyl eater (JME) were produced each using KOH & NaOH. Properties of the various biodiesel (B100) & blends (B25D75) were compared and the performance of the blends was analyzed on diesel engine. The homogeneous KOH transesterification process gave more yield as compared to homogeneous NaOH catalyst. Homogeneous transesterification with KOH forming Jatropha ethyl ester yields better results forming cleaner, more efficient fuels.

Key Words: — Biodiesel, homogenous catalyst, base catalyzed transesterification, FAME/FAEE, vegetable oils, catalyst, esterification, transesterification

1. INTRODUCTION

Biofuels are the fuel of the future. Increasing energy demands and reducing fossil availability turns mankind towards biofuels for its energy demands. Biofuels are a solution to multifaceted problems of energy security, waste disposal, employment generation, etc. and more so for developing agricultural economies of the third world.

The biomass conversion to energy efficient fuels via thermal or chemical method can result in a fuel in solid, liquid, or gas form.

Biofuels are environment friendly and theoretically carbon neutral as the CO_2 released on burning the fuels is equivalent to that taken up by the plant from the environment.

Focus is to be on increasing the yield of the biofuel and reducing the carbon footprint of the engines. In this regard, constantly new catalysts are introduced with changing reaction conditions in order to yield better results.

1.1 Oil Extraction

Firstly, in case of Jatropha Curcas, the seeds are put in desiccation oven and dried for 24 hrs. They are then broken separately to achieve the optimum oil extraction and are then chopped using a grinder machine and oil is extracted using oil extraction machine depending upon power and capacity.

1.2 Esterification

As a pre-treatment, the oil is first treated with Methanol & H2SO4. This process reduces the amount of impurities in the oil. In this, 1% w/w H_2SO_4 is used and mixed with 13% w/w Methanol so as to get high percentage yield and it is heated up to 50 °C using magnetic stirrer. This mixture is added to the Jatropha oil and the mixture is heated and stirred at 300 rpm for 90 minutes. This solution is transferred to separating funnel and it is allowed to settle for a time period of 24 hrs.

Fig 1.1: Process of Esterification

1.3. Transesterification

Transesterification of natural glycerides with methanol to methyl esters and ethanol to ethyl esters is a technically important reaction that has been used extensively in the soap and detergent manufacturing industry worldwide for many years. The transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. During the esterification process, the triglyceride is reacted with alcohol in the presence of a homogeneous catalyst.

In this process, the product of esterification is further treated with Methanol/Ethanol in the presence of a base as KOH/NaOH. The alcohol is heated with the base at 50 °C and added to the products of esterification and heated to 60 °C with constant stirring at 300 rpm for 120 minutes and the product is then let to settle for a time period of 24 hrs. The impurities settle at the base of the separating funnel.

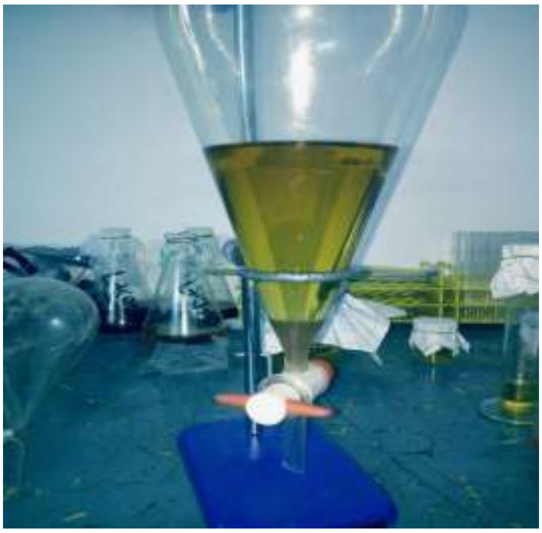

Fig 1.2: Settling products of transesterification

1.4 Washing of Biofuel

Fig 1.3: Washing of biofuel

After the transesterification reaction is complete, there is still a need to purify the fatty methyl and ethyl esters so washing is done. The products of transesterification are washed with warm water for 3 times. After washing, the oil is heated in order to remove excess moisture from it.

1.5 Blends Preparation

For various properties and testing of biodiesel we have used four blends:

1. JEE (KOH) + DIESEL: In the process of this blend formation we have reacted the product of esterification with Methanol/Ethanol in the presence of KOH.

2. JME(KOH) + DIESEL: In the process of this blend formation we have reacted the product of esterification with Methanol in the presence of KOH.

3. JEE (NaOH)+DIESEL: In the process of this blend formation we have reacted the product of esterification with Ethanol in the presence of NaOH.

4. JME (KOH)+DIESEL: In the process of this blend formation we have reacted the product of esterification with Methanol in the presence of KOH.

All these four blends are taken in the proportion of 25(Oil): 75(DIESEL) represented for example as JEE(KOH)+D

2. PROPERTIES CALCULATIONS

2.1 Viscosity

The *viscosity* of a fluid is a measure of its resistance to deformation at a given rate. Fuel viscosity plays a significant role in the lubrication of fuel systems. Lower fuel viscosities lead to greater pump and injector leakage, which reduces maximum fuel delivery and power output. The viscosity of the blends was measured with the help of Redwood Viscometer. The viscosity was found to increase with the increase in percentage of jatropha oil in blends.

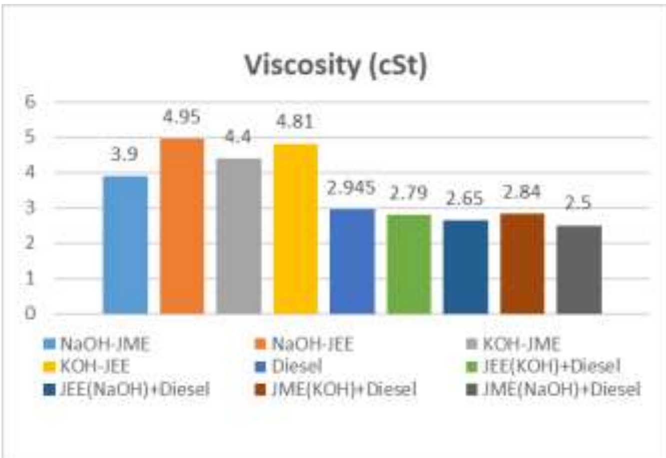

Fig 2.1: Viscosity of different blends

As evident from the above values, the viscosity of the blends was higher than that of diesel. However, all the values were found to be within the specified BS-IV standards norms (2.0-4.5 cSt at 40°C). Among the blends, the blend of JME (NaOH) with diesel had the lowest viscosity.

2.2 Calorific value

The *calorific value* of a fuel is a measure of the amount of heat released during its complete combustion. It was measured with the help of a bomb calorimeter

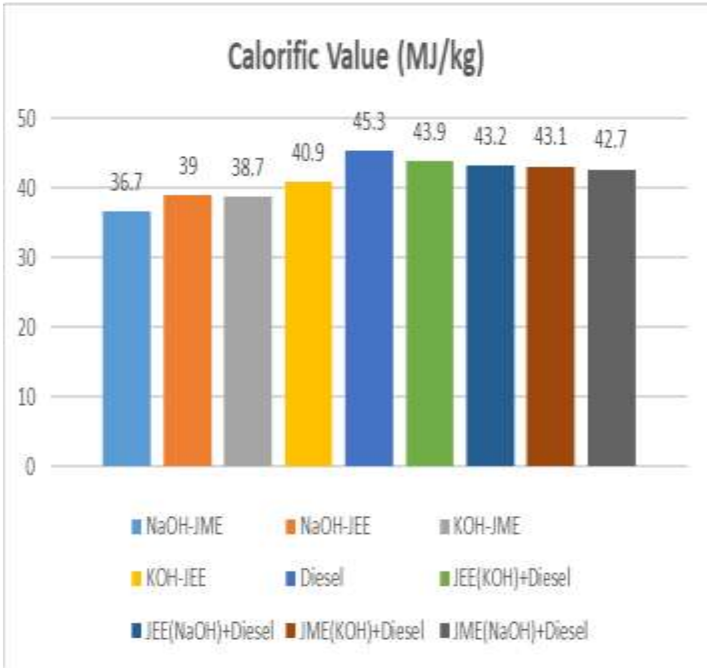

Fig 2.2: Calorific Value of different blends

As jatropha oil has slightly lower calorific value than diesel the blends were found to have a lower CV as compared to pure diesel which further decreased with increase in jatropha percentage. Among the blends, the blend of JEE (KOH) with diesel was found to have a Calorific Value slightly lesser than diesel.

2.3 Cloud Point & Pour Point

Cloud point refers to the temperature below which wax in diesel or bio wax in biodiesels forms a cloudy appearance. The presence of solidified waxes thickens the oil and clogs fuel filters and injectors in engines. The cloud points for biodiesel blends were found to be lower than diesel meaning jatropha blends can be used at lower temperatures.

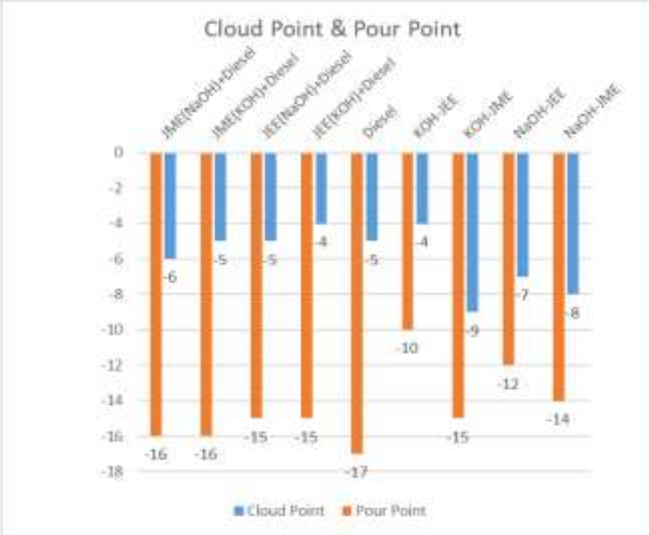

Fig 2.3: Cloud point & pour point

2.4 Flash point & Fire point

The *flash point* of a volatile material is the lowest temperature at which vapors of the material will ignite, when given an ignition source.

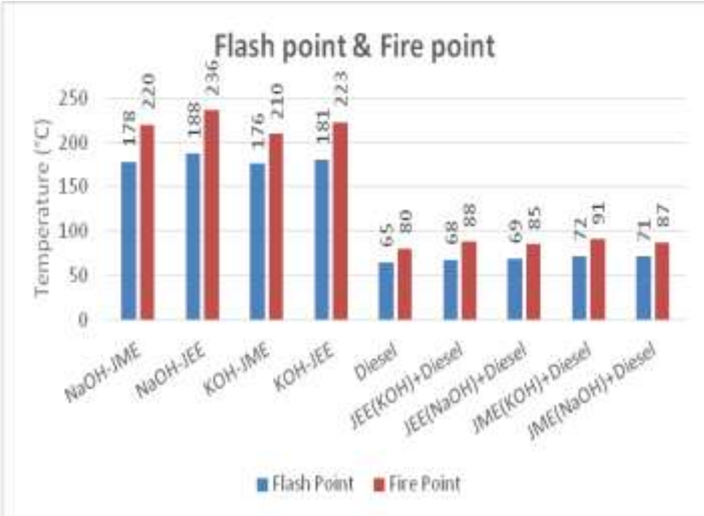

Fig 2.4: Flash point & Fire point values for different blends

In general flash point of fuel affects the shipping and storage classification of fuels and the precautions that should be used in transporting and handling the fuel. The flash point for the blends were found to be in accordance with the ASTM D 93A standards that requires fuels to have a minimum value of 66 °C.

The *fire point* of a fuel is the lowest temperature at which the vapors of that fuel will continue to burn for at least 5 seconds after ignition. As per standards, the fire point of the fuel should be at least 10° C higher than its flash point.

For the blends tested, the fire point for each blend was at least 15 °C higher than its flash point (fig 2.4).

2.5 Relative Density

Relative density, or we say it specific gravity is defined as the ratio of the density of a substance to the density of a reference material.
Density is a measure of mass per volume. It was measured using hydrometers.

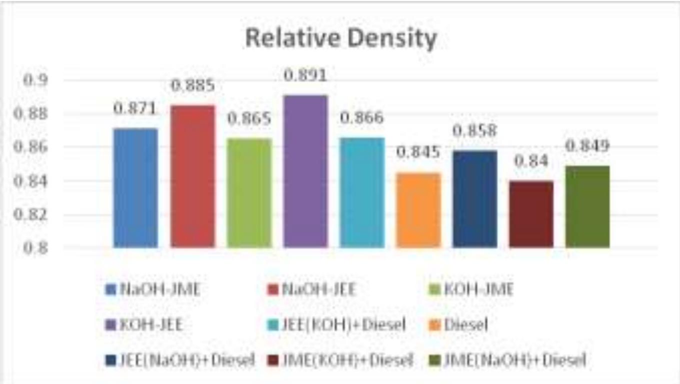

Fig 2.5: Relative Density for different fuel blends

According to BS-IV standards, the RD for the fuel should be in the range of 0.815- 0.845. Diesel has a RD of 0.845 whereas the blend of JME(KOH) with diesel had a RD of 0.84(fig 2.5).

3. PERFORMANC ANALYSIS

The performance of the fuel blends was analyzed on a 4-stroke, single cylinder, C.I. engine (Kirloskar Oil Engines Ltd., India) whose specifications are as follows:

Type	Single Cylinder Direct Injections, 4-Stroke
Bore*Stroke	87.5mm*110mm
Cubic Capacity	661.45cc
Compression Ratio	17.5:1
Rated Power	4.4kW at 1500rpm
Starting	Hand start with cranking handle
Cooling system	Air cooled

An eddy current dynamometer was coupled to the engine to apply the load on the engine for loading to the engine. The fuel flow rate was measured by timing the consumption for known quantity of fuel from burette.

The performance data was analyzed regarding smoke, brake thermal efficiency, specific fuel consumption and specific energy consumption of all blends.

The engine was run using different blends and various values calculated and graphs plotted.

3.1 Brake Thermal Efficiency

Brake thermal efficiency is the brake power of a heat engine as a function of thermal input from the fuel. A higher BTE is therefore desired.

The torque was varied from 0 to 23.544 N-m and the brake thermal efficiency was calculated at torque of 5.886, 11.772, 17.658, 23.544 N-m using the formula:
Brake thermal efficiency (BTE): BP*3600/mass fuel rate * calorific value (kJ/kg)

The BTE vs torque curve was plotted and the results are obtained as follows:

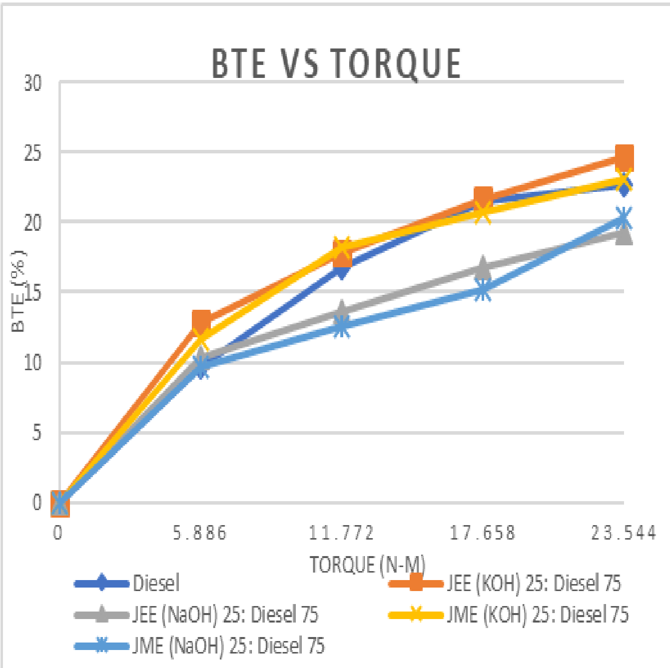

Fig 3.1(a): BTE vs Torque

The BTE for the blends was found to be more than that for diesel for most of the blends at most of the loads. It means that the ratio of energy converted into useful work to the energy present in the fuel is least for diesel.

Among all the 4 blends, the blend of JEE(KOH) with diesel gave the maximum BTE for different loads.

The brake power for various torque was calculated using B.P.= (2*3.14*N*T)/60 (W) and BTE vs BP was plotted as shown:

The curves for the NaOH catalyzed blends appear to the lower side of the diesel whereas those for KOH catalyzed blends are above the diesel curve. However, the range within which the values for diesel and the 4 blends appear is quite small as observed.

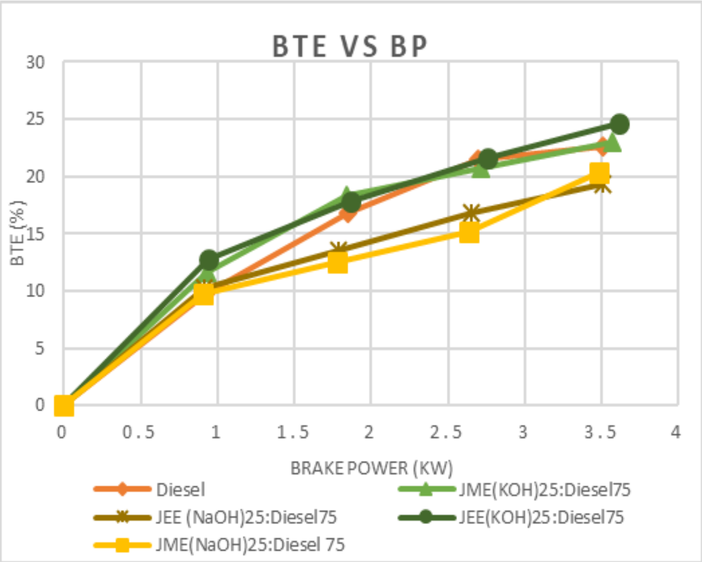

Fig 3.1(b): BTE vs BP

3.2 Brake specific fuel consumption

BSFC is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft power. It is the rate of fuel consumption divided by the power produced.
Brake specific fuel consumption (BSFC): (TFC/BP) in kg/kWh
where,
TFC : Total fuel consumption in kg/h
BP : Brake power in kW.
The curve of BSFC at various loads was obtained as shown:

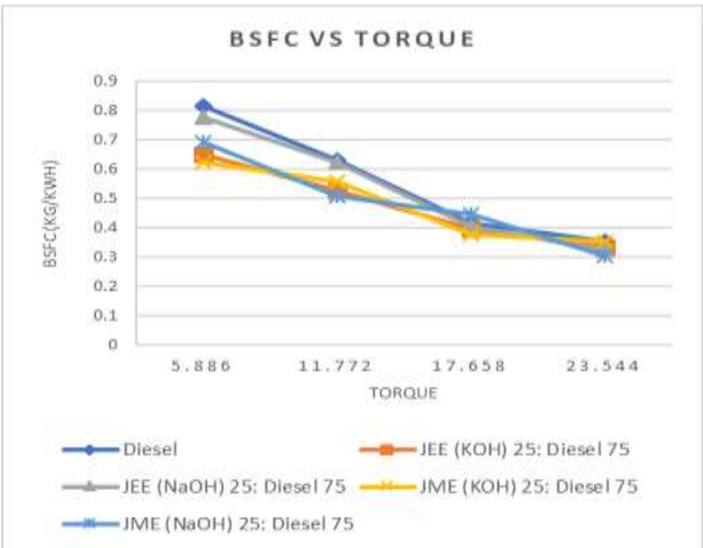

Fig 3.2 (a): BSFC vs Torque

The results obtained indicate that the BSFC for all fuel blends (including diesel) first decrease rapidly as the torque increases but at full load conditions, the BSFC become nearly constant and lie within a very small range of values. It can also be seen that the BSFC for the blends is lower than that for neat diesel at most of the loads. This may be attributed to better vaporization and lower ignition delay for biodiesel.

The curve of BSFC vs BP shows that the BSFC as a function of BP follows the similar trend as for torque as it first decreases sharply and then becomes constant as the brake power increases.

This is clearly understood as the brake power is a function of the torque applied.

The similarity in the curves for diesel and the 4 blends is an indication of the fact that the blends can be used in a diesel engine alike diesel without the need to make any drastic changes in the engine design and material.

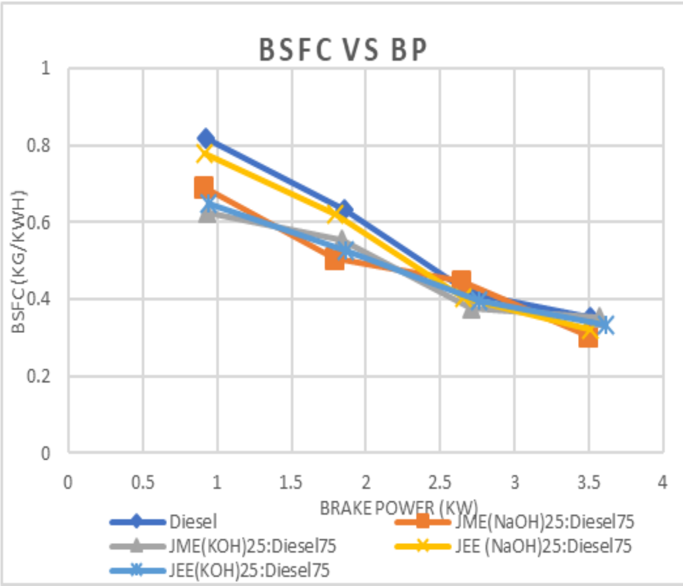

Fig 3.2 (b): BSFC vs BP

3.3 Exhaust gas temperature

The exhaust gas temperature gives an indication of the energy carried away by the exhaust gases as the leave the combustion chamber. The higher the EGT, the lesser is the Brake thermal efficiency.

Since the BTE was the least for diesel, the EGT was found to be the highest for diesel at most of the loads as compared to rest of the 4 blends as shown:

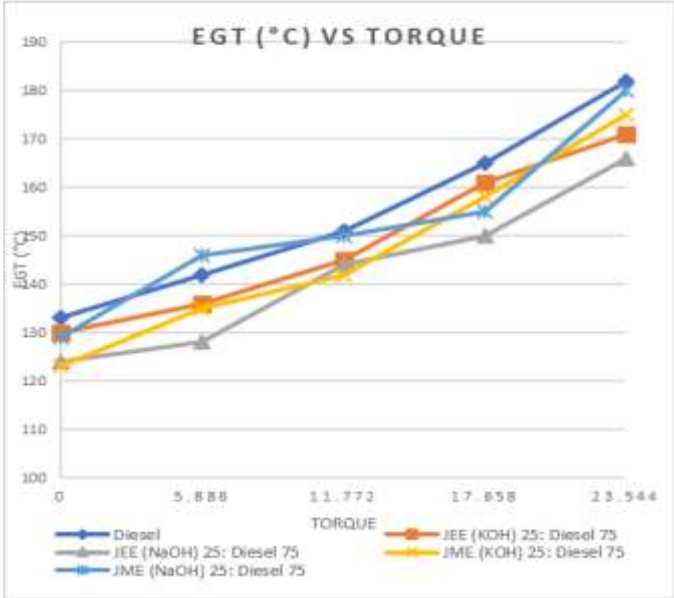

Fig 3.3: EGT vs Torque

The average EGT was found to be minimum for JEE(KOH) and diesel blend. This is in line with the findings that the BTE was highest for this blend.

Diesel has one of highest EGT as its BTE was lowest.

3.4 Smoke emissions

Smoke density is expressed in terms of Hartridge smoke unit (HSU). It basically quantifies the ability of a smoke containing the gas sample to obscure light. The smoke density tells about the number of smoke particles per unit of gas volume. It is in an indicator of the combustion process.

The plot of HSU vs the torque is shown:

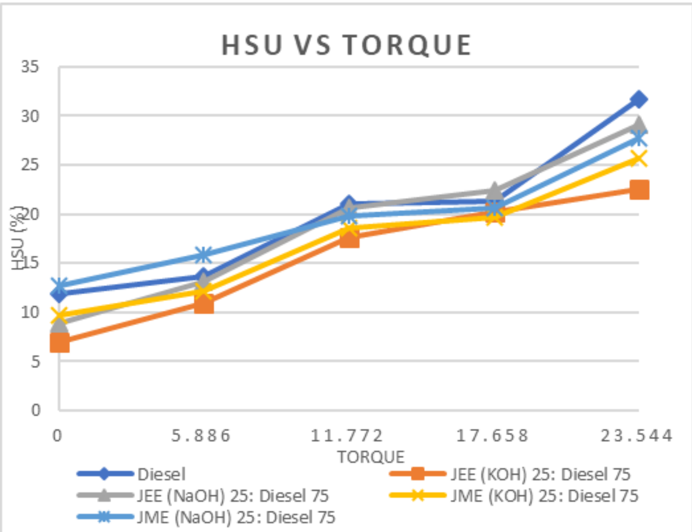

Fig 3.4: HSU vs Torque

4. CONCLUSIONS

1. **Enhanced brake thermal efficiency**: There is an increase in brake thermal efficiency in case of Jatropha blends as compared to pure diesel for nearly all blends at all loads. The BTE was highest for JEE (KOH) 25: Diesel 75 blend. Increased brake thermal efficiency means that lesser energy is being wasted in form of energy of flue gases. This may be caused due to better vaporization, atomization and mixing rate of Jatropha blends.

2. Reduced brake specific fuel consumption: The specific fuel consumption of an engine can be defined as fuel consumption per unit brake power. The BSFC of Jatropha blends is lower than that of diesel for most if not all blends at all loads which is a good indication. JEE (NaOH) 25: Diesel 75 was the best performer here with the values for all 4 blends reaching nearly the same range for maximum torque.

3.Decreased exhaust gas temperature: The exhaust gas temperature for the blends is lower than diesel. Hence less heat is lost to the environment hence more efficient working. EGT does not show a regular trend at different loads. For a given blend, it may either be more or less than diesel at different loads. Moreover, higher EGT leads to formation of more harmful compounds and increases pollution.

4.Lesser emissions: The smoke density was found to be lesser for the blends as compared to diesel. This means that there is a decrease in number of unburnt hydrocarbons in the exhaust gases and the combustion of the fuel is better and more of its energy is utilized in an even more efficient manner. However, this trend is also not linear and variations for different blends at different loads do exist.

On basis of the calculated values and performance characteristics, it was concluded that JEE (KOH) 25: Diesel 75 was the best blend among the 4. Its calorific value was highest, efficiency was more, emissions lesser than others and other values were also well within range as per the BS-IV norms. On a whole, the KOH blends were found to be better performing than their NaOH counterparts.

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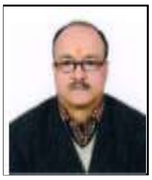

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