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# INVESTIGATION ON THE EMISSION REDUCTION TECHNIQUE IN ACETONE-BIODIESEL ASPIRATED DIESEL ENGINE

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## ABSTRACT

*In this work, palm biodiesel was evaluated as an alternative to the petroleum diesel in compression ignition engine. This work would pave the way for the evaluation of the technological feasibility of employing palm biodiesel (BD100) in a diesel engine and also to discover the prospect of running a diesel engine on acetone in the dual-fuel blending mode to view its emission characteristics. Acetone was blended with palm biodiesel and operated at a compression ratio of 16. A base-catalysed transesterification process was employed to convert palm oil into palm biodiesel. Acetone with 96.4% purity was used as an oxygenated additive. The experimental results have revealed that the acetone to palm biodiesel blends gave a significant reduction in HC (hydrocarbons), CO (carbon monoxide),* $NO_x$ *(nitrogen oxides) and smoke emissions when compared to palm biodiesel under naturally aspirated conditions.*

**Keywords:** acetone; palm bio-diesel; blends; emissions.

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## INTRODUCTION

Diesel engine produces more torque than petroleum engine, and is more fuel efficient (Yuvarajan and Ramanan, 2016a,b). Hence, it is extensively deployed in high power and automobile applications. However, the diesel fuel emits higher emissions of compounds which form a primary source of global dimming, global warming and acid rain. A lower environmental impact and a reduction in air pollution can be achieved by using biofuels. The combustion of biofuels in the engine would reduce smoke, carbon monoxide (CO) and hydrocarbons (HC) emissions. However, biofuels have some drawbacks. These include poor cold flow properties, high viscosity, poor oxidation stability and high nitrogen oxides ($NO_X$) emissions.

Alcohols have been found to be an alternative fuel in view of storage and handling (Yuvarajan *et al*., 2017). Many studies have proven that doping alcohols into diesel improves the diesel-properties. Many works have been focused on adding alcohols and biodiesel to diesel. But very few works have been carried out on neat alcohol-biodiesel (Venkata Ramanan and Yuvarajan, 2015a, b; Devarajan *et al*., 2017; 2016). Dual-fuel blending is an effective technique for reducing the emissions from diesel engines (Radhakrishnan *et al*., 2017; Santhosham and Aghalayam., 2016; Devarajan *et al*., 2017a, b). Hence in this work, the author makes the effort to reduce the emissions of neat biodiesel fueled engine by adding acetone to biodiesel as an emulsion. Further, this investigation would pave the way to evaluate the technological feasibility of employing palm biodiesel (BD100) in a diesel engine. It would also help discover the prospect of running a diesel engine on biodiesel/acetone in a dual-fuel technique, and to view its emission characteristics.

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## MATERIALS AND REAGENTS

### Palm Biodiesel

Palm oil was then converted into palm biodiesel by the simple transesterification process which involves potassium hydroxide (catalyst) and methanol (basic alcohol). Palm oil was added to a mixture containing 15% of methanol and 5% of potassium hydroxide (catalyst) and stirred for 75 min at 60°C. The main chemical properties of palm biodiesel (BD100) and diesel are examined as per ASTM norms and are listed in *Table 1*.

### Experimental Set-up

Experimental trials were carried out on a stationary single cylinder, water-cooled 4.4 kW variable compression diesel engine. The complete specifications of the tested engine and equipment are detailed in *Table 2*. AVL Digas 444 flue gas analyser was employed to carry out the emission analysis of the test fuel. HC, $NO_X$ and CO emissions are measured by the analyser.

## RESULTS AND DISCUSSION

### Carbon Monoxide

The variation of the CO emission with changing loads for tested fuels is shown in *Figure 1*. (Yilmaz *et al*., 2016). CO emissions from biofuels are less than diesel at all conditions owing to its oxygen-rich nature (Yilmaz *et al*., 2016). CO emission reduces with increase in acetone content. By adding acetone to palm biodiesel, a significant reduction in CO emissions, was observed, at all loads when compared to the neat palm biodiesel. The lower CO emission is attributable to the improved combustion rate. Gaseous fuel makes the mixture leaner and promotes combustion (Schroder *et al*., 2013). CO emissions for BD100, BD100 + Acetone and Diesel are 0.11%, 0.09% and 0.14% respectively at peak load conditions.

### Hydrocarbons

The variation of the HC emissions with changing loads for the tested fuels is shown in *Figure 2*. HC emissions from biofuels are less than diesel at all conditions owing to its oxygen-rich nature (Yilmaz *et al*., 2016; Yuvarajan *et al*., 2017). HC emission increases with load for all the tested fuels. At the higher load, the mixture is too rich to deliver the power resulting in higher HC emission. HC emission reduces with increase in the acetone content. By adding acetone to palm biodiesel resulted in a significant reduction in HC emissions, at all loads when compared to neat palm biodiesel. The lower HC emission is attributable to the improved combustion rate. Acetone makes the mixture leaner and promotes combustion (Schroder *et al*., 2013). HC emissions for BD100, BD100 + Acetone and Diesel are 69, 65 and 71 ppm respectively at peak load conditions.

TABLE 1. PROPERTIES OF TESTED FUELS

| Properties | POBD100 | Diesel | Method |
|---|---|---|---|
| Water content (%) | 0.03 | 0.001 | ASTM D2709 |
| Density @ 18°C (g $m^{-3}$) | 0.8833 | 0.8210 | ASTM D4052 |
| Kinematic Viscosity @35°C ($mm^2\ s^{-1}$) | 4.30 | 2.5 | ASTM D445 |
| Calorific value (kJ $kg^{-1}$) | 38 108 | 42 950 | ASTM D240 |
| Cetane index (CI) | 52 | 46 | ASTM D976 |
| Flash point in °C | 140 | 50 | ASTM D93 |
| Sulphur content | - | - | - |
| Iodine value (g/100 g oil sample) | 65 | - | ASTM D1510 |
| C (%) | 77.2 | - | ASTM D5291 |
| H (%) | 11.4 | - | ASTM D5291 |
| O (%) | 11.4 | - | - |

Note: POBD100 – palm biodiesel.

TABLE 2. SPECIFICATION OF EXPERIMENTAL SET-UP

| | |
|---|---|
| Make | Tafe |
| Rated power | 50 hp |
| Cylinder | Three |
| Rated speed | 1 500 rpm |
| Bore diameter (D) | 87.5 mm |
| Stroke (L) | 110 mm |
| Compression ratio | 17:1 |
| Cone angle | 110° |
| Injection type | Direct injection |
| Fuel injection pressure | 200-1 400 bar |
| Injection timing | 23° bTDC |

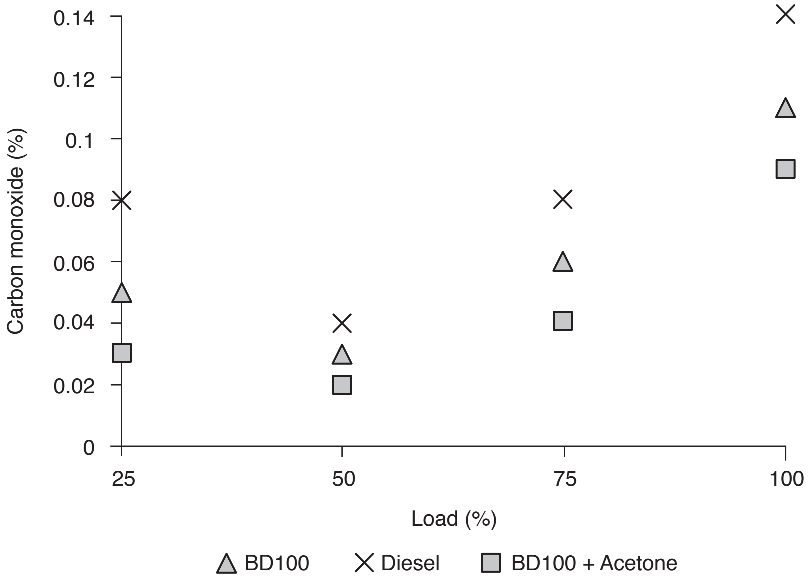

*Figure 1. Variation of carbon monoxide (CO) with load.*

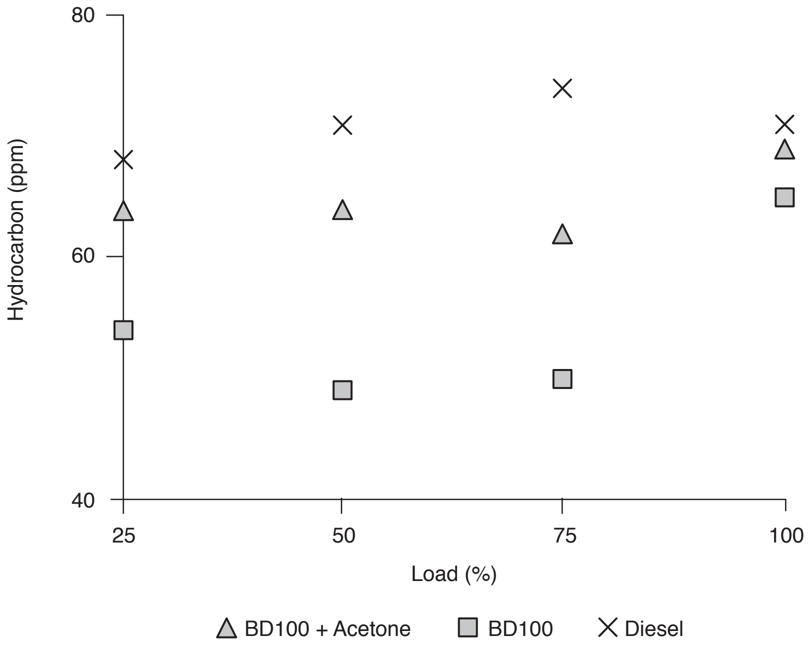

*Figure 2. Variation of hydrocarbon (HC) with load.*

## Oxides of Nitrogen

The variation of the $NO_x$ emissions with load changes for tested fuels is shown in *Figure 3*. $NO_x$ emission increases with a load for all the tested fuels. At the higher load, the combustion temperature increases resulting in a higher $NO_x$ emission. $NO_x$ emission reduces with increase in the acetone content. By adding acetone to palm biodiesel resulted in a significant reduction in $NO_x$ emissions, at all loads when compared to neat palm biodiesel. The lower $NO_x$ emission is attributable to the lower volatility of acetone-biodiesel mixture (Schroder *et al.*, 2013; Yuvarajan *et al.*, 2017). $NO_x$ emissions for BD100, BD100 + Acetone and Diesel are 1415, 1355 and 1035 ppm respectively at peak load conditions.

## Smoke Opacity

The variation of the smoke emissions with load changes for tested fuels is shown in *Figure 4*. Smoke emission increases with load for all the tested fuels.

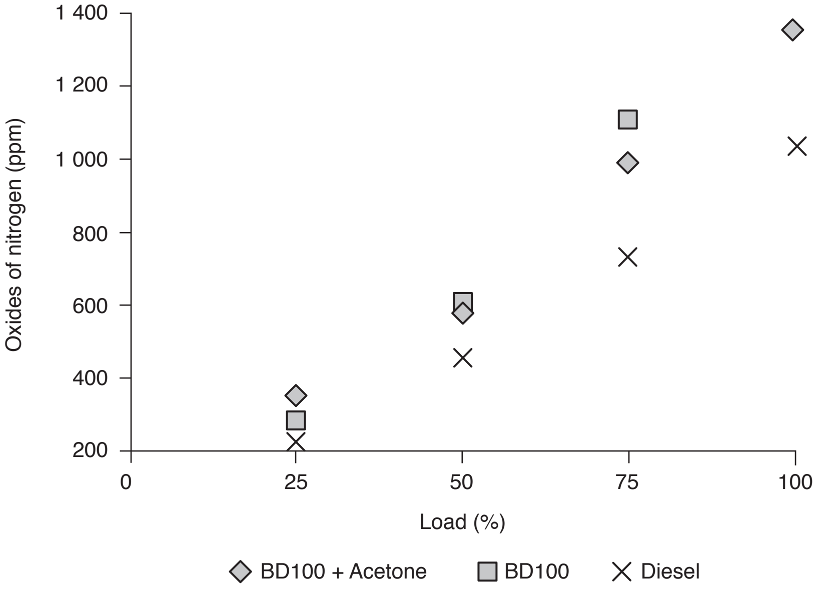

*Figure 3. Variation of nitrogen oxides ($NO_X$) with load.*

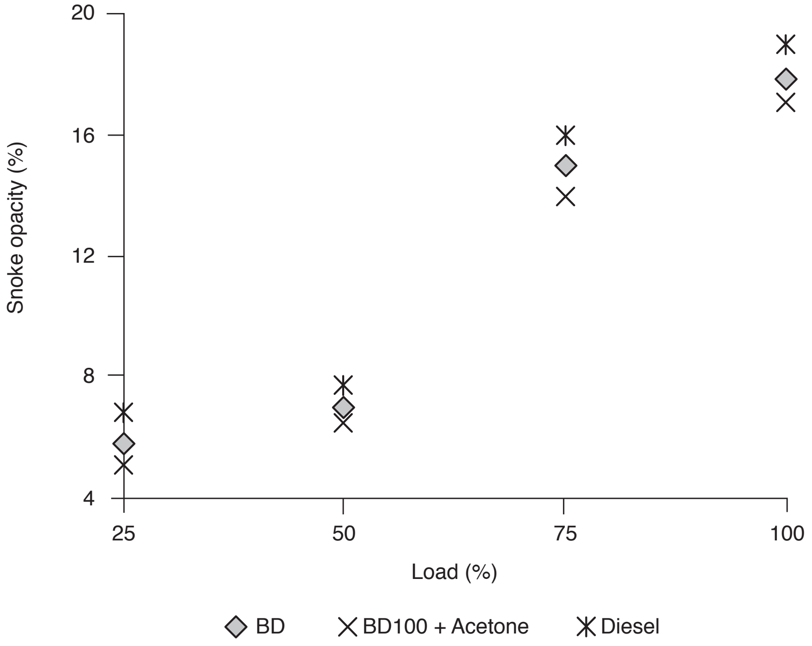

*Figure 4. Variation of smoke emissions with load.*

At the higher load, the combustion temperature increases resulting in a higher smoke emission (Yuvarajan *et al.*, 2017). Smoke emission reduces with increase in the acetone content. By adding acetone to palm biodiesel resulted in a significant reduction in smoke emissions, at all loads when compared to neat palm biodiesel. The oxygen atoms present in acetone gets bonded during the phase of combustion and lowers the formation of soot (Schroder *et al.*, 2013). Smoke emissions from BD100, BD100 + Acetone and Diesel are 1415, 1355 and 1035 ppm respectively at peak load conditions. A similar trend of reduction in smoke emissions was observed in many studies (Aydin and Ogut, 2017; Kim and Choi, 2010).

## CONCLUSION

The following conclusions can be made from this work: (a) it is experimentally feasible to develop the dual-fuel system using acetone-biodiesel, (b) CO emissions were found to be lower for biodiesel and biodiesel-acetone mode than neat diesel at all loads. Further, CO emission levels were lower in biodiesel-acetone mode than neat biodiesel operation, (c) HC emissions in biodiesel and biodiesel-acetone mode was lower than diesel at all loads. HC emissions in biodiesel-acetone mode were found to be lower than neat biodiesel at all loads, (d) $NO_X$ emission was higher for palm biodiesel and palm biodiesel-acetone dual fueling mode than diesel at all loads. However, $NO_X$ emission for palm biodiesel-acetone dual fueling mode was lower than neat biodiesel. (e) Smoke emissions from neat palm biodiesel and palm biodiesel-acetone mode were lower than neat diesel in all conditions. Smoke emissions decreased at palm biodiesel-acetone dual-fuel mode owing to improvement in the combustion.

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