Use of Nahar biodiesel-diesel blend in a agricultural diesel engine

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Abstract. This paper presents the features of a non-edible feedstock Nahar oil derived B15 blend of Nahar biodiesel powered single cylinder DI diesel engine. Various output parameters such as thermal efficiency of the engine, specific fuel consumption and temperature of the exhaust gas; different emission parameters such as specific CO, specific HC, NOx, smoke opacity and combustion parameters such as ignition delay have been studied. The experimental investigation reveals that the thermal efficiency slightly reduced. At highest load, the BTE for the blend is 31.56\% and for the diesel it is 32.49\%. All pollutant emissions significantly reduced, and ignition delay also reduced for the B15 blend. CO and HC emission observed to be 3.11 and 0.035 g/kWh. Overall, it is suggested to use Nahar biodiesel blend as a diesel supplement in engine.

Keywords: Biodiesel; Nahar; Diesel engine; Performance; Emission

1. Introduction

People and their wants for energy are ever-growing. However, the traditional sources of energy are not sustainable and the consequence of excessive fossil fuel use on the planet is something to ponder upon. Increase of fossil fuel prices and its limited availability poses grave menace to the security of energy supplies in the country [1]. Researchers and scientists are developing and exploring non-conventional energy sources to satisfy the energy thirst of humankind. Various renewable energy sources have been explored and the energy mix is shifting toward lower carbon emissions. Amongst several alternative energy sources, biodiesel proves to be promising as a clean vehicular fuel, which offers diesel comparable performance and at the same time reduce pollutants. Biodiesel is usually prepared from various vegetable oils and fats [2]. Owing to the high cost of the edible oils in developing countries, usually non-edible oils or waste based oils are used for the production of biodiesel. It is known that alkyl ester is prepared by synthesizing fats or oil with suitable alcohols and this process is called as “transesterification”[3]. However, if the oil or fat contains high free fatty acids (more than 3\%), then it has to be pretreated with sulfuric acid to reduce FFA level and the process is known as “esterification” process [4]. If pretreatment step avoided, then the FFA present in the oils
will reacts with alcohol to produce soaps and inhibit the chemical reaction, which resulted into lower yields or even failed to deliver any biodiesel. Usually, all the non-edible oils possess high acid value or FFA content and hence needs to be pretreated [5][6][7][8][9][10]. Many non-edible oilseeds are there, which have been tried for biodiesel production and its diesel engine utilizations [11][12]. In Indian scenario, feedstocks such as Jatropha, Karanja, Neem, Mahua, Rubber, Linseed, Polanga, Nahar etc. has been tried for biodiesel production [13][3][14]. Recently, the authors have stressed on biodiesel preparation from Nahar oil and its diesel engine utilization [15][16][17]. Choice of catalysts plays a crucial role in reducing costs and the authors used heterogeneous catalyst CaO for transesterification process [18]. The experimental investigation with different blends also shows promising results in terms of improvement in emission and diesel comparable performance. In this study, a lower order blend B15 (15% Nahar biodiesel mix with 85% diesel fuel) is used in an agricultural single cylinder DI diesel engine. This study was deliberated to measure performance of diesel engine run by B15 blend of Nahar biodiesel.

2. Materials and method

| Properties            | Diesel fuel | B15   |
|-----------------------|-------------|-------|
| Density (g/cc)        | 0.830       | 0.836 |
| Calorific value (MJ/kg) | 42         | 41.642|
| Pour point (˚C)       | -8.6        | -6.9  |
| Cetane number         | 48.06       | 48.55 |

![Test engine setup](image)

Fig. 1. Test engine setup
The test fuel properties are given in Table 1. The details of the engine trial setup and engine testing methodology has been given in literature [17]. Volume wise 15% raw biodiesel added to diesel fuel and stirred sufficiently and left for few days for miscibility test. No separation of the biodiesel from the blend is observed.

The engine trial setup is shown in Fig. 1. AVL DITEST 1000 and AVL 437 smoke meter was used for the exhaust gas study.

3. Results and discussion

3.1 Brake thermal efficiency (BTE)

![Fig. 2. Effect of load level on brake thermal efficiency](image)

The effect of load level on the BTE of the engine is shown in Fig. 2. It is obtained that the BTE for the blend is higher compared to baseline fuel for low load to mid-load operation. For two higher load operation i.e., at 75% and 100% loading the BTE of the blend is lower. This could be due to the higher fuel consumption as a result of lower calorific value at higher load for the blend in order to meet the required brake output. At highest load, the BTE for the blend is 31.56% and for the diesel it is 32.49%. The noise of the engine was under controlled level, which is a desirable aspect for a diesel engine.

3.2 Brake specific fuel consumption (BSFC)

The effect of load level on the BSFC of the engine is shown in Fig. 3. It is seen that for all load condition the BSFC is higher for the blend compared to the baseline. This could due to the lower heating value, high viscosity of the blend. At full load, 2.6% higher BSFC obtained for the B15 compared to diesel, whereas at lower load (25%), the BSFC for the blend is higher by 5.91% compared to diesel. Even though high BSFC for the lower order blend, higher BTE at low load is attributed to the lubricity characteristics of the lower concentration blend, which reduced frictional
loss of power. As the load increases the power requirement is more and could not be met by lower energy dense blend. At highest load, the BSFC for the blend is 0.269 kg/kWh, whereas for diesel fuel it is 0.262 kg/kWh.

![Fig. 3. Effect of load level on brake specific fuel consumption](image1)

3.3 Exhaust gas temperature (EGT)

![Fig. 4. Effect of load on exhaust gas temperature](image2)
The effect of the load level on the EGT is shown in Fig. 4. With an ascending of the load level, the EGT increased both for blending and base fuel and for all engine load operation, the EGT was lower for blending than for diesel fuel. At the upper limit load, the EGT for the blend is 341.15 °C, while for diesel fuel it is 346.23 °C. Overall, a decrease of 6-8 °C temperature for the blend is observed at all loading operations. This is possibly due to the low temperature oxidation of the biodiesel fuel. The chemical structure of the derived fuel helps in good combustion, for which the exhaust heat loss got reduced.

3.4 Brake specific CO emission

![Fig. 5. Effect of load on brake specific CO emission](image)

The effect of load on the brake specific CO (BSCO) emission of the engine is shown in Fig. 5. It is observed that with ascending of load the BSCO emission drastically dropped. At 25% load, the BSCO emission for the diesel and blend is 41.3 and 31.52 g/kWh respectively, whereas at full load, it is 3.31 and 3.11 g/kWh respectively. With increase in load the combustion temperature increases and better atomization results in complete combustion for which the BSCO emission decreased. Because of the more oxygen content, the BSCO emission decreased for the blend. For diesel engine less CO emission is always desired.

3.5 Brake specific HC emission

The impact of loading on the brake specific HC (BSHC) emission of the engine is shown in Fig. 6. Like BSCO emission, the trend of BSHC emission with load reveal that for all load operation the BSHC emission is lower for the blend. The BSHC emission is recorded to be 0.1065, 0.076, 0.058 and 0.041 g/kWh for diesel at 25%, 50%, 75% and 100% load respectively, whereas for the blend these values are 0.095, 0.068, 0.048 and 0.035 g/kWh for the load ranges respectively. HC emission is primarily caused by incomplete combustion [19]. Very less value of HC has been seen in this study.
Fig. 6. Effect of load on brake specific HC emission

3.6 NOx emission

Fig. 7. Effect of load on NOx emission
The impact of loading on NOx emission of the engine is shown in Fig. 7. It is seen that for all load level the NOx emission decreased for the blend compared to base fuel. The lower combustion heat of biodiesel fuel blend is ensured from EGT graph. As the combustion temperature strongly influences the NOx emission, it is decreased for the blend. At highest load, the NOx for the B15 and diesel is recorded to be 954 ppm and 1025 ppm respectively. It is also examined that with the increase in load the NOx peaked as a result of increase in combustion temperature [20].

3.7 Smoke opacity

The impact of load on the smoke discharge of the engine is appeared in Fig. 8. At lower load the smoke for blend has been seen to be in line with the diesel. At peak load, the smoke emanation for the blend declines compared to baseline. This may be owing to the more oxygen infusion of the blend. The smoke opacity is observed to be 20.2% and 18.6% for diesel fuel and B15 respectively at maximum load.

![Fig. 8. Effect of load on smoke opacity](image)

3.8 Ignition delay

The impact of load on the ignition delay (ID) of the engine is appeared in Fig. 9. It is seen that for the entire load spectrum the ID decreased for the blend compared to diesel. This could due to the more ignition index value of the blend. It is seen that with rise in load the ID declines. This is due to the increase of in-cylinder temperature, which enhances the fuel spray formation and atomization and early evaporation, resulted in reduction of ignition delay period. At maximum load, the ID for the blend and diesel is recorded to be 8.8 °CA and 9.12 °CA respectively.
Fig. 9. Effect of load on ignition delay

4. Conclusions

Biodiesel processed from Nahar oil is blended with diesel fuel to get B15 blend. The prepared blend is investigated in an agricultural diesel engine. Followings are the conclusions drawn from this experimental investigation.

- The BTE reduced slightly at higher loads and the BSFC increased for the blend for all load level.
- The brake specific CO and HC exhaust declined with load level and observed to be lower for the blend in contrast to diesel fuel.
- Both NOx and smoke emission observed to be lower for the blend in contrast to diesel fuel.
- Ignition delay reduced for the blend compared to baseline fuel.
- Nahar blend B15 can be a good supplement for diesel powered equipment.

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