Journal of Mines, Metals and Fuels, *71(10): 1657-1662; 2023. DOI: 10.18311/jmmf/2023/35864*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.com/index.php/jmmf*

Identification of Different Features of the Reported Alternative Fuels using Exploratory Data Analysis (EDA)

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Abstract

To reduce the carbon footprint in automobiles and other allied industries and to get rid of the dependency on exhaustible fossil fuels, researchers have been searching for alternatives to gain widespread acceptance. There are many performance and emission parameters on which a particular fuel (authentic/alternative) is dependent in terms of acceptability. So far, many researchers have reported a huge number of biofuels or biofuel blends that can be used as an alternative. In this study, the potential alternative fuels or biofuel blends are reviewed which were reported in different literature and are considered for Exploratory Data Analysis (EDA). An entire report is presented based on the features, this may help to identify biofuels for different operations. The correlations between the features are also investigated in this study, as well.

Keywords: *Alternative Fuels, Bio-Fuels, Correlation, Exploratory Data Analysis, Statistics*

1.0 Introduction

As per the statistics, the global production of ethanol, bio-diesel, and Hydrotreated Vegetable Oil (HVO) is being increased since 2019. In 2019 the production was 115 billion liters, 41 billion liters, and 7 billion liters for ethanol, bio-diesel, and Hydrotreated Vegetable Oil (HVO), respectively. Whereas, it is forecasted that 119 billion liters, 46 billion liters, and 17 billion liters would be produced by 2023-2025[1]. It indicates that the demand of using alternative fuels is increasing with time as the blends can be used to get equivalent emission and performance outcomes. Many researchers pointed out that the usage of alternative fuels promotes sustainable development and it might help to reduce the emission of greenhouse gases[2]. It has been observed that the Engine Power (BP) got reduced when bio-fuel was fed to the engine cylinder. Due to low heating value, viscosity, and density the fuel consumption happens to be on the higher side in the case of biofuels compared to authentic diesel and again, it is concluded in a few kinds of literature that biofuel helps to reduce carbon deposit and the wear of the internal engine parts. PM emission is noticeably reduced for biofuels because it has high oxygen content and fewer aromatic compounds[3]. The effect of Karanja biodiesel on tribological properties of lubricating oil in a compression ignition engine by Dhar and Atul[4]. Emission characteristics of Mahua and linseed biodiesel operated at varying injection pressure on the CI engine has been analysed[5]. Kamboj and Kirimi compared performance parameters with the use of ethanol and methanol fuel blends on SI engine[6]. Czerwinski analysed performance of Diesel engine and reported that ethanol decreases particulate emissions, increases ignition delay due to the lower cetane number and shortens combustion duration[7].

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Zhu *et al.*[8] analysed the effect of dimethoxy-methane and exhaust gas recirculation on combustion emission.

High NO_x emission has been observed for biofuels as it has a higher oxygen content but lower cetane number and different injection characteristics can be the reasons among many, due to the lower carbon to hydrogen ratio, the CO emission is observed to be reduced for biofuels. Many researchers across the globe have investigated that different blends could help to get different outcomes depending on the operational criteria. There are so many different types of biofuels reported and each biofuel/ biofuel blend exhibits different performance and emission characteristics depending on the operational parameters. In this study, a complete Exploratory Data Analysis (EDA) is carried out to know the insights of the data that were reported in previous works of literature.

EDA is an approach to analyzing a dataset to bring out insights and summarize the characteristics, sometimes visual methods are used with this. It helps to identify the different patterns, oddities, and relations . It is advisable to practice EDA before making any ML model. The steps of EDA are –

Observe the dataset
Check the total number of entries
Check any null values
Check duplicate entries
Plot distribution of numeric data

2.0 Analysis and Results

In the first stage of this analysis, a few popular and effective bio-fuels were considered and their characteristics were tabulated. The correlations are calculated among the parameters and the outliers are identified. Then, by using the data visualization technique was applied to bring out insights into the dataset. The source dataset and the correlation table are mentioned below (Table 1).

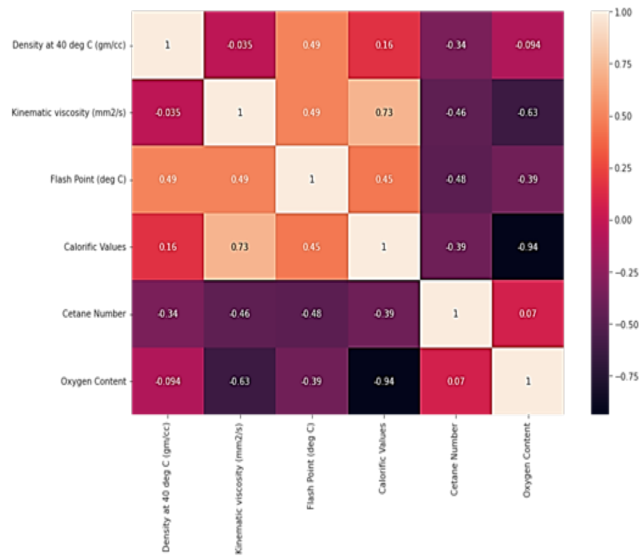

Figure 1. Heat map of the correlations between all the features.

Table 1. Source Dataset: Different important properties of a few reported alternative fuels

Fuel	Density at 40 deg C (gm/cc)	Kinematic viscosity (mm^2/s)	Flash Point (deg C)	Calorific Values	Cetane Number	Oxygen Content
Diesel	0.83	2.7	57	42000	45	0
Jatropha biofuel	0.855	4	135	34220	53	11
Karanja biofuel	0.797	7	97.8	37120	51	12
Neem biofuel	0.61	5.96	110	38150	48	10
Linseed biofuel	0.88	3.32	196	37251	45	
Diethyl ether	0.704	0.23	35	26589	135	21
Dimethyl ether	0.67	1.84	41	28882	62	34
Ethanol	0.789	0.7893	74.4	26900	54	34.8
Methanol	0.792	0.599	64.9	20000	50	49.9

Table 2. Correlation table among the parameters of the source dataset

Correlation	Density at 40 deg C (gm/cc)	Kinematic viscosity (mm²/s)	Flash Point (deg C)	Calorific Values	Cetane Number	Oxygen Content
Density at 40 deg C (gm/cc)	1	-0.034764404	0.49333135	0.162482	-0.33991	-0.0937
Kinematic viscosity (mm2/s)	-0.034764404	1	0.492580793	0.725152	-0.4623	-0.62981
Flash Point (deg C)	0.49333135	0.492580793	1	0.451807	-0.47842	-0.3855
Calorific Values	0.162482268	0.725151989	0.451806905	1	-0.38685	-0.93897
Cetane Number	-0.339912339	-0.462303386	-0.478418062	-0.38685	1	0.06963
Oxygen Content	-0.093702361	-0.629814132	-0.385497471	-0.93897	0.06963	1

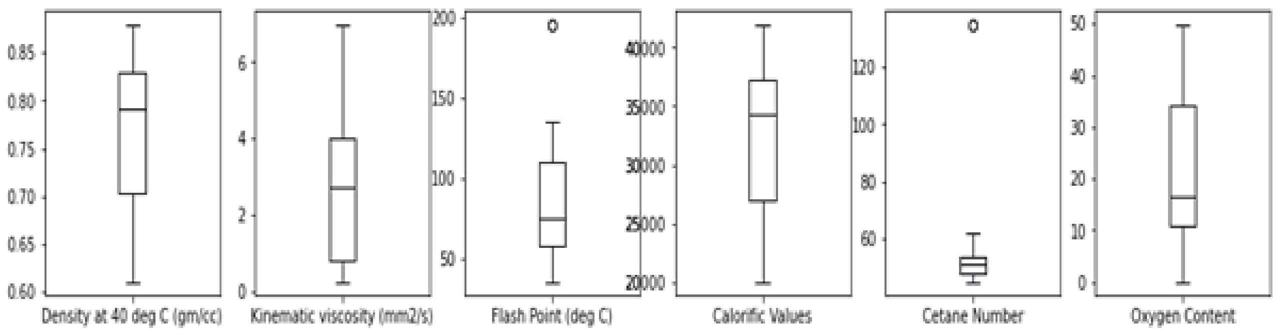

Figure 2. Boxplots of the attributes to identify the outliers.

Table 3. Description of the source dataset based on different statistical attributes

	Density at 40 deg C (gm/cc)	Kinematic viscosity (mm2/s)	Flash Point (deg C)	Calorific Values	Cetane Number	Oxygen Content
count	9	9	9	9	9	8
mean	0.769667	2.937589	90.12222	32345.78	60.33333	21.5875
std	0.089759	2.387191	51.36886	7110.495	28.47806	16.62566
min	0.61	0.23	35	20000	45	0
25%	0.704	0.7893	57	26900	48	10.75
50%	0.792	2.7	74.4	34220	51	16.5
75%	0.83	4	110	37251	54	34.2
max	0.88	7	196	42000	135	49.9

The correlation is a statistical measure to express the relationship among the independent features. Here, the correlation analysis has been done to understand the relationship among the reported features. The result is tabulated in Table 2.

The heat map of the correlations is presented to understand the inter-relationships among all the attributes of the source dataset, visually (Figure 1).

Now, plotting the boxplots, we can have an idea about the outliers, we have identified and omitted the outlier data points for further analysis (Figure 2).

Now, the pair plots provide us with an understanding of the relationship between the attributes of the source data set (Figure 3).

The reported alternative fuels are visually analysed using matplotlib, based on the attributes. The representations are outlined in Figure 4.

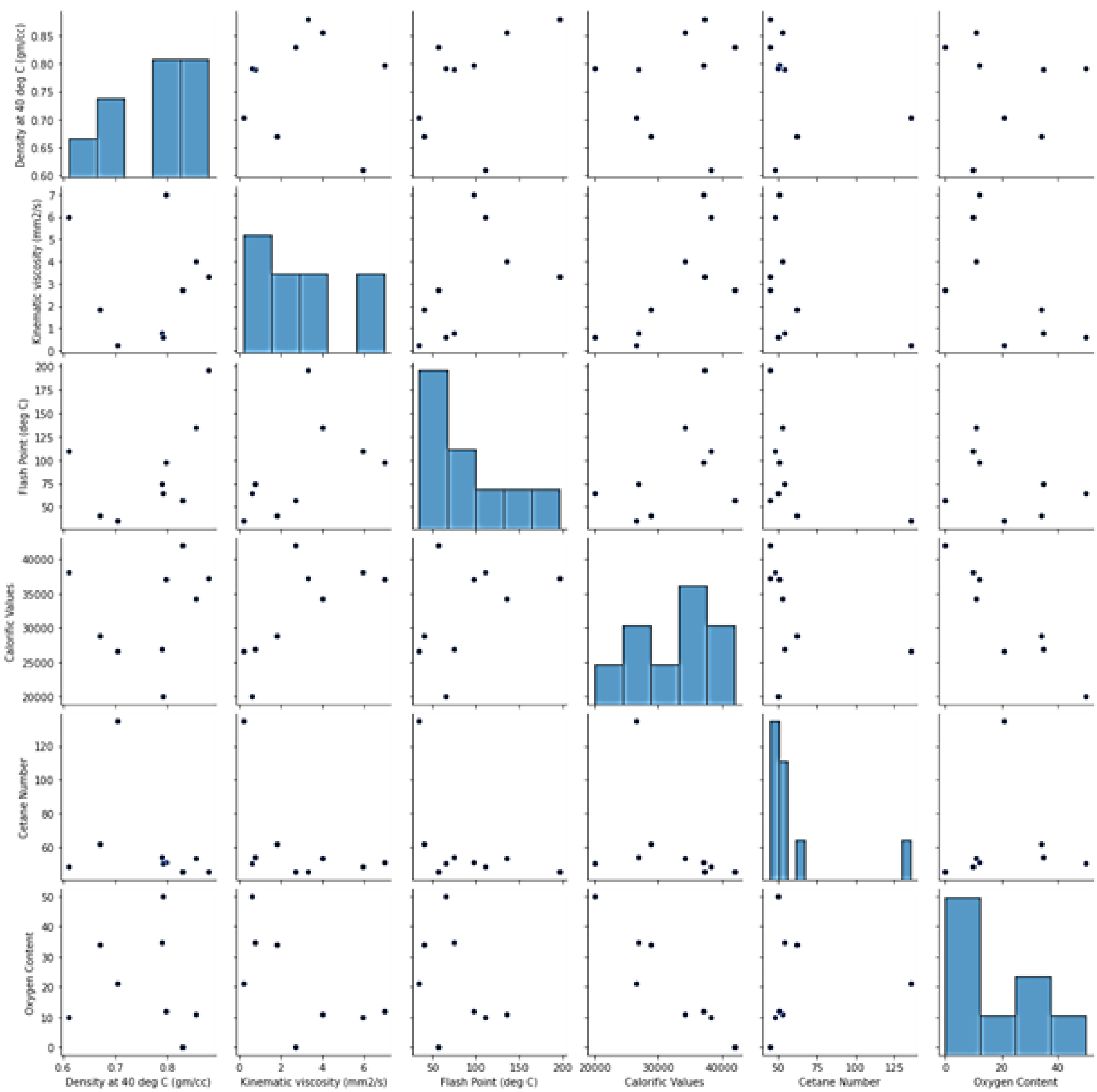

Figure 3. Pairplots between the attributes.

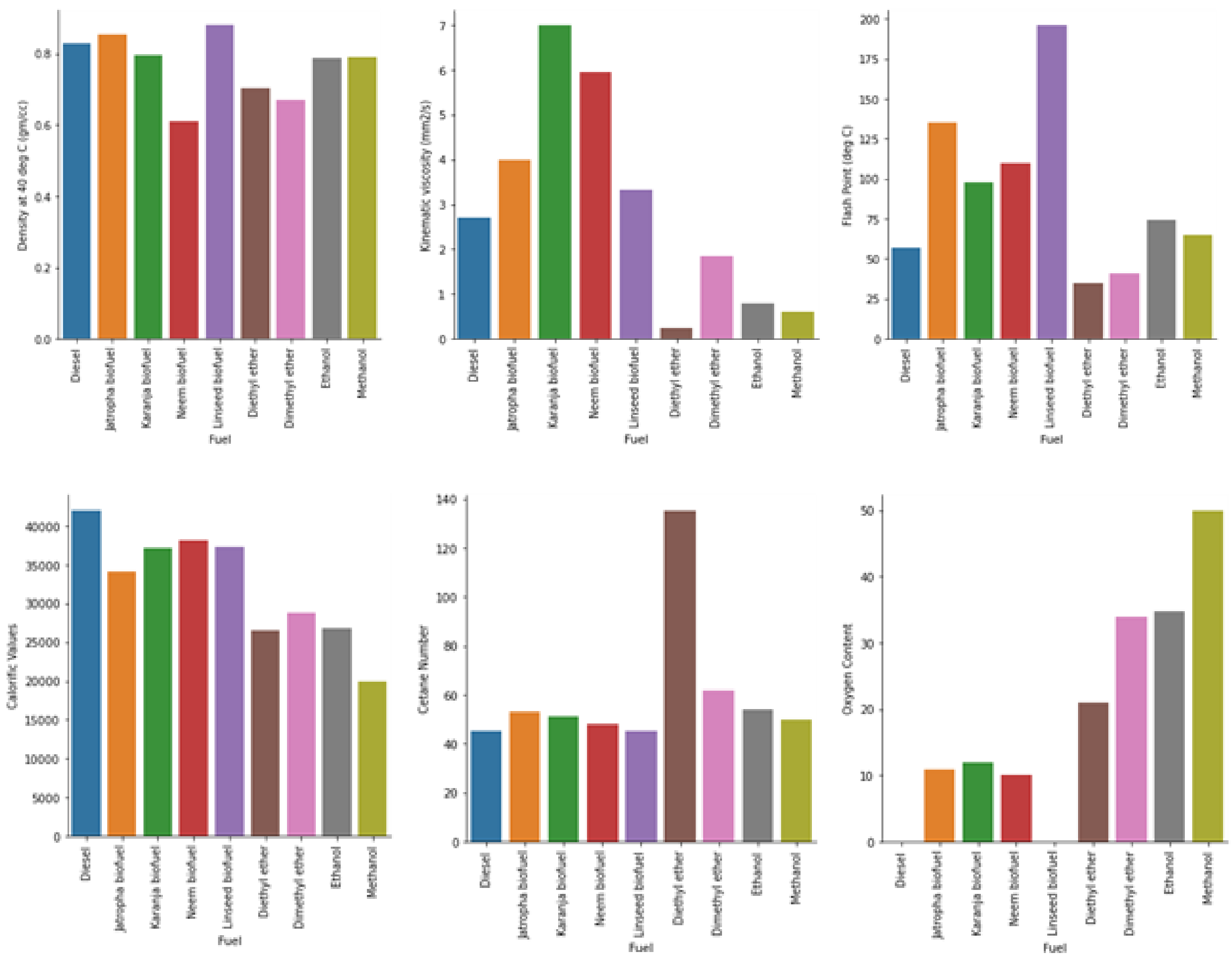

Figure 4. The comparative analysis among the reported alternative fuels based on the attributes.

The entire data has been tabulated in terms of different statistical attributes in Table 3.

3.0 Conclusions

For better combustion, density plays an instrumental role. Higher density promotes NOx emission and in the source dataset, neem bio-fuel exhibits lesser density (0.61 gm/cc) among all the reported bio-fuels and it is observed that it is highly correlated to the flash point.

As lower viscosity of fuel improves fuel economy and reduces greenhouse gas emission, diethyl ether shows the least viscosity among all and it has got a strong correlation with the calorific value.

With the increment of the cetane number, the temperature inside the cylinder increases which helps to increase the oxidation rate. Consequently, the emission of unburnt HCs and specific fuel consumption is reduced. Diethyl ether exhibits the best cetane number among all the potential bio-fuel and it has got a strong correlation with the kinematic viscosity.

EDA helps us to recognize particular features of the above alternative fuels depending upon operational criteria.

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