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COMPARISON OF PERFORMANCE AND EMISSION CHARACTERISTICS ON MADHUCA INDICA LONGIFOLIA (MAHUA) BIO DIESEL-DIESEL BLENDS AT DIFFERENT COMPRESSION RATIO USING RESPONSE SURFACE METHODOLOGY

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Abstract : Mahua oil methyl ester was synthesized from mahua oil using trans-esterification with potassium hydroxide as a catalyst. The essential fuel attributes of mahua biodiesel blends were compared to those of full speed diesel and biodiesel standards. The variation of specific fuel consumption (BSFC), brake thermal (BTE), Pmax, CO, NOx, hydrocarbon, and smoke opacity across compression ratio, blending ratio, and load was effectively analyzed utilizing response surface approach based on a Central composite rotatable design. Trends corresponding to the general theory of compression ignition engines (CI) were obtained. Optimal performance and emission parameters were found by taking into account the key variables impacting the diesel engine. During the procedure, Analysis of variance was analyzed to calculate both 'F' and 'P' values for absorbed variance data and the value of 'F' was 54.28% B20 at CR 14 blend and the 'P' value was <0.0001 whereas the break thermal efficiency was 42.19% and the specific fuel consumption was noted 0.09 Kg/kWhr at load 9kg. At optimal input variables, a significant decrease in emissions was seen at a blending ratio of 23% when compared to neat diesel.

IndexTerms - Mahua Bio Diesel, ANOVA, Transesterification, Performance, Compression Ratio

INTRODUCTION

M. Thirumarimurugan Et al [1] suggests converting waste sunflower oil into biodiesel using a process named Transesterification using an alkali catalyst. As we know that sunflower is the leading oilseed crop and biodiesel is gaining more importance as an alternative fuel. During the process sodium hydroxide (na) is used as an alkaline catalyst and the characteristics of the biodiesel produced were studied. According to Eman N. Ali and Cadence Isis Tay [2], biodiesel is an alternative fuel that may be produced from domestic natural resources like as palm oil, soybeans, rapseeds, coconuts, and even recycled cooking oil. Because of high petroleum costs, there has been an increase in interest in biodiesel, and the bulk of biodiesel produced today is created by a process known as transesterification with methanol. Siddharth Jain et al [3] investigated reports on the two-step Transesterification process from waste cooking oil, which is carried out at a pre-determined optimal temperature for both esterification and transesterification by employing both acidic (Methanol) and basic (NaOH) components. The results showed that both processes are first-order rate reactions.

Zahira Yaakob et al [4] explored how biodiesel is produced using a technique known as microwave-assisted transesterification, with the oil utilized being Jatropha oil and waste palm oil in the presence of methanol and sodium hydroxide. The effect of catalyst amount, reaction temperature, and time on biodiesel yield was examined. Ragul Karthick Elango Et al [5] discovered that batch scale biodiesel manufacturing was carried out using castor oil and a method known as transesterification. The usual approach was used to optimize parameters such as reaction duration, catalyst concentration, reaction temperature, and oil-methanol molar ratio. Simple evaporation and adsorption procedures were used for purification

According to Avinash Kumar Agarwal and Atul Dhar, [5] he use of biofuel in DICI engines is problematic due to excessive viscosity and instability. However, the experimental investigates the performance, emission, and combustion characteristics of Karanja oil blends on DICI engine at varied speeds and constant loads. M. Mani Et al [6] demonstrated that the oil and oil qualities obtained from waste plastic solid are compared with biodiesel properties and evaluated in terms of performance, emission, and combustion characteristics of waste plastic oil. Thus, it was established that a steady performance with brake thermal efficiency and emissions such as CO2, Co, and unburned hydrocarbons. The MOME fuel qualities acquired by V. Ranjith Kumar Et al [7] were compared with ASTM and DIN standards, but they were equivalent with diesel fuel. The chemical makeup is similar to that of non-edible oil. They investigated the performance, emission, and combustion characteristics of MOME at various loads and compared it to diesel. Ali et al [8] evaluated a catalytic method for biodiesel at catalyst concentration on both the pyrolysis temperature range and biodiesel production. The results indicate that NaOH was more successful than KOH catalyst in terms of energy consumption. The biodiesel was then mixed at various ratios and tested in a CI engine to observe various characteristics at an engine load of around 50%.

J. Galinodo Et al [9] studied to analyze the exhaust gases' thermal energy saving on engine dynamic performance during load transient of high-speed DI diesel engine. This analysis was performed on a 4-2-1 pulse exhaust manifold, which is manufactured and tested on an engine at constant speed loads, Finally, they concluded with the optimum design that not only improves engine transient performance. T. Noguchi Et al [10] examined in the finite element method is applied to predict transient temperature distribution and thermal stress and deformation in both elastic and plastic ranges. The predicted results showed good results with measured ones. Ali found Et al [11] describe a catalytic process for biodiesel at catalyst concentration on both the pyrolysis temperature range and biodiesel yield were investigated. The result suggests NaOH was more effective than KOH catalyst on the bases of energy consumption, the biodiesel was subsequently blended at various ratios, and later tested in a CI engine to observe various parameters at an engine load of about 50%.

Harveer Singh Pali Et al [12] describes us that biodiesel is referred to as alternate fuel for CI engine but its fuel is restricted compared to diesel due to its cost and quality parameters. Kusum oil is used to produce biodiesel by a process named transesterification. In present [work case the model is optimized through Response surface method (RSM) using MINITAB 17. Aditya Kolakoti Et al [13] suggests us that for obtaining maximum mahua oil biodiesel yield four important parameters were studied and optimized using Box Behnken assisted response surface method (RSM) and genetic algorithm (GA). For this purpose, 27 experiments were conducted using statistical software Minitab 2019. The obtained biodiesel from the transesterification process is blended with standard diesel and is tested for different fuel properties.

Katcoine s. Moreira Et al [14] described the residual babassu and Morozym0 435 Arce were investigated to obtain biodiesel. RSM and Central composite design were used to optimize the esterification and study the effects of four factors such as molar ratio, biocatalyst content, reaction time, and temperature en tee conversion into fatty acid ethyl extras, under optimized conditions it was 96-8% It was found et 9 mare num a very small change of activity of 587. Annam renita et al [15] illustrated that production of biodiesel from the brown seaweed to obtain algal oil, it was transerterified using methanol and sodium hydroxide and optimized by design- expert software version 8.0.7.1. The effect such as temperature, time and oil alcohol ratio were investigated by response surface methodology using central composite design. T. Ganapathy et al [16] investigated the influence timing, load torque and engine speed on the performance & emissions. To optimize these parameters using RSM for Jatropha biodiesel in a Diesel engine. evaluated the experimented parameters were designed by using full factorial design with 27 runs.

MATERIALS AND METHODS

Two stage transesterification

Transesterification is the general term used to describe the important class of organic reactions, where the esters are be transformed into another through interchange of alkyl groups. This is also called as alcoholysis. The transesterification is an equilibrium reaction and the transformation occurs by mixing the reactants. However, with the presence of a catalyst accelerates considerably by the adjustment of equilibrium condition in reaction and equation for transesterification is given below.

$$\mathbf{RCOOR' + R''OH \longrightarrow RCOOR'' + R'OH}$$

Triglyceride is the primary component of vegetable oils. Triglycerides make up 90-98 percent of vegetable oils, with minor quantities of mono, diglycerides, and free fatty acids. The triglyceride combines with alcohol in the presence of a strong acid or base to produce a combination of fatty acid alkyl esters and glycerol during transesterification of vegetable oils. Excess alcohol is utilized, however, to enhance the output of alkyl esters and to facilitate phase separation from the produced glycerol.

The kind of catalyst (base or acid), vegetable oil molar ratio, temperature, purity of the reactants (primarily water content in alcohol), and free fatty acid levels all have an impact on the transesterification process. The transesterification of vegetable oils progresses quicker in the base-catalyzed reaction than in the acid-catalyzed reaction when alkaline catalysts are used, which are less corrosive than acidic substances. In the first stage of the reaction. the base reacts with alcohol to create alkoxide and the protonated catalyst. The diagram below depicts the process of producing biodiesel. Glycerol is produced and must be removed from biodiesel. Alcohol must be removed and recycled from both glycerol and biodiesel. To eliminate undesirable side products, mainly glycerol, that may remain in the biodiesel, water is added to both the biodiesel and the glycerol. The wash water is separated from the biodiesel in a manner similar to solvent extraction (it contains some glycerol), and the trace water is evaporated. To create neutralized glycerol, acid is applied to the glycerol.

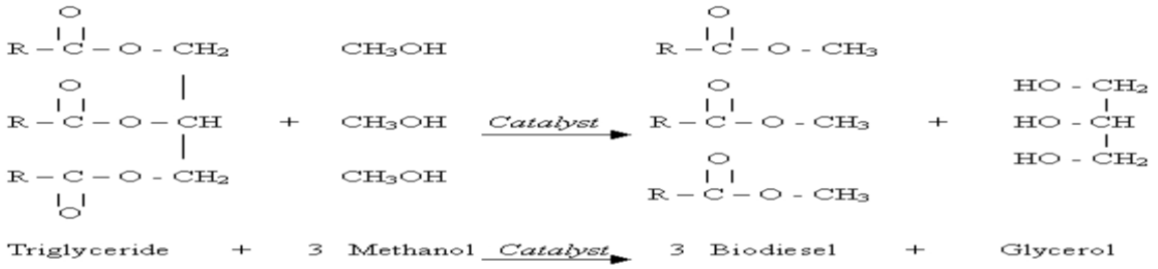
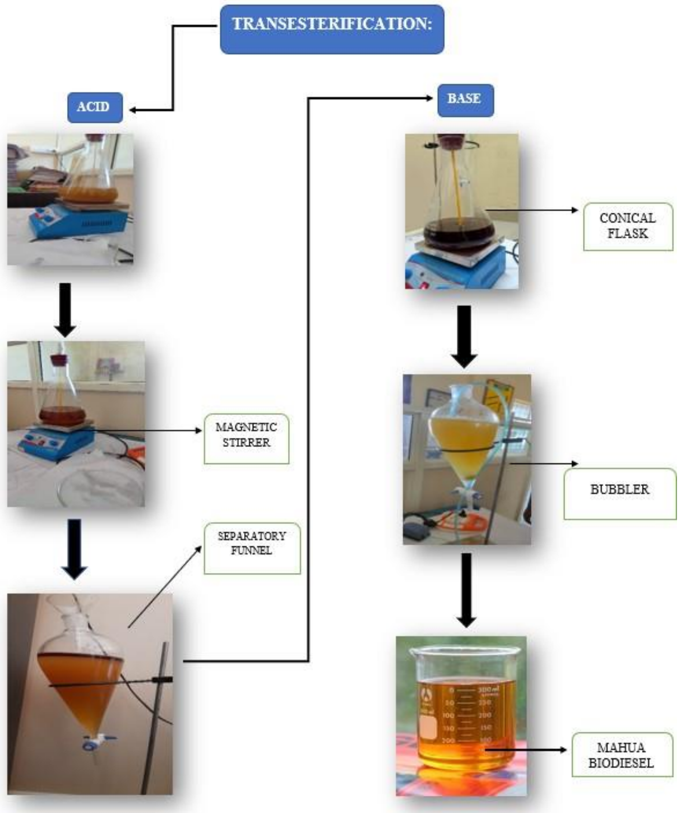

Catalyst
Triglyceride + 3 Methanol Catalyst 3 Biodiesel + Glycerol

Figure 1


TRANSESTERIFICATION:
ACID
BASE
CONICAL FLASK
MAGNETIC STIRRER
BUBBLER
SEPARATORY FUNNEL
MAHUA BIODIESEL

RESULTS AND DISCUSSION

4.1 Load Vs specific fuel consumption

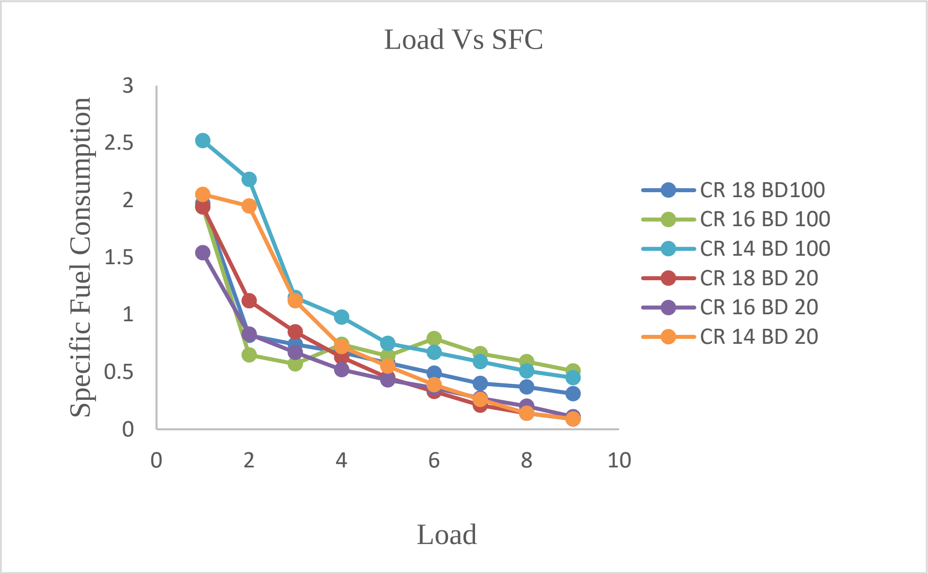


Figure 3: Load Vs Specific fuel consumption

The above graphs are for load Vs specific fuel consumption, it is clearly evident that at compression ratio 16 and at B20 bio diesel blend the specific fuel consumption is better when compared to other fuel blends at different compression ratios. Moderate fuel consumption at full load will deliver overall fuel efficiency as well as reduction in emissions.

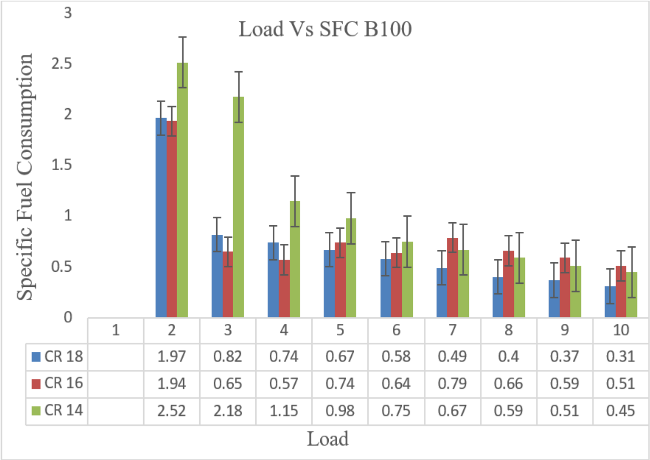


Figure 4: Load Vs Specific fuel consumption B100

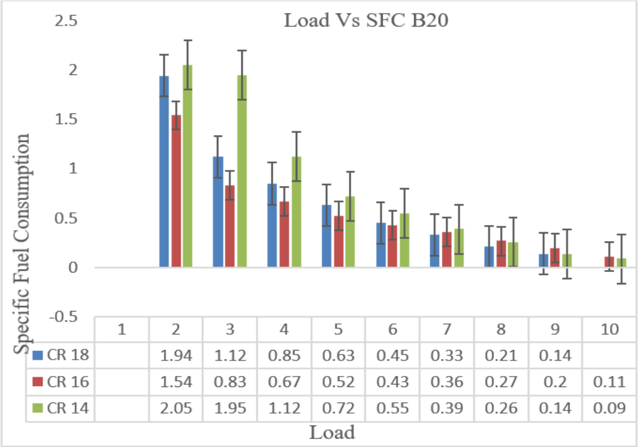


Figure 5: Load Vs Specific fuel consumption B20

The figures above show load vs specific fuel usage at various compression ratios of blend B20 and B100. According to the graph, the best specific fuel consumption values for B20 blend are 0.09 Kg/kWhr, and moderate fuel consumption at full load would give overall fuel economy as well as emissions reduction.

4.2 Load Vs Break Thermal Efficiency

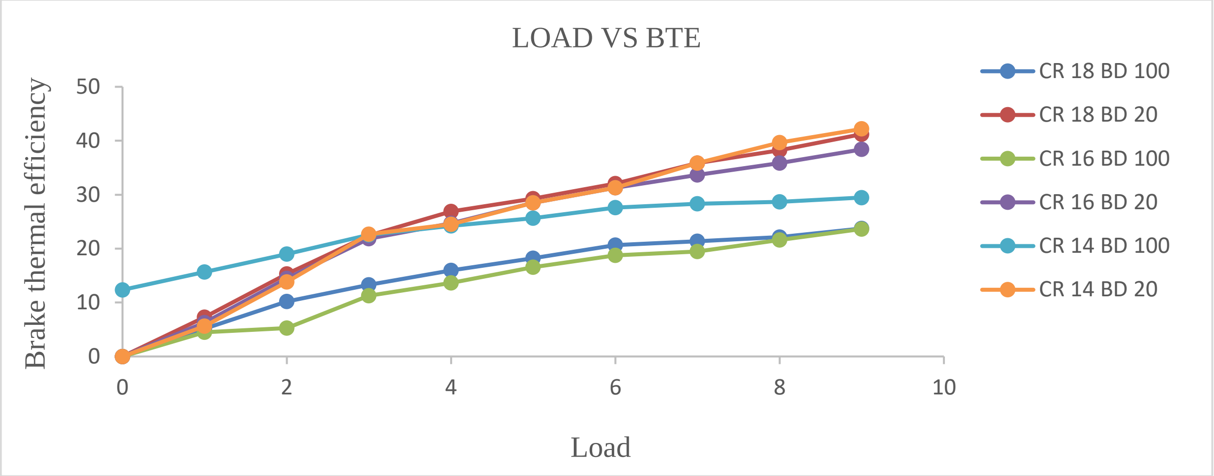
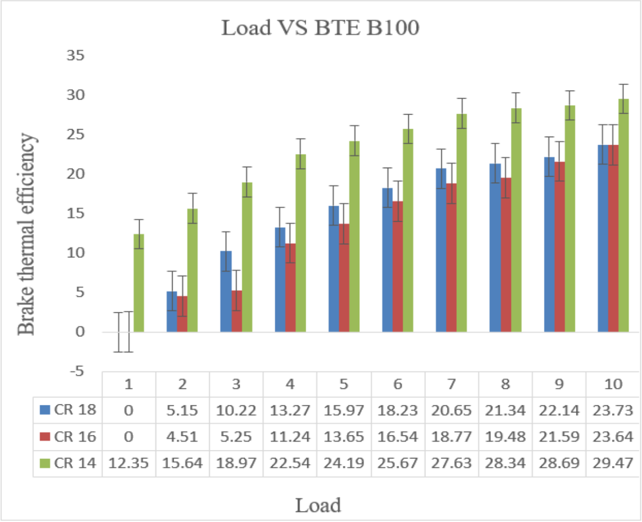
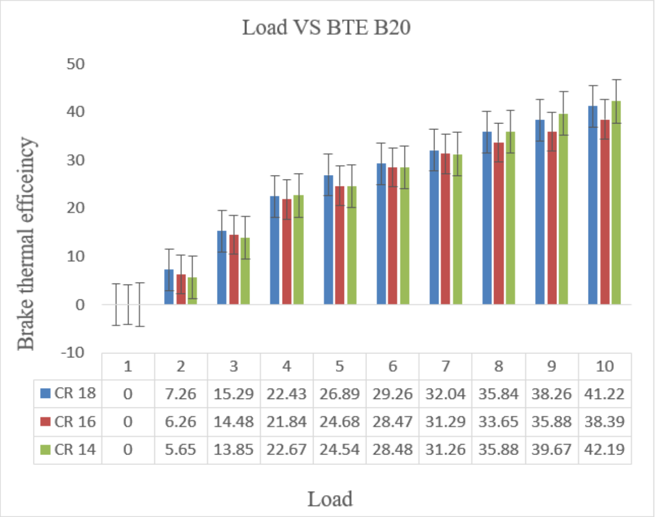


Figure 6: Load Vs Brake thermal efficiency

The graph above depicts load vs. brake thermal efficiency. It stipulates that a Compression Ratio14 and a B20 bio-diesel blend have higher brake thermal efficiency than other fuel blends at other compression ratios. This is due to the action of EGR, which normally shortens the ignition delay, raises the cetane number, and oxygenates the fuel.



	1	2	3	4	5	6	7	8	9	10
🟦 CR 18	0	5.15	10.22	13.27	15.97	18.23	20.65	21.34	22.14	23.73
🟥 CR 16	0	4.51	5.25	11.24	13.65	16.54	18.77	19.48	21.59	23.64
🟩 CR 14	12.35	15.64	18.97	22.54	24.19	25.67	27.63	28.34	28.69	29.47



	1	2	3	4	5	6	7	8	9	10
🟦 CR 18	0	7.26	15.29	22.43	26.89	29.26	32.04	35.84	38.26	41.22
🟥 CR 16	0	6.26	14.48	21.84	24.68	28.47	31.29	33.65	35.88	38.39
🟩 CR 14	0	5.65	13.85	22.67	24.54	28.48	31.26	35.88	39.67	42.19

Figure 7: Load Vs Brake thermal efficiency B100

Figure 8: Load Vs Brake thermal efficiency B20

The mahua biodiesel bar graphs illustrate the brake thermal efficiency related to the load at various compression ratios of B20 and B100. According to the graph, at 9 kg load, the brake thermal efficiency of values B20 and B100 at CR 18 is 41.22 percent and 23.74 percent, respectively. This implies that the B20 blend has a higher brake thermal value than the B100 biodiesel owing to the influence of EGR. As a result, we may conclude that the B20 blend is more efficient.

4.3 Load Vs Frictional Power

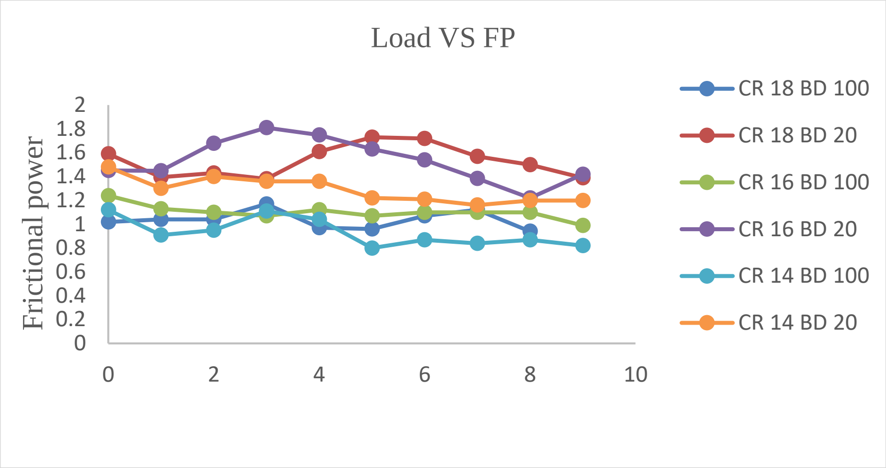


Figure 9: Load Vs Frictional Power

The graph above demonstrates the relationship between load and frictional power. It states that a Compression Ratio1:14 and a B100 bio-diesel blend have lower frictional power than other fuel blends at different compression ratios. The graph shows that Compression ratio 1:14 BD 20 is the ideal mean value, implying that CR 14 B20 is effective.

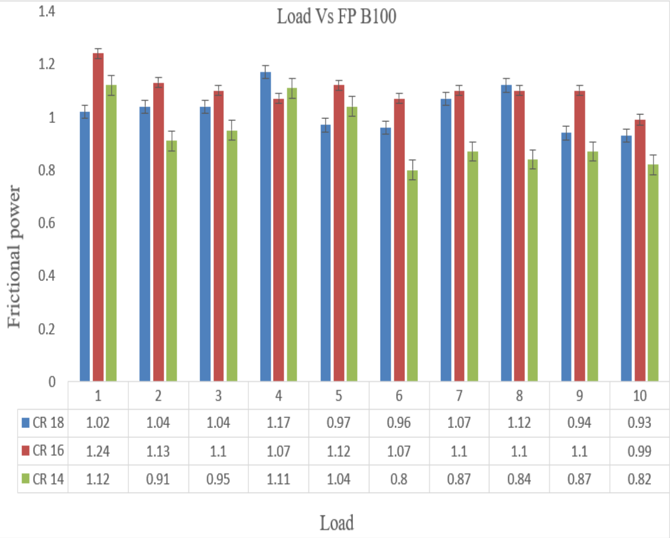


Figure 10: Load Vs Frictional Power B100

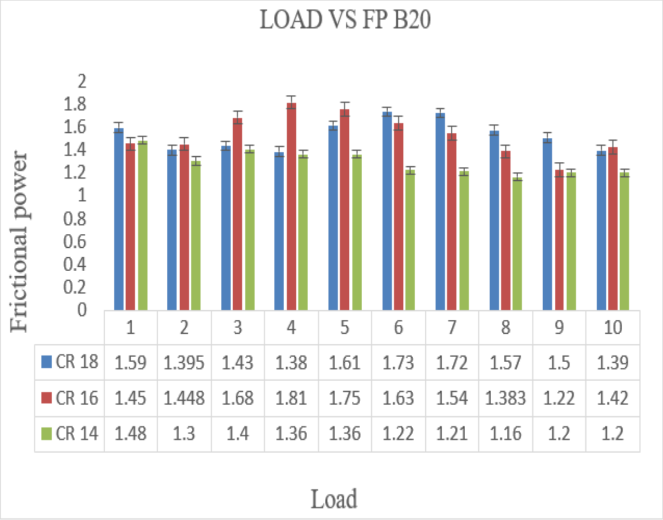


Figure 11: Load Vs Frictional Power B 20

The figures above show the load against frictional power at various compression ratios. It shows that the best frictional power value for CR 14 B20 compression ratio is 1.2Kw. We may conclude that the B20 blend is more efficient than the B100 blend.

EMISSIONS

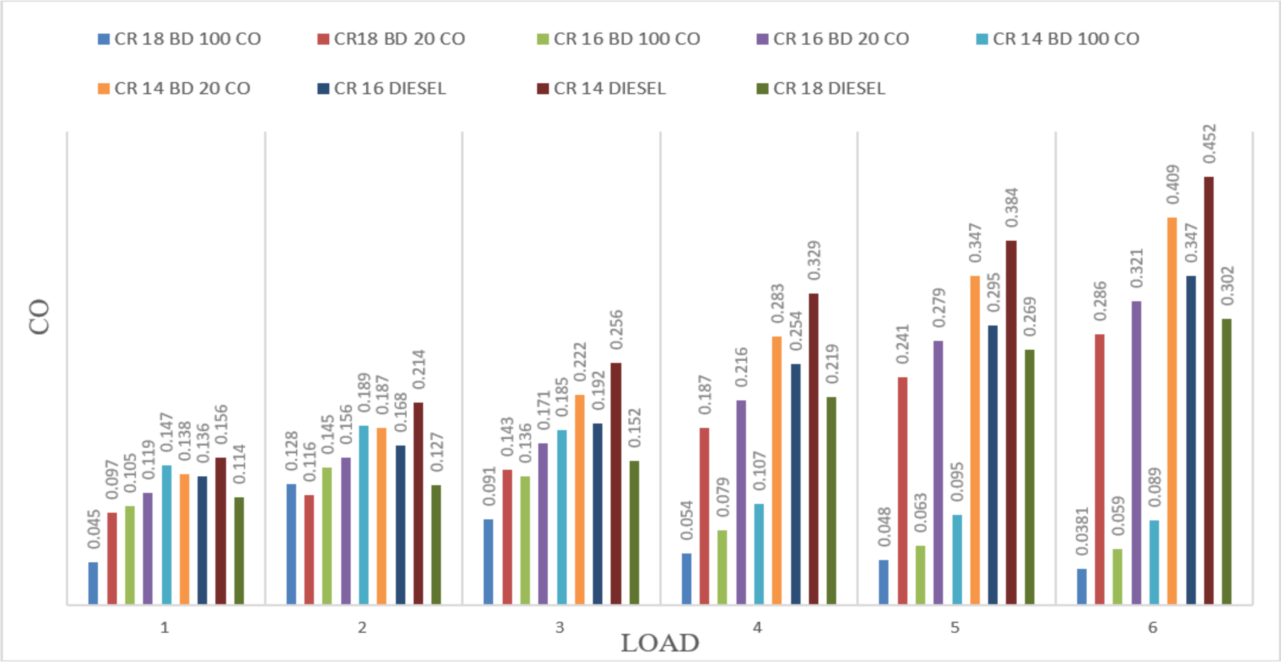


Figure 12: Load Vs CO Emissions

The graph above depicts the load vs CO emissions of the B100, B20, and Diesel. It has been found that the CO emissions of B100 are significantly lower than those of B20 and diesel, but biodiesel is likely to provide less power with higher fuel consumption than diesel due to the lower gross calorific value of biodiesel. As a result, blends are extensively employed. According to the statistics, the CR 16 B20 is the most efficient among the others, emitting 0.321 % CO with a load of 6kg.

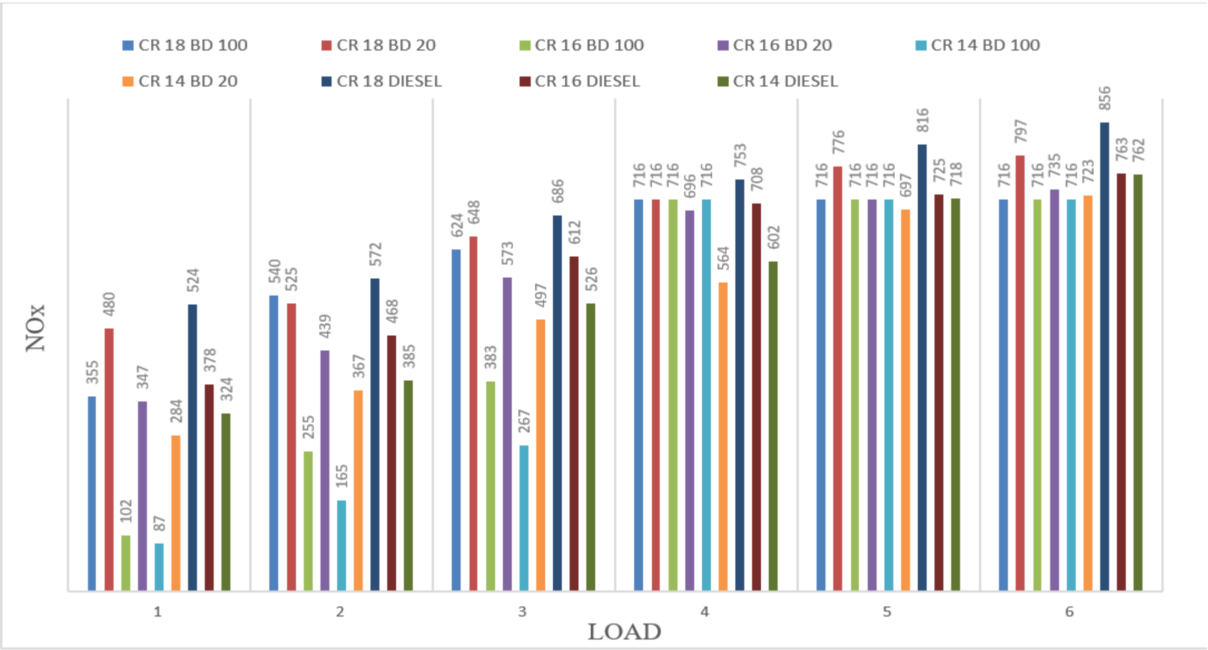


Figure 13: Load Vs NOx Emissions

The graph above demonstrates the relationship between load and NOx emissions. The NOx emissions of B100 have been determined to be much lower than those of B20 and diesel, although biodiesel is anticipated to offer less power with higher fuel consumption than diesel due to its lower gross calorific value. As a result, mixes are frequently used. Statistics show that the CR 14 B20 is the most efficient of the bunch, releasing 723 ppm NOx with a load of 6kg.

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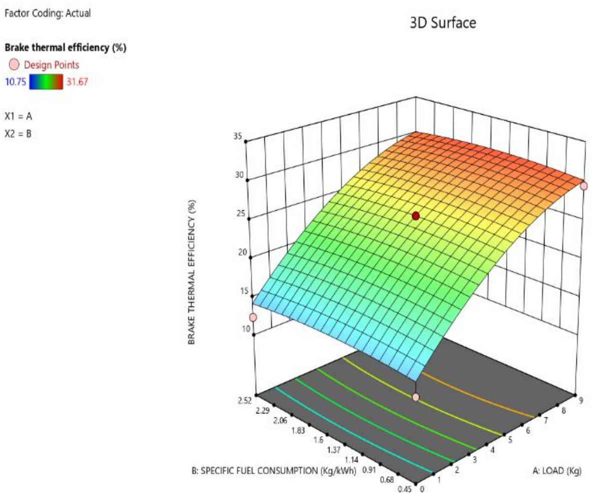

Fig 14 (a): Load Vs Specific fuel consumption (CR14 B100)

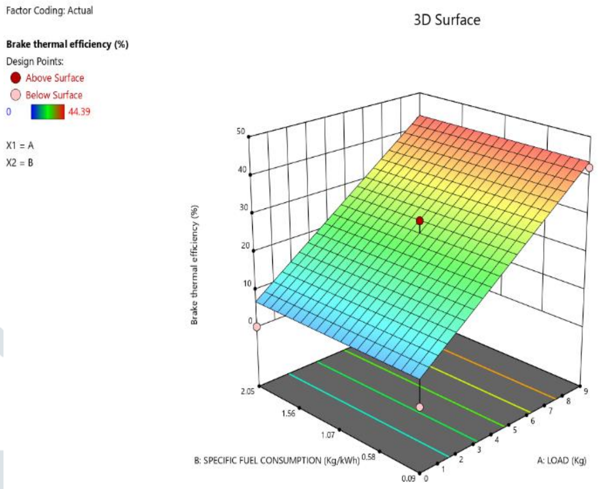

Fig 14 (b): Load Vs Specific fuel consumption (CR14 B20)

The above plot 1(a) is a plot for load vs specific fuel consumption to obtain optimal brake thermal efficiency at compression ratio of 1:14 and for neat mahua bio diesel. Results indicate that optimal brake thermal efficiency was obtained at 31.67 % when it is compared with biodiesel- diesel blend from mahua oil. A common phenomenon shows that higher the brake thermal efficiency the lower will be fuel consumption and lower with greenhouse gases. Fig 1(b) shows the plot for load vs specific fuel consumption to obtain optimal brake thermal efficiency at compression ratio of 1:14 and for B20 blend of mahua bio-diesel. Results indicate that optimal brake thermal efficiency was obtained at 44.39% when it is compared with biodiesel from mahua oil. This phenomenon suggests that higher the brake thermal efficiency the lower will be fuel consumption and lower with greenhouse gases.

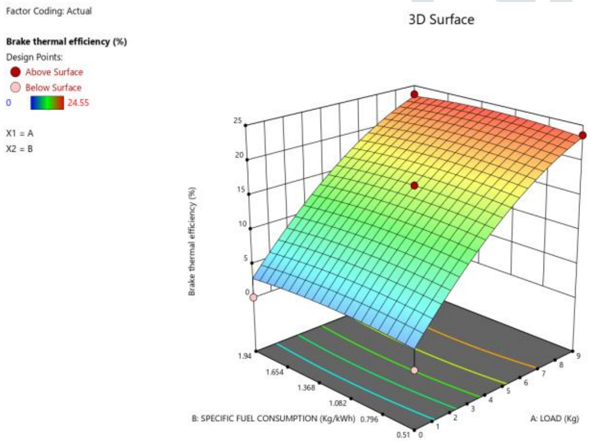

Fig 15(a): Load Vs Specific fuel consumption (CR16 B100)

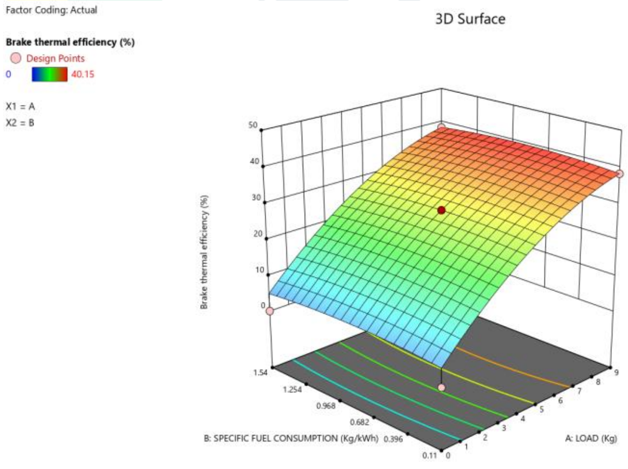

Fig 15(b): Load Vs Specific fuel consumption (CR16B20)

The above graph 14(a) is a plot for load vs specific fuel consumption to obtain optimal brake thermal efficiency at compression ratio of 1:16 and for neat mahua bio diesel. Results indicate that optimal brake thermal efficiency was obtained at 24.55 % when it is compared with biodiesel- diesel blend from mahua oil. A common phenomenon shows that higher the brake thermal efficiency the lower will be fuel consumption and lower with greenhouse gases. Fig 14(b): The above graph is a plot for load vs specific fuel consumption to obtain optimal brake thermal efficiency at compression ratio of 1:16 for B20 blend of mahua bio-diesel as it is coupled with the EGR. Results indicate that optimal brake thermal efficiency was obtained at 40.15% when it is compared with biodiesel from mahua oil. This phenomenon suggests that higher the brake thermal efficiency the lower will be fuel consumption and lower with greenhouse gases.

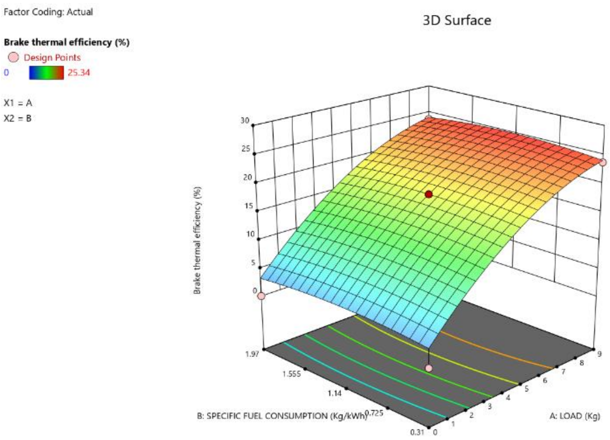

Fig 16(a): Load Vs Specific fuel consumption (CR 18 B100)

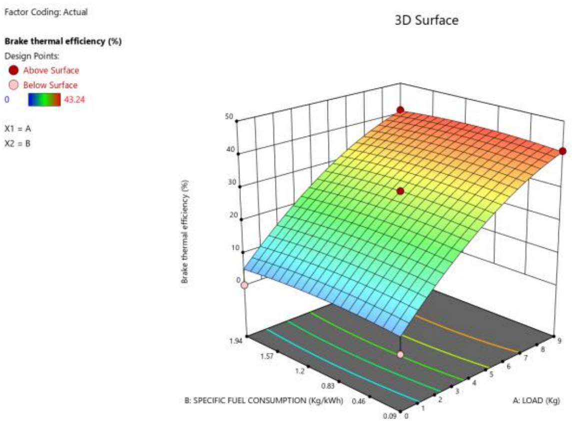

Fig 16(b): Load Vs Specific fuel consumption (CR18 B20)

The above graph 15(a) is a plot for load vs specific fuel consumption to obtain optimal brake thermal efficiency at compression ratio of 1:18 and for neat mahua bio diesel. Results indicate that optimal brake thermal efficiency was obtained at 25.34% when it is compared with biodiesel- diesel blend from mahua oil. A common phenomenon shows that higher the brake thermal efficiency the lower will be fuel consumption and lower with greenhouse gases. Fig 15(b): The above graph is a plot for load vs specific fuel consumption to obtain optimal brake thermal efficiency at compression ratio of 1:18 and for B20 blend of mahua bio-diesel as it is coupled with the EGR. Results indicate that optimal brake thermal efficiency was obtained at 43.24% when it is compared with biodiesel from mahua oil. This phenomenon suggests that higher the brake thermal efficiency the lower will be fuel consumption and lower with greenhouse gases.

S No.	Compression Ratio	Fuel Name	'F' Value %	'P' Value %
1	1:14	MAHUA BIODIESEL (B 100)	34.56	< 0.0001
2	1:16	MAHUA BIODIESEL (B 100)	27.89	< 0.0001
3	1:18	MAHUA BIODIESEL (B 100)	38.80	< 0.0001
4	1:14	MAHUA BLEND (B 20)	54.28	< 0.0001
5	1:16	MAHUA BLEND (B 20)	39.59	< 0.0001
6	1:18	MAHUA BLEND (B 20)	33.62	< 0.0001

Table 1

The above table describes an ANOVA (Analysis of variance) model on Design Expert software that split absorbed variance data into distinct components to be used for future tests. Here we learn about F value, which tells us about the model's relevance. Overall, the higher the F value, the better the model; the table shows that CR 14 B20 of Mahua Biodiesel has the best F value. The P value indicates our probability value, and the value of P in the given table is < 0.0001.

CONCLUSION

Specific fuel consumption, frictional power, brake thermal efficiency, and emissions of a mahua biodiesel blend at various loads and compression ratios are represented in graphs. We calculated the load versus specific fuel consumption using the ANOVA approach of DOE (design of expert) to achieve optimal brake thermal efficiency at different compression ratios for B100 and B20 biodiesel blends, respectively. Based on the findings of all the graphs, we can infer that the B20 blend is more efficient in terms of performance and emissions.

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