International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 3 Issue 11, October 2016

ISSN: 2394-4404

# The Effect Of Supercharging On A Dual-Fuel Engine With Bio-Mass Gas Diesel And Soybean Oil Blend

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***Abstract:*** ***The effects of Bio-ass gas-diesel and soybean oil blends on the performance and exhaust emissions of a supercharged dual-fuel multi-cylinder diesel engine have been experimentally investigated. In this study, Bio-mass gas that was generated from a downdraft gasifier and intake air by air compressor were injected separately into the engine intake manifold. The pilot fuel injection timing was advanced to 22° before top dead centre and the primary fuel injection pressure was maintained at 2.5 bar throughout the experiment. The soybean oil was blended with diesel fuel at 5%,10,15,25,30,35,45, 50,60,70,75 and 100% volume ratios. The experiments were carried out by varying the injection flow rate of both the Bio-mass gas and the air at different engine loads and at constant engine speed. It was observed that at 70% engine load, the brake thermal efficiency of 20% soybean oil blends was 20.10% as compared to the percentage in Bio-mass gas-diesel dual fuel that was 21.38% and 24.11% in diesel fuel. Emissions of CO and NOx were 0.42% and 230 ppm as compared to 0.38 and 208 ppm in Bio-mass gas-diesel duel fuel operation. These showed that the engine performance of the Bio-mass gas-diesel and soybean oil blends were reduced and the emission characteristics were increased at the rated loads compared with the Bio-mass gas-diesel fuel. This is mainly due to the lower calorific value, high viscosity and higher density of the soybean oil compared with diesel fuel. Based on critical analysis of the graphs, the 25%soybean oil with 75% diesel mixture is the best-suited blend for the dual-fuel mode of the Bio-mass gas-diesel engine without a preheating process and engine modifications. Therefore, the experimental results indicate that soybean oil can be used as an alternative to diesel in supercharged dual-fuel Bio-mass gas engines.***

***Keywords: Bio-mass gas-diesel, Downdraft Gasifier, Gasification, Supercharging, Preheating process.***



## I. INTRODUCTION

Increasing environmental concerns and the shortage of petroleum-based fuels have encouraged studies on alternative sources of fuels for diesel engines. Producer gas and vegetable oils are two potential alternative fuels capable of replacing diesel fuel partially in the dual-fuel mode of a diesel engine. In addition, diesel and vegetable oil blends reduce the viscosity of vegetable oils there by avoiding blockage of fuel lines, atomization and heavy particulate emissions. This has encouraged a number of studies using various vegetable oils. The usage of producer gas in dual-fuel mode diesel engines reduces the running cost but the only problem with producer gas is its lower heating value. Supercharging of intake air is one way to improve the combustion characteristics of dual-fuel -engines. There are number of studies related to dual-fuel engines fueled with producer gas-diesel and vegetable oil blends.They found that the right blend ratios ensure smooth engine operation with lower NOx emissions. This technique can be more advantageous by introducing supercharging. This study presents the effects of supercharging on the performance and exhaust gas emissions of a dual-fuel engine fueled with producer gas-diesel and palm oil blend.

## II. METHOD AND PROCEDURES

### BASIC SETUP

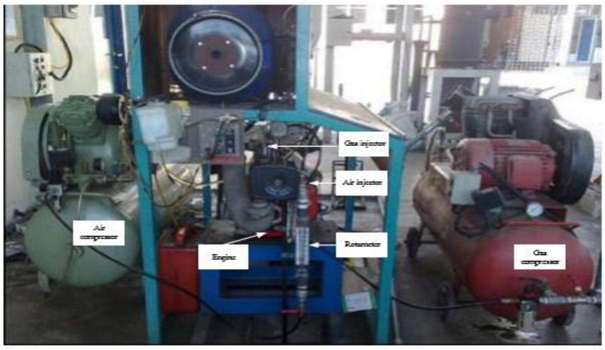


*Figure 1: Schematic Diagram of Gasifier-Engine System*

| Sr. No. | Item | Description |
|---|---|---|
| 1 | Model | Yanmar L70AE-DTM |
| 2 | Capacity | 296 cc |
| 3 | Maximum Power | 4.9 kW @ 3600 rpm |
| 4 | Compression Ratio | 19.1 |
| 5 | Injection Timing | 14° ± 1° BTDC |
| 6 | Injection Pressure | 19.6 MPa |

*Table 1: Specifications of the Engine*

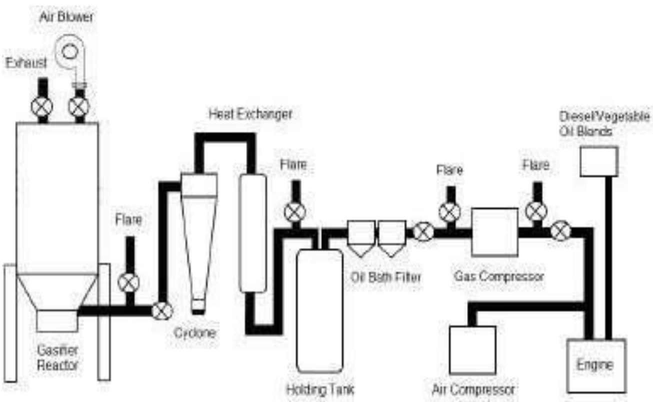


*Figure 2: Schematic Diagram of Gasifier-Engine System*

| | |
|---|---|
| Biomass fuel | Off cut furniture wood |
| Biomass size | 50 mm-100 mm |
| Conversion efficiency | 70%-75% |
| Typical gas composition | $CO=20\pm4\%$, $H_2=14\pm2\%$ |
| | $CO_2=12\pm3\%$, $N_2=45\%$ |
| | $CH_4$=up to 2.5%, |
| Average gas calorific value | 4.2-4.5 $MJ/m^3$ |

*Table 2: Specifications of the Downdraft Gasifier*

The experimental setup consisted of a downdraft gasifier system, an air compressor and a diesel engine. The gasifier was specifically designed and developed by the (my college) with its specification given in Table 2. The calorific value of Bio-mass gas is comparable with Rathore et al. [11]. The experiments were carried out on a four-stroke single cylinder direct injection (DI) diesel engine, with specifications shown in Table 1. An electrical eddy current dynamometer was directly coupled to the engine and the engine load applied is measured through the engine controller. A glass burette with 100 ml volume capacity and a stopwatch were used to determine the fuel consumption. The exhaust emissions and exhaust gas temperature were measured using a Kane automotive gas analyzer and a K-type thermocouple, respectively. Two types of experiments were conducted in this study; a supercharged dual-fuel Bio-mass gas-diesel experiment and then a Bio-mass gas-diesel and vegetable oil blends experiment. The soybean oil used in this study is a refined, bleached and deodorized (RBD) palm cooking oil. Based on the literature, the soybean oil and diesel were blended at 5%,10,15,25,30,35,45, 50,60,70, 75 and 100% mixtures, designated as P5,P10,P15,P25,P35,P45, P50,P60, P75 and P100, representing the percentage of RBD palm oil in the mixture (e.g., P25 contains 25% RBD palm oil and 75% diesel fuel in the volume). The properties and characteristics of the blended diesel and RBD palm oil at various volume ratios are shown in Table 3. All tests were conducted at start up with diesel fuel only. The experiment using the supercharged dual fuel setup was started 30 minutes after the gasifier was started up. Engine torque was set to 3, 5, 7 and 9 Nm and each load was applied at a constant engine speed of 1600 rpm and an advanced fuel injection timing of 23° before top dead centre. To supercharge the engine, the Bio-mass gas generated by the gasifier was first compressed using a gas compressor, as illustrated in Figure 2. The compressed Bio-mass gas and compressed air were then injected simultaneously through a port injection at constant injection pressures of 2 bar into the engine cylinder. A pressure regulator and a gas flow meter were used to maintain the required pressure and flow rate of both the compressed producer gas and the air, as shown in Figure 1. The supply of producer gas was adjusted manually to obtain the maximum percentage of diesel displacement. In all cases, the engine was operated at a standard pilot fuel injection pressure of 196 bars and the experiment for each test was replicated three times.

| Diesel/RBD Palm Oil Blends (%) | 100/0 | 75/25 | 50/50 | 25/75 | 0/100 |
|---|---|---|---|---|---|
| Heating Value (J/kg) | 44318 | 43246 | 42528 | 41101 | 39426 |
| Kinematics Viscosity (cSt) @ 32°C | 5.32 | 10.61 | 18.24 | 37.42 | 54.73 |
| Density ($kg/m^3$) | 828.28 | 835.12 | 849.40 | 861.08 | 872.76 |

*Table 3: Properties of Diesel and RBD Palm Oil Blends at Various Volume Ratios*

| Mixing ratio of DF, soyabean oil & BMG | Thermal efficiency (in %) | Diesel Displacement (%) | CO emission (%) | Nox emission |
|---|---|---|---|---|
| 100% DF | 23.11 | - | 0.11 | 394 |
| DF+BMG | 21.11 | 68.42 | 0.38 | 208 |
| P5+BMG | 17.41 | 54.61 | 0.43 | 243 |
| P10+BMG | 18.37 | 58.34 | 0.42 | 238 |
| P15+BMG | 18.97 | 59.44 | 0.42 | 241 |
| P25+BMG | 19.54 | 61.52 | 0.41 | 230 |
| P30+BMG | 18.77 | 60.21 | 0.43 | 242 |
| P35+BMG | 18.34 | 60.10 | 0.43 | 241 |
| P45+BMG | 18.12 | 56.77 | 0.41 | 238 |
| P50+BMG | 18.34 | 57.78 | 0.42 | 240 |

ISSN: 2394-4404

| | | | | |
|---|---|---|---|---|
| P60+BMG | 17.21 | 53.14 | 0.44 | 244 |
| P70+BMG | 17.11 | 52.08 | 0.45 | 246 |
| P75+BMG | 17.38 | 52.12 | 0.46 | 248 |
| P100+BMG | 16.18 | 49.48 | 0.50 | 265 |

*Table 4: Summarized of the results*

## III. RESULTS AND DISCUSSIONS

Brake Thermal Efficiency (BTE): Figure 3 shows the variation in BTE of the diesel engine operated under supercharged conditions using producer gas-diesel, as well as producer gas-diesel and RBD palm oil blends in terms of the brake mean effective pressures (BMEP). The BTE was higher for the producer gas-diesel compared with the producer gas-diesel with RBD palm oil blends over the entire load range. As the producer gas is commonly used in the engine, the properties of the injected fuel have a major effect on the engine performance. The RBD palm oil has higher viscosity, higher density and lower calorific value than diesel fuel, thus resulting in lower BTE. The maximum BTE values of the producer gas-diesel with RBD palm oil blends were 20.10% 19.29%, 18.38% and 17.18% for the P25+PG, P50+PG, P75+PG and P100+PG blending ratios respectively compared with 21.38% for the producer gas diesel dual fuel (DF+PG) and 24.11% for the pure diesel fuel (DF) operations. Specific Energy Consumption (SEC): In dual fuel mode operation, the SEC is the preferred parameter for comparing the performance of fuels with different calorific values and densities. Even though the producer gas-diesel and RBD palm oil blends provide the same power as the producer gas-diesel operation, its SEC is higher at all operating conditions, as shown in Figure 4. This is mainly due to the combined effects of the fuel density, viscosity and lower heating value of the blends compared with pure diesel fuel. Higher density blends containing higher percentages of RBD palm oil leads to increased fuel flow rate for the same injection pressure by the fuel injection pump, thereby increasing SEC. The values of SEC at 80% load in diesel fuel and producer gas-diesel operation were 15.17 and 17.67 MJ/kWh, respectively. Using producer gas-diesel/RBD palm oil blends, the SEC at P25+PG, P50+PG, P75+PG and P100+PG blending ratios were 20.21, 21.17, 22.37 and 22.52 MJ/kWh, respectively.

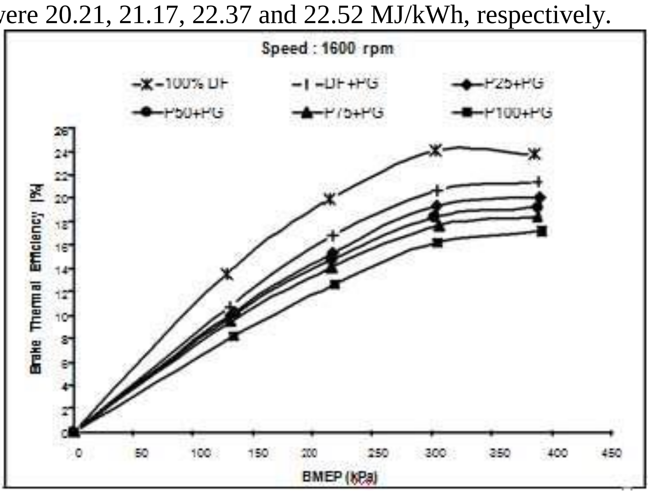


*Figure 3: Effect of BMEP on Brake Thermal Efficiency*

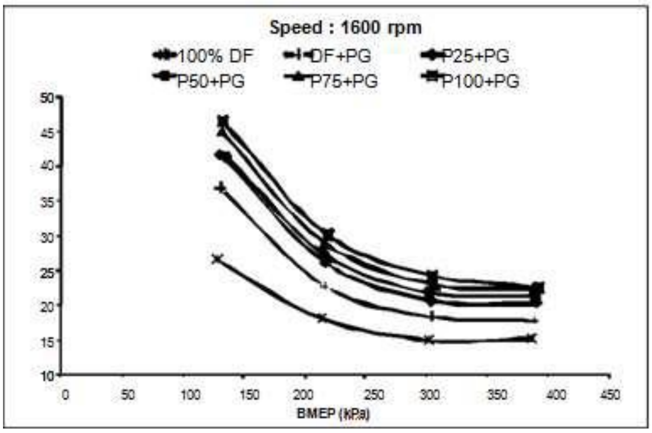


*Figure 4: Effect of BMEP on Specific Energy Consumption*

*DIESEL DISPLACEMENT (DD):* The use of producer gas in dual fuel mode operation reduces the consumption of diesel fuel at all engine loads, as shown in Figure 5. The DD decreased at low and high load conditions, as well as with displaced maximum at the mid load. This phenomenon was due to insufficient oxygen for complete combustion at low load, whereas at high load, the insufficient producer gas flow decreased the diesel displacement. Diesel displacement was maximal in producer gas-diesel operation compared with the producer gas-diesel and RBD palm oil blends. The differences in fuel properties such as cetane number, viscosity and calorific value could account for this observed trend. The maximum percentage of respective fuels displaced with producer gas-diesel fuel was 70.42%, whereas the producer gas-diesel/RBD palm oil blends at P25+BG, P50+BG, P75+BG and P100+BG ratios were 61.52%, 57.78%, 52.12% and 49.48%, respectively.

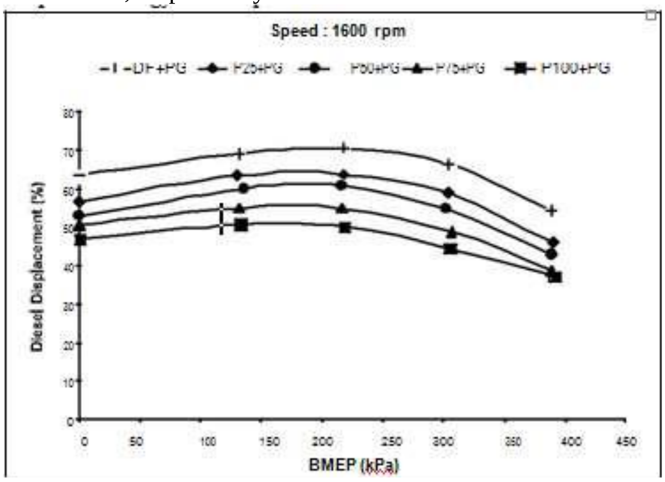


*Figure 5: Effect of BMEP on Diesel Displacement*

Carbon Monoxide (CO) Emission: The CO emission in producer gas-diesel and RBD palm oil blends operation is always higher than of producer gas-diesel at all operating conditions as shown in Figure 6. The most possible reason is due to the high viscosity of RBD palm oil and its blends. The higher the viscosity, the more difficult it is to atomize for the RBD palm oil and its blends, hence resulted in locally rich mixtures in the combustion chamber. Since the producer gas is used in the dual fuel mode, more CO emission was generated during the combustion process due to insufficient supplied of oxygen. Minimum CO was found to be 0.41%, 0.42%, 0.46% and 0.50% for P25+PG, P50+PG, P75+PG and P100+PG blending ratios, respectively as compared to 0.1% and 0.39% in pure diesel and producer gas-diesel fuel operation, respectively. Nitrogen Oxides (NOx) Emission: The variations in NOx emission in terms of the BMEP for the producer gas-diesel and the different producer gas-RBD palm oil blends are shown in Figure 7. As shown therein, the NOx emissions increased with the engine load due to the high temperature in the combustion chamber. The NOx emission in dual fuel engines is always lower than of diesel fuel operation due to low peak cylinder and residence time in the combustion chamber. In diesel alone mode, organic nitrogen in the air is a main cause of the NOx formation. However, producer gas does not have organic nitrogen and it only has atmospheric nitrogen which is inorganic nitrogen [8]. Singh *et al*. [8] also found reduction in NOx emission in dual fuel producer gas diesel/ vegetable oil blends as compared to diesel fuel operation. The higher NOx emissions observed with the producer gas-diesel and RBD palm oil blends compared with the producer gas-diesel may be due to the availability of more oxygen present in the injected RBD palm oil molecular structure. Moreover, for the same power output,

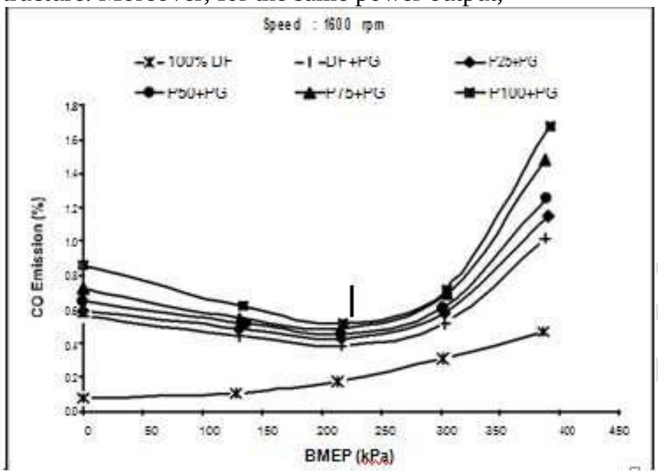


*Figure 6: Effect of BMEP on CO Emission*

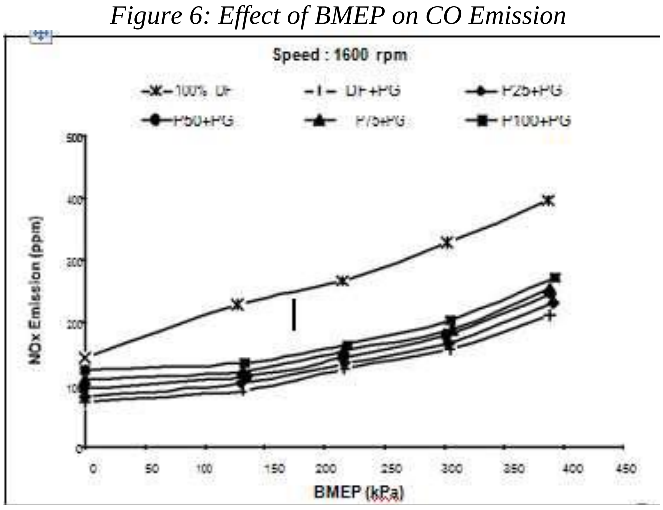


*Figure 7: Effect of BMEP on NOx Emission*

more RBD palm oil in the blends is required for combustion, leading to delayed injection. At 80% load, the NOx emissions were 210, 230, 240, 248 and 265 ppm using DF+BG, P25+BG, P50+BG, P75+BG and P100+BG blending ratios respectively. However these values were still lower compared with the 396 ppm NOx emission using pure diesel fuel. Exhaust Gas Temperature (EGT): Figure 7 shows the EGT for both the producer gas-diesel and the producer gas-RBD palm oil blends in terms of BMEP. In the dual fuel operation, the higher EGT in the combustion chamber is commonly used as a basic indicator of high NOx emissions. The EGT obtained was higher with the increasing percentage of RBD palm oil in the diesel blend compared with producer gas diesel operation. This may be due to the presence of constituents in RBD palm oil with higher boiling points than that of diesel fuel [1]. These constituents with higher boiling points are not sufficiently vaporized during the combustion phase and continue to burn in the late combustion, which resulted in the high EGT released by the engine. There are number of studies related to dual-fuel engines fuelled with producer gas-diesel and vegetable oil blends [8, 9]. All the dual fuel engines used in the literature studies reviewed were naturally aspirated diesel engine, both in producer gas-diesel or producer gas-diesel and vegetable oil blends. However, until today, there is no systematic study on the supercharged and turbocharged producer gas from downdraft biomass gasification, both in SI or CI dual fuel producer gas engines. Therefore, this study is an attempt to investigate from the aspects of engine performance and exhaust emission of supercharged dual fuel producer gas-diesel/vegetable oil at various blending ration. The findings showed that the dual fuel producer gas diesel/ vegetable oil under supercharged condition exhibited better thermal efficiency, CO and NOx emission as well as percentage of diesel displacement as compared to naturally aspirated condition. Final Remarks: Renewable fuel in this study was utilized by the blending of RBD palm oil/diesel (blended fuel) and replacement of this blended fuel with producer gas from biomass gasification. The findings of the study are viewed from three categories; engine performance (brake thermal efficiency and specific energy consumption), exhaust emissions (CO and NOx) and economic point of view (percentage of diesel displaced by blended RBD palm oil/diesel).Despite the technical feasibility, until to-date, vegetable oil as fuel still cannot be fully accepted as the current price is higher than petroleum fuel. Our main concern in this study is to displace RBD palm oil/diesel blend fuel with producer gas as maximum as possible and at the same time maintaining the engine performance and exhaust emission to the satisfactory levels. Based on the research in some additional literature studies, experimental investigation carried out by Agarwal (2007) showed that a blend of 20% vegetable oil and 80% mineral diesel provided optimum blending mixture without any operational difficulties throughout the experiment. A study reported that75% of diesel fuel blend with 25% of VO in dual fuel engine would result in smooth running with satisfactory engine performance [12]. Another investigator, Singh *et al*. [8] claimed that blends containing up to 75% of RRBO with diesel was found satisfactory without any effect on the engine. Above 75% of RRBO blends, the engine produced more white smoke and un-burnt oil particles. Based on the results shown in Table 4, a blend of 25% RBD palm oil and 75% diesel shows a better engine performance and exhaust emission as compared to other blending ratio. The output from 25% RBD palm oil and 75% diesel also close to that of diesel fuel-producer gas (DF+PG). In our experimental study, running the engine at 50% RBD palm oil and 50% diesel blend caused white smoke in the exhaust, thus the overall operation was not in satisfactory condition. Therefore, based on the above mentioned reasons, we would like to insist our conclusion that producer gas-diesel and RBD palm oil of 75% and 25% blending ratio would result in smooth running with satisfactory engine performance and exhaust emission. We do hope that the above explanation will resolve the issue that arose.

## IV. CONCLUSION

- ✓ The engine performance and exhaust emission of dual fuel producer gas-diesel and producer gas-diesel and RBD palm oil blends were experimentally investigated under supercharged conditions. Therefore, the main conclusions from this study can be summarized as follows:
- ✓ Without pre-heating of RBD palm oil and any major engine modification, the study proved that RBD palm oil and its blends are potentially good substitute fuel for diesel in the dual fuel producer gas CI engine under supercharged conditions.
- ✓ The BTE and SEC of producer gas-diesel and RBD palm oil blends were found to be lower and higher respectively compared to the producer gas-diesel operation over the entire load range of dual fuel engine.
- ✓ The producer gas-diesel and RBD palm oil of 75% and 25% blending ratio would result in smooth running with satisfactory engine performance and exhaust emission compared to producer gas-diesel operation.

The engine has no satisfactory performance when mixing ratio below and above from 25% due to poor spray character and no effective utilization of air resulting incomplete combustion.

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