Performance features enhancements and trade off study of NOx emission of diesel engine by using ternary blends of karanja - cotton seed biodiesel -diesel.

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Abstract: In this work, Karanja and cotton seed biodiesel were blended with the mineral diesel fuel. The effect of addition of the two biodiesels at different proportion were investigated for the performance and oxides of nitrogen emission of the diesel engine. All the blends exhibit higher brake thermal efficiency than that of the diesel. Trade-off analysis was done with respect to efficiency, fuel consumption and oxides of nitrogen to reflect the emission pattern.

Key words: Biodiesel, Cotton, Karanja, Trade-off analysis.

1. Introduction

Compression ignition engines enjoy prominence in internal combustion engines owing to comparatively better fuel efficiency, lesser hydrocarbon and carbon monoxide tail end discharge compared to petroleum fuelled engines. However, nitrogen oxides and particular matter tail end discharge were high [1-3]. Fast depletion of the oil reserves combined with increase in the pricing, environmental issues and new technologies in automobile sector led to the look for the different fuel combination along with the diesel [4]. Biodiesel is a more appealing comparison to the other sources of oil, because it forms the lower pollution and smoke in line with environmental concerns. The tail-end pollution generated from the compression ignition engine may be greatly decreased by utilizing biodiesel [4,5]. Complete replacement of the diesel in the diesel engine is task which involves many technical modification and lot of economic implications. However partial replacement of the diesel by using the one or two biodiesels along with diesel needs no modifications of the engine. Karanja biodiesel-diesel blend and cotton seed biodiesel-diesel blend exhibit the better thermal properties, performance and emission pattern for diesel engine which are in line with the diesel operations [6-10]. In this work, Karanja and cotton seed biodiesel were blended with the mineral diesel fuel. The effect of addition of the two biodiesels at different proportion was investigated for the performance and NOx emission of the diesel engine.
2. Related works
In this section different ternary blend investigations carried out by the researchers has been reviewed. Pankaj et al. [11] conducted experiments in compression ignition engine fuelled with 10% and 20% of Karanja and Roselle biodiesel with diesel. The studies indicated that chemical energy conversion efficiency (BTE) reduced by 1.82% and 4.36% for 20% blends of karanja (KB20) and Roselle (LA20) biodiesel with diesel respectively. Specific fuel consumption with respect to break power reduced by 6.48% for KB20 and 8.58% for LB20. Tail end exhaust temperature reduces by 4.43OC and 6.11OC for KB20 and LA20 blend respectively indicating the lower peak cylinder temperature. Lower peak cylinder temperature reduces the NOx emission by 3.83% and 6.01% for KB20 and LA20 blend respectively when compared to diesel fuel. Ignition delay reduced by 13.49% for LA20 and 13.4% for KB20 when compared to diesel at full load. They attributed this trend to higher cetane number of the biodiesel which in turn reduces ignition delay.

Prem et al. [12] conducted the experiments by using waste cooking biodiesel, Pongamia and diesel (WCB: PB:D). Prepared three blends containing 10%, 20% and 30% of the biodiesel each with the diesel fuel. The 10% of the ternary blends have showed almost similar pour and cloud point as of diesel fuel. The BTE of 10% ternary blend is 12% which is very near to diesel fuel (12.63%). Concluded the research by stating that the ternary blend are suitable alternatives for the CI engine.

Prabhu et al. [13] operated the diesel engine by using ternary blend consist of diesel, jatropha biodiesel and pentanol blends. Prepared two fuel combinations first combination consist of 70% diesel, 20% jatropha biodiesel, 10% pentanol and second consist of 60% diesel, 20% jatropha biodiesel, 20% pentanol. Reported that the little reduction in the output power and torque for the pentanol addition. Finally concluded that the blend with 20% biodiesels were shown the reduction in the tail end emissions.

Saeid et al. [14] evaluated the viscosity and density of the binary and ternary biodiesel diesel blends. Investigation concluded that the viscosities and densities of blends decreased nonlinearly and linearly with temperature which will affect the behaviours of the blends at different operating conditions.

Saumitra et al. [15] conducted the experiments on the diesel engine by using ternary blends consist of waste Cooking Oil, diesel and ethanol. Investigation reported that the 10% raise in the BTE as compared to that of diesel. As compared to the diesel fuel decrease of 13%,30%,43% and 45% in NOx, CO, HC and smoke respectively.

3. Preparations of the fuel combinations
Three fuel combinations were prepared by volume percentage viz. 5K10C85D (5% Karanja biodiesel +10% cottonseed biodiesel + 85% Diesel), 5K15C80D (5% Karanja biodiesel +15% cottonseed biodiesel + 80% Diesel) and 5K20C75D (5% Karanja biodiesel +20% cottonseed biodiesel + 75% Diesel). Elementary biodiesel properties and their blends with the diesel were presented in table 1.

| Table 1. Biodiesel and blends characters |
|----------------------------------------|
| Properties                | Unit   | Diesel | Karanja biodiesel | Cotton Seed biodiesel | 5K10C85D | 5K15C80D | 5K20C75D |
|----------------------------|--------|--------|-------------------|-----------------------|----------|----------|----------|
| Density                   | Kg/m³  | 850    | 840               | 887                   | 853      | 855      | 856      |
| Kinematic viscosity       | cSt    | 2.46   | 3.11              | 4.34                  | 2.63     | 2.71     | 2.78     |
| Calorific value           | KJ/kg  | 4400   | 37700             | 39234                 | 43194    | 42948    | 42704    |
4. Methods
The experiments were carried out on the single cylinder, water cooled engine and specification of the setup were tabulated in the Table 1. The experimental setup is as shown in Figure 1. For all experiment Eddy Current dynamometer reading, time taken for the 10 ml of fuel consumption, exhaust gas and ambient temperature were recorded. On the exhaust side all the emissions were recorded by tail end gas analyzer. Measurements time interval of fifteen minutes was given for the subsequent test to ensure that no previous fuel residue was left in the fuel injection system. With all the variations of fuel all the tests were replicated four times.

![Experimental setup](image)

**Table 2. Instruments and device Specification**

| Make and type | Kirloskar, single cylinder, 4 stroke diesel engine |
|---------------|--------------------------------------------------|
| Rated power output | 3.37 Kw 1500 RPM |
| Bore and stroke | 85 X 110 mm |
| Compression ratio | 16.5:1 |
| Starting | By hand cracking |
| Injection system | Mechanical Injection |
| Intake system | Natural aspiration |

**Dynamometer**

| Make | Powermag Control Systems(P) Ltd |
|------|---------------------------------|
| Type | FTAC |
| Duty | S-1 |
| Torque | 2.4 kg-m |
| RPM | 1500 rpm |
| Excitation max | 80 V |
| Insulation | Class -F |

**Exhaust Gas Analyzers**

| Make | AVL |
|------|-----|
| Type | AVL Digas 444 |
| Power supply | 110V-220V 15 W |
| CO Measuring Range | 0-0.15% Volume |
| CO2 Measuring Range | 0-20 % |
| HC Measuring Range | 0-30000 ppm Volume |
| NO Measuring Range | 0-5000 ppm Volume |
5. Outcome and discussion

5.1 Engine performance:

5.1.1 Brake specific fuel consumption

The SFC (specific fuel consumption) of an engine is the rate of fuel burnt to produce a unit of power. As load raises the decrease in BSFC trend was noticed as seen in figure 2, 3 and 4. All ternary blend BSFC were found to be less than diesel and pure biodiesel. It is detected that 5K15C80D blend gives the minimum BSFC of 0.16 kg/kW-hr which is less than the mineral diesel at full load.

![Figure 2. BSFC for 5K10C85D at different load](image1)

![Figure 3. BSFC for 5K15C80D at different load](image2)
5. 1. 2 Conversion efficiency (BTE)
For all fuel combinations used in the test, BTE increases with load as seen from the Figure 5, 6 and 7. All the fuel blends exhibits higher BTE then the mineral diesel. It is observed that the blend 5H20C75D generates the peak BTE of 37% at peak load which is greater than the BTE of the mineral diesel.
5.2 Trade-off analysis
Trade off analysis involving NOx emission, BSFC and BTE has been carried at 50% and full load which has been presented in the figure 8 and 9. NOx emission for biodiesel operation found to be low as compared to the diesel operations. Same decrease in the trend was noticed by the Hao [16], attributed to the fact that the higher density imparted the negative effect on the spray pattern which results in the lower chamber temperature intern reduces the NOx at medium loads. The study mainly deals with determine the best possible fuel combination at 50% and full load which produces the less NOx with
optimum BSFC and BTE. The fuel blend 5K20C75D was the better fuel combination which produces less NOx compared to the other two blends with optimum BTE and BSFC for both 50% and full load.

Figure 8. NOx-BTE-BSFC trade-off at 50% load

Figure 9. NOx-BTE-BSFC trade-off at full load

6. Conclusion
The motivation behind the current test study was to examines the performances and emissions of Karanja and cotton seed biodiesel combinations with mineral diesel. The subsequent derivations are evolved from the test study results:

- The BTE of all the fuel combinations are improved with respect to mineral diesel. BSFC is lesser for all testing fuel combinations then that of the diesel, 100% Karanja and cotton seed biodiesels at all load conditions.
- In trade-off investigation it has been detected that at 50% and full load condition 5K20C75D is the optimal fuel combination for the less NOx emission with the optimum BTE and BSFC.
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