Investigation on Performances of the Engine for the Electrical Power Generator Using Biomass Gases and Biodiesel as Fuels

Kulachate Pianthong, Prachasanti Thaiyasuit*, Chayarnon Saengmanee, Veerayoot nonchana and Sorawit Nunt-Jaruwong

***Abstract*— *In this study, performances of the engine for the electrical power generator using biomass gases (or producer gas) and biodiesel as fuels were investigated. Downdraft gasifier was used to produce biomass gas from dried wood chip. The generator set, PLC 5110 (maximum power of 48 kW), was installed and tested. The performance of the engine of electrical power generator, fuel consumption, fuel oil saving, and black smoke level, were investigated experimentally. The inlet air flow rate (into the gasifier) at 198 L/min., 330 L/min. and 462 L/min. were supplied. In the tests, neat biodiesel (B100), biodiesel blends with the diesel at ratio of 50% (B50), and neat diesel (D100) were used as liquid fuels and mixed with the biomass gas obtained from the gasifier. Therefore the engine is working in the dual fuel mode in all tests. The power output of electrical power generators were varied at 10 kW, 20 kW and 30 kW. From the experiments, when the inlet air flow rate was increased, the lower fuel consumption could be obtained. At the inlet air flow rate of 462 L/min., averagely, neat biodiesel (B100) saving is 64%, biodiesel (B50) saving is 68% and diesel saving is 71%, at all electrical loads. In the dual fuel mode of operation, the smoke density can be reduced. When the inlet air flow rate was increased, the lower smoke density was usually obtained. At the same inlet air flow rate, smoke density was found to be highest in the diesel case comparing to biodiesel (B50) case and neat biodiesel (B100) case respectively. The lowest smoke density in the dual fuel mode of operation was around 1 to 3%, at 10 kW of electrical load and the inlet air flow rate of 462 L/min.*

***Keywords*— Biomass gas, biodiesel, dual fuel, downdraft gasifier.**

1. INTRODUCTION

The biomass is a very important renewable energy in many parts of the world. In Thailand, the biomass can be produced from all of agricultural products, around 32 million tons per year [1]. At present, the awareness of the environmental concerns and the fossil fuels price has prompted new research to establish gasification as a key source for energy production.

Gasification is the process of converting carbonaceous materials into gaseous fuel. This can be used in a modern conversion device, such as gas turbines and internal combustion engines, for electricity and heat production. Using biomass gases dualling with diesel fuel, lower diesel consumption and emission are benefit in diesel engine [2]-[4].

Mostly researchers used wood chip to produce biomass gas [5]-[7]. Some researchers used other raw materials to produce biomass gas such as rice husk [8], wood sawdust [9], and cashew nut shell [10]. A typical composition of biomass gases generated by biomass gasification on volumetric basis is given in Table 1.

Kulachate Pianthong, Prachasanti Thaiyasuit (corresponding author) and Chayarnon Saengmanee are with the Mechanical Engineering, Faculty of Engineering, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand. Phone: +66 45 353 309; +66 89 917 6733; E-mail: prachasanti_t@hotmail.com.

Veerayoot nonchana is with the Research and Service on Energy Center, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand.

Sorawit Nunt-jaruwong is with the Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy 10330, Thailand.

Table 1. Biomass Gases Composition [2]

Constituents biomass gas	
Carbon monoxide	18 to 22%
Hydrogen	15 to 19%
Methane	1 to 5%
Hydrocarbons	0.2 to 0.4%
Nitrogen	45 to 55%
Water vapor	4%

In this study, performances of the engine for the electrical power generator using biomass gases and biodiesel as fuels were investigated. Downdraft gasifier was used to generate biomass gas (or producer gas) from dried wood chip. The performance of power engine of electrical power generator, fuel consumption, fuel oil saving, black smoke, were investigated experimentally. The effect of performance of the engine for the electrical power generator from difference the inlet air flow-rates (into the gasifier) was presented.

2. EXPERIMENTAL METHOD

Apparatus

The schematic diagram of experimental system is show in Fig. 1. The downdraft gasifier was used to generate biomass gas (or producer gas) from dried wood chip. The biomass was loaded into gasifier from the top of gasifier. The partial combustion of biomass in gasifier generates biomass gas, which the enters the cooling and cleaning unit. The valves were installed in the passage of gas and airflow (to the engine) to control the gas and airflow rate individually. Anemometer was used to measure the inlet

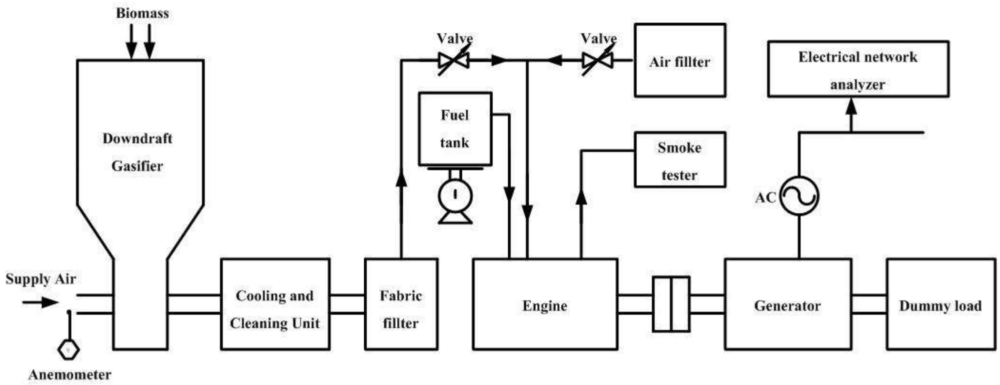

Fig. 1. The schematic diagram of experimental system.

air flow rate (into the gasifier). Neat biodiesel (B100), biodiesel blends with the diesel at ratio of 50% (B50), and neat diesel (D100) were used as fuels. The performance of power engine of electrical power generator, fuel consumption, fuel oil saving, black smoke, were investigated in diesel mode and dual fuel mode. The dual fuel mode of operation was carried out by supplying the gas-air mixture to the combustion chamber of the engine through inlet manifold. The inlet air flow rate (into the gasifier) at 198 L/min., 330 L/min. and 462 L/min. were supplied. The power output of electrical power generators were varied at 10 kW, 20 kW and 30 kW. Diesel smoke tester was used for the measurement of smoke density of the exhaust gases. The exhaust gas was induced through the paper filter by the diesel smoke tester. Smoke density is measured by diesel smoke tester, based on lux intensity thorugh the filter. The Fig. 2 shows examples of the opacity on the paper filter which is equal to 10% and 40%, respectively. Note that, the new white paper filter presents 0% smoke density.

The experimental facility consists of a downdraft gasifier and cleaning unit as shown in Fig. 3. The electrical generator set (details are given in Table 2) is shown in Fig. 4. The power engine of electrical generator, details is given in Table 3. The electrical dummy load is shown in Fig. 5. It was used to generate pseudo electrical load. The electrical network analyzer is shown in Fig. 6, using to analyses electrical load. Also the Diesel smoke tester is shown in Fig. 7.

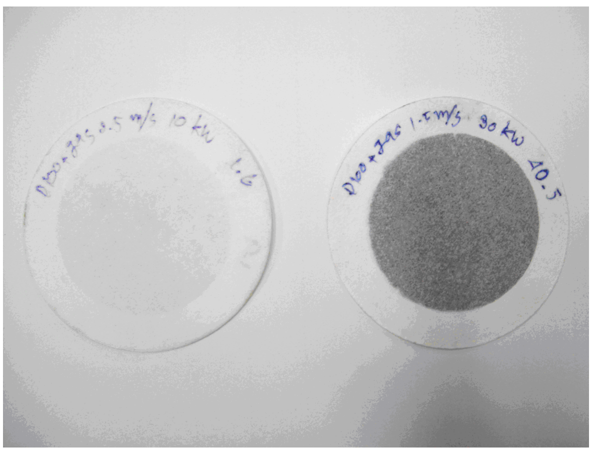

Fig. 2. Paper filter of diesel smoke density.

Fig. 3. Downdraft gasifier and cleaning unit.

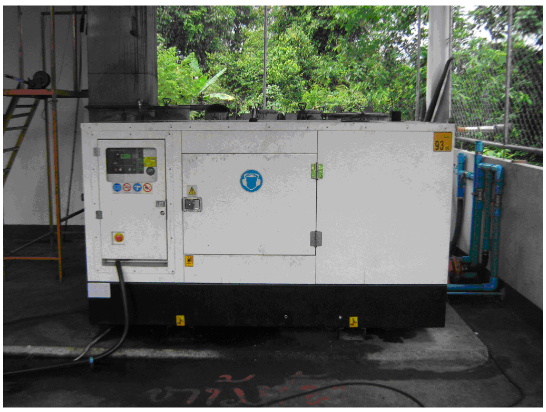

Fig. 4. Electrical generator set.

Table 2. Specification of Power Generator

General Detail	
Model of Generator	PLC5110
AC Alternator	3 phase
Volt	380 V
Frequency	50 Hz
Max. Power	48 kW

Table 3. Specification of the Engine

Name and Model of Engine	Cummins, 4BTA3.9
General Details	Four Cylinder, Direct Injection Turbo, Inter Cooler
Rate Speed	1500 rpm
Compression Ratio	16.5:1
Bore	102 mm
Stoke	120 mm
Displacement	3.9 liter

Fig. 5. Electrical dummy load.

Fig. 6. Electrical network analyzer.

Raw Material

Dried wood was used for all the experiment as the fuel. Wood were dried by using small charcoal kiln and crushed into pieces, in volume around 1 in^3. It was then stocked in the storehouse for experiments. The properties of woods [11] using in this study compared to those of charcoal [3] are given in Table 4. The properties of diesel (D100) and biodiesel (B100), wood ships biomass gas composition are given in Table 5 and 6 respectively.

Fig. 7. Diesel smoke tester.

Table 4. Properties of Woods and Charcoal

Proximate Analysis	Woods [11]	Charcoal [3]
Moisture	8.38 - 10.29 %	0.27%
Ash	0.1 - 1.51 %	3.20%
Volatile Matter	73.42 - 78.15 %	20.38%
Fixed Carbon	11.9 - 16.7 %	76.15%

Table 5. Properties of Diesel and Biodiesel [12]

Properties	Standard	Diesel (D100)	Biodiesel (B100)
Specific Gravity	ASTM D1298	0.87	0.888
Viscosity 40° C (cSt)	ASTM D88	4.1	6.44
Flash Point (°C)	ASTM D97	52	155
Ignition Point (°C)	ASTM D97	74	160
Cetane Number	ASTM D976-9	52	50.9
High Heating Value (MJ/kg)	ASTM D1250	42	39.4

Table 6. Wood Chips Biomass Gas Composition [11]

Constitutional Biomass Gas	
Carbon monoxide	17.63%
Oxygen	3.87%
Methane	1.03%
Hydrogen	9.98%
Nitrogen	67.49%

3. RESULTS AND DISCUSSIONS

Diesel Fuel Consumption

Rate of the diesel consumption for both diesel fuel operation and dual fuel operation at various electrical loads are shown in Fig. 8. Diesel consumption in diesel mode is definitely the highest one compared to those of dual fuel modes. When the inlet air flow rate was increased, the lower fuel consumption could be obtained. The lowest diesel consumption was obtained, at the inlet air flow rate of 462 L/min.

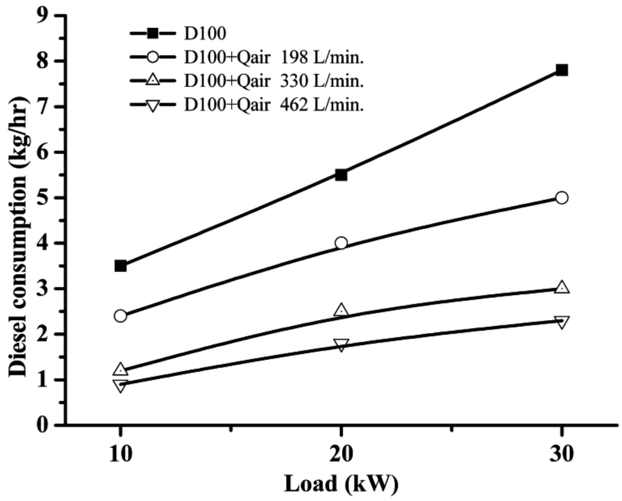

Fig. 8. Diesel consumptions obtained in diesel and dual fuel mode operation.

Diesel Saving

Rate of the diesel saving for dual fuel operation is shown in Fig. 11 as function of electrical power. The lowest diesel saving was obtained, at the inlet air flow rate of 462 L/min. At the inlet air flow rate of 462 L/min., averagely, diesel saving is around 71%, at any electrical load.

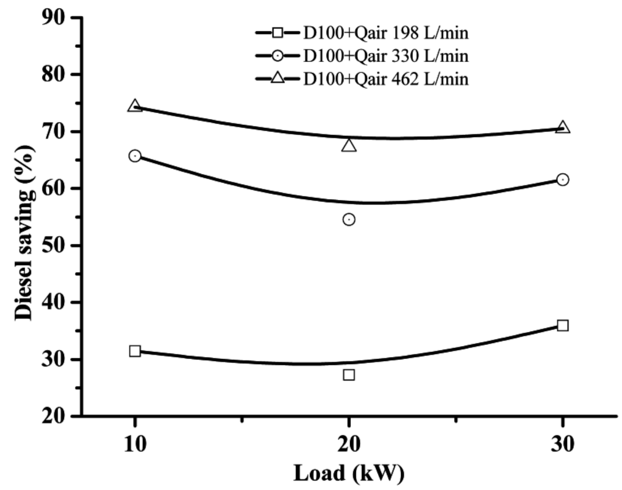

Fig. 9. Diesel savings obtained in dual fuel mode operation.

Biodiesel (B100) Fuel Consumption

Rate of the biodiesel (B100) consumption for both diesel fuel operation and dual fuel operation are shown in Fig. 10. as function of electrical power. Biodiesel (B100) consumption in diesel mode is higher than that of dual fuel mode. When the inlet air flow rate was increased, the lower fuel consumption could be obtained. The lowest biodiesel (B100) consumption was obtained, at the inlet air flow rate of 462 L/min.

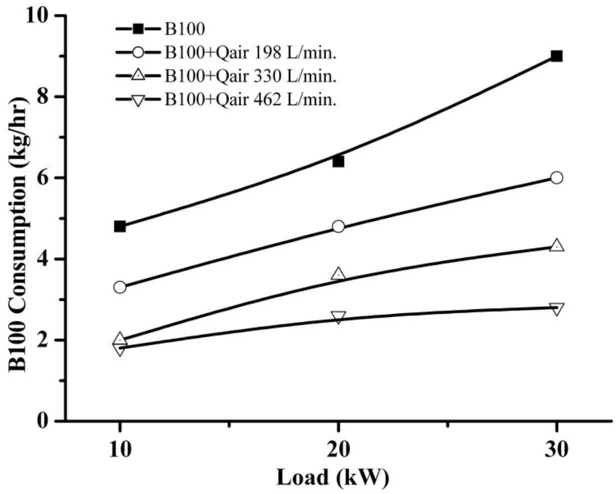

Fig. 10. Biodiesel (B100) consumptions obtained in diesel and dual fuel mode operation.

Biodiesel (B100) Saving

Rate of the biodiesel (B100) saving for dual fuel operation is show in Fig. 11 as function of electrical power. The lowest biodiesel saving was obtained, at the inlet air flow rate of 462 L/min. At the inlet air flow rate of 462 L/min., averagely, biodiesel saving is around 64%, at all electrical loads.

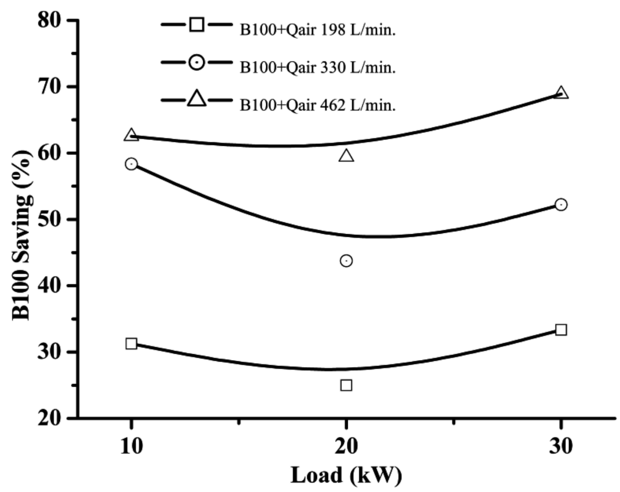

Fig. 11. Biodiesel (B100) savings obtained in dual fuel mode operation.

Biodiesel (B50) Fuel Consumption

Rate of the biodiesel (B50) consumption for both diesel fuel operation and dual fuel operation are show in Fig. 12 as function of electrical power. Biodiesel (B50) consumption in diesel mode is higher than that of dual fuel mode. When the inlet air flow rate was increased, the lower fuel consumption could be obtained. The lowest biodiesel (B50) consumption was obtained, at the inlet air flow rate of 462 L/min.

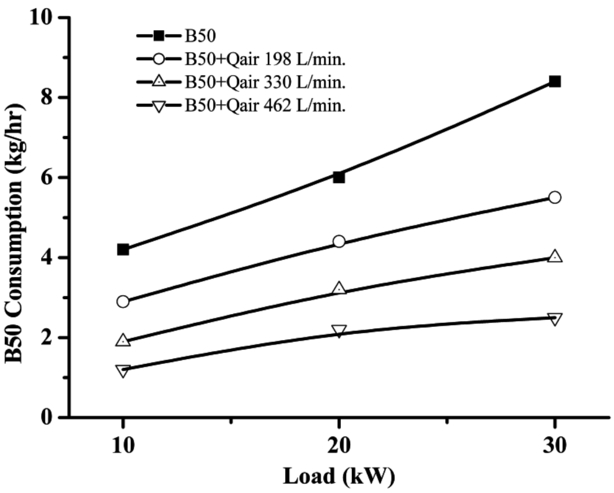

Fig. 12. Biodiesel (B50) consumptions obtained in diesel and dual fuel mode operation.

Biodiesel (B50) Saving

Rate of the biodiesel (B50) saving for dual fuel operation is show in Fig. 13 as function of electrical power. The lowest biodiesel (B50) saving was obtained, at the inlet air flow rate of 462 L/min. At the inlet air flow rate of 462 L/min., averagely, biodiesel saving is around 68%, at the electrical loads.

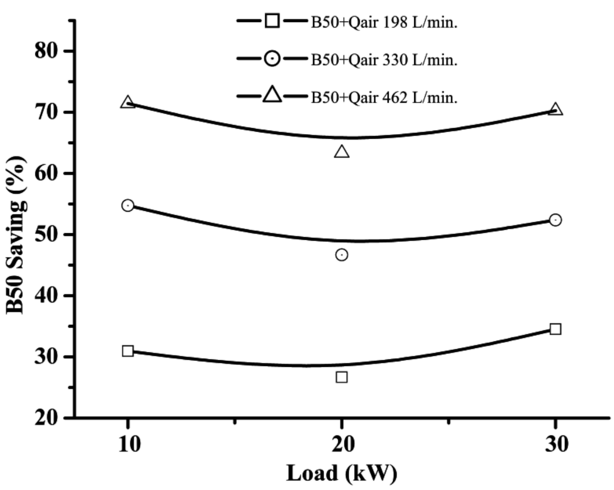

Fig. 13. Biodiesel (B50) savings obtained in dual fuel mode operation.

Diesel Smoke Density

Rate of the diesel smoke density for both diesel fuel operation and dual fuel operation are shown in Fig. 14 as function of electrical power. Diesel smoke density in the diesel mode is higher than that of dual fuel mode. When the inlet air flow rate was increased, the lower smoke density could be obtained. The lowest diesel smoke density was obtained, at the inlet air flow rate of 462 L/min.

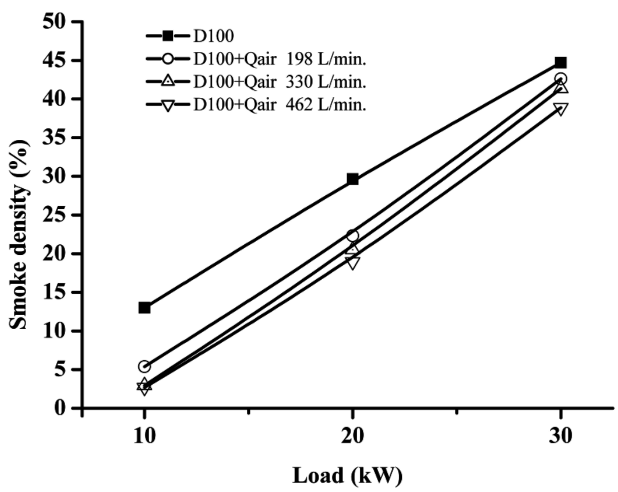

Fig. 14. Diesel smoke densities obtained in diesel and dual fuel mode operation.

Biodiesel (B100) Smoke Density

Rate of the biodiesel (B100) smoke density for both diesel fuel operation and dual fuel operation are show in Fig. 15 as function of electrical power. Biodiesel (B100) smoke density in diesel mode is higher than that of dual fuel mode. When the inlet air flow rate was increased, the lower smoke density could be obtained. The lowest diesel smoke density was obtained, at the inlet air flow rate of 462 L/min.

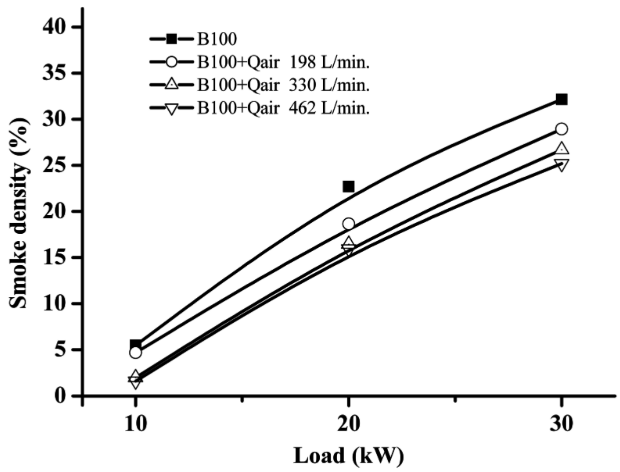

Fig. 15. Biodiesel (B100) smoke densities obtained in diesel and dual fuel mode operation.

Biodiesel (B50) Smoke Density

Rate of the biodiesel (B50) smoke density for both diesel fuel operation and dual fuel operation are show in Fig. 16 as function of electrical power. Biodiesel (B50) smoke density in diesel mode is higher than that of dual fuel mode. When the inlet air flow rate was increased, the lower smoke density could be obtained. The lowest biodiesel (B50) smoke density was obtained, at the inlet air flow rate of 462 L/min.

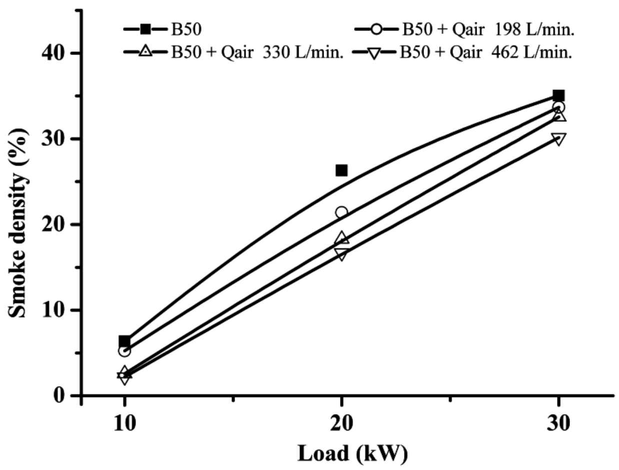

Fig. 16. Biodiesel (B50) smoke densities obtained in diesel and dual fuel mode operation.

Thermal Efficiency

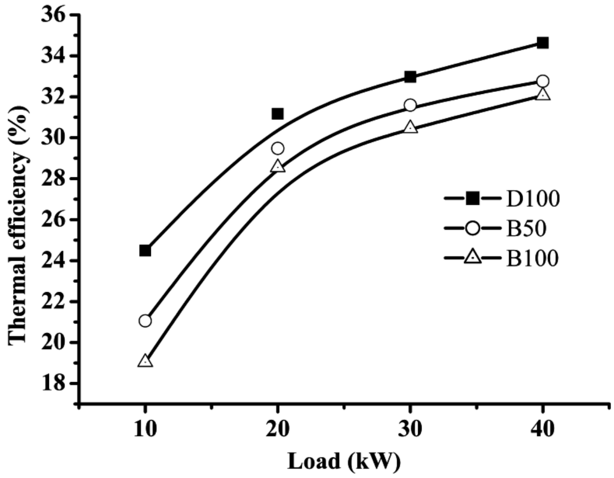

Fig. 17. Thermal efficiency of obtained in diesel fuel mode operation.

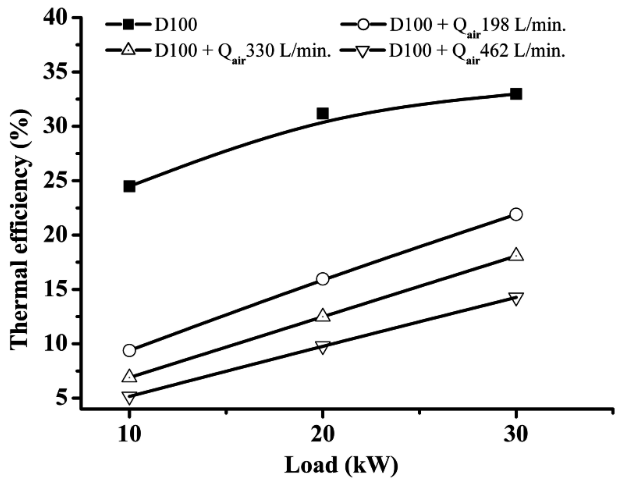

Fig. 18. Thermal efficiency with diesel fuel obtained in diesel and dual fuel mode operation.

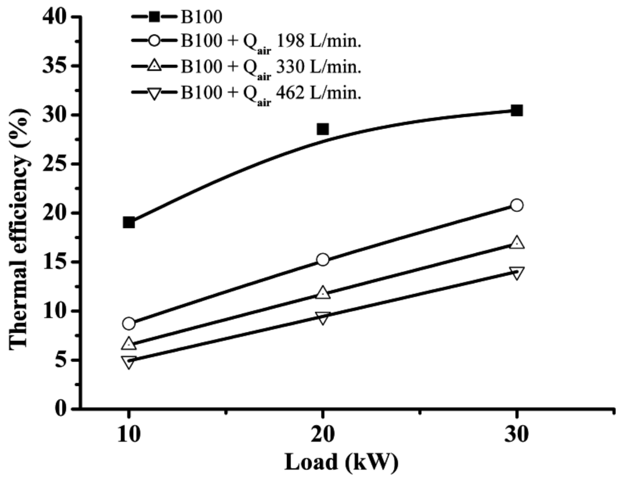

Fig. 19. Thermal efficiency with biodiesel fuel obtained in diesel and dual fuel mode operation.

The thermal efficiency of the diesel fuel mode is shown in Fig. 17 as function of electrical power. The highest thermal efficiency was obtained at any electrical loads, when the diesel was used as fuel. Because the specific fuel consumption of diesel fuel was less than biodiesel (B50, B100) at the same load. The highest thermal efficiency was around 35%, at the electrical load as 40 kW. When the electrical load was increased, the higher thermal efficiency could be obtained.

The thermal efficiencies of the dual fuel mode are shown in Fig. 18 and 19. The thermal efficiency of diesel fuel mode was higher than dual fuel mode. Because specific fuel consumption in diesel fuel mode is less than dual fuel mode.

In dual fuel mode, the highest thermal efficiency was obtained at any electrical loads, at the inlet air flow rate (into the gasifier) as 198 L/min. The highest thermal efficiency was around 23% at the electrical load as 30 kW. When the inlet air flow rate was increased, the lower thermal efficiency was obtained. When the electrical load was increased, the higher thermal efficiency could be obtained.

4. CONCLUDING REMARKS

Some important findings on the engine performance and smoke density of electric power generation in dual fuel mode of operation while using dried wood chips are highlighted in the present paper. This study proved that the diesel engine is capable to run in dual fuel mode of operation with the suitable biomass gases from the gasifier and biodiesel fuel.

For the short-term testing, it is found that biodiesel and biomass gases fuel has no significant effect to the power engine of electrical power generator. When the inlet air flow rate was increased, the lower fuel consumption could be obtained. At the inlet air flow rate of 462 L/min., averagely, neat biodiesel (B100) saving is 64%, biodiesel (B50) saving is 68% and diesel saving is 71%, at the entire electrical load compared to its pure liquid fuel mode.

In the dual fuel mode of operation, the smoke density can be reduced. When the inlet air flow rate was increased, the lower smoke density was usually obtained. At the same the inlet air flow rate, smoke density was found to be highest in the diesel case comparing to biodiesel (B50) case and neat biodiesel (B100) case respectively. The lowest smoke density in the dual fuel mode of operation was around 1-3%, at 10 kW of electrical load and the inlet air flow rate of 462 L/min.

ACKNOWLEDGMENT

The authors acknowledge the support provided by the Department of Alternative Energy Development and Efficiency, Ministry of Energy, Thailand. This research was performed under the Ayeyawady-Chao Phaya-Mekong Economic Co-operation Strategy (ACMECS) and the co-operation to develop renewable energy and conservation of energy among Cambodia, Lao PDR, Myanmar and Thailand (Study and demonstration of biomass gasification for electricity project in LAO PDR).

REFERENCES

[1] Na Pattalung, Thanakorn 2008. Benefit of biomass. *Song serm technology*, 34(196): 76-80.

[2] Ramadhas, A.S.; Jayaraj, S.; and Muraleedharan, C. 2006. Power generation using coir-pith and wood derived producer gas in diesel engines. *Fuel Processing Technology*, 87: 849-853.

[3] Bhattacharya, S.C., San Shwe Hla and Hoang-Luang Pham 2001. A study on a multi-stage hybrid gasifier-engine system. *Biomass and Bioenergy*, 21: 445-460.

[4] Uma, R.; Kandpal, T.C.; and Kisshore, V.V.N. 2004. Emission characteristics of an electricity generation system in diesel alone and dual fuel mode. *Biomass and Bio energy*, *27*: 195-203.

[5] Henriksen, Ulrik and et al. 2006. The design, construction and operation of a 75 kW two-stage gasifier. *Energy*, 31: 1542-1553.

[6] Singh, R.N.; Singh, S.P.; and Pathak, B.S. 2007. Investigations on operation of CI engine using producer gas and rice bran oil in mixed fuel mode, *Renewable Energy*, 32: 1565-1580.

[7] Zainal, Z.A. and et al. 2002. Experimental investigation of a downdraft biomass gasifier. *Biomass and Bioenergy*, 23: 283-289.

[8] Mansaray, K.G. and et al. 1999. Air gasification of rice husk in a dual distributor type fluidized bed gasifier. *Biomass and Bioenergy,* 17: 315-332.

[9] Yan, Cao and et al. 2006. A novel biomass air gasification process for producing tar-free higher heating value fuel gas. *Fuel Processing Technology*, 87: 343-353.

[10] Singh, R.N. and et al. 2006. Feasibility study of cashew nut shells as an open core gasifier feedstock. *Renewable Energy*, 31: 481-487.

[11] Department of Alternative Energy Development and Efficiency 2008. *Ayeyawady - Chao Phaya - Mekong Economic Co-operation Strategy (ACMECS) and the co-operation to develop renewable energy and conservation of energy among Cambodia, Lao PDR, Myanmar and Thailand (Study and demonstration of biomass gasification for electricity project in LAO PDR)* (full report). Ministry of Energy, Thailand.

[12] Worapun, Ittipon; Pianthong, Kulachate and Thaiyasuit, Prachasanti 2008. The effect ratio of biodiesel-ethanal blends for performance and emission in high speed diesel engines. *Journal of Ubon Ratchathani University,* 10(3): 61-80. (in Thai)