Comparative Study on Bio-Diesel production & Engine Performance Parameters from waste cooking oil (WCO) using KOH & CaO as catalyst on a Kirloskar Variable Compression Ratio Engine

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ABSTRACT

The production of Bio-Diesel from vegetable based oils is a new and versatile method for energy generation in the present scenario. Bio-Diesel is obtained by the trans-esterification of fatty acids in the presence of alcohol and catalyst. The purpose of this process is to lower the viscosity of the oil. Bio-Diesel is a renewable and non-toxic source of energy. The Bio-Diesel formed can be used for blending with diesel engines in various proportions. Bio-Diesel is one of the most important alternate sources of energy because of many environmental benefits associated with it. This paper discusses the bio-diesel production from two catalysts KOH and CaO, where KOH is a homogenous basic and CaO being heterogeneous basic catalyst. The yield of bio-diesel produced from both the samples is compared quantitively. The bio-diesel is produced from soybean based oil with 6:1 alcohol to oil ratio, 65ºC reaction temperature, 120 rpm for water bath equipment and 1hour as reaction time for KOH and 6 hours for CaO. The samples prepared were then tested on a variable compression ignition engine and the necessary performance parameters like brake thermal efficiency, mechanical efficiency, fuel flow, brake specific fuel consumption, indicated thermal efficiency were measured. Thus by the comparative study the efficiency of using bio-diesel in conventional engines was analysed. The experimental results proved that the bio-diesel can be used as an alternative fuel in the diesel engines.

Keywords: Biodiesel, efficiency, engine, performance, renewable

I. INTRODUCTION

Major part of all energy consumed worldwide comes from fossil fuel sources like: petroleum, coal and natural gas. They are important energy sources utilized in heating, transportation, power generation, agricultural and industrial sectors (Sharma at al 2013). The International Energy Agency (IAEA) reported in 2007 that the energy need of the world is expected to grow by 55% between 2005 and 2030. Regarding the consumption, transportation accounts fpr about 27% usage of primary energy [1]. Diesel & petroleum fuels have an essential

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impact on economy as they account for most of the transportation in a developing nation. This high energy demand in transportation as well as pollution problems makes it necessary to look for renewable energy sources like biodiesel.

The fuel consumption has been increasing rapidly, estimated to be at 61.5% of total, as per the last decade (Carlimia et al 2014). Recent researches expect that the amount of petroleum in the world can be used merely for next 46 years. Currently, India produces only 30% of total petroleum fuel required for its consumption (Farooq et al 2015) and remaining 70% is imported which costs about Rs 80,000 million per year (Javidial esaadi and Raedssi 2013). Due to this, India has been facing many problems like energy shortage, environmental problems and rising fuel prices (Raqeeb and Bhargavt, 2015).

In our day to day life, diesel engine fitted vehicles are dominating the automobiles sector owing to its superior performance and low cost (Kathirvel et al). This contributes to depletion and hike of diesel fuel price to a great extent in the current scenario (Datta and Mandal, 2016). Thus the world needs to look forward for alternative sources of clean and renewable energy such as hydropower, biomass, wind, and solar (Bana puremath et al 2008. Biodiesel is also a renewable source of energy which can be prepared from transesterification of oil and alcohol. The challenge involved is to look for better and clean energy sources in optimal cost.

Biodiesel could be a possible alternative prepared from the transesterification of triglycerides naturally available in animal fat or vegetable oils, with the use of alcohol. Because of its benefits of biodiesel over petroleum & diesel like significant reduction in greenhouse gas emission, non-sulphur emissions and non-particulate matter pollutants, low toxicity, biodegradable and is obtained from renewable source like vegetable oils and animal fats(Banerjee and Ramakrishrana, 2014). It is evident that mixing of 5% biodiesel fuel to present diesel fuel can save Rs 40,000 million per year (Nanthagopal et al 2014).

Biodiesel is a type of liquid fuel produced from vegetables oils, non-edible oils and animal fats. The presence of monoalkylic esters and hydrocarbon chains in the range of 14 - 22 carbon atoms makes it capable for proper combustion diesel engines (Vicente Crespo et al, 2001). Biodiesel has different names depending on raw material or feedstock:

- RME: Rapeseed methyl ester
- SME: Soybean/sunflower methyl ester
- PME: Palm Methyl Ester
- FAME: Fatty Acid Methyl Ester, generally for vegetable or waste cooking oils(WCO).[2]

Restaurants need to dispose need to dispose of large amount of waste frying oil (WFO) which is frequently poured down drains with no prior treatment and can contaminate local water supplies (Medina-valtierrant and Raminaz-ortiz, 2013). It can be a promising alternate for production of biodiesel because it is a cheaper raw material, avoids the cost of waste product disposal and treatment and also reduces the need to use land for biodiesel producing crops (Supple et al, 2002).

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II. BIO-DIESEL PRODUCTION

2.1Differentiation of catalyst

Generally there are three categories of catalysts used for biodiesel preparation like alkalis, acids and enzymes [3]-[4].Mostly, alkali and acid catalysts are used in biodiesel production categorized as homogeneous and heterogeneous catalysts [5]. Enzyme catalysts can't be commercially used because of longer reaction times and high cost.

Homogeneous basic catalysts like KOH used here; is more preferable and commonly used since trans-esterification is quicker with it [6].KOH is used because of several advantages like high conversion rate in shorter time, economically availability, ability to catalyze at low temperature, etc. [7] Also, the alkaline catalyst like KOH doesn't water during trans-esterification[8].

Heterogeneous basic catalysts like CaO used here is an alkaline earth metal oxide type over large surface area (Helwani, et al., 2009). In addition, calcium oxide (CaO) provides many advantages like higher activity & long catalyst life [9]. However, CaO as catalyst slows down the reaction rate of production [10]. CaO in its raw form can't be used as such and needs to be activated by heating in a furnace at 700 º C for a period of 6-7 hours.

2.2**Production of Biodiesel (Step-Wise)**

1. Filtration: The *WCO* (waste cooking oil) (*Soybean*) once collected from *Hostel M; Thapar University* has been filtered through the filter paper to remove the food particles from it to avoid the hindrance with the catalytic activity.
2. Pretreatment of WCO: The WCO once filtered has been heated at 100 C for a time period of about 15 mins. The pretreatment has been done to evaporate the possible Water droplets in the WCO and increase the reactivity of the oil.
3. Material Preparation: The required materials for this process needed are :

- Methanol
- WCO
- Catalysts being KOH & CaO

The Methanol to Oil ratio used in the reaction is 6:1, which gives us 24g of methanol per 100g of WCO. The catalyst used is 0.5% by wt. which gives us 0.5g of catalyst per 100g of oil.

The catalyst being CaO has to be calcined at 700 C because CaO being in its natural form needs to be activated & to remove the moisture content. The process of activation is known as calcinations, which is heating the raw CaO in a crucible flask at 700 C in a furnace for a period of 6-7 hours.

4. Reaction: As explained above, the reaction proceeds through a process known as transesterification which involves mixing of methanol (24g) with 100 gram of WCO in a conical flask followed by through mixing. The conical flask in then placed inside the water bath for Bio-Diesel preparation. The only difference associated here is the difference in reaction time for two catalytic reactions, since CaO takes more time to complete the reaction than the KOH.

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Table 1.

S.No	Catalyst	Reaction Time	Temperature of Water Bath
1.	CaO (Activated)	5 hours	60 C
2.	KOH	hour	

The reaction time has been done because the heterogeneous Basic Catalysts like CaO take a much longer time for the preparation of biodiesel, and To remove the chances of Saponification, which can be identified through the formation of 3 distinct layers in fig 1. Fig1. shows an incomplete reaction which proceeds with CaO catalyst but with much less reaction time of 1-2 hours. Hence, the reaction couldn't proceed and saponification occurs.

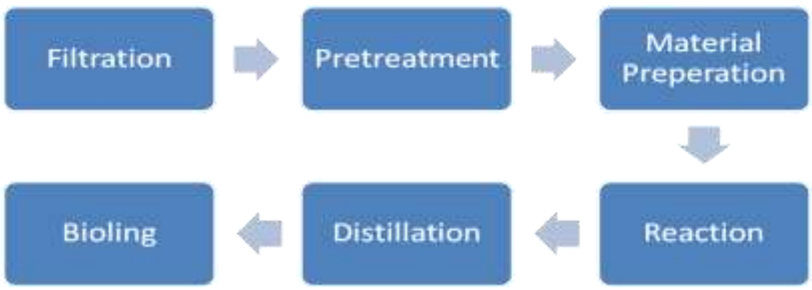
5. Distillation: The Biodiesel once formed needs to be distilled through the Separatus Funnel for a period of 1 hour to remove the glycerin and the remaining particles which settle down due to gravity, and further removed.
6. Boiling : The Biodiesel once formed need to be prepared need to be separated from the excess Methanol and Water droplets through boiling the mixture over a heater for a time period of about 10 mins. Since the boiling point of methanol and water being less than that of bio-diesel, these evaporate first.

Table 2.

2.3Yield Comparison

Table 3.

Catalyst	Temperature,ºC	Alcohol to Oil Ratio	Catalyst loading, wt %	Reaction Time, hours	Mixing, Rpm	Bio-Diesel yield
Potassium (KOH)	60	6:1 (Methanol)	0.5	1	100	Soyabean Oil, 94%
Calcium Oxide (CaO)	60	6:1 (Methanol)	0.5	6	100	Soyabean Oil, 96%



Above Table 3. shows how the yield varies with the catalyst and reaction time; here we have used two types of catalyst being KOH and CaO. One of the most common homogeneous basic catalysts used here is KOH, which accounts to better catalytic activity at low temperature, higher conversion rate, and easy availability [7].

The other type of catalyst used is heterogeneous catalyst used is CaO, as most of the heterogeneous catalysts used are either alkaline or alkaline oxide earth metals supported over a large surface area (Helwani, *et al.*, 2009) Heterogeneous basic catalysts are far more active than their homogenous counterparts, which accounts to more yield than the KOH derived Bio-Diesel [11]. In addition, alkaline catalysts, like, calcium oxide (CaO) accounts to higher activity and long catalyst life time [9].

III. EXPERIMENTAL SETUP

1. Engine Details: ICEngine set up under test is Kirloskar TV1 having power 5.20 kW @ 1500 rpm which is 1 Cylinder, Four stroke , Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Compression Ratio 18.00, Swept volume 661.45 (cc).
2. Combustion Parameters: Specific Gas Const (kJ/kgK) : 1.00, Air Density (kg/m^3) : 1.17, Adiabatic Index : 1.41, Polytrophic Index : 1.26, Number Of Cycles : 10, Cylinder Pressure Referance : 7, Smoothing 2, TDC Reference : 0
3. Performance Parameters: Orifice Diameter (mm): 20.00, Orifice Coeff. Of Discharge: 0.60, Dynamometer Arm Legnth (mm):185, Fuel Pipe dia (mm): 12.40, Ambient Temp. (Deg C): 27, Pulses Per revolution: 360, Fuel Type: Diesel, Fuel Density (Kg/m^3): 820, Calorific Value Of Fuel (kj/kg): 44630
   Kirloskar Engine was equipped with several measurement units i.e. flow measuring unit, gas
   Analyzer, temperature analyser etc. The engine was equipped with two different fuel tanks for diesel and biodiesel separately.

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IV. METHODOLOGY & PROCEDURE

The type of blend used here is B10 (10% Bio-Diesel & 90% Diesel), prepared on a volumetric basis with the help of measuring flask for engine testing. The two separate fuel tanks were filled separately with diesel and bio-diesel, the engine was started with no-load condition and allowed to run for 20 minutes, and the inlet valve for diesel is closed and the inlet valve for biodiesel is opened. The performance is then measured by gradually varying the load from 0 to 2,4,6,8 pounds on a eddy current dynamometer by setting the compression ratio at 18. The cycle is repeated again for another catalyst and the readings are taken. During switching off, the bio-diesel valve is closed and the diesel inlet valve is opened again. The cycle is repeated and the readings are taken again on I.C Engine software 9.

The parameters measured are indicated power (I.P), which could be stated as energy converted into mechanical power of piston movement. Frictional Power (F.P) is the energy required to overcome the frictional losses and the remaining is delivered as power output of engine as Brake Power (B.P). The tests were conducted at various

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loads and several parameters related to performance like specific fuel consumption (SFC), total fuel consumption (TFC), brake thermal efficiency (BTE) and indicated thermal efficiency (ITE) were measured.

V. RESULTS & DISCUSSIONS

Brake Thermal Efficiency (BTE): The variation of Brake Thermal Efficiency of engine with Soyabean biodiesel prepared with two catalysts is shown in Fig.1. It is found that the as we increase the load the BTE for both oils increases. This figure shows that for the CaO sample the BTE is quite low due to low calorific value, higher viscosity and higher density as compared to diesel. The same trend is seen for biodiesel with KOH sample. All these factors combined lead to poor atomization and improper burning inside the engine, at a CR of 18.

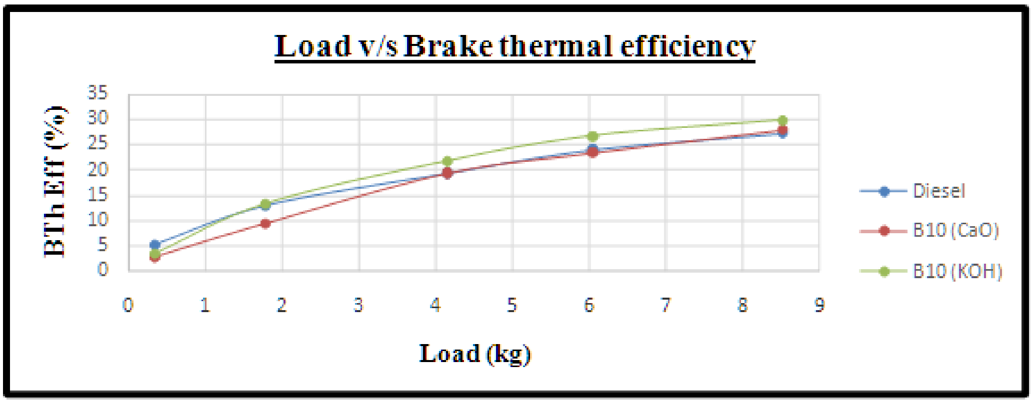

Fig 1. Load v/s Brake Thermal Efficiency

Mechanical Efficiency (ME): The variation of Mechanical efficiency of engine with Soybean biodiesel with KOH & CaO is shown here in Fig 2. It is found that B-10(CaO) gives better mechanical efficiency at higher loads as compared to Diesel and B10 (KOH). This can be attributed to better properties of CaO catalyst which yield better quality biodiesel than other homogenous catalysts.

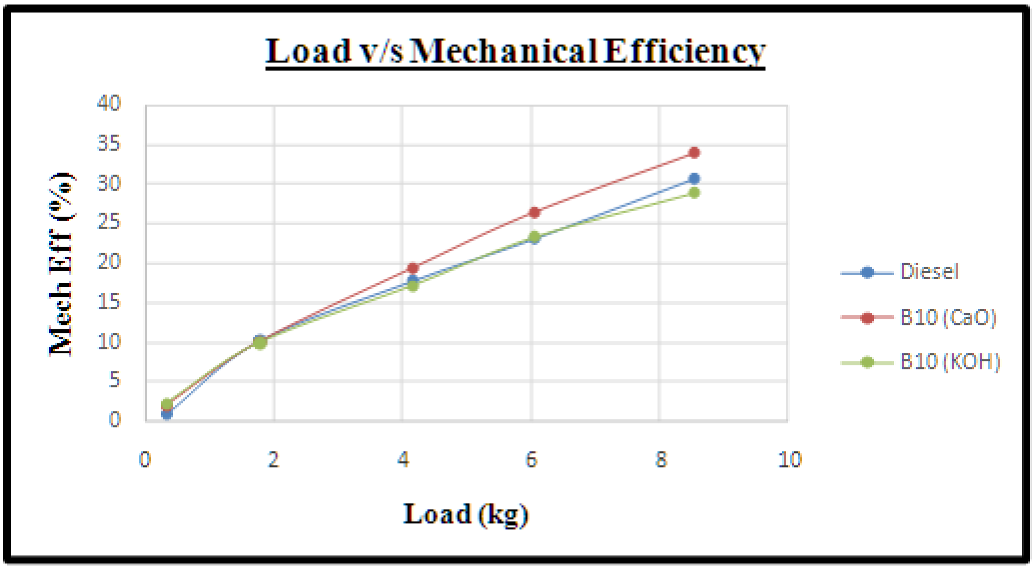

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Fig 2. Load v/s Mechanical Efficiency

Brake Specific Fuel Consumption (BSFC): BSFC is known as the mass of fuel consumed per hour for per kg of brake power output. B-10 (KOH) has slightly lower calorific value than that of B-10 (CaO) and diesel; hence the BSFC is slightly higher. At low loads, the noted BSFC is quite high but as the load is increased; the BSFC decreases because at high loads the temperature increases inside the cylinder due to which viscosity decreases and proper atomization and burning occurs. The variation noticed with the load is shown in the Fig.3.

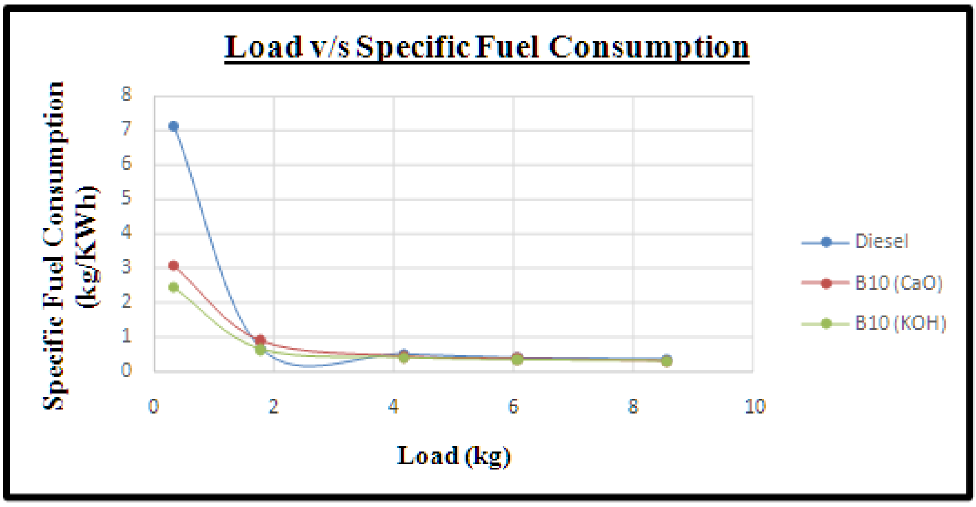

Fig 3. Load v/s Brake Specific Fuel Consumption

Indicated Thermal Efficiency (ITE): Thermal Efficiency indicates the extent to which a given energy is converted to work added with heat. Thermal Efficiency is a dimensionless performance parameter for a device which uses thermal energy. Technically, it is the ratio between the indicated power output (IPO) and the rate of supply of energy of fuel. Here, in the Fig.4 we have traced a base line for diesel oil and other two for B-10(KOH) and B-10(KOH), the trend noticed is that the ITE is quite high for B-10(KOH) followed by the B-10(CaO). This is because of higher viscosity of biodiesel oil and a high indicated power output for the biodiesel samples, which gives a high value as load increases.

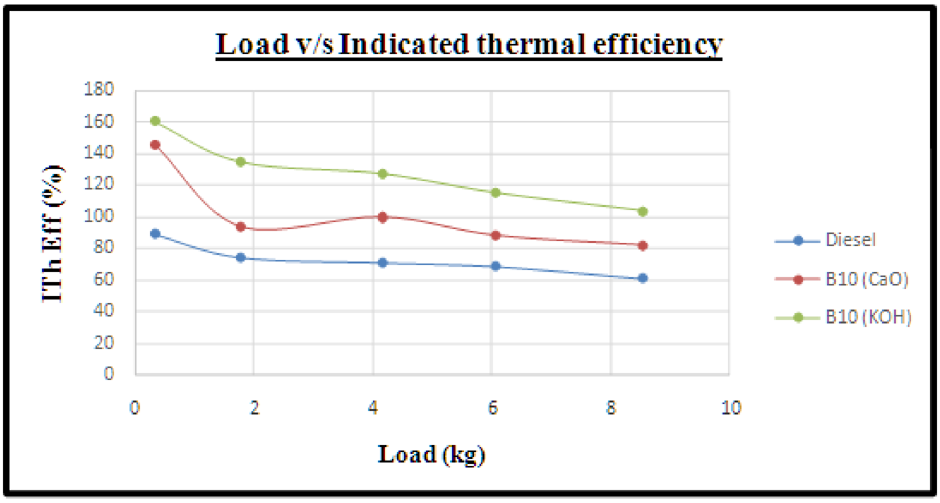

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Fig 4. Load v/s Indicated Thermal Efficiency

Fuel Flow: The variation of fuel flow is noticed with load for all the samples like diesel, B-10(KOH) & B-10(CaO). Here, in Fig.5 fuel flow increases with the load, but the B-10(CaO) shows higher readings along with Diesel, while the readings for B-10(KOH) are quite low.

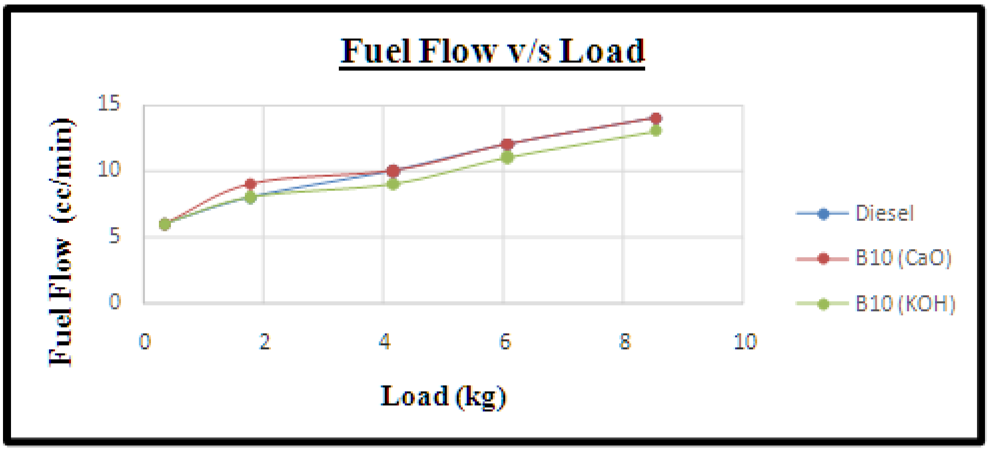

Fig 5. Load v/s Fuel Flow

V. CONCLUSION

The performance parameters for two samples of bio-diesel with B-10(KOH) and B-10(CaO) are investigated at various load points and the obtained results are then compared with the standard base data line for diesel sample. The parameters analyzed are fuel flow, indicated thermal efficiency (ITE), brake specific fuel consumption (BSFC), mechanical efficiency (ME) and brake thermal efficiency (BTE). The results reordered are as follows:

1. Brake thermal efficiency (BTE) for all the samples increases with increase in load due to better combustion at higher loads.
2. Brake thermal efficiency (BTE) for the CaO sample is quite low due to low calorific value, higher viscosity and higher density as compared to diesel which leads to low efficiency.
3. BSFC is found to have a higher value at low load condition but as the load increases it becomes constant for all the samples.
4. BSFC is found to have a lower value for the B-10(KOH) than the B-10(CaO) at low load condition.
5. As the load increases the BSFC decreases due to better quality of combustion and increasing brake power.
6. The mechanical efficiency for B-10(CaO) at higher loads is better as compared to Diesel and B10 (KOH). This can be attributed to better properties of CaO catalyst.
7. The trend noticed in the Indicated Thermal Efficiency is that the ITE is quite high for B-10(KOH) followed by the B-10(CaO) due to higher viscosity of biodiesel oil.
8. Fuel Flow increases for all the blends at higher loads since the fuel consumed is more at high load condition, here the B-10(CaO) and diesel shows higher readings than the B-10(KOH).

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