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Performance of Synthetic Gas with Diesel in a Single Cylinder Compression Ignition Engine

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ABSTRACT

Background: Replacing diesel fuel with alternative like syngas from biomass can help mitigating problems related to depletion of fossil fuels and emissions. However, syngas from biomass gasification is known for its fluctuation of content and composition due to complex parameters involving syngas composition, temperature, emission and calorific value. In this paper, imitated syngas is burned in a diesel engine, and the performance is analysed. The result shows that in comparison to 100% diesel, syngas will reduce the engine's brake power by up to 20%.

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INTRODUCTION

The idea of syngas implementation emerges when the environmental factors like petroleum liquid fuel depletion and emission of hazardous gases are taken into consideration. Syngas can be produced from gasification of biomass. Therefore, it is expected that syngas can be a suitable alternative to cope the depletion of liquid fuel. However, the implementation of syngas still requires many researches since the technologies existed are not fully enhanced. Apart from that, currently there are no engines that can run on fully syngas. This is because a certain amount of diesel is still required to initiate the operation of the engine, which emergence the introducing of the dual-fuel mode (Thayagarajan V, 1985).

In this concept, the gaseous fuels are used as a supplement for liquid diesel fuel (Sahoo, *et al*., 2009). However, the duel – fuel engine is expected to run with 100 percent of gaseous fuel provided. While the diesel liquid fuel is available during the ignition, and its amount is gradually decreasing throughout the process. In terms of emission, the dual – fuel engine produces a virtually insignificant amount of Sox and relatively low amount of NOx, which is the main constituent for acid rain (Uma, *et al*., 2004). Besides that, combustion of syngas in dual fuel mode is associated with low carbon dioxide emissions (Henham and Makkar, 1998) and high CO emissions (which indicating incomplete combustion) (Uma, *et al*., 2004). The brake thermal efficiency for dual fuel engine is usually lower compared to fully diesel engine operation. One of the possible reasons is due to the effect of the secondary fuels compositions (Saleh, 2008), and its low charge temperature at the end of the compression process. Moreover, the gaseous air-fuel mixture in dual fuel mode has a lower flame velocity compared to diesel fuel mixture (Lata and Misra, 2010).

Since, syngas from biomass gasification is known for its composition fluctuations (Hassan, *et al*., 2011), the engine performance would be difficult to understand. Table 1 shows the typical variations of the syngas composition. As a result, studies are required to observe the engine performance when syngas is used as secondary fuel in dual fuel engine operation. Therefore, the objective of this work is to study the engine performance when syngas of controlled conditions and composition is used as secondary fuel in duel fuel mode operation.

Experimental Setup:

The experimental setup consists of a single-cylinder 5-hp Tecumseh diesel engine, gas analyzer unit, imitated syngas and instrumentation unit. Table 2 shows the specification of the diesel engine used in the experiment. The air intake manifold of the engine is modified to supply the syngas to the engine.

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Table 1: Syngas composition from gasification of biomass (Mahgoub, *et al*., 2012).

Gas Constituents	Percentage [%]
CO	15 – 30
H_2	10 – 20
CH_4	2 – 4
CO_2	5 – 15
N_2	45 – 60
H_2O	6 – 8

Table 2: Specifications of the engine.

Item	Description
Model	TECUMSEH 5HP
Bore Dimension	67 mm
Stroke	49 mm
Maximum Power	3.75 kW @ 2000 RPM
Operating Speed	1000 to 3400 RPM

In the work, the syngas composition was mixed by using a custom five ways gas mixture. There were five gases used in order to imitate the syngas compositions. The used gases are CO, CH_4, CO_2, N_2, and H_2. In order to verify the composition, an online gas analyzer was used after the gas was mixed in the mixture. During engine tests, engine operation parameters like engine speed, engine torque, fuel consumption, and air intake as shown on the instrumentation unit. The schematic diagram of the setup is shown in Figure 1. The engine speed was fixed at 1200 RPM. The syngas was supplied at a rate of up to 17 L/min.

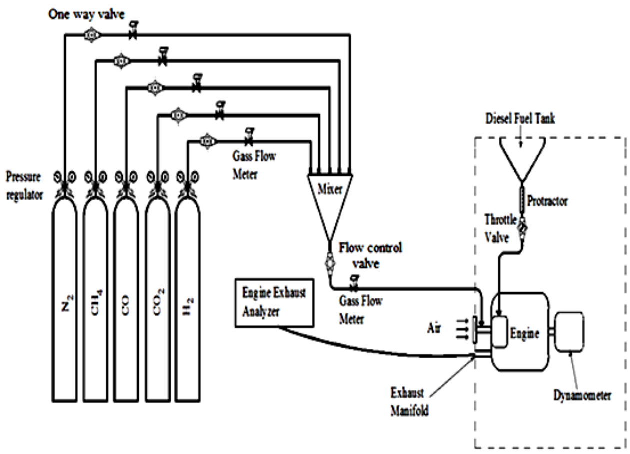

Fig. 1: Schematic of the experimental setup.

RESULTS AND DISCUSSIONS

Three syngas mixture labeled as Compositions 1, 2, and 3 were used in this study, as shown in Table 3. The individual supply flow rate and pressure of the component gases are also shown. The amount of the lower heating value for Compositions 1, 2 and 3 were 4671kJ/kg, 5655 kJ/kg and 3927kJ/kg, respectively.

Table 3: Syngas compositions.

Syngas	Gases	N_2	CO_2	CO	H_2	CH_4
Composition 1	Volume percentage (%)	45.00	14.5	22.00	16.00	2.50
	Flow rate (L/min)	22.50	7.25	11.00	8.00	1.25
	Pressure (mm H_2O)	54.05	20.00	24.92	4.80	2.50
Composition 2	Volume percentage (%)	49.00	6.00	24.00	18.00	3.00
	Flow rate(L/min)	24.50	3.00	12.00	9.00	1.51
	Pressure(mm H_2O)	59.98	5.44	28.22	5.40	3.00
Composition 3	Volume percentage (%)	55.00	12.00	18.00	12.00	3.00
	Flow rate(L/min)	27.50	6.00	9.00	6.00	1.50
	Pressure(mm H_2O)	70.00	16.00	20.40	3.50	3.00

Figure 2 shows the variation of engine brake power with the syngas flow rate as obtained from the test. It is shown that syngas Composition 2 produces the highest value of brake power. This is expected since Composition 2 has the highest amount of heating value among the three compositions. However, at a certain operating point, it is shown in Fig. 2 that the brake power produced by Composition3 is higher than that of

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Composition 1 even though the heating value of Composition 1is higher than that of Composition 3. This was due to the higher density of Composition 3 as compared to that of Composition 1.

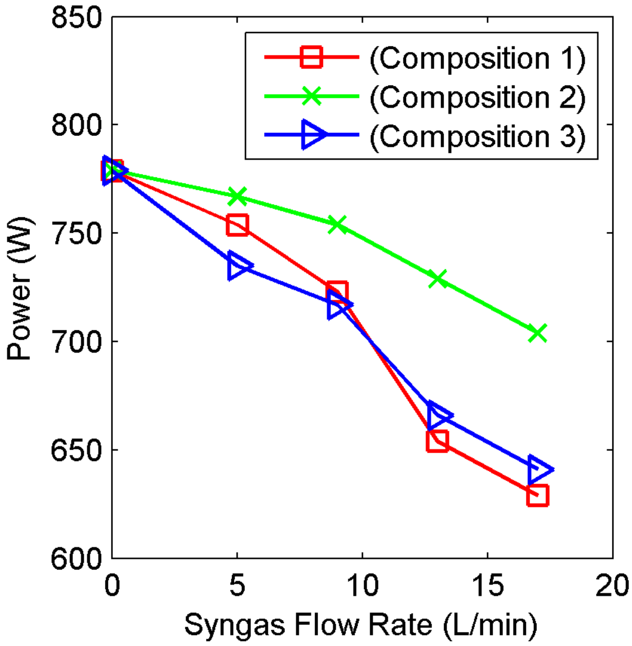

Fig. 2: Variation of brake power with syngas flow rate at 1200 rpm.

Figure 3 shows the variation of specific fuel consumption with syngas flow rate for the selected syngas compositions. Considering the fact that the heating value of syngas is lower in comparison to that of diesel fuel, it would be that higher fuel consumption is needed when using syngas for combustion; and this leads to high brake specific fuel consumption. It is noted that for syngas flow rate up to 8 L/min all syngas compositions were shown the same SFC, while variation occurred at values higher than 8 L/min, where Composition 3 recorded up to 6% increase in SFC as compared with Compositions 1 and 2. This is because Compositions 1 and 2 have larger heating values than Composition 1.

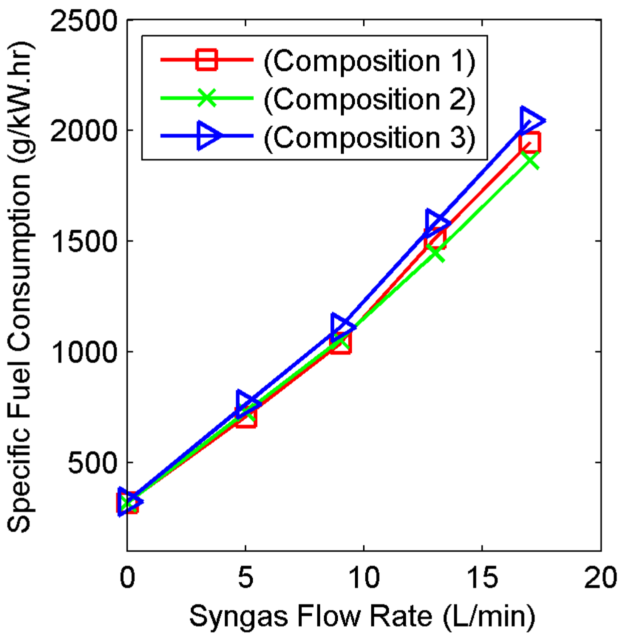

Fig. 3: Variation of specific fuel consumption with syngas flow rate at 1200 rpm.

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Air to fuel ratio is an informative parameter for defining mixture composition. Figure 4 shows that the air fuel ratio decreases as the syngas flow rate increases. This is due to displacement of air (and thus oxygen) by syngas which leads to reduction in the quantity of air, and thus resulting in a richer combustion. Composition 2 showed the lowest air fuel ratio. This is largely due to the highest density of Composition 2 as compared to those of other compositions, which leads to replacement of high amount of oxygen.

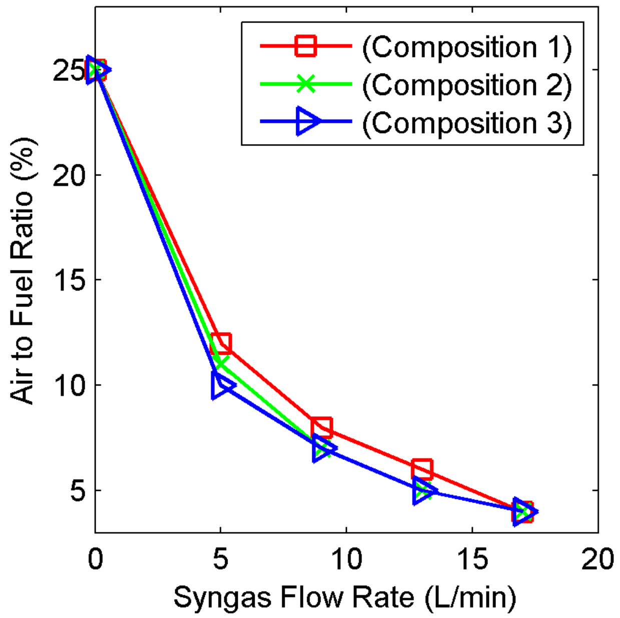

Fig. 4: Variation of air to fuel ratio with syngas flow rate at 1200 rpm.

Brake thermal efficiency is the ratio between the power output and the energy introduced through fuel injection. The inverse of brake thermal efficiency is the brake specific fuel consumption. Besides the heating values, brake thermal efficiency would be more appropriate for comparison of the performance of different fuels. Figure 5 depicts the behavior of the brake thermal efficiency with the syngas flow rate for the three selected syngas compositions. The difference in results among the three gases is shown to be small. By looking at Figure 5, all syngas compositions have shown almost the same brake thermal efficiency.

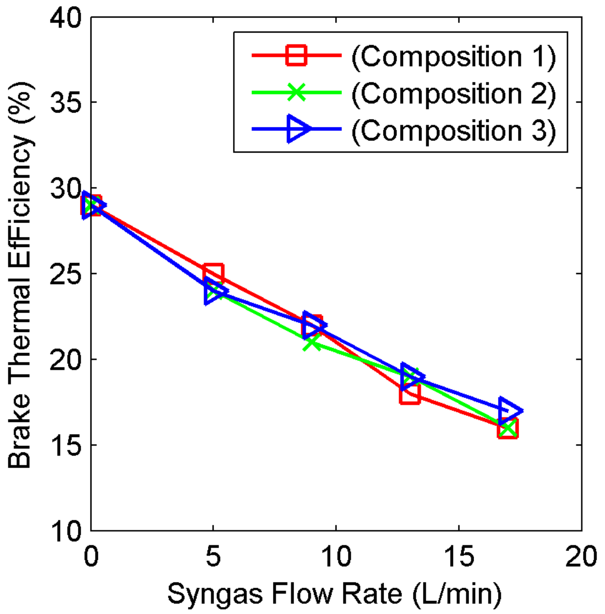

Fig. 5: Variation of brake thermal efficiency with syngas flow rate at 1200 rpm.

Shown in Fig. 6 is the variation of diesel replacement rate with flow rate of syngas. Generally, it is shown that the diesel replacement for each composition exhibits an inconsistent pattern. The possible reason for this behavior may be due to the inhomogeneous syngas mixture.

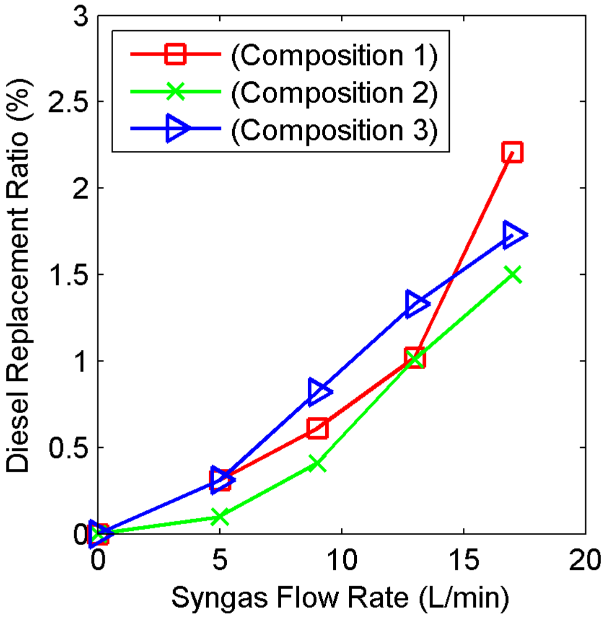

Fig. 6: Variation of diesel replacement rate with syngas flow rate at 1200 rpm.

Conclusions:

The effect of burning controlled amounts of syngas-diesel fuel mixture on the performance of a single-cylinder diesel engine was studied. It is found that the introduction of syngas in dual fuel mode reduces the brake power of the engine. It is also observed that the diesel replacement ratio does not produce any constant pattern throughout the experiment. This is probably due to the inhomogeneous mixing of the syngas before it is introduced to the engine, so it is recommended that the mixing process of the syngas to be improved.

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