AN INVESTIGATION ON PERFORMANCE CHARACTERISTICS OF C.I ENGINE USING BIOGAS AND DIESEL IN DUAL FUEL MODE

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***ABSTRACT*- Biogas derived from organic wastes is a potential alternative to the partial substitution of petroleum derived fuels because it is from renewable resources that are widely available. The effect on performance of engine using biogas and diesel dual fuel operation is presented in this paper and also find the level of mixing ratio of biogas and diesel to effective run the C.I engine. To determine the performance characteristics of C.I engine using biogas for practical use, the intake system of the engine is properly modified to operate with biogas as a fuel. In this paper, the important parameters of performance characteristics (such as: power output, thermal efficiency, fuel consumption and exhaust emission) of biogas-fueled C.I engine are studied and estimated with change of engine speed and load. The obtained results when operating with biogas are used to compare with that of diesel fuel under the same operating conditions. The experimental results show that the tested engine operated with richer biogas-air mixture than that of diesel-air mixture under the same test conditions.**

***Key words* -Biogas, dual fuel, performance test, BSFC, C.I engine, BTE**

I. INTRODUCTION

The conventional sources of energy are being depleted at a faster rate and the world is heading towards a global crisis. The greatest task today is to exploit the renewable energy resources for power generation. Biogas is easily makeable by anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material and crops. Biogas can also be cleaned and upgraded to natural gas standards and becomes bio methane. An overall evaluation of the results indicated that the biogas and diesel dual fuel operation could be substituted for diesel fuel in power generation possible to work satisfactorily under long term engine operation without any major troubles. This idea of biogas as a diesel fuel substitute is not new, but it is a very attractive and efficient alternative, especially in countries having work more on agricultural products and demand in petroleum resources. There have been continuing efforts in research work for alternative fuel source, development and demonstration to utilize biogas to provide heat and power. Biogas can be used as an alternative to the partial substitution of diesel fuels without requiring extensive engine adjustments or modifications.

To operate with biogas, diesel engines can be conveniently converted to a fumigated dual fuel engine, which is the most practical and efficient method. Since biogas has a high octane number, it can be employed in a high compression ratio engine to maximize its conversion efficiency. In dual fuel operation mode, biogas is mixed with air prior to entering the combustion chamber. At the end of compression stroke, a pilot amount of diesel fuel is injected to ignite the mixture, as long as proper spray penetration and evaporation are achieved. One advantage of this method is that the engine can be switched back to conventional diesel operation mode when the biogas supply is not available. In this investigation testing of compression ignition engine is operated with

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biogas and diesel dual fuel mode. The main objective is to evaluate performance characteristics of a small, naturally aspirated, direct injection C.I engine using diesel and biogas in a dual fuel mode.

II. EXPERIMENTAL PROGRAMME

The tests and estimation of engine performance characteristics (like brake power, thermal efficiency, specific fuel consumption and exhaust emission) of biogas internal combustion engines are limited by the lack of specially testing devices and measuring equipments. It is expected that the performance characteristics of biogas-fueled engine must be studied for a wide change of engine speed and load. Then the obtaining results should be used to compare with operation the conventional fuels like diesel. Thus, the main objectives of this study are to evaluate the performance characteristics of biogas fueled C.I engine.

2.1 Experimental procedure.

The experiment was carried out with the conventional diesel fuel and the engine was kept running till it reached the operating temperature. The load was kept constant for various RPM throughout the experiment. For diesel and biogas consumption by the engine, all the parameters were observed at different speed and load on the engine. Moreover, time for fuel consumption by the engine was also noted to calculate the specific fuel consumption under various conditions. To reduce the effect of dispersion in the data each set of experiment was repeated two times. The Brake Power, Brake Specific Fuel Consumption, Brake Thermal Efficiency and exhaust emission were calculated.

In order to draw conclusion, the experiments were conducted by varying RPM and volume of Biogas and Diesel over wide ranges. To evaluate comparatively of performance characteristics of C.I engine using diesel and biogas, engine speed is changed from 1400 rpm to 1600 rpm with a step of 50 rpm. a total of five measurement points (1400, 1450, 1500, 1550, 1600 rpm).

2.2 Experimental Set Up

The particular type of engine used in this investigation is a single cylinder 3.7 KW diesel engine. Setup of the investigation engine is illustrated in Fig.1 and its specifications are noted in the table 1.The engine is cooled by water cooling system fitted in the engine itself. There is only one change in the engine was biogas and air are mixed in the one chamber like T joint near intake manifold.

The engine was run at the idling condition for certain period of time. The engine was properly fitted with the mechanical loading arrangement for better results. After running the engine with this condition for certain time, readings were taken for different load conditions. The performance test was carried out with same test set up and then the engine run with dual fuel of diesel and biogas.

Table 1. Engine Specifications

. Engine	Kirloskar
Type	Water cooled
B P	3.7 KW
Number of Cylinders	1
Bore	80 mm
Stroke	110 mm
Rated speed	1500 RPM
Combustion	Compression Ignition

Fig.1 Experimental setup of biogas-fuelled C.I engine

Biogas used in the tests was supplied from a biogas plant. It was stored and compressed in a collapsible rubber balloon from where it was fed to the engine intake manifold. Before storing in the balloon it was upgraded through purification to reduce CO_2 and some amount of H_2S. Its compositions were

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60% CH_4, 30% CO_2, 5% N_2, and 2% O_2 with some traces of H_2S. The biogas was also compared along with diesel for the properties obtained from the literature shown in Table 2.

Table 2. Property of diesel and biogas

Property	Biogas	Diesel
Cetane number	-	50
Heating Value (MJ/Kg)	24.50	45.91
Viscosity @ 40ºc (cSt)	-	3.34
Specific gravity @15 ºc	0.001	0.830
Sulphur content (%wt.)	0.12	0.037

III. RESULTS AND DISCUSSION

3.1 Brake power

Brake power of engine is measured by a rope brake dynamometer. The experiment is conducted at the same conditions with biogas and diesel. When the engine speed increases, the brake torques for both cases increases. However, the difference in brake power at each operating point is less than 5%. Engine speed is set at 1400 rpm (idle speed), 1450, 1500, 1550, 1600 rpm. Theoretically, brake power of same engine fuelled with diesel is higher than that using biogas, because diesel has higher LHV than biogas. In this study, however, brake power (determined by dynamometer) is constantly kept in order to estimate the power output, fuel consumption and thermal efficiency for two study cases. The trend shows (fig.2) that brake engine power increases with the increase of engine speed. This is due to a reduction in ignition delay at high temperature in engine cylinder at high speeds. The brake engine power decreases as the percentage of biogas increases, as a result of lower energy contents in fuel mixture. It is also found that conventional diesel fuel always has higher brake engine power as compared to diesel and biogas.

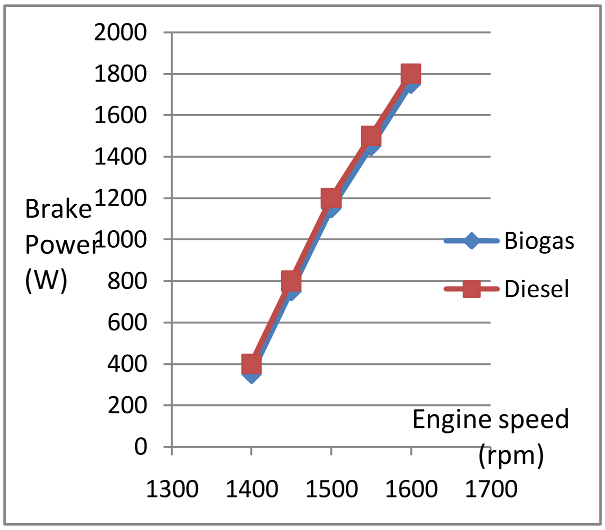

Fig.2 Variation of Brake Power vs. Engine Speed

3.2 Intake air and biogas mass flow rate

Fig.3 shows the change of air mass flow with engine speed. Both intake air flow and biogas flow increase and the variation of A/F rate of air-biogas mixture has a similar tendency. At 1400 rpm, air-fuel mixture is quite dense because biogas has high impurities (CO_2 more than 30%), engine is difficult to start and keep stability in low load. In that case, engine need to close air throttle to reduce air mass flow. When engine speed increases up to 1450 rpm, engine operation has conducted smoothly and air mass flow increase relatively linear. Varying trends and causes of intake air and diesel supply in Fig. 3 which is quite similar to Fig. 4.

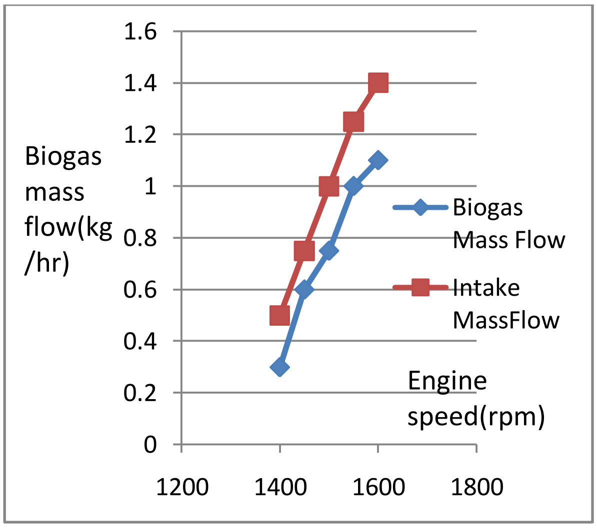

Fig.3 Variation of intake air mass flow and biogas mass flow with respect to engine speed

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It shows that the supplied amount of biogas is higher than diesel at the same experimental conditions (with the same brake power at each engine speed). This demonstrates that the diesel engine operated with biogas needs higher fuel consumption than diesel operation. To produce the same brake power, in other words, the engine using biogas-air mixture is burned denser than diesel-air mixture. The main reason, as explained above, is due to lower calorific value of biogas in comparison with diesel. This is indicated for brake specific fuel consumption in Fig. 5.

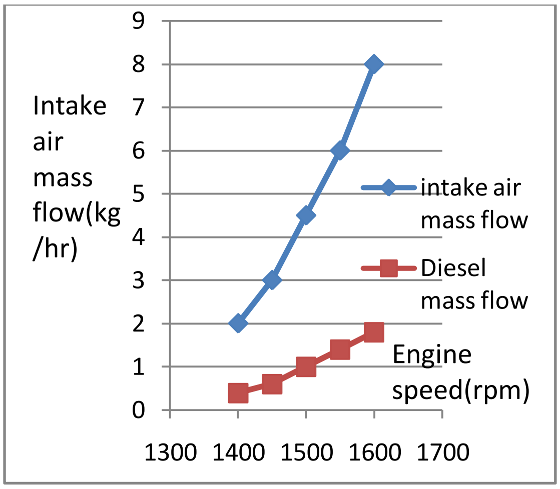

Fig.4 Variation of intake air mass flow and diesel mass flow with respect to engine speed

3.3 Brake specific fuel consumption (BSFC)

The variation in Brake Specific Fuel Consumption at different engine speeds is shown in Fig. 5. The Brake Specific Fuel Consumption is proportional to mass of fuel consumed as well as brake engine power. The Brake Specific Fuel Consumption increases as the percentage of diesel increases in the diesel and biogas combustion as compared to pure conventional diesel fuel. This is due to the lower energy contents in diesel fuel with biogas. The BSFC is increased with the increase or decrease in engine speed because of the decrease in volumetric efficiency of the engine.

As shown in Fig. 5, for each engine speed, the BSFC of engine operated with diesel is lower than that operated with biogas. At idle speed of 1400 rpm, BSFC for two cases is almost similar without load conditions. Measurement and estimation at idle speed is used as an important reference for estimation of CO and HC emission. When speed engine increase from 1500 to 1600 rpm, the difference of BSFC is about 30%. This is caused by the increase of consumption fuel for the operation of same power.

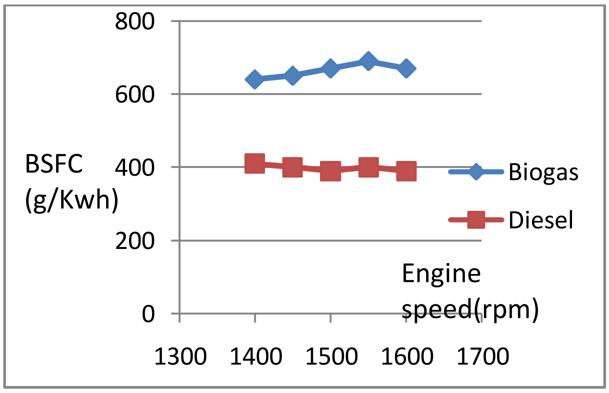

Fig.5 Comparison BSFC of two cases with respect to engine speed

3.4 Brake Thermal efficiency

The variation in Brake Thermal Efficiency at different engine speeds is shown in Fig. 6. Due to low BSFC of pure conventional diesel fuel, its Brake Thermal Efficiency is higher than diesel fuel with biogas. It is evident from the figure that the Brake Thermal Efficiency is decreased as the percentage of biogas increased. It may be attributed to lower energy contents in fuel mixture. Thermal efficiency of engine is inversely proportion to BSFC tendency and LHV of tested fuel. In Fig. 5, the BSFC of engine using biogas is higher than that of using diesel. Thus, for whole range of engine speed, brake thermal efficiency of biogas-fueled diesel engine is lower as shown in Fig. 6. This is because, biogas has many impurities like CO2, O2, H2S and other components limiting the combustion and mechanical durability of the engine. Reduction in brake power of engine leads to reduce thermal efficiency. In addition, thermal efficiency of biogas operation is lower by lower heating value.

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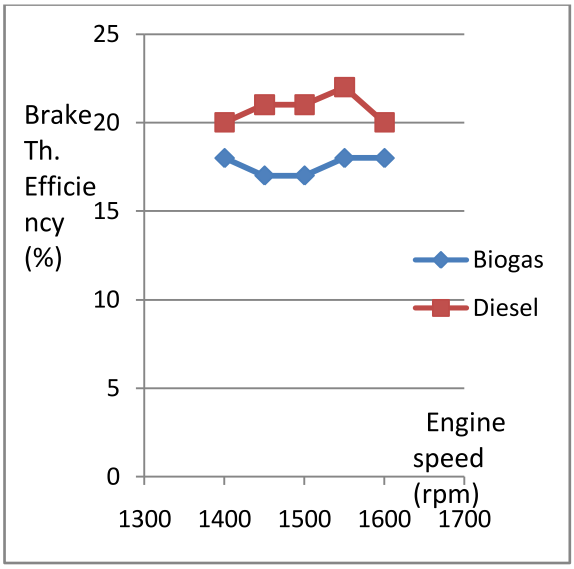

Fig. 6 Variation of brake thermal efficiency versus engine speed

3.5 Mechanical efficiency

Initially engine runs with the diesel fuel and after some time engine runs with dual fuel operation. Readings are taken at different load conditions.Fig.7 shows, at dual fuel mode the comparison of mechanical efficiency is more with diesel as fuel and less with dual fuel operation. It means fuel consumption is more at more load with higher efficiency. The brake thermal efficiency with respect to fuel consumption difference is also higher.

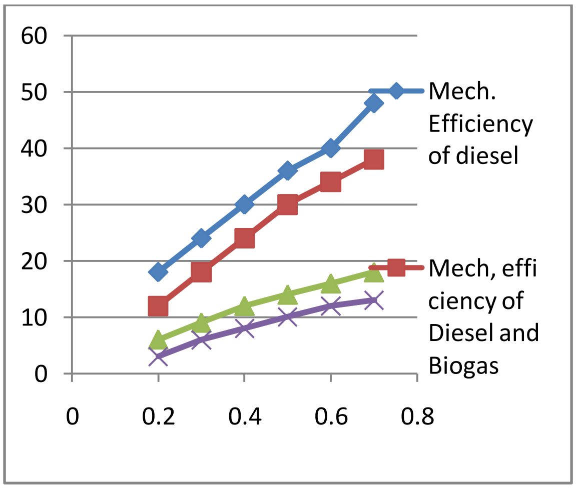

Fig.7 Comparison of Mech. Efficiency and Brake Th. Efficiency

3.6 Effect of load conditions

3.6.1Comparison of fuel consumption with different loading

Fuel consumption of the engine with different loading arrangements is shown in fig.8. The difference in diesel consumption is up to 20% at the engine loading condition and up to 50 % diesel consumption for further loading.

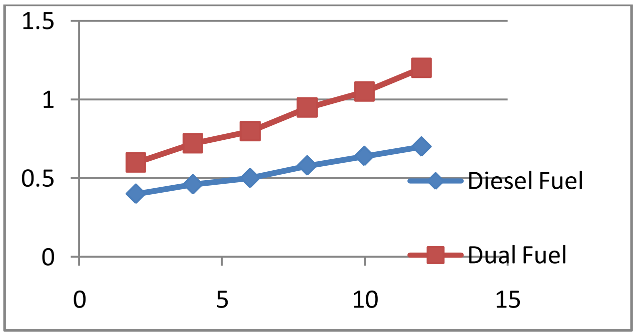

Fig.8 Comparison of fuel consumption with different loading

3.6.2 Biogas mass flow

Effect of load (brake power) on the variation of biogas mass flow is shown in Fig.9. When load increases, the amount of biogas increases linearly. At each point of load, higher engine speed, higher biogas mass flow due to higher volumetric efficiency.

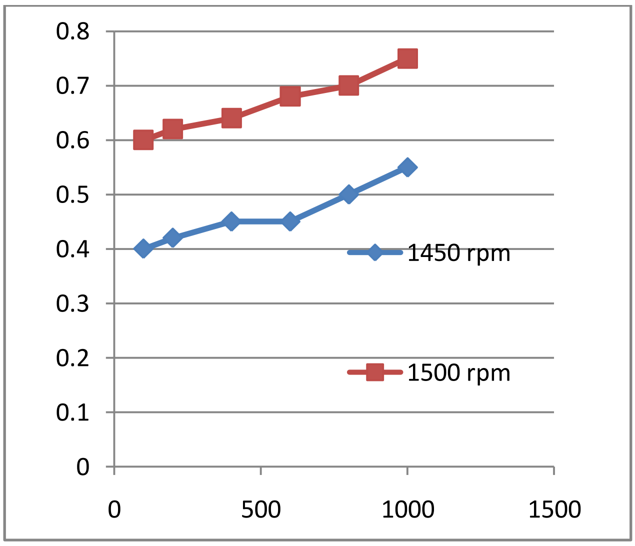

Fig. 9 Change of intake biogas mass flow with respect to brake power for two cases

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3.6.3 Brake specific fuel consumption (BSFC)

Fig. 10 shows the change of BSFC with respect to load for two different speeds. As shown in figure, the amount of biogas supply at speed of 1500 rpm is higher than that of 1450 rpm. This may be caused by the increase of volumetric efficiency at high speed. Also, when engine load increases, BSFC decreases.

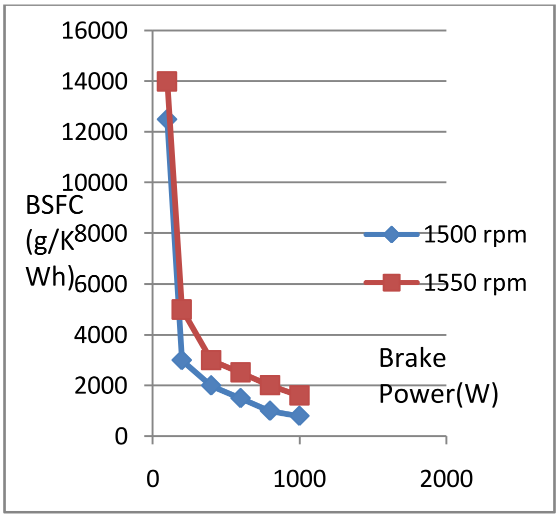

Fig. 10 Change of BSFC with respect to load

3.7 Exhaust emission

Fig. 11 shows the variation of CO_2 with change of engine speed. It is clearly from the figure that, at speed of 1500 rpm, CO_2 concentration of biogas and diesel is nearly the same. When speed increases from1400 rpm to 1600 rpm, both CO_2 concentration for both cases increases. The concentration of CO_2 in exhaust of diesel engine increases faster than that of dual fuel operation. Even through, the availability of CO_2 in biogas composition, the burning of biogas-air mixture generates still less CO_2 than the burning of diesel-air mixture, because of diesel has higher hydrocarbon in composition. The result shows that the conversion of CH_4 into CO_2 in the combustion products of biogas-air is less than diesel operation and this contributes to reduce greenhouse gas effectively.

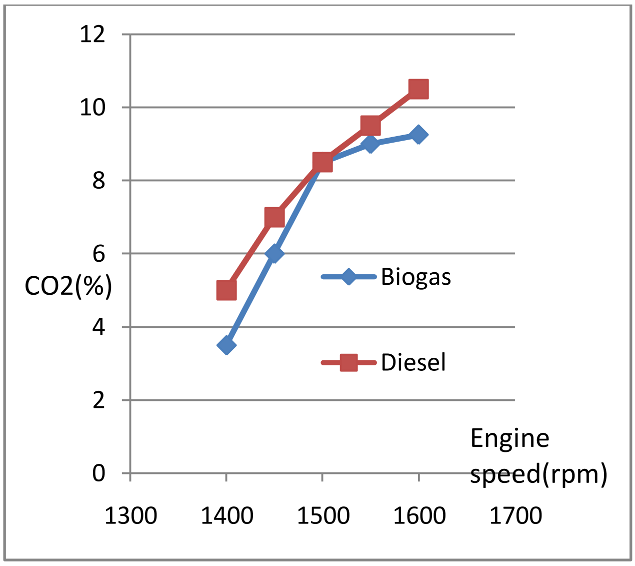

Fig.11 Variation of concentration of CO2 versus engine speed for two cases

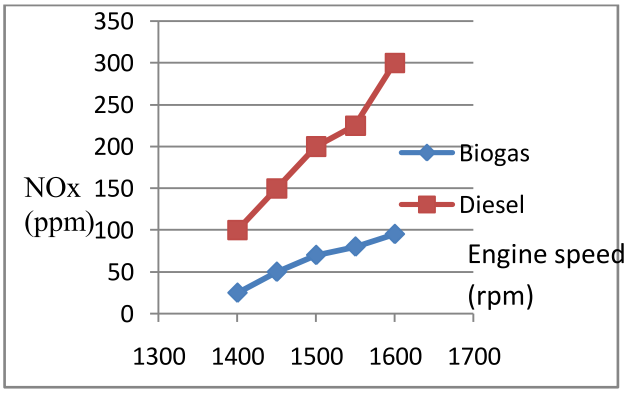

Fig. 12 Variation of concentration of NOx with respect to engine speed for two cases

Fig. 12 shows when engine speed increases from1400 to 1600 rpm, both concentrations of NO_x from exhaust of engine using biogas and diesel also increases, which is theoretically true for NO_x formation. This is because at the higher speed under high load conditions, the combustion temperature is higher to form NO_x emission. Based on Fig. 12, the increase of NO_x in engine using diesel is higher than that in engine using biogas. The main reason is the combustion temperature of engine using diesel is higher (with higher calorific value) than biogas case. In addition, high levels of CO_2 in the biogas reduced the temperature of burning biogas-air mixture.

IV. CONCLUSION

In this study, investigation of engine performance test operating on biogas-diesel dual fuel in a small

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diesel injection engine at different speed and load conditions has been carried out. Diesel engine performance and exhaust emissions have been experimentally investigated and the following conclusions may be drawn.

1) Diesel consumption by this small diesel engine at different loading arrangement is around 50% diesel we can save by using biogas-diesel as a fuel in that engine.

2) Efficiency of the engine 20% is increased by using dual fuel arrangement.

3) The Brake Specific Fuel Consumption increased as the percentage of biogas increased in the diesel fuel as compared to pure conventional diesel fuel. This is due to lower energy contents in diesel fuel with biogas.

4) The Brake Thermal Efficiency is decreased as the percentage of biogas increased as compared to pure conventional diesel fuel. This is due to lower energy contents in diesel fuel with biogas. .

5) By using biogas there is a reduction in CO emissions and HC emissions. The hydrocarbons emissions and Carbon Monoxide emissions decreased as the percentages of biogas increased in fuel as compared to pure conventional diesel fuel.

6) The brake engine power decreases as the percentage of biogas increases. This is due to lower energy contents in biogas. It is also found that conventional diesel fuel has higher brake engine power as compared to diesel and biogas.

REFERENCE

[1] Ozkan, M., Ergenç, A. T. & Deniz, O. (2005). Experimental performance analysis of biodiesel, traditional diesel and biodiesel with glycerine. *Turkish J. Eng. Env. Sci*., Vol. 29, pp. 89-94.

[2] Huynh Thanh Cong, Pham Xuan Mai, NguyenDinh Hung, Tran Minh Tien, A Study on Characteristics of Power Generation System fuelled with Biogas, Journal of Transaction of the Korean Hydrogen and New Energy Society, Vol. 21, No.5, 2010, pp. 435-441.

[3] Sorathia, Harilal S. Yadav, Hitesh J. "Energy analyses to a CI-Engine using diesel and biogas dual fuel-A review study," International journal of advanced engineering research and studies. IJAERS/Vol.I/Issue II/January-March, 2012/212-217.

[4] Tippayawong, N. Promwungkwa, A. and Rerkkriangkrai, P., "Durability of a small agricultural engine on Biogas/diesel dual fuel operation," Iranian Journal of Science & Technology, Transaction B: Engineering, Vol. 34, No. B2, pp 167-177.

[5] Huang, Z., Lu, H., Jiang, D., Zeng, K., Liu, B., Zhang, J. & Wang, X. (2004). "Combustion behaviours of a compression-ignition engine fuelled with diesel/methanol blends under various fuel delivery advance angles". *Bio resource Technology*, Vol. 95, pp. 331–341.

[6] Li, D., Zhen, H., Xingcai, L., Wu-gao, Z. & Jian-guang, Y. (2005). "Physico-chemical properties of ethanol– diesel blend fuel and its effect on performance and emissions of diesel engines". *Renewable Energy*, Vol. 30, No. 6, pp. 967-976.

[7] Shahid, E. M. & Jamal, Y. (2008). "A review of biodiesel as vehicular fuel". *Renewable and Sustainable Energy Reviews*, Vol. 12, No. 9, pp. 2484-2494.

[8] Sayin, C. (2010). "Engine performance and exhaust gas emissions of methanol and ethanol–diesel blends". *Fuel,* Vol. 89, pp. 3410-3415.

[9] Zhang, Z. H., Cheung, C. S., Chan, T. L. & Yao, C. D. (2010). "Experimental investigation of regulated and unregulated emissions from a diesel engine fueled with Euro V diesel fuel and fumigation methanol", *Atmospheric Environment*, Vol. 44, pp. 1054-1061.

[10] Sayin, C., Ozsezen, A. N. & Canakci, M. (2010). "The influence of operating parameters on performance and emissions of DI diesel engine using methanol-blended-diesel fuel". *Fuel*, Vol. 89, pp. 1407-1414.

[11] Roskilly, A. P., Nanda, S. K., Wang, Y. D. & Chirkowski, J. (2008). "The performance and the gaseous emissions of two small marine craft diesel engines fuelled with biodiesel". *Applied Thermal Engineering*, Vol.28, Nos. 8-9, pp. 872-880.

[12] Rosillo-Calle, F. & Cortez, L. A. B. (1998). Towards ProAlcool II- "A review of the Brazilian bioethanol programmes". *Biomass and Bioenergy*, Vol. 14, No. 2, pp. 115-124.

[13] Bayraktar, H. (2008). "An experimental study on the performance parameters of an experimental CI engine fueled with –Methanol-dodecanol blends". *Fuel*, Vol. 87, No. 2, pp. 158-64.

[14] Bui Van Ga, Le Minh Tien, Truong Le BichTram, "Possibility of CO2 Emission Reduction in Vietnam by Utilization of Biogas for Electricity Production", University of DaNang, 2009.

[15] Bui Van Ga, Tran Van Nam, Nguyen Thi Thanh Xuan, "Utilization of biogas engines in rural area: A contribution to climate change mitigation", Colloque International RUNSUD 2010 University' Nice Antipolos.

[16] Kisenyi, J. M., Savage, C. A. & Simmonds, A. C. (1994). "The impact of oxygenates on exhaust emissions of six European cars". *SAE Technical Paper, 940929*.

[17] Kojima, M., Brandon, C. & Shah, J. (2000). "Improving urban air quality in south Asia by reducing emissions from two-stroke engine vehicles". *World Bank Report*.

ISSN: 2278 – 7798

[18] Bauer, T., Lorenz, N. & Willson, B. (2004). "Emissions characterization of a direct injection retro-fit kit for small two-stroke cycle engines". *Better Air Quality (BAQ) conference*, Agra, India.

[19] Tran Minh Tien, Nguyen Dinh Hung, Pham Xuan Mai, Huynh Thanh Cong, "Characteristics of Biogas-fueled Power Generation System", The 3rd ASEAN Environmental Engineering Conference, University of Philipine, Metro Manila, November 11–12, 2010.

[20] Huynh Thanh Cong, Pham Xuan Mai, Nguyen Dinh Hung, "A Study on Characteristics of Power Generation system fueled with Biogas," in Proceeding of Innovations for Renewable Energy 2010 and 7th SEE Forum Meeting, 21-23 October,2010; Hanoi, Vietnam, 2010.

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