Global NEST Journal, Vol 25, No 7, pp 99-104

Investigational study of significance of propanol addition in performance and emission distinctiveness of compression ignition engine fuelled through cotton seed oil blended with diesel

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Received: 15/03/2023, Accepted: 29/07/2023, Available online: 10/08/2023
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https://doi.org/10.30955/gnj.004899

Graphical abstract

Abstract

Numerous alternative fuels such as biodiesel as well as alcohols have been commercialized in both the industrial and transportation sectors. Cottonseed oil and propanol piqued our curiosity in this context. Many researches has been conducted on a single cylinder four strokes diesel engine competent of generating 6.3 kW at 2000 r.p.m and in changing load conditions for mixture of Cottonseed oil as well as Propanol by means of diesel geared up on a volume base, namely D90-C10, D85-C10-P5, D80-C10-P10, D80-P20, D75-C20-P5 and D70-C20-P10. The results suggest that adding cottonseed oil to diesel improves thermal efficiency while lowering specific fuel usage. With an increase in HC emission, escalating the percentage of cottonseed oil in the merge trim down emanation parameters like CO, CO_2 and NO_X. Propanol added to a cottonseed oil merged along with diesel has a comparable consequence to adding pure cottonseed oil in various proportions.

Keywords: Air quality, emission, cotton seed oil, diesel, compression ignition

1. Introduction

The diesel engine has always been subjected to stringent pollution norms and regulations that are impossible to achieve by just changing engine characteristics, necessitating the modification of the fuel itself. Essential qualities like cetane number, heating value in addition to viscosity play an significant influence in engine performance and emanation testing. Because the diesel engine was designed for running with vegetable oil and other biodiesels (Rajan *et al.*, 2022; Hazar and Sevinc, 2023), it is a great alternative to diesel. In general, this characteristic is taken into consideration when assessing engine performance, particularly when vegetable oil and other biodiesel (Arunkumar *et al.*, 2021; Musthafa *et al.*, 2023) be used since its viscosity is elevated when compared with diesel. Transesterification, combining with diesel and Micro emulsion are some of the ways utilized to reduce kinematic viscosity. Koli *et al.* (2014) demonstrated the performance characteristics of a twofold vegetable oil combined by through diesel. DMP10 (Diesel-90%, Mustard oil-5% and Palm oil-5%) and DMP20 (Diesel-80%, Mustard oil-10% and Palm oil-10%) mixes provided greater BTE, inferior overall fuel utilization along with minor BSFC when compared to other merge (DMP30, DMP40 and DMP50). Devan *et al.* (2009) tested tidy poon oil in addition to its merge through petroleum diesel. They found that when the engine is fed by means of inferior poon oil-petrodiesel merge contrast to petrodiesel, the engine power output along with fuel consumption are nearly identical. They found a 32 percent diminution in NOx emissions on behalf of poon oil at full load and a 4% decline on behalf of its 20% merge. CO emanation from tidy poon oil and its mixtures were greater, with the exception of the tidy 20 merge, which saw a 12 percent reduction. With neat poon oil, they saw an 18% rise in HC emissions, but with neat 20 blend, they saw a 14 percent reduction. Finally, they came to the conclusion that lower-

Ravi S., Sathish Kannan, Seikh A.H. and Ghosh A. (2023), Investigational study of significance of propanol addition in performance and emission distinctiveness of compression ignition engine fuelled through cotton seed oil blended with diesel, *Global NEST Journal*, **25**(7), 99-104.

poon oil-petrodiesel mixes could be a good alternative fuel for diesel engines

Improvement in karanja oil as biodiesel is shown in this work (Bajpai *et al*., 2009). When compared to gasoline, gasoline ethanol merge through additives like cyclooctanol and cycloheptanol boosted brake thermal efficiency with a decline in CO, CO_2, as well as NOx whilst HC and O2 augmented reasonably, according to Balaji *et al*. (2010). Biodiesel in the midst of Diethyl Ether in a C.I engine abridged NOx emanation while improving brake thermal efficiency slightly, according to VenkataSubbaiah *et al*. (2010). Michikawauchi *et al*. (2011) Adding ethanol with diesel biodiesel merge improved brake thermal efficiency while lowering carbon monoxide emanation while increasing hydrocarbons, nitrogen oxides, and carbon dioxide emanation. According to Zhang *et al*. (2005), adding Di-Methyl-Carbonate with diesel improves competence slightly while lowering NOx emissions and lowering PM and soot emissions significantly. In their experiment, Ziesjewski *et al*. (2016) mixed 25% sunflower oil with 75% petrodiesel and utilized in a CI engine. They came to the conclusion that diluting sunflower oil with solvents reduces their viscosity. Engine performance issues for instance, injector coking in addition to increased carbon deposits, could be solved this manner. Based on their research through Jatropha, karanja and polanga biodiesels, Sahoo and Das *et al*. (2009) concluded that the appropriate merge for most favourable performance and squat emanation characteristics depends on the specific feedstock as well as succeeding biodiesel configuration in addition to Jatropha, karanja and polanga seed oils are moderately appropriate as a substitute towards diesel. Propanol provides a variety of advantages over ethanol and methanol, including a lower risk of corrosion, a superior calorific value, a advanced Cetane number, subordinate polarity and superior solvent properties for mixing by way of diesel as well as vegetable oils (Fırat *et al*., 2022; Khan *et al*., 2022). Based on literature reviews, it has been identified that no research has been carried on Cotton seed oil and Propanol blends.

Propanol is chosen over other frequent alcohols when combining through diesel fuel because of these benefits. The goal of present swot was to look at the consequences of several fuel blends (Yilmaz *et al*., 2014; Ajav *et al*., 1999; He *et al*., 2003) such as D90-C10 (Diesel 90%, Cotton seed oil 10%), D85-C10-P5 (Diesel 85%, Cotton seed oil 10%, Propanol 5%), D80-C10-P10 (Diesel 80%, Cotton seed oil 10%, Propanol 10%), D80-C20 (Diesel 80%, Cotton seed oil 20%), D75-C20-P5 (Diesel 75%, Cotton seed oil 20%, Propanol 5%) and D70-C20-P10 (Diesel 70%, Cotton seed oil 20%, Propanol 10%). The findings of the mixes tests be evaluated to the findings of the diesel fuel tests.

2. Techniques and Methodology

The performance and emission characteristics of a elevated speed direct injection diesel engine were acquired by utilizing cottonseed oil blended with 10%, 20%, 5%, and 10% Cotton seed oil by volume with the Diesel and Propanol at 2000 rpm correspondingly. The experimentation was carried out on an investigational unit consisting of a 4-stroke direct injection diesel engine linked to an eddy current type dynamometer, producing a load throughout a scope of 0–18 kg, but merely up to a maximum weight of 16 kg. The engine is a steady speed category through a stable speed of 2000 revolutions per minute. Figure 1 represents the experimental setup. Various sensors are installed throughout the engine to measure various factors, for instance speed, crank angle, temperature as well as pressure. The engine is a Kirloskar made by means of a 5000psi range and a piezo pressure sensor made by PCB Piezotronics. The load sensor is a load cell category made by Sensotronics Sanmar Ltd and has a 50 kilogram range. The crank angle sensor is a Kubler-Germany product with a 360O range. A ‘k’ type thermocouple is used as the temperature sensor. The Table 1 represents the specifications of engine.

Figure 1. Engine Setup

Table 1. Specifications of engine

Make and model	Kirloskar, TAF1
Number of cylinders	1
Combustion chamber	Hemispherical
Piston	Shallow Bowl-in
Bore mm	87.5
Stroke mm	110
Connecting rod length mm	220
Swept volume, cm3	661
Clearance volume, cm3	36.87
Compression ratio	17.5:1
Rated power, kW	4.4
Rated speed, rpm	2000

Injection type	Direct Injection
Number of Nozzle holes	3
Spray hole diameter, mm	0.25
Injection pressure, bar	210

The emanation numbers were calculated by means of an AVL DiGas 444 analyzer, which can measure four gases such as CO, CO_2, NOx, and HC. The analyser is a pipe category, which means we must slot in the probe into the tail pipe furthermore monitor the results intended for a period of time to determine the value present in the emission. The merge were made with blending diesel by means of cottonseed oil as well as propanol directly in a blender, with no requirement for preheating or other aids because both components were miscible in diesel. Even after a long period of stagnation, no distinct strata were visible in the mixture. As a result, the components are said to have strong mixing qualities. Cottonseed oil was used in 10 percent and 20 percent of the blends, and propanol was used in 5 percent and 10% of the blends, respectively. The Table 2 represents the test fuel properties. Figure 2 represents the blends of Diesel, Propanol and Cotton seed oil.

Table 2. Properties of test fuel

Fuel/blend	Density (Kg/m^3)	Calorific value (Kj/Kg)	Kinematic viscosity (mm^2/s)	Cetane ındex
Diesel	837	42500	2.6	45
Cotton Seed Oil	914	39648	50	42
Propanol	811	33800	2.32	18
D90-C10	835	42360	6.7	43
D85-C10-P5	843	41729	6.61	43
D80-C10-P10	841	41243	6.38	42
D80-C20	852	41930	11.08	44
D75-C20-P5	850	41458	10.64	43
D70-C20-P10	848	40987	10.19	42

Figure 2. Diesel, Propanol and Cotton seed Oil blend

3. Results and conversation

3.1. Brake thermal efficiency

Figure 3 depicts the current disparity in BTE Cottonseed oil as well as Cottonseed oil-Propanol fuel mixes in comparison to unadulterated diesel fuel. With the addition of 5% and 10% propanol to the biodiesel, there is a very minor rise in BTE. When contrast to diesel at full load, D80-C10-P10 displays a 3 percent greater BTE. The engine produces rather towering BTE values for the merged fuel in the current test by means of diesel, cottonseed oil as well as cottonseed oil merge, which can be endorsed in the direction of elevated combustion owing to the oxygen concentration of the merge (Khan *et al.*, 2022). In addition, adding Propanol to cottonseed oil in various blends does not result in a substantial reduction in heating value or Cetane number of the fuel. Aside from the blended fuel's energy level, the higher BTE could be attributed to the inside cylinder's elevated temperature, which allows the fuel to vaporize as quickly as other mixes, resulting in better mixing and burning. Similar observations have been made with the other research work (Fırat *et al.*, 2022).

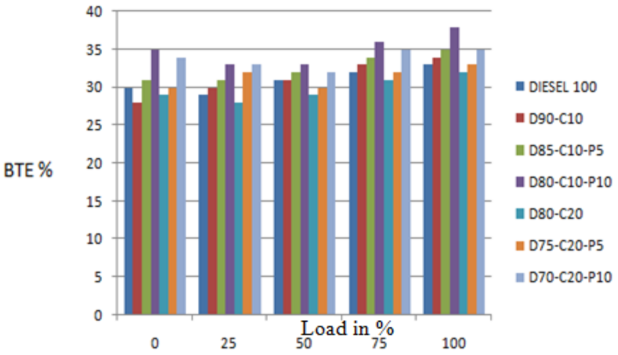

Figure 3. BTE Vs Load

3.2. Brake Specific Fuel Consumption (BSFC)

The maximum BSFC on behalf of the mix D90-C10 is shown in Figure 4, indicating that the fuel was spent supplementary for the equivalent quantity of power production. Figure 3 depicts the current discrepancy in BSFC of cottonseed oil and cottonseed oil-propanol mixtures in comparison to unadulterated diesel. As can be seen in Figure 3, diesel has the least possible BSFC, which is on average 10% elevated than the other merge. The BSFC for D85-C10-P5 and D80-C10-P10 is 0.3 (kg/kWh), which is the identical as diesel at complete loading stipulation. Aside from the mixtures poor heating value when compared to others, the above-mentioned mixing of fuel and air could be the cause of the same BSFC. When shown in Figure 3, as the quantity of cottonseed oil grows, the heating value drops, implying that a large quantity of fuel is requisite to create the quantity of energy needed to meet the power demand (Heywood, 1988). Another cause could be the increased volatility of propanol, which raises the integration velocity of the air/fuel assortment, accelerates the combustion progression and improves combustion efficiency (Qi *et al.*, 2011).

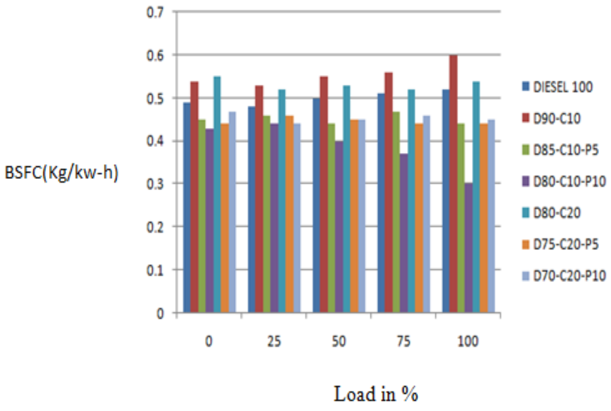

Figure 4. BSFC Vs Load

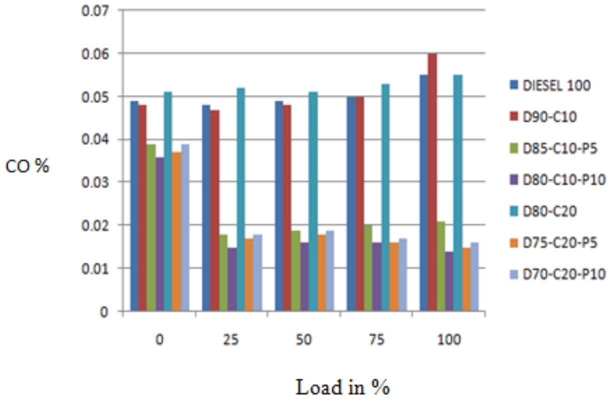

Figure 5. CO Vs Load

3.3. Carbon monoxide (CO)

Figure 5 depicts CO emission levels in percent volume plotted against load with no variation in speed. The curve exhibits a typical flow as it diminishes with growing load, reaches a low point in the cruising assortment and then rises. The consequence of CO in the exhaust continues to fall as the importance of Cotton seed oil in the merge rises. It is due to the existence of additional oxygen in the mixtures, which appears to have the dominant influence even in locally (fuel) rich zones (Sureshbabu *et al.*, 2023; Xiao *et al.*, 2014; Bhanu Teja *et al.*, 2022). As we raise the amount of Cotton seed oil in the merge, this continues to rise. It's possible that this is due to the need for a distinct C/H ratio. Cottonseed oil merged with Propanol reduces CO emissions by 15–20 percent on average, one reason for the decline in CO emissions with the blends could be Propanol's substantially subordinate C/H ratio (Atmanl *et al.*, 2014).

3.4. Carbon dioxide (CO_2)

The measurements of CO_2 emission in percent volume are displayed versus load without changing the speed in Figure 6. The characteristic curve in Figure 5 peaks at 75 percent load. The effect of adding Cottonseed oil and propanol has distinct effects on CO_2 formation at different loads, as shown in Figure 5, and D90-C10 has always been at the top of the curve and D70-C20-P10 has always been at the bottom. However, based on average data, we can assume that the quantity of CO_2 in the exhaust decreases as the quantity of cottonseed oil in the combine grows, which is reciprocal in the case of adding propanol, tumbling the quantity of CO_2 in the exhaust. CO_2 production is also influenced by the carbon/hydrogen ratio in the fuels. Carbon content in merge with higher carbon content result in higher CO_2 emissions in exhaust gases. Other blends' carbon levels are inferior in the similar quantity of fuel devoted at the equivalent engine speed when compared to diesel fuel, which explains why CO_2 generation is low (Xiao *et al.*, 2014).

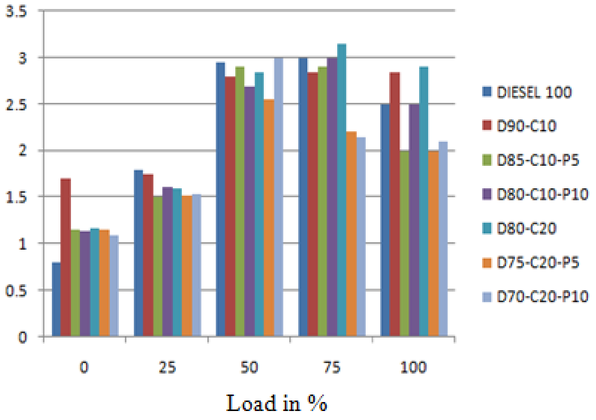

Figure 6. CO_2 Vs Load

3.5. Oxides of Nitrogen (NO_X)

The Figure 7 represents the quantity of NOx emanation in ppm with load devoid of changing the speed. The curve resembles a normal NOx curve in that it rises with load, raising the temperature in the cylinder and so producing more NOx. When contrast to diesel and other merge, there is a drop in NOx for the mixture D70-C20-P10 at full load. When compared to diesel, a 2 percent drop was seen at maximum load. The amount of propanol in the mix is usually proportionate to the reduction in NOx emissions. NOx emissions from diesel engines are affected by a number of factors, including fuel characteristics and engine operating conditions. Higher combustion temperatures and oxygen concentrations in the cylinder are known to generate NOx emissions. The use of D70-C20-P10 has a combined impact of reducing NOx emissions by lowering combustion temperature, lengthening ignition delay, and having a low heating value. Similar observations has been made with the other research work (Sureshbabu *et al.*, 2023).

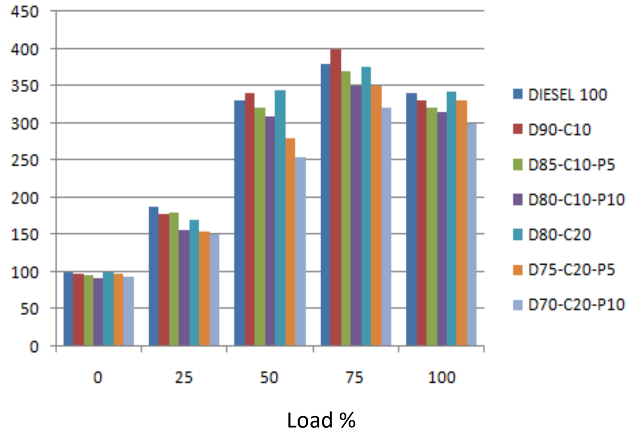

Figure 7. NO_X Vs Load

3.6. Hydrocarbon (HC)

The variation for HC in units of ppm with variable load as well as at constant speed of 2000 rpm is shown in Figure 8. It shows the variance in the engine's HC emission with propanol–diesel fuel merge compared to unadulterated diesel fuel. When comparing all of the mixes tested to diesel fuel, there is typically a significant increase in HC emanation. With the use of blends, the normal augment in HC emanation relative to diesel fuel is between 5.8% and 23%. Furthermore, the decreased density as well as viscosity of Propanol–Diesel mixtures, which results in the creation of smaller fuel droplets, can be contributed to the rise in HC emissions. These droplets reach the cylinder walls' closer sections, causing a quenching effect due to the leaner mixture, as well as more unburned fuels. When a result, as the propanol content in the merge increases, so does the HC emanation, which peaks with the application of D75-C20-P5.

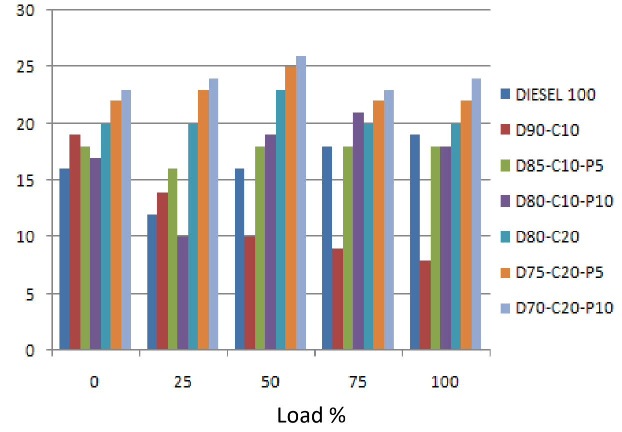

Figure 8. HC Vs Load

4. Conclusion

The tests were conducted on an experimental setup at 2000 rpm as well as under varied load conditions for merge of cottonseed oil and propanol by means of diesel created on a volume basis and given the names D90-C10, D85-C10-P5, D80-C10-P10, D80-C20, D75-C20-P5 and D70-C20-P10. At various loads, the consequence of adding cottonseed oil in the direction of diesel as well as adding propanol to diesel in accumulation to cottonseed oil were noted as well as plotted furthermore the subsequent results were strained. Cotton Seed Oil enhances the density, viscosity, and oxygen content of diesel while lowering the calorific value. With the addition of 5% and 10% propanol to the biodiesel, there is a very minor rise in BTE. When contrast to diesel at full load, D80-C10-P10 displays a 3 percent greater BTE. As can be seen in Figure 2, diesel has the least possible BSFC and is on average 10% superior than the other merge. The BSFC for D85-C10-P5 and D80-C10-P10 is 0.3 (kg/kWh), which is similar as diesel at complete load. The temperatures of the exhaust gases produced by the merge are habitually lesser than those produced by diesel fuel. The pressure peak ascends as the Propanol fraction increases, and the pinnacle crank angle occurs before Top dead centre. Cottonseed oil combined through propanol results in a reduction of 15% to 20% on average. When compared to diesel, the D70-C20-P10 demonstrates a 4.3 percent reduction in emissions at full load. The amount of Propanol in the mix is usually proportionate to the reduction in NOx emissions. The HC emission increases as the propanol content in the mix increases, reaching its maximum value when D75-C20-P5 is used. According to the test results, cottonseed oil as well as propanol can be utilized as fuel additives, and the merge executes superior as both amalgamation materials augment in the merge, implying that the D70-C20-P10 merge is the most appropriate merge that can be used in consign of unadulterated diesel devoid of causing any engine modification. The limitations of using bio diesel in Internal combustion engines is, we couldn't even produce oil for our own citizen's needs. To meet the needs, we are importing oil from other countries. In such situation we couldn't produce biodiesel from edible oils like other countries. The feedstock inputs you need for biodiesel are more expensive than petroleum products. On top of that, the processes for producing the fuel aren't yet efficient enough so that you can produce it very cheaply.

Acknowledgments

The authors appreciate the support from Chennai Institute of Technology. The authors would like to acknowledge the Researchers Supporting Project number (RSP2023R373), King Saud University, Riyadh, Saudi Arabia.

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