Performance and Experimental analysis of a Safflower biodiesel and Diesel blends on C.I. Engine

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Abstract - *Due to continuous increase in the dependency on fossil fuel and hiking its price because of fast depletion of petroleum resource and increasing environmental pollution have promoted to shift toward green energy source such as alternative renewable fuel which is obtain from biomass and animal fats. Biodiesel is an attractive alternative fuel for diesel engines. Biodiesel produced from edible and non-edible oil. However, as the production of biodiesel from vegetable oils and animal fats, there are concerns that biodiesel feedstock may compete with food supply in the long-term. Hence, the recent focus is to find oil bearing plants that produce non-edible oils as the feedstock for biodiesel production. The aim of this experimental investigation is to optimize biodiesel production from non-edible safflower seed oil followed by transesterification process. The performance of biodiesel obtained from safflower oil and its blend were measured and evaluated in four stroke, single cylinder, direct injection, water cooled diesel engine. The properties of biodiesel obtained from safflower oil and its blend with diesel fuel and additive at various extents are considered including engine tests. This investigation gives the comparative measures of brake power (BP), brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC).*

From the examination it can be presumed that biodiesel can be utilized as another option to diesel in a compression ignition engine without any engine modifications.

***Key Words*: Non-edible plant oil, Safflower, Transesterification, Biodiesel, Additive, Engine performance.**

1. INTRODUCTION

With the socio-economic growth of the society, the energy requirement has increased multifold globally as the consumption pattern in a particular country depends upon the availability of energy resources. The various sectors that require energy from some sources are industry, transport, agriculture, domestic etc. Different energy sources are wood, coal, petroleum products, nuclear power, solar, wind etc. [1–3]. Out of these, the world surface transport depends primarily on petroleum fuels. The overbearing dependence on petroleum products and related economic and environmental problems have created disquieting situation [4].

1.1 What is biodiesel

Biodiesel is an alternative fuel similar to conventional or fossil diesel. Biodiesel can be produced from edible or non-edible oil like straight vegetable oil, animal fats/oil, tallow and waste cooking oil. The process used to convert this oil to biodiesel is called transesterification.

1.2 Resource of biodiesel

Biodiesel mainly produced from vegetable oil, animal fat. We can divide source of biodiesel in two categories from edible and non-edible oil source.

1.3 Identification of Non-edible Seeds

A fuel produced from natural, renewable sources such as vegetable oil, seeds and fats is the best alternative to present source of energy produced from fossil resource. Initially, the most commonly used oils for the production of Bio-diesel were soya bean, sunflower, palm, rapeseed, canola, cottonseed and jatropha [5]
Biodiesel based on non-edible oil is best due to following reasons:

- Non-edible oil species, which can grow on wasteland.
- Can be cultivated as agro-forestry crops.
- Hardy plants have superior survivability under drought conditions.
- Yielding of seeds can be obtained over long period.

1.4 Properties of Safflower (*Carthamus tinctorius)*

Safflower Oil is extracted from the Safflower seeds (seeds of Carthamus Tinctorius). The seeds are white and contain a high amount of proteins and good fat. The oil extracted from safflower seeds is colourless and flavourless. Its nutritional value is comparable to sunflower oil. There are two types of edible oil one contains monounsaturated fatty acid (oleic acid) and second contains polyunsaturated fatty acids (high linoleic). It contains less saturated fatty acids than olive oil.

Fig.: 1.1Safflower

Safflower seed contain approximately 40% oil by its weight.

1.5 Oil Extraction Techniques

There are two main methods that have been identified for commercial oil extraction: (1) Mechanical extraction and (ii) Solvent extraction. Before the oil extraction takes place, seeds have to be dried. Seed can be either dried in the oven or sun dried. Mechanical expellers or presses can be fed with either whole seeds or kernels or a mix of both, but common practice is of using whole seeds. However, for chemical extraction only kernels are used as feed.

Fig.: 1.2 Safflower Seed

1.6 Objectives of present work

The proposed work has been conducted with biodiesel obtained from safflower oil with the following objectives.

1. Optimization of biodiesel production derived from safflower oil by transesterification process.

2. Determination of physicochemical properties of optimized biodiesel.

3. Evaluation of performance parameters such brake power, brake specific fuel consumption, brake specific energy consumption and brake thermal efficiency of safflower biodiesel blend fuels and comparison with petro diesel.

4. Comparative study of SOME blends fuels with diesel fuel.

2 MATERIALS AND METHODS

The present study deals with optimization of biodiesel production from safflower oil as well as evaluation of performance characteristics of six blends (Blend A, Blend B, Blend C, Blend D, Blend E, Blend F) of this oil methyl ester used in VCR engine. The optimized parameters for biodiesel production are methanol to oil molar ratio, catalyst concentration and time of reaction. The performance parameters have been studied in this experimental work namely brake power (BP), brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC),brake thermal efficiency (BTE).

2.1 Materials

The safflower seed oil was purchased from Balaji Export Pvt. Ltd, Durg, Chhattisgarh, India. All reagents such as methanol (GR grade, moisture<0.02%), ethanol (GR grade, moisture<0.02%) and analytical grade catalyst potassium hydroxide (KOH) were obtained from local chemical store and used as received.

2.2 Procedure of production of safflower oil methyl ester by transesterification process

- 200 g of safflower oil was taken in a 250 ml glass vessel and preheated up to 105-110 °C to remove the moisture content of oil and then allowed to cool up to 45-60 °C.
- Now methyl alcohol (CH_3OH) was taken with the distinct molar percentage 35% of oil and catalyst potassium hydroxide (KOH) was taken as 2 wt% (weight percent), of the oil taken. The methyl alcohol and catalyst KOH were mixed together.
- This homogeneous mixture of methyl alcohol and catalyst KOH is mixed with 200 g safflower oil.
- The conical flask containing the mixture of oil, alcohol and catalyst was heated at constant temperature 50-60 °C [6] and it was stirred simultaneously inside a water bath shaker its about 200 rev/min for 60 minute respectively.
- After completion of the reaction time, the products were poured into the separating funnel and kept 1-2 hour for separation of phases. In separating funnel, products were separated into two layers. Due to higher specific weight, glycerol was settled down at the bottom and the upper layer was biodiesel (Fig. 2.1). The glycerol was taken away.
- After separation, the biodiesel was then washed with hot distilled water in order to remove remained methyl alcohol, catalyst, and impurities present in biodiesel fuel.
- Finally, the biodiesel was placed in the hot air oven and heated at 100 °C to remove excess water content present in biodiesel fuel.

Fig 2.1: Separation of biodiesel and glycerine

2.3 Various Properties of Bio Fuel

CI engines are basically designed to run with Diesel as fuel, therefore it is necessary that the alternative fuels have properties close to that of diesel, because the large variation in properties of fuel may lead to erratic running of engine and may cause damage to the engine and poor performance.

Table 2.1: Property test results of Diesel, Safflower Biodiesel, Methanol, Ethanol.

Properties	Density (kg/m^3)	Calorific value (KJ/kg)	Kinematic viscosity (mm^2/sec)	Flash point (°c)
Diesel	830	42800	3.6	86
Methanol	792	19800	.68	12
Ethanol	790	28500	1.5	17
Safflower Biodiesel	860	32629	5.67	176

Properties of Safflower biodiesel is tested from Raipur institute of technology, Raipur (C.G.). The testing method of Calorific value, kinematic viscosity, Flash point is ASTM D240, ASTM D445, ASTM D93 respectively.

2.4 Preparation of Blends

Total six different blends are produced and properties test is done for all blends sample.

The blends are;

Blend A (5% Methanol + 5% Safflower biodiesel + 90% Diesel),

Blend B (5% Methanol + 10% Safflower biodiesel + 85% Diesel),

Blend C (5% Methanol + 15% Safflower biodiesel + 80% Diesel),

Blend D (5% Ethanol + 5% Safflower biodiesel + 90% Diesel),

Blend E (5% Ethanol + 10% Safflower biodiesel + 85% Diesel),

Blend F (5% Ethanol + 15% Safflower biodiesel + 80% Diesel)

The below table show the properties of six different blends.

Table 2.2: Properties of six different blends

Type of blend	**Amount of Methanol/ Ethanol over 1000 ml**	**Amount of Biodiesel over 1000 ml**	**Amount of Diesel over 1000 ml**	**Density (kg/m^3)**	**Calorific value (KJ/kg)**
Diesel	0	0	1000	830	42800
Blend A	50	50	900	829.6	41141.45
Blend B	50	100	850	831.1	40632.9
Blend C	50	150	800	832.6	40124.35
Blend D	50	50	900	829.5	41576.45
Blend E	50	100	850	831	41067.9
Blend F	50	150	800	832.5	40559.35

2.5 Performance Test

Engine performance is an indication of how well the engine performs its assigned task, i.e. the conversion of the chemical energy contained in the fuel into the useful mechanical work. The engine performance parameters, which we going to use in this thesis works are;

Brake power, Brake thermal efficiency, Brake Specific fuel consumption, Brake Specific Energy Consumption.

- **Brake power (BP)**

The power developed at the output shaft of the engine is termed as Brake Power; it is the power available at the crankshaft of the engine.

- **Brake thermal efficiency (BTE)**

It is the ratio of output shaft power (Brake power) to the Heat input supplied to the engine. It can also understand as brake power of a heat engine as a function of the thermal input from the fuel. It is used to assess how well an engine converts the heat from a fuel to mechanical energy.

- **Brake Specific fuel consumption (BSFC)**

It is defined as the ration of fuel consumed per unit time to power output. It is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational or shaft power.

- **Brake Specific Energy Consumption (BSEC)**

It is defined as the ration of Energy consumed per unit time to power output. It means how efficiently fuel energy obtained from given fuel.

2.6 Experimental Test Rig

The test rig -consist of a four stroke diesel engine connected to a hydraulic dynamometer brake through a flexible coupling. The engine is water cooled type and therefore both load test as well as heat balance sheet can be conducted. It runs at a maximum speed of 1500 rpm. The test rig is complete with base, air measurement system, and fuel measurement system and temperature measurement arrangement using thermocouples to measure temperature digitally.
The various components of experimental setup are described below.

2.6.1 The Engine

The engine used to carry out experimentation is a single cylinder, four stroke, vertical, water cooled, Kirloskar make CI engine.

Table2.3: Specification of Engine

Make	Kirloskar
Speed	1500 rpm
No. Of cylinder	01
Compression ratio	16:5:1
Bore	80 mm
Stroke	110 mm
Brake Horse Power	5 H.P.
Loading	Hydraulic Dynamometer
Cooling	Water cooled

2.6.2 Dynamometer

The hydraulic dynamometer is used for the experiments. Loads increased by closing the valve of dynamometer loads calculated by spring balance and the distance between dynamometer shafts center to center of spring balance in meters is 0.34. This distance can be used for calculation of torque.

Figure 2.2: Engine where experiment performed

Figure 2.3: Hydraulic Dynamometer

Fig.2.4: Required fuels for blend preparation

2.7 Formulae used

Formula used for calculation of various parameters is described below:

1) Quantity of fuel used,

$$m_f \text{ (kg/sec)} = \frac{X(ml)}{t(sec)} \times \frac{S.G.}{1000}$$

Where X (ml) = Volume of fuel consumed
"t" = time taken for X(ml) of fuel consumed
S.G. = Specific gravity of fuel

2) Brake power output,

$$B.P. = \frac{2\pi NT}{60000} \quad \text{(KW)}$$

Where, T = Torque in (N-m) = P × r × 9.81
P = Net load in (kg)
r = Distance between dynamometer shaft centre of spring balance (meter)
N = Rated RPM of the engine

3) Brake specific fuel consumption,

$$B.S.F.C. = \frac{m_f \times 3600}{B.P.} \quad \text{(kg/KW-hr)}$$

4) Heat Supplied to the engine,

$$Q_f = m_f \times C.V. \quad \text{(KW)}$$

Where, C.V. = Calorific Value of fuel (KJ/kg)

5) Brake Thermal Efficiency,

$$\eta_{BTE} = \frac{B.P.}{Q_f}$$

6) Brake specific Energy Consumption,

$$B.S.E.C. = \frac{B.S.F.C. \times C.V.}{1000} \quad \text{(MJ/KW-hr)}$$

2.8 Performance Evaluation

To assess the present condition of the engine a constant speed test with diesel as a fuel was carried out and base line data were generated. Now for the different loads time taken for consumption of 10 ml of fuel, RPM of shaft and temperature values are noted down. After performing test with fuel pure diesel, the test were performed with Blend A (5% Methanol + 5% Safflower biodiesel + 90% Diesel), Blend B (5% Methanol + 10% Safflower biodiesel + 85% Diesel), Blend C (5% Methanol + 15% Safflower biodiesel + 80% Diesel), Blend D (5% Ethanol + 5% Safflower biodiesel + 90% Diesel), Blend E (5% Ethanol + 10% Safflower biodiesel + 85% Diesel), Blend F (5% Ethanol + 15% Safflower biodiesel + 80% Diesel).

3 RESULTS AND DISCUSSIONS

3.1 Performance Characteristics for Diesel as compared with Blend A, Blend B and Blend C

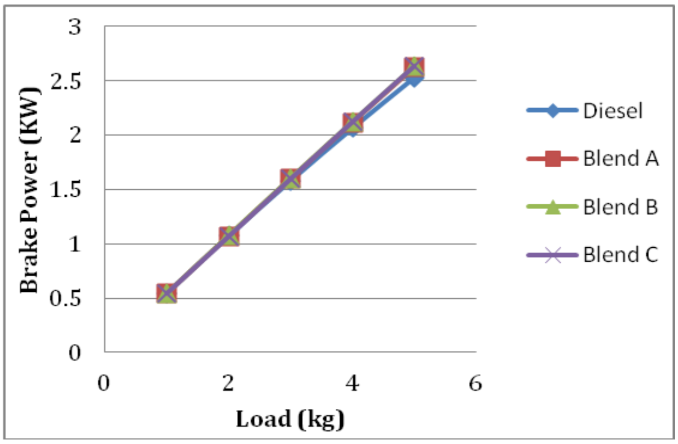

Figure 3.1: BP v/s Load for Diesel, Blend A, Blend B, Blend C

Figure 3.1 shows the variation of brake power with respect to load for different biodiesel blends. The results show that Brake power of biodiesel blends, Blend A and Blend B and Blend C shows approximately same value and it is very close to diesel. But when load increased BP of all three Blends indicates somewhat more value of BP as compare to Diesel.

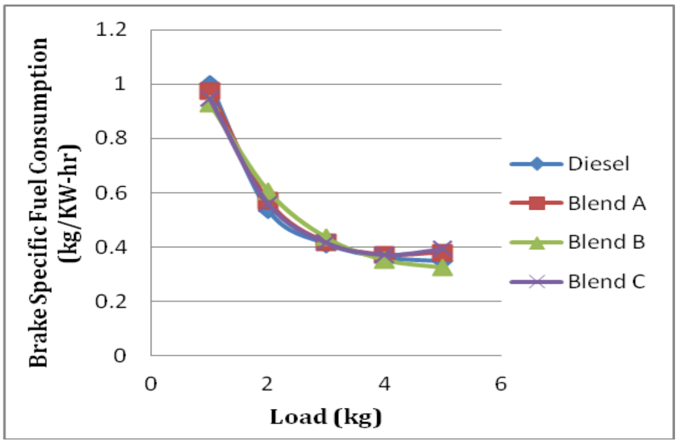

Figure 3.2: BSFC v/s Load for Diesel, Blend A, Blend B, Blend C

Figure 3.2 shows the variation of brake specific fuel consumption with respect to load for different blends. The brake specific fuel consumption for all blends of biodiesel shows the same trend as diesel fuel whereas the

BSFC for Blend A and Blend C is more than Blend B. And BSFC for Blend B is even more than diesel at middle load conditions but at higher loads Blend B shows least BSFC.

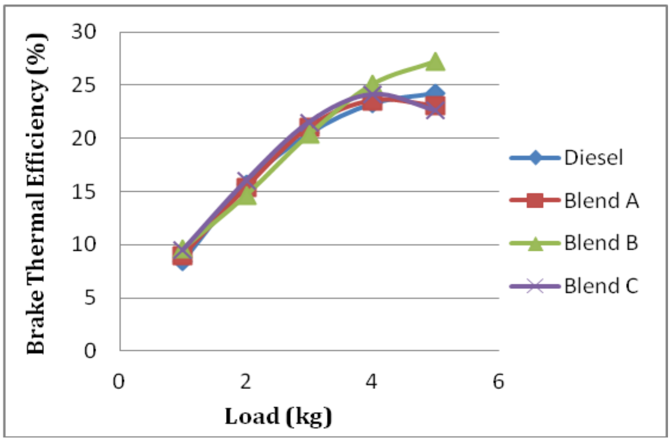

Figure 3.3: BTE v/s Load for Diesel, Blend A, Blend B, Blend C

Figure 3.3 shows the variation of brake thermal efficiency with respect to load for different blends. The results show that brake thermal efficiency for all blends of biodiesel shows the same trend as diesel fuel whereas the BTE for Blend B is less than among Blend A and Blend C. But BTE for Blend B is even less than diesel at middle load condition but at higher loads BTE of Blend B is highest.

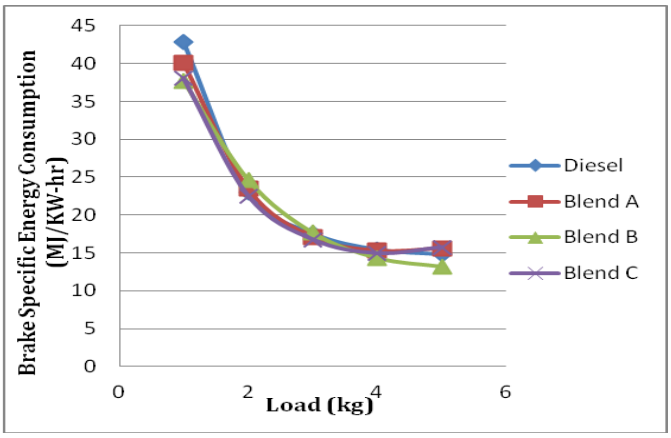

Figure 3.4: BSEC v/s Load for Diesel, Blend A, Blend B, Blend C

Figure 3.4 shows the variation of brake specific energy consumption with respect to load for different blends. The results show that brake specific energy consumption for all blends of biodiesel follow the same trend as diesel fuel whereas the BSEC for Blend A Blend B and Blend C is less then Diesel at low load condition. At middle loads

Blend B shows the more brake specific energy consumption with respect to all but at higher loads BSEC is lowest.

3.2 Performance Characteristics for Diesel as compared with Blend D, Blend E and Blend F

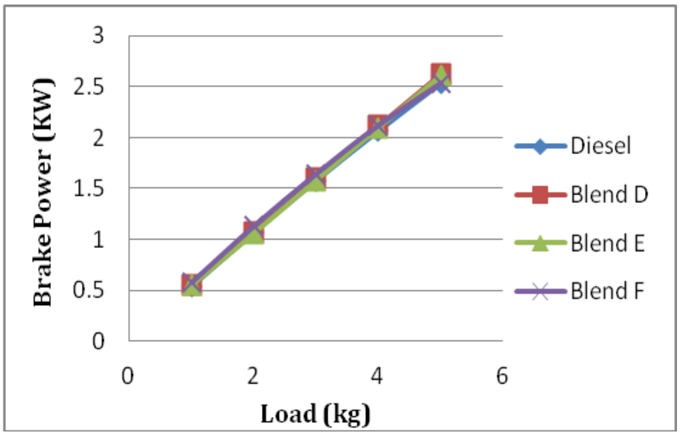

Figure 3.5: BP v/s Load for Diesel, Blend D, Blend E, Blend F

Figure 3.5 shows the variation of brake power with respect to load for different blends. Brake power of all biodiesel blends say Blend D, Blend E and Blend F are found approximately same and very close to diesel.

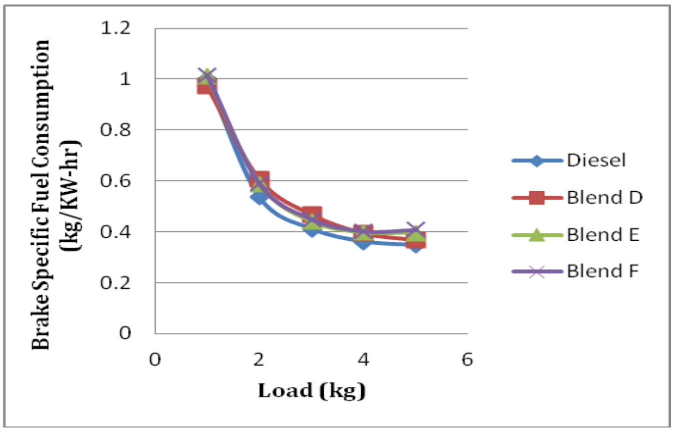

Figure 3.6: BSFC v/s Load for Diesel, Blend D, Blend E, Blend F

Figure 3.6 shows the variation of brake specific fuel consumption with respect to load for different blends. The brake specific fuel consumption for all blends of biodiesel follows the same trend as diesel fuel at initial conditions. Pure Diesel shows the least brake specific fuel consumption as compared to Blend D, Blend E and Blend F. And BSFC for Blend D is close to diesel when compared with Blend E and Blend F at higher loads.

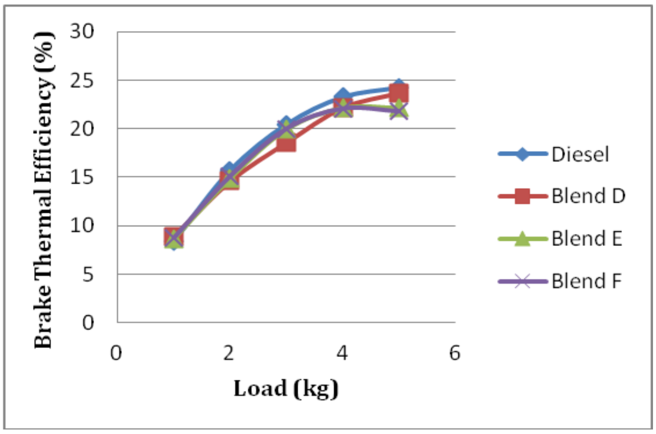

Figure 3.7: BTE v/s Load for Diesel, Blend D, Blend E, Blend F

Figure 3.7 shows the variation of brake thermal efficiency with respect to load for different blends. The brake thermal efficiency for all blends of biodiesel follows the same trend as diesel fuel at low load conditions. Pure Diesel shows the highest brake thermal efficiency as compared to Blend D, Blend E, Blend F. BTE for Blend D is close to diesel when compared with Blend E and Blend F at higher loads.

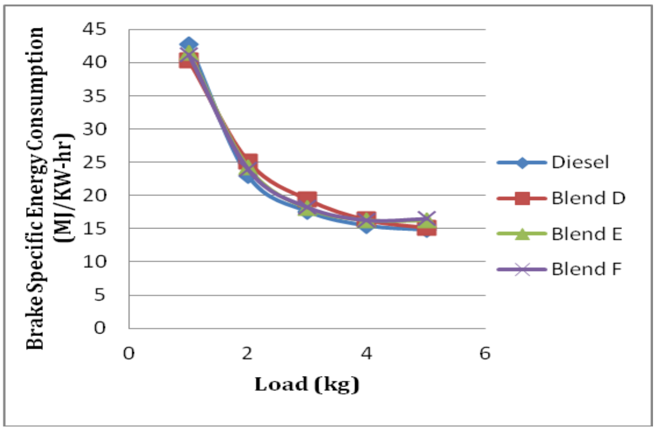

Figure 3.8: BSEC v/s Load for Diesel, Blend D, Blend E, Blend F

Figure 3.8 shows the variation of brake specific energy consumption with respect to load for different blends. The brake specific energy consumption for all blends of biodiesel follows the same trend as diesel fuel at low load. Pure Diesel shows the least brake specific energy consumption as compared to Blend D, Blend E, Blend F at middle load. BSEC of Blend D is close to diesel when compared with Blend E and Blend F at higher load.

4. CONCLUSIONS

The performance characteristics of a single cylinder four stroke diesel engine with blend of Safflower biodiesel, Diesel and additive as fuel are experimentally investigated and compared with diesel. It is observed that, the viscosity and density of the blend goes up with increased percentage of biodiesel. However its calorific value is reduced and it gives reduced energy per litter as the biodiesel percentage increases. The salient observations are,

- Safflower biodiesel + diesel can be directly used in diesel engine without any engine modification.
- Brake Power increases with an increase in biodiesel concentration with load increases.
- Brake Specific fuel Consumption decreases in the case of blend A and blend C, but it is increases with rest of them.
- Brake Thermal Efficiency increases in the case of blend B and blend D.
- Brake Specific Energy Consumption decreases in the case of blend B, but it's approximately same as diesel in rest of them.

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