International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 21s, 2025
https://theaspd.com/index.php

Performance Analysis Of Blended Cashew Nut Shell Oil In Diesel Engine

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Abstract

This study investigates the performance of a single-cylinder compression ignition (CI) engine fuelled with cashew nut shell oil (CNSO) biodiesel blends, explored as a viable alternative to conventional diesel. CNSO was blended with diesel in varying proportions to reduce its high viscosity, which was further analysed across different temperatures. The engine's performance was evaluated under varying load conditions and compared against neat diesel. Results indicated that reducing the viscosity of CNSO blends led to significant improvements in engine performance. Furthermore, increasing the injection pressure enhanced Brake Thermal Efficiency, Mechanical Efficiency, and Volumetric Efficiency. Among the tested blends, B15 and B50 demonstrated optimal performance without requiring any engine modifications.

Key Words: *diesel engines, biodiesel blends, cashew nut shell oil, injection pressure*

1. INTRODUCTION

Only compression ignition engines are used as the primary mode of transportation. Heavy loads are used with diesel engines because they have a higher torque than other types of engines [1].Diesel fuel is the most important factor in maintaining demand, and the supply of diesel fuel is the most difficult scenario for this period. Many studies will be conducted in order to find an alternative to diesel fuel in order to meet demand. Similarly, reducing fuel consumption is another difficult aspect of engine design [2].In this regard, innovative combustion system technology will improve in automotive engines. Biodiesel, which is made from plant oils, is a common alternative fuel for diesel [3]. In India, biodiesel may be produced from a variety of resources, including edible and non-edible oils derived from crops and animals. The CI engine was examined with use of biodiesel by varying loads and compression ratios like 16.5:1, 17.5:1, 18.5:1 and 19.5:1. As per obtained results, increased efficiency of engine and NOx emission was raised due to high exhaust temperature.Biodiesel is a diesel substitute, and among the several types of biodiesel produced from vegetable seeds, cashew shell seed liquid as biodiesel is being tested for engine performance. And, as a result of the results, CO, HC, NOx, and other emissions have been reduced in a sustainable manner [13].Another researcher did the experiment using a diesel engine powered by cotton methyl seed oil biodiesel. CO, HC, NOx, and smoke levels are analysed based on engine results [6].If cashew nut shell liquid biodiesel is used, the engine is run with varying proportions of biodiesel (10%, 20%, and 30%) with methanol (10 %). Various engine loads were used, such as 25%, 50%, 75%, and 100%, respectively. The injection pressure employed in the test was 200bar, and the injection timing was 27.5^{o} BTDC. According to engine findings, 20% Biodiesel of cashew nut shell liquid and 10% methanol blends were determined to be satisfactory [7, 20].

The goal of this study is to look into a single cylinder diesel engine that uses a cashew nut shell liquid biodiesel blend with diesel in various ratios such as 15%, 30%, 45 %, and 60%. Experiment with a constant engine speed of 1500rpm and determine the performance of the engine with various injection pressures such as 140bar, 150bar, 160bar, 180bar, and 200bar. To determine the best injection pressure and biodiesel blend for producing good results from a diesel engine.

2. METHODOLOGY

EXPERIMENTAL SETUP

The experiment has been carried out using a single cylinder four stroke water cooled diesel engine with a rated output of 5HP at 1500 rpm. For loading, the engine is connected to an electrical dynamometer. The engine's speed is indicated using a photo sensor and a digital display. The injection pressure nozzles (140,150,160,180, and 200 bars) are used to evaluate the engine's performance.The fuel monitoring in this Kirloskar engine is done manually [8]. The fuel usage is manually metered using a burette and a stop watch. A stopwatch is used to time how long it takes the engine to consume 10cc of diesel [10]. The burette has a cubic centimetre of fuel indication on it [9]. The graphic below depicts the fuel burette installed in the engine, which is used to manually compute the quantity of gasoline consumed by the engine [10]. Figure 1 shows the engine setup was used in this work.

Figure 1. Engine Setup

A tyre coupling connects the 5 HP water-cooled Kirloskar engine to the Bharat AC 200-240Volt alternator. The alternator powers an electrical loading device. The loading unit is made up of a number of bulbs (200-100W) [13, 17]. A switching system is supplied, which switches the light as needed. Load variability is obtained by altering the precise number of bulbs [11].The engine specifications employed in this experiment are shown in Table 1.

Table 1. Engine Specification

Engine	Kirloskar water cooled vertical four stroke Single cylinder multi fuel diesel engine model AVINo.1159/0400443 fitted with high torque 24VDC self-motor.
Alternator	Bharat AC 200-240 volts
Power	3.7kW (5hp) at 1500rpm
Rated speed	1500rpm at RTP condition
Bore size	80mm diameter
Stroke or bore length	110mm
Compression ratio	20:1
Specific fuel consumption	238-860 Kg/kW-hr, at full load/nominalEngine
oil	20-40W grade engine oil at 3.75 to 5Litres

Fuel	Diesel
Loading	Electrical loading with 200W
Maximum load	Maximum load up to 5000kW
Starting system	Hand starting
Specific gravity of	0.83
diesel Calorific value	43400 kJ/kg

Figure 2. Replacement of nozzle

The fuel injector's purpose is to distribute finely atomized fuel into the combustion chamber, aiding in getting each droplet of fuel into touch with just enough oxygen in the air. Impact on fuel pressure, high-pressure fuel from the pump flows through the channel to the nozzle end. Its valve is raised against the power of the spring [16]. As a result, the nozzle's hole is opened. Thru the hole, fuel is pumped into the combustion chamber and atomized.

USED BIODIESEL

Experiments have proven that biodiesel generated from non-edible oil seeds and edible seeds may be utilised in existing diesel vehicle designs without requiring significant modification. According to state government authorities, there is a considerable scope for the production of non-edible oil seeds plants as well as edible oil seeds plants in most states. In this work, used biodiesel was cashew nut shell liquid [18]. Cashew nut Shell Liquid (CNSL) is a viscous reddish brown liquid with the honeycomb pattern of the shell of a cashew nut derived from a cashew tree. Cashew Nut Shell Liquid (CNSL) is a useful cashew industry by-product. Within the nut is a delicate honey comb structure carrying a dark reddish brown sticky liquid. The nut does have a shell about 1/8 inch thick. This seed coat fluid of the cashew nut is known as cashew nut shell liquid [19]. It is frequently regarded as that of the superior and less expensive source for conjugated phenolic acids.Figure 3 shows the Cashew nut and its parts.

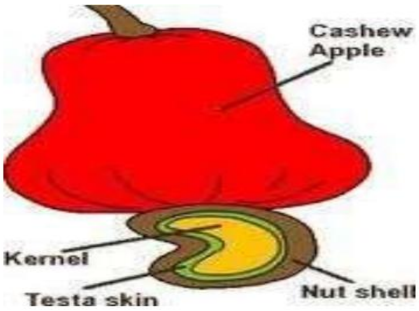


Figure 3. Cashew nut

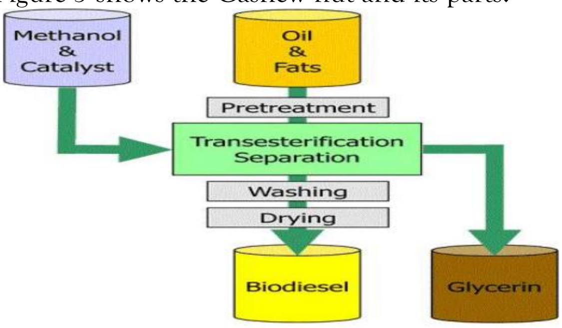


Figure 4. Flow diagram of biodiesel production

Cashew nut shell liquid extracted with low boiling petroleum contains about 90% Anacardic acid and 10% Cardol. Distillation of cashew nut shell liquid yields the light yellow phenolic compound cardanol. Natural cashew nut shelling liquid includes 80% Anacardic acid, 15% Cardol, and trace quantities of other compounds, most notably Cardol methyl variants. Many sophisticated extraction procedures have recently been developed. Figure 4 shows the flow diagram of biodiesel production. Similarly, biodiesel blends for various biodiesel and diesel ratios have been developed. Blends that have been created for the analysis include B15, B30, B45, and B60 in terms of biodiesel concentration [21].Table 2 shows the properties of cashew nut shell liquid biodiesel.

Table 2. Properties of fuels.

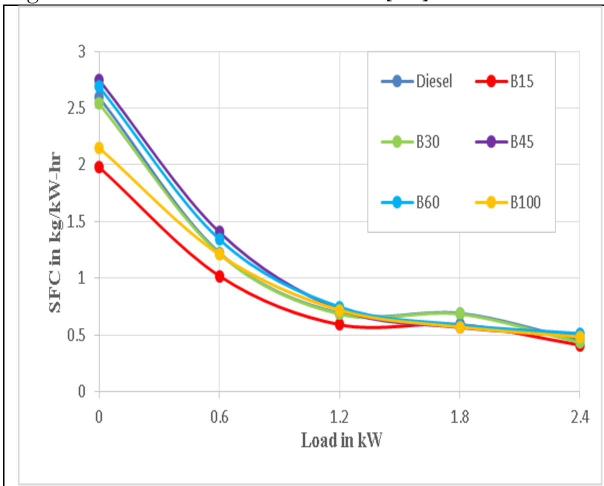
PROPERTIES	DIESEL	B15	B30	B45	B60	B100
Density (gm/cc)	0.84	0.82	0.83	0.86	0.88	0.9
Viscosity at 40°C(centipoise)	1.382	0.469	0.627	0.833	1.066	1.202
Flash point 40°C	42	42	60	62	76	210
Fire point 40°C	65	50	63	65	84	226
Gross caloric value (kJ/kg)	44500	40983	40699	39418	38124	36488
Calculated cetane index	55	57	53	48	46	40

3. RESULTS AND DISCUSSION.

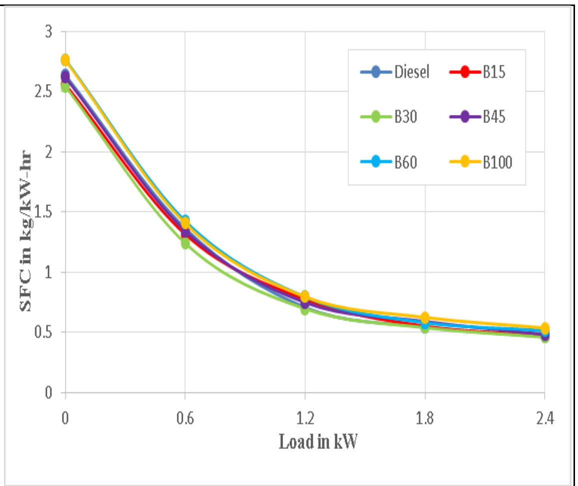
Experiment was performed with single cylinder diesel fuelled by different blends of cashew nut shell liquid biodiesel and diesel fuel. For study, different types of injection pressures (140, 150, 160, 180 and 200bar) are used to found outcomes of engine. As per the obtained results, graphs are generated and compared to each blends of biodiesel with pure diesel. It was discussed in this section. Particularly, analysis done with diesel engine performance characteristics such as specific fuel consumption (SFC), brake thermal efficiency (BTE), volumetric efficiency, mechanical efficiency.

Impact of specific fuel consumption

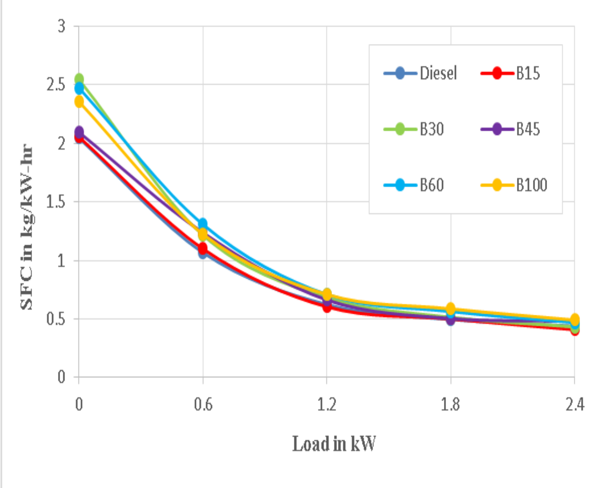
Figure 5(a) to (e) depicts the effect of specific fuel consumption (kg/kW-hr) on various load circumstances.In this investigation, five different injection pressures were used: 140, 150, 160, 180, and 200 bar. This SFC is used to characterise the fuel economy of an engine in proportion to thrust output. According to the results, increasing the load condition of the engine and decreasing the specific fuel consumption in all injection pressures [14, 15]. The minimal specific fuel consumption in diesel fuel at 2.4kW load conditions is 0.401kg/kW-hr at 200bar injection pressure. Similarly, at 150bar of injection pressure, the highest specific fuel consumption in B60 under 0kW load conditions is 2.768kg/kW-hr.When raising the biodiesel blend ratio at 0kW, the specific fuel consumption increases in all injection pressure situations [9].Specific fuel consumption is higher in B60 and B100 than in B15, B30, and B45 in all injection pressure settings at 0kW and 1.6kW load situations. Overall, compared to other biodiesel blends, the B15 has the best satisfying specific fuel usage across all injection pressures. Because it has a higher calorific value than diesel [22].



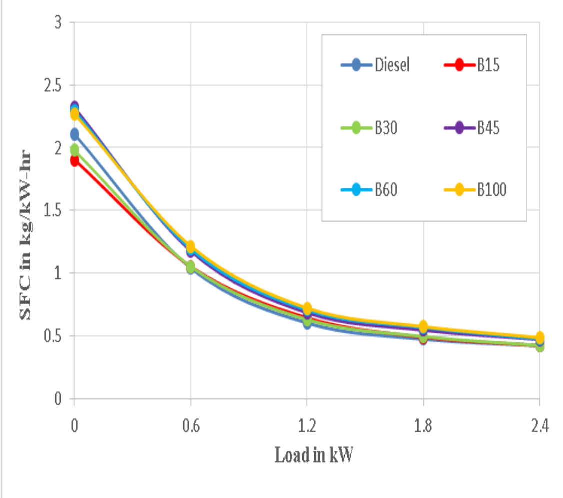
(a) 140 bar



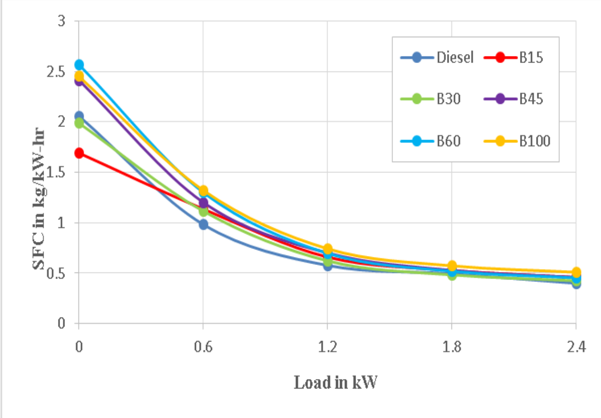
(b) 150 bar



(C) 160 bar



(d) 180 bar

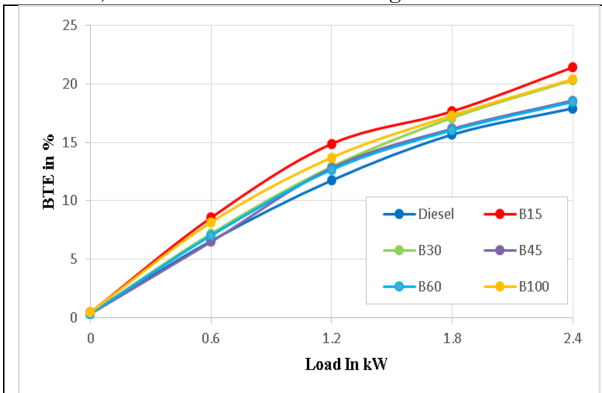


(e) 200 bar

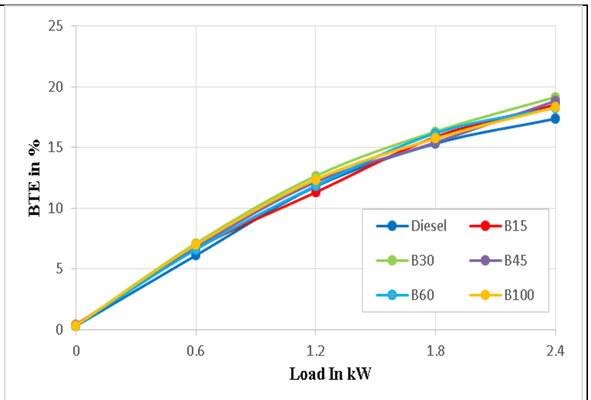
Figure. 5 Variation of Specific Fuel Consumption (SFC)

Impact of Brake Thermal Efficiency (BTE)

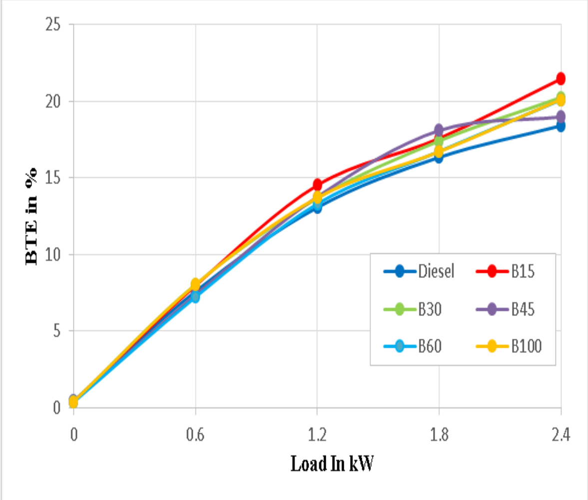
Figure 6(a) to (e) show the effect of brake thermal efficiency (%) under various load conditions. In this investigation, five different injection pressures were used: 140, 150, 160, 180, and 200 bar. The brake thermal efficiency is a critical statistic for determining engine performance. According to engine efficiency, it is justified to be beneficial for specific applications [10]. According to the data obtained from various injection pressures, increasing the load condition of the engine and increasing the brake thermal efficiency condition in all injection pressures[16]. The greatest brake thermal efficiency in B15 at 2.4kW load conditions is 21.47 % at 160bar of injection pressure [17]. Similarly, at 140bar of injection pressure, the minimum brake thermal efficiency in B45 under 0kW load circumstances is 0.327 %.Due to the comfort ability at this specific blend ratio and injection pressure, the B30 outperforms the B15 at 150bar injection in all load circumstances [23]. Brake thermal efficiency is high in B15 and B30 blends compared to diesel, but low in the remaining biodiesel blends.



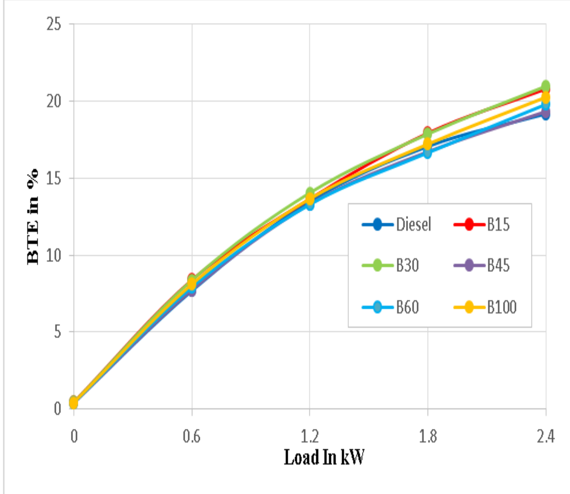
(a) 140 bar



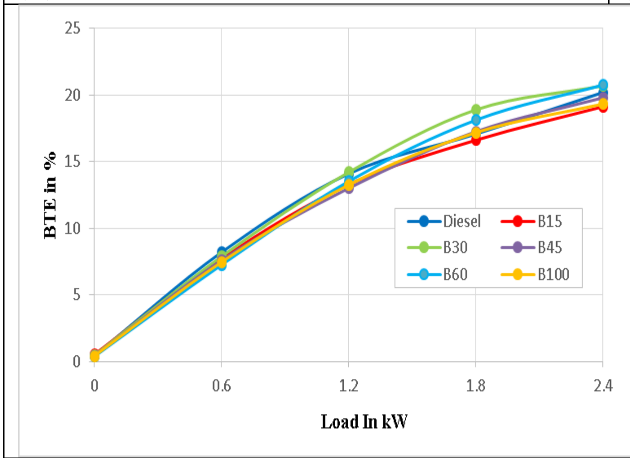
(b) 150 bar



(C) 160 bar



(d) 180 bar

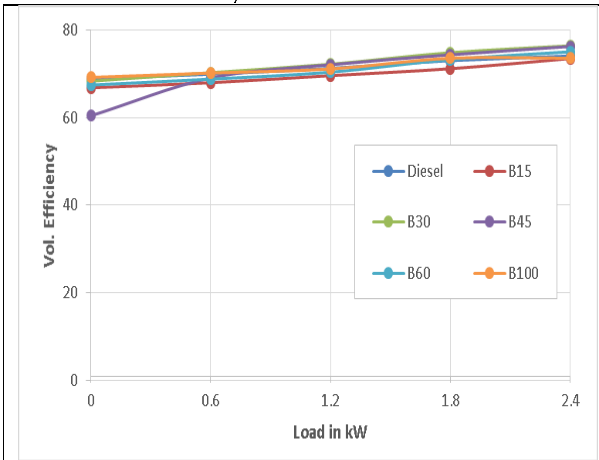


(e) 200 bar

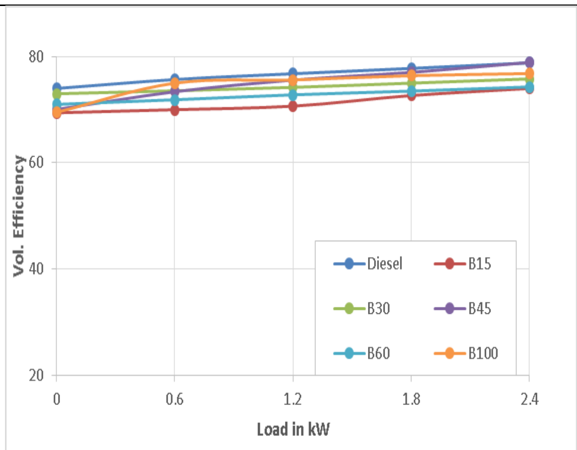
Figure. 6 Variation of Brake Thermal Efficiency (BTE)

Impact of Volumetric efficiency

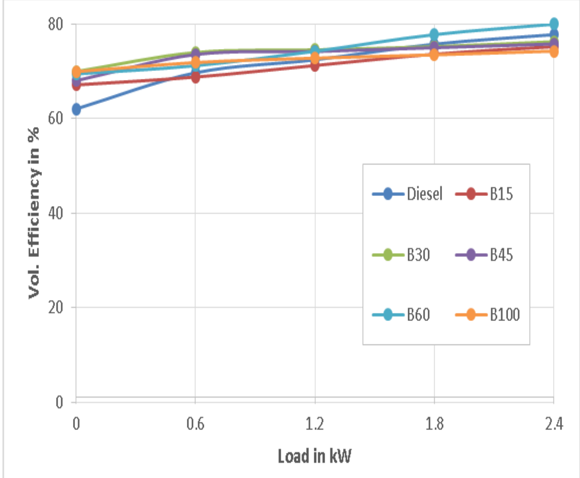
Figure 7(a) to (e) show the effect of volumetric efficiency (%) under various load conditions. In this investigation, five different injection pressures were used: 140, 150, 160, 180, and 200 bars. More power and torque are generated by higher volumetric efficiency [6]. It leads to an increase in engine performance. As a result, this is also important for the IC engine. According to the results, volumetric efficiency varies from 10% to 20% across all injection pressures and loads [11]. In a 2.4 kW load condition, the highest volumetric efficiency is 79.98 % for B60 at 160bar and diesel at 200bar. Similarly, diesel has the lowest volumetric efficiency of 62.05 % at 160bar and 0kW load.



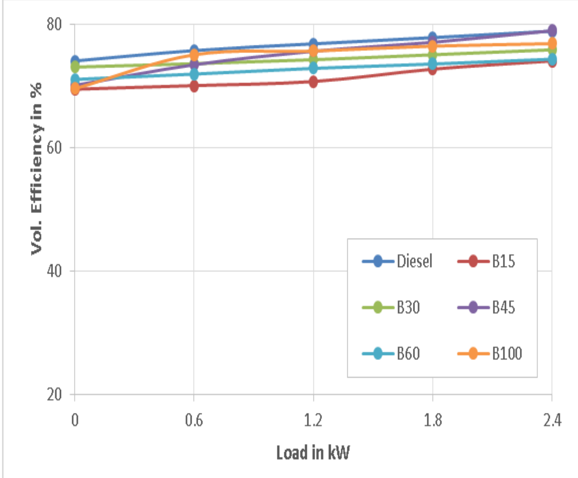
(a) 140 bar



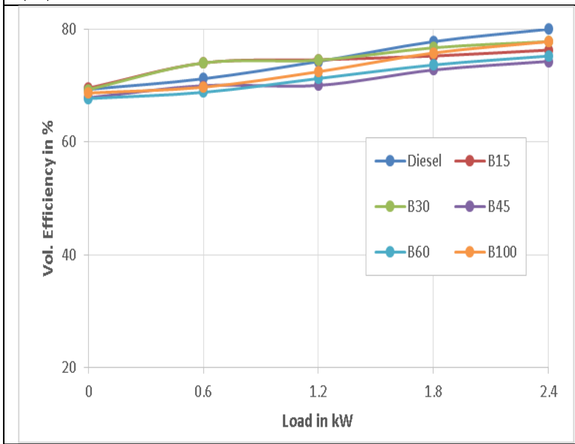
(b) 150 bar



(C) 160 bar



(d) 180 bar

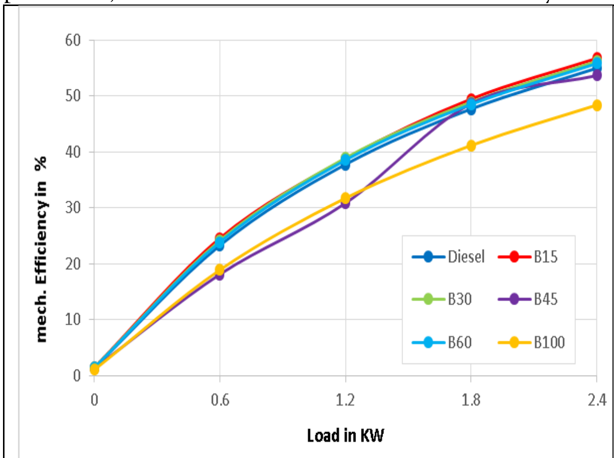


(e) 200 bar

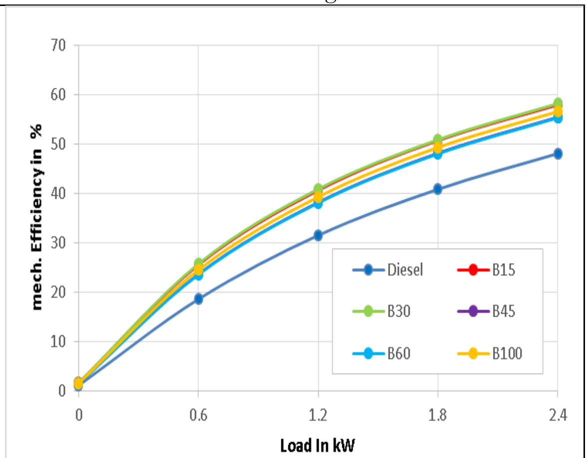
Figure. 7 Variation of Volumetric efficiency

Impact of mechanical efficiency

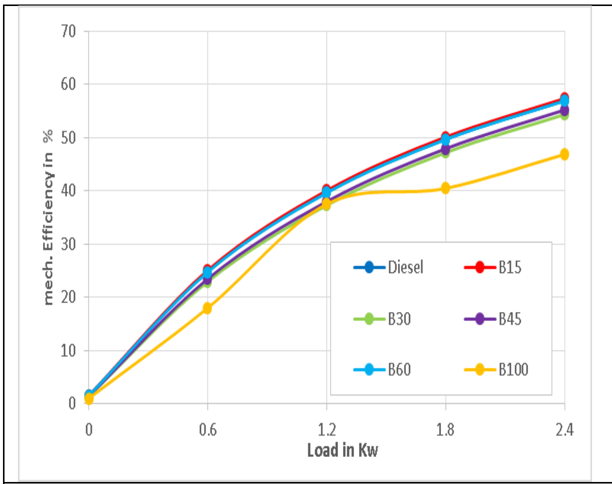
Figure 8 (a) to (e) depict the effect of mechanical efficiency (%) under various load conditions. In this study, five different injection pressures were used: 140, 150, 160, 180, and 200 bars. Mechanical efficiency is another important engine parameter. Based on this, justify the engine parameter and monitor engine mileage. When the engine's load is increased, the mechanical efficiency is increased in all injection pressure conditions[12, 24]. Mechanical efficiency is 58.13 % maximum for B30 at 150bar injection pressure in 2.4kW load condition and 1.01 % minimum for B100 at 160bar injection pressure in 0 kW load condition, according to the results [13]. B15 has higher mechanical efficiency than other biodiesel blends such as B30, B45, B60, and B100 when compared to diesel. In all load conditions and injection pressures, B100 has lower mechanical efficiency than diesel fuel and the remaining biodiesel blends.



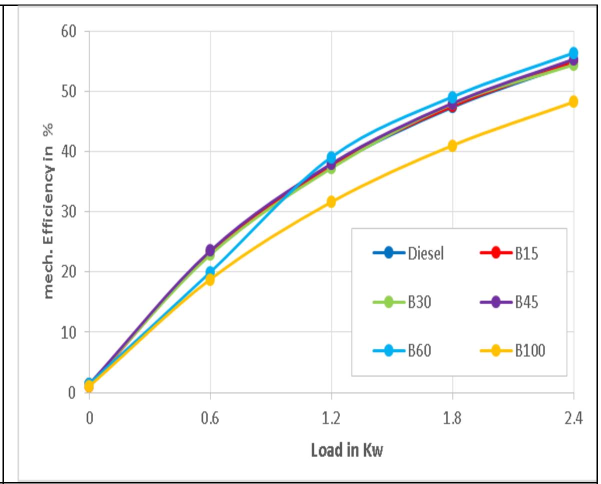
(a) 140 bar



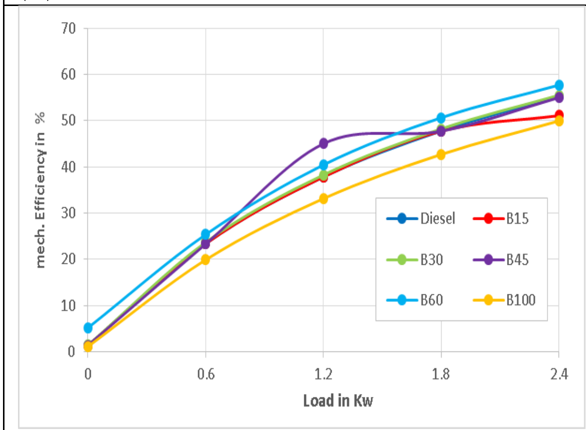
(b) 150 bar



(C) 160 bar



(d) 180 bar



(e) 200 bar

Figure. 7 Variation of mechanical efficiency

4. CONCLUSION

The investigation of a single cylinder diesel engine fuelled diesel and various cashew nut shell oil biodiesel blends such as B15, B30, B45, B60, and B100 was successfully completed in this study. Diesel engine was run with different injection pressures like 140, 150, 160, 180, and 200 bars are used. Only performance parameters such as specific fuel consumption, brake thermal efficiency, mechanical efficiency, and volumetric efficiency were used to obtain the results. The results obtained are compared to diesel and different cashew nut shell oil biodiesel blends. The following conclusion was reached based on the findings:

- At 200bar injection pressure, the minimum specific fuel consumption in diesel fuel at 2.4kW load conditions is 0.401kg/kW-hr.
- At 160bar of injection pressure, the highest brake thermal efficiency in B15 is 21.47% at 2.4kW load conditions.
- The highest volumetric efficiency for B60 at 160bar and diesel at 200bar is 79.98%.
- Mechanical efficiency is 58.13 % at 150bar injection pressure in 2.4kW load condition for B30.

In all injection pressure conditions, satisfied results were obtained in B15 and B30 biodiesel blends when compared to diesel fuel.

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