Effect of Advanced Injection Timing on the Performance Improvement of a Dual-Fuel Diesel Engine with Producer Gas from a Down-Draft Gasifier for Power Generation

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Abstract

Alternative fuels are of interest due to fuel crisis. There are many alternative fuels in Thailand, for example natural gas for vehicle (NGV), bio-diesel, gasohol, etc. On the other hand, producer gas acquired from bio-mass, such as wastes from agricultural products which is generated from a gasifier, can be used as an alternative fuel for power generation. A dual-fuel diesel engine is employed, in which the diesel is the main fuel and the producer gas is a substitute fuel. By using the dual fuel system, the injection timing of the engine has to be considered because of the slow combustion speed of the air and gas mixture. Therefore, the effect of the injection timing on the performance and emissions of a dual-fuel diesel engine is investigated. In this experiment, a 15 kg/hr downdraft gasifier is used to generate the producer gas which is wood as biomass feedstock. The engine has a standard timing injection of 12˚ before top dead centre (BTDC). The injection was advanced by 5˚, yielding an injection timing of 17˚ BTDC. Dual fuel mode with advanced injection timing is found to improve engine performance (in terms of system efficiency, fuel substitution, specific fuel consumption and emissions) compared with dual fuel mode with standard injection timing, except in terms of NO_x emissions.

1. Introduction

Nowadays alternative fuels are of interest to every one in Thailand due to the fuel crisis. There are many alternative fuels in Thailand, such as gas fuel, bio-diesel, gasohol and others. Anyway for gas fuels, NGV and LPG are widely used in the taxi and bus. However the Thailand government promotes only the NGV but there are other alternative gas fuels that can be used as the fuel in vehicles. One of them is the producer gas acquired from bio-mass such as wastes from agricultural products. Mostly, the producer gas is used in the manufactory as the fuel for the electricity generation system. This system is operated by the dual fuel diesel engine which the diesel is main fuel while the producer gas is the secondary fuel. By using the dual fuel system, the injection timing of diesel has to be concerned and found the appropriate injection timing. Therefore, the timing injection was investigated on electricity generation system in dual-fuel diesel engine.

The objectives of this paper are to investigate the effects of the injection timing on performance and emissions of the instigated dual fuel CI engine using diesel with a producer gas. Cummins diesel engine 4-strokes, 4-cylinders, 3.9 L were tested at constant engine speed, 1500 RPM, and different fuel conditions as follows:

- Pure diesel mode
- Diesel and producer gas at standard injection timing (12˚ BTDC)
- Diesel and producer gas at advanced injection timing (17 ˚ BTDC).

2. Experimental Details

The schematic diagram of the biomass gasifier system for this study is shown in Figure 1. The gasification plant consist of a gasifier, gas cleaning system and power generation system for detail are described as follows:

a) Gasifier; the producer gas is produced from wood in a 50 kg/hr downdraft batch type gasifier, and it can feed 400 kg of wood for 8 hours of operating time. The air for gasifier exchange heat with producer gas that exit from gasifier before it is feeded into gasifier.
b) Gas cleaning system; the producer gas clean before using as feed in CI engine to present the engine failure. The gas cleaning system consists of cyclone filter, venturi scrubber, tar box, mistseparator, moisture separator and paper filter.
c) Power generation system; normally, diesel engine uses to drive the generator for produce electricity but in this experiment the engine is modified for using dual fuel which diesel is mainly fuel and the producer gas is secondary fuel. Moreover electrical heated loading resistance (finned heater) was used for loading the engine. Details are given in Table1.

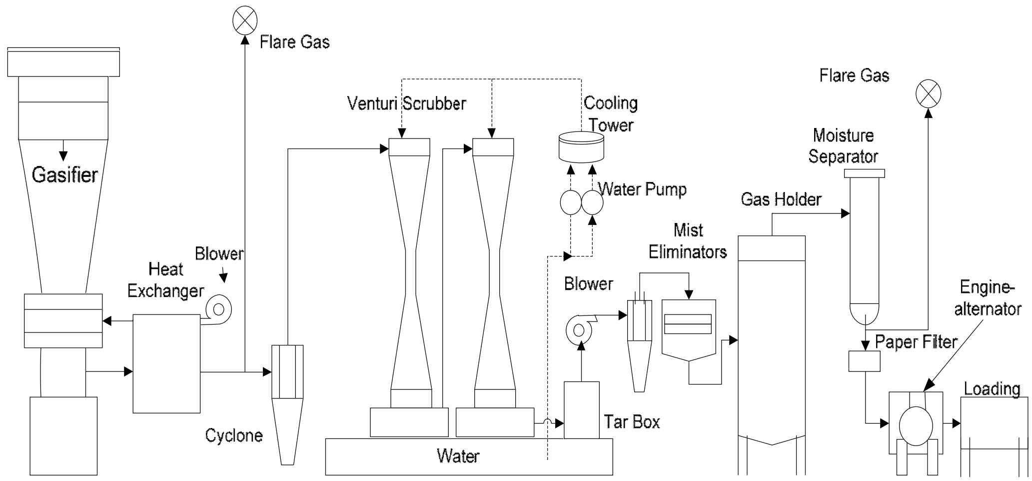

Figure 1. Schematic diagram of the biomass gasifier system used in this study.

Table 1. Specifications of engine-alternator.

Type	Direct injection, four cylinder, vertical, four stroke engine
Engine model	CUMMINS 4BTA 3.9-G2
Engine Speed (rpm)	1500 (Constant)
Cylinder bore (mm)	102
Stroke (mm)	120
Cubic capacity (l)	3.9
Compression ratio	16.5:1
Specific diesel rated consumption(g/kWh)	220
Generator rating (kW)	50 (base output power)

The producer gas properties are shown in Table 2. The average chemical compositions consists of 26.37% CO, 3.5% CH_4, 21.93% H_2, 38.37%N_2 (by calculations) and 9.82% CO_2. The calculated Calorific Value is 6.89 MJ/Nm^3.

Table 2. Composition and calorific value of producer gas.

Sample No.	Producer Gas Composition (%)					Calorific Value (MJ/Nm^3)
	CO	CH_4	H_2	N_2	CO_2	
1	24.80	3.50	22.39	38.35	10.95	6.76
2	26.70	3.70	21.58	38.62	9.39	6.96
3	27.60	3.30	21.83	38.13	9.13	6.94
Average	26.37	3.50	21.93	38.37	9.82	6.89

3. Results

The engine performance was tested at various loads representing 13.2, 39.6, 66.0, and 92.4% of maximum engine load. The results of this experiment are presented in the next sections in terms of brake thermal efficiency, specific energy consumption and diesel replacement rate.

(1) Brake Thermal Efficiency

It can seen in Figure 2 that the brake thermal efficiency of the dual fuel engine in standard injection timing mode is lower than in diesel mode, but the dual fuel engine at advanced timing injection mode has highest efficiency.

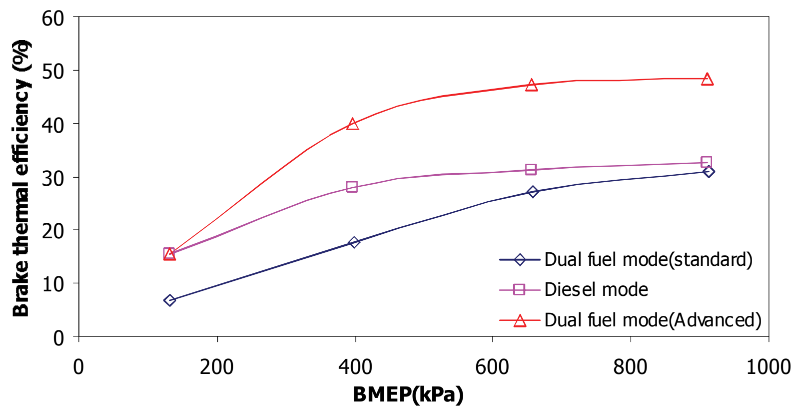

Figure 2. Brake thermal efficiency of the engine with BMEP.

(2) Specific Energy Consumption

The specific energy consumption of dual fuel mode with standard injection timing is highest showing that when increasing the specific energy consumption, the efficiency is decreased in dual fuel mode at standard injection timing. The specific energy consumption of dual fuel mode at advanced injection timing is lower than diesel and dual fuel mode at standard injection timing at all load conditions, this imply that the better performance when advanced the timing injection. It is also found that specific energy consumption increases with increased producer gas flow through the intake manifold of the engine. This should be due to the incomplete combustion and lower flame velocity at relatively higher charge temperature.

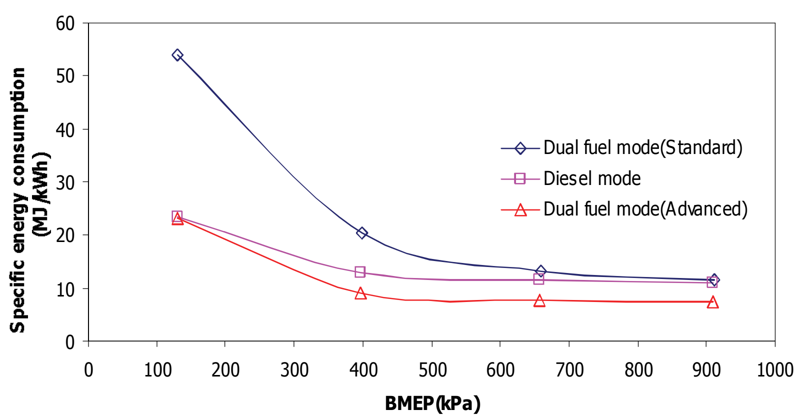

Figure 3. Specific energy consumption of the engine with BMEP.

(3) *Diesel Replacement Rate*

The diesel replacement rate under different load conditions is calculated from the diesel consumption in diesel mode and the diesel consumption in dual fuel mode as shown in Figure 4 explains the percentage of diesel replacement under different load conditions which is received in both dual fuel mode operations. The percentage of diesel replacement in advanced injection timing is higher than in standard injection timing for all load conditions. It can be seen that the diesel replacement rate goes up to 76.5%. The maximum diesel replacement rate is achieved at 40% of full load. The decrease in diesel replace rate is found in both low and high conditions. At the low load operation, there is insufficient oxygen to complete the combustion.

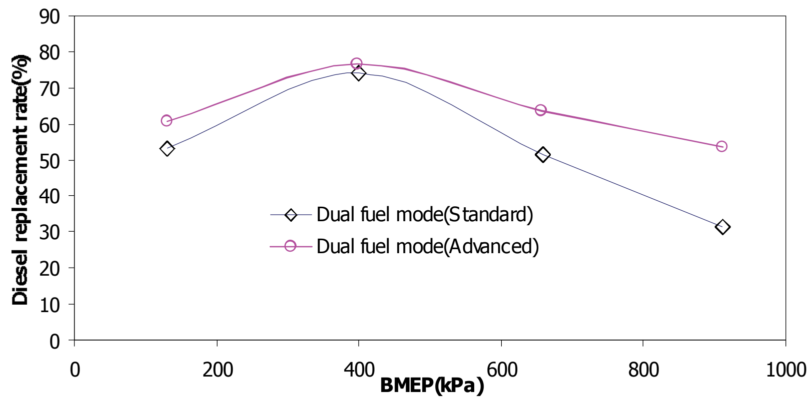

Figure 4. Diesel replacement rate in the dual fuel mode operation.

(4) Exhaust Emission

In the value of exhaust composition from measurements and engine load are summarized in Figures 5, 6 and 7. It is indicated the application of producer gas in compression ignition engine at dual fuel mode at the pollutant. The reduction of carbon monoxide was found more at about 66% of full load in dual fuel mode which is carbon monoxide emission on advanced injection timing however lower when comparing with dual fuel mode on standard timing and carbon dioxide in both dual fuel mode is slightly different. Nitrogen oxide is increased at all engine load conditions. In addition, nitrogen oxide of dual fuel mode on standard injection timing is lower than dual fuel mode on advanced injection timing, this is indicated that in case of advanced injection timing the nitrogen oxide can be increased and carbon dioxide is decreased due to more time in combustion.

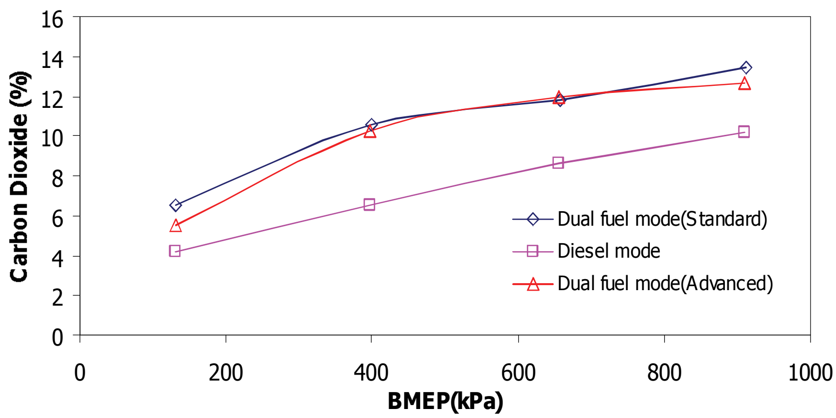

Figure 5. Carbon dioxide emission of the engine with BMEP.

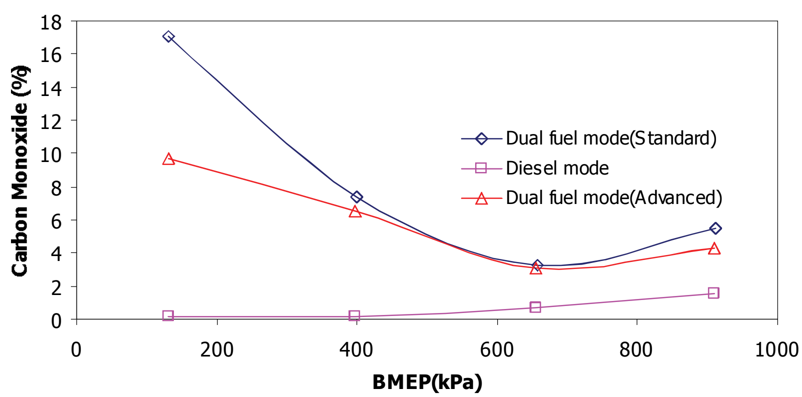

Figure 6. Carbon Monoxide emission of the engine with BMEP.

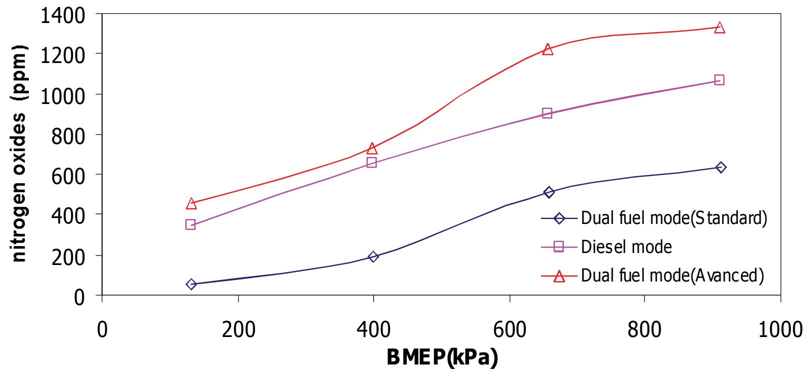

Figure7. Nitrogen oxides emission of the engine with BMEP.

4. Conclusions

An experimental study on the effect of advanced injection timing in the dual fuel diesel engine by using mainly fuel is diesel and secondary fuel is producer gas, which focus on performance and emission of the engine. The following conclusions can be drawn.

i) Performance of Dual Fuel Diesel Engine: For the performance of dual fuel diesel engine on advanced timing injection, dual fuel engine has higher break thermal efficiency than the diesel engine on standard timing injection. While for the diesel replacement rate, the producer gas can be replaced the diesel more when the timing injection advance increasing. Moreover increasing in timing injection, the specific energy consumption is less than standard timing injection indicated that the engine gives the same power but consumes less fuel. For the conclusion, the thermal performance of dual fuel diesel engine is better when advancing the injection timing.

ii) Exhaust Emission of Dual Fuel Diesel Engine: Exhaust emission is increased when the engine performance is decreased at part load for both diesel and dual fuel operation. For carbon monoxide emission, dual fuel has the higher emissions than pure diesel at all load conditions. Moreover the carbon monoxide is lower when the timing injection is advanced but for carbon dioxide is just slightly different. For the nitrogen oxide, at advance injection timing mode, the nitrogen oxide emission is highest.

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