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DEVELOPMENT AND IMPROVMENT OF KEROSENE ENGINE TO OPERATE ON BIOGAS

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Abstract

This research work was carried out in the biogas laboratory of the Agricultural Engineering Department, Faculty of Agriculture, Mansoura University. The main objectives were to utilize biogas as a fuel for operating a modified kerosene engine that was used to drive an electric generator. The modification constituted the design of a mixing chamber connected to the intake manifold of the engine. The performance and efficiency of the engine were studied under all possible operating conditions using biogas fuel with six different nozzle diameters (4, 5, 6, 7, 8, and 9 mm) and generator electric loads (0, 0.29, 0.58, 0.87, 1.16, 1.43, and 1.62 kW). It was compared with an engine operating on kerosene fuel only. The obtained results showed that the biogas can be used as a new fuel for operating the modified engine-generator unit at the rated and maximum output of generator (1.43 and 1.62 kW, respectively) using nozzle diameter of 5 mm under biogas pressure ranging from 19 to 21 mbar. Under these conditions, high brake thermal efficiency and mechanical efficiency of the engine and high generator thermal efficiency and electric generation efficiency were 28.03, 80.33 and 81.93%, respectively. The obtained data also revealed that, using nozzle diameter of 5 mm, resulted in reduction in the biogas consumption and specific biogas consumption rate.

INTRODUCTION

The technology and utilization of biogas have recently attracted the attention all over the world. The rational behind it, is seen in the ecological benefits of the utilization of natural resources, pollution control, environmental sanitation, and exploitation of new resource of energy. Biogas is a high quality fuel, can be used in running dual fuel engines for agro-processing, pumping water and generating electricity. Using biogas as a fuel for internal combustion engines will make discharges safer than before and at the same time it will be a useful alternative source of power. Biogas has energy content similar to that of natural gas and the technical feasibility of using biogas to generate electricity is well established. Excess heat from generators can be circulated through a heat exchanger to improve the efficiency of anaerobic digestion (Climate–Energy Matters, 2002). The use of the electricity generated from recovered methane will further offset the use of fossil fuels and their resultant greenhouse impacts. Biogas can be used directly for numerous applications such as: cooking, lighting, space heating, water heating, grain drying, gas-fired refrigeration or air conditioning. Moreover, it can be transformed into electricity through internal combustion engine-driven generator. For engine applications, it may be advisable to scrub out hydrogen sulfide. Such a technology has the advantage to preserve the environment from the emission of biogas, guaranteeing, at the same time, a higher safety of discharges (Barker, 2001, Bodensteiner, 2002, EREC, 2003, and Consorzio, 2001).

Moreover, using biogas as fuel for internal combustion engines provide the power "in-house", thereby reducing the amount of electricity, which would otherwise need to be purchased (Matthews, 2001). In rural areas, biogas technology makes optimal utilization of the valuable natural resource of dung, it provides nearly three times more useful energy that dung directly burnt, and also produces nutrient-rich manure (TERI, 1994)

An essential modification of spark-ignition or diesel engine to permit the use of biogas is the addition of a simple mixer to add biogas to the engine's air intake stream. A stoichiometric mixture of air and biogas consists of 6–7 volumes of air for each volume of biogas, so it is only necessary to add about 15% biogas to the intake air. A spark-ignition engine operates very nicely on only the mixture of air and biogas (Mahin, 1984). The mixing-device is designed to enable the engine to operate at its rated maximum power even if it should be mainly operated at a lower power output for economical reasons. The actual shape of the mixing chamber whether spherical or cylindrical may be chosen in accordance with the availability of space, material and the best mode of connection to the manifold (Mitzlaff, 1988). Biogas engines reject approximately 75 to 82 percent of the energy input as waste heat. This waste heat can be used to heat the digester and/or provide water or space heat to the facility. Commercial heat exchangers can recover waste heat from the engine water cooling system and the engine exhaust, recovering up to 7.385 MJ/ hour (7,000 Btu/hour) for each kW of generator load. Waste heat recovery increases the energy efficiency of the system to 40 - 50 % (McNeil Technologies, 2000). The biogas consumption for 13 kW engine with a 7.5 kW electrical generator was around 4 m^3 of biogas per hour (0.533 m^3/kWh).. The efficiency of a co-generation plant (a simple gas engine with a generator) of around 30% to turn the burning power into electricity 60% go into heat and 10% occur as losses (Dobelmann, 2000).

The main objectives of this research work were to modify a small electric generator engine to operate on biogas. Also to investigate the effect of biogas fuel on the mechanical performance and efficiency of engine and generator using six different nozzle diameters (4, 5, 6, 7, 8, and 9 mm) with seven different electric loads (0, 0.29, 0.58, 0.87, 1.16, 1.43, and 1.62 kW).

MATERIALS AND METHODS

The procedures were accomplished through two stages, compressing the biogas in cylinders using modified air compressor, and modifying a kerosene engine-generator unit to operate on biogas by adding mixing chamber of biogas and air connected with the engine carburetor to help the engine to operate on biogas.

Compressor modifications:

The compressor (1 hp motor power, 2800 rpm, 150 cm^3 cylinder volume and 1245 rpm piston speed) was modified for compressing biogas in 60 liter cylinder volume. The modifications were executed on air suction orifice and delivery tube of the compressor. The air suction orifice was developed to receive biogas instead of air. It was fulfilled by removing the air filter and fixed a suitable joint in order to connect with biogas tube. The delivery tube was modified by added T-connection joint, which connected to the compressor tank from one end through a safety non-return valve. The other end of the T-joint was connected to the biogas cylinder through a three components, safety non-return valves, pressure control valve and pressure gauges.

Engine-Generator Unit Specifications:

The specifications of kerosene engine are listed in Table (1). The type of electric generator is GENESTAR (GS2600RK) with maximum electricity generation of 1.7 kW while the rated power is 1.4 kW at 6.5 Amber, 220 Volt and 50 Hz.

Table 1. Specifications of kerosene engine:

Item	General Specs.
Type	Robin
Model	EY20DK
Number of cylinders	1
Displacement (cm^3)	183
Compression ratio	5.6
Pore diameter (cm)	6.65
Stroke (cm)	5.27
Maximum power output (kW)	3.21 @ 4000 rpm
Rated power (kW)	2.31 @ 3600 rpm 1.94 @ 3000 rpm

Engine modification (mixing chamber of biogas and air):

The main modification of the engine to operate on biogas was associated with the mixing chamber of biogas and air connected with carburetor. The modified mixing chamber consisted of two cylindrical parts. The first part was fixed inside the second part and has diameter and length of 50 and 85 mm, respectively. The second part has diameter of 76 mm and length of 100 mm, as illustrated in Fig. (1). The inside part is connected to an air tube 35 mm diameter, which equipped with a control valve to control the inlet air. Meanwhile, the biogas tube was passed through the center of the two cylindrical parts and had a diameter and length of 9 and 125 mm, respectively. The first inlet part of biogas tube (50 mm long) was provided with many holes (each one has 1 mm diameter) around the tube. These holes were made to distribute the biogas during the mixing operation with air. The outlet part of biogas tube was provided with a nozzle positioning connection (20 mm diameter and 17 mm long) and a control valve, which is connected to the biogas source. The outside cylindrical part is connected to the engine carburetor by a tube of 27 mm diameter and 60 mm long. The mixing chamber was equipped with 6 nozzles of 4, 5, 6, 7, and 8 mm inlet diameter and 17 mm long in addition to 9 mm which the inlet diameter of the biogas tube of mixing chamber was used as a nozzle. The function of nozzles was to supply the mixing chamber with biogas during engine operation.

Laboratory Equipment:

Many of the equipment were used for measuring biogas pressure using pressure control valve (Harris, USA) and U-tube manometer, biogas flow rate using the "Ritter Drum type Gas meter" type of TG05, Germany, water vapour in biogas using silica gel filter, torque and speed, using the torque transducer (Model 1228), Digital strain indicator (model P-3500) and digital speedometer, and electricity output from generator in power (W), voltage (V) and current intensity (A) at different loads using energy meter (model of WSE, Bedienungsanleituing LVM 210, Germany). Biogas compositions were analyzed at chemical laboratory, Alexandria Petroleum Company using ASTM-D-1945 method. The ASTM-3588 method was used for determining the biogas calorific value and UOP9 method for hydrogen sulphide.

Data analysis :

Excel spreadsheet was used to determine the averages of engine fuel and specific fuel consumption, torque, brake power, fuel energy, engine efficiencies including: (brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, electric thermal efficiency, electric generation efficiency), brake, friction and indicated mean effective pressure .

Power determination:

The torque was measured as a strain. It was indirectly determined by the equation resulted from calibration curve of the torque transducer using strain indicator. The brake power, brake mean effective pressure, friction mean effective pressure, friction power, and indicated power were computed using the standard equations (Hunt, 1995, and Plint and Martyr, 1995)

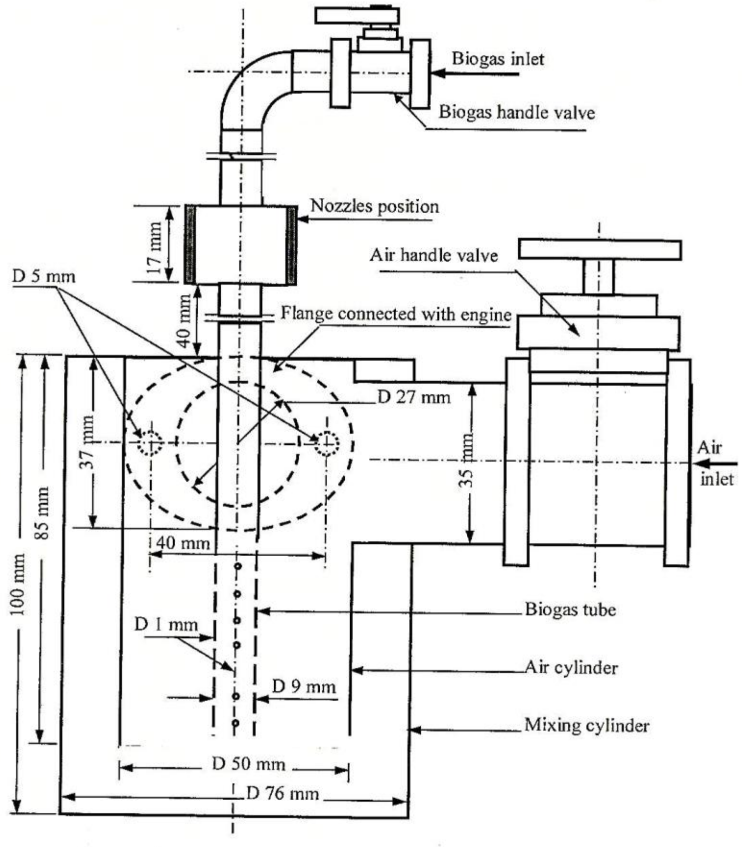

Fig. 1. schematic diagram of mixing chamber

Fuel measurements:

The application methods and all of the equations used for determination of the fuel consumption, specific fuel consumption, and energy provided were cited from (Mitzlaff and Mkumbwa, 1984)

Engine and generator efficiencies:

The engine and generator efficiencies were calculated using the standard equations (El-Ashry, 2003, and Mitzlaff, 1988).

Experimental procedure:

Biogas compression:

The inlet of compressor was connected to biogas digester (Chinese type) through manual control valve and the compressor output tube was connected with biogas cylinder through non-return safety valve, pressure control valve and pressure gauge. To begin the compression, the biogas valve was fully opened and then, the compressor operated for 3-5 minutes and stopped for 5 to 10 minutes in order to cool the compressor head and then operated again. This procedure was repeated several times until obtaining the desired pressure inside the cylinder. The maximum pressure of biogas reached to 15 bar inside the cylinder.

Utilization of biogas for operating engine-generator unit:

To evaluate the engine and generator performance and efficiencies when operating on biogas, many factors were studied such as the fuel type (kerosene as main fuel and biogas as a new fuel), six biogas nozzle diameters (4, 5, 6, 7, 8 and 9 mm) and seven generator electric loads (0, 0.29, 0.58, 0.87, 1.16, 1.43 and 1.62 kW). The biogas nozzle diameters and the generator electric loads were considered as main factors affecting engine performance and efficiencies when operating on biogas. Meanwhile, the generator loads were the main factor affecting engine performance when operating on kerosene. Fig. (2) illustrates the schematic diagram of the experimental set-up (engine, generator, biogas supply system and measuring equipment)

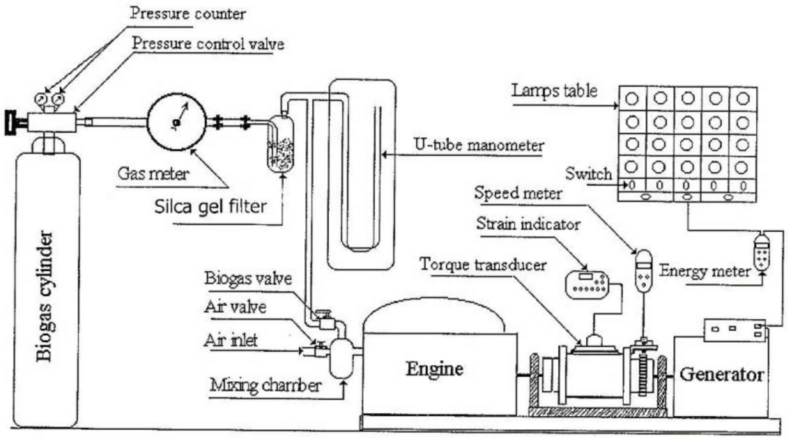

Fig. 2. Schematic diagram of the engine, generator, biogas supply system and measuring equipment.

Generator loading:

To achieve the output power of generator, three different electric capacities of lamps (60,100 and 200 W) were employed as a loading unit. These lamps were tested at 220 V. the actual power of these lamps in average were, 56, 96, and 194 W respectively.

Engine and generator performance with the original fuel (kerosene):

The engine was firstly tested on the kerosene fuel to evaluate the engine and generator performance. The engine and all measuring equipment were tested under the operating conditions. The engine started using gasoline for few minutes then it converted to operate with kerosene. The engine speed was increased until the output voltage of generator reached 220 ±1 V without load (0 kW) at engine speed of about 3161 ± 5 rpm. The measurements of fuel consumption, engine speed, strain, and generator output were executed. After that, the generator was tested at different loads of 0.290, 0.58, 0.87, 1.16, 1.43 and reached the maximum load of 1.62 kW with previous measurements at every load. All experiments were executed at an ambient air temperature ranged from 22 to 27 °C and every experiment period was about 15 minutes.

Engine and generator performance with biogas:

The engine and generator performance test with biogas as alternative fuel was executed at different loads as well as kerosene fuel and the same measurements at every load were recorded. The air-biogas mixing chamber was connected with the engine carburetor and the first nozzle of biogas (4 mm) was applied. The engine was started with gasoline for few minutes and then the biogas control valve was opened slowly until the engine began to show signs of steady ignition and smooth operation. The engine speed was increased by increasing the biogas pressure using the pressure control valve until the output of generator reached 220 V without load (0 kW). The same measurements were taken in addition of generator output (Watt, Ampere and Voltage). the engine and generator were tested at other loads (0.58, 0.87, 1.16, 1.43, and 1.62 kW). The procedure was repeated with all nozzles of biogas (5, 6, 7, 8, and 9 mm diameter). All the experiments were carried out at the same temperature and operation time for kerosene fuel. All the experiments at different loads and nozzle diameters with biogas or kerosene application were executed at constant speeds. This is because the output voltage of generator (220 V) at different loads and nozzles was obtained at constant speeds. Therefore, the torque and the brake power were constant at the same loads for all the experiments.

RESULTS AND DISCUSSION

The obtained results of biogas analysis illustrated that the biogas composition were 77.29% methane (CH_4), 18.83% carbon dioxide (CO_2), 3.88% nitrogen (N_2) and hydrogen sulphide (H_2S) was NIL. The gross and net calorific values of biogas were 29.08 and 26.181MJ/m^3. The gas density was 0.921 kg /m^3.

Biogas Compression:

Measured gas volume inside the cylinder was plotted against pressure. The results showed that, with increasing pressure from 5 to 15 bar the biogas volume inside the cylinder was increased from 292.4 to 894.8 liter. Also as pressure increased the biogas volume increased with the same ratio until the pressure reached 12 bar, then the increase in pressure above 12 bar resulted in increasing the gas volume by higher ratio, this is in agreement with Barker (2001). Moreover, the energy consumed for compressing the biogas reached 0.213 kWh at maximum pressure of 15 bar (about 3.3% of the total energy stored inside the cylinder).

Engine Performance:

The averages of engine torque, brake power, brake and friction mean effective pressure, friction and indicated power, fuel consumption, specific fuel consumption, fuel energy provided and engine efficiencies including: (brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, electric thermal efficiency, electric generation efficiency), were taken as a criteria to describe the performance and efficiencies of the engine and generator when operating with biogas at different nozzles diameters and generator electric loads as compared with kerosene fuels.

Effect of electric loads and nozzle diameters on operating biogas pressure:

The effect of different electric loads and nozzle diameters on operating biogas pressure are shown in Fig. (3). The obtained results revealed that, increasing the electric loads from 0 to 1.62 kW and nozzle diameters from 4 to 9 mm resulted in increasing the operating biogas pressure. Moreover, the reduction in biogas pressure at nozzle diameters of 4 and 5 mm resulted in lower biogas consumption as compared with the other nozzles. The higher biogas pressure occurred at nozzle diameter of 9 mm caused in higher biogas consumption rate. Therefore, the best operating biogas pressure was achieved with nozzle diameters 4 and 5 mm (ranged from 8 to 21 mbar) and this is in agreement with data published by Mitslaff (1988).

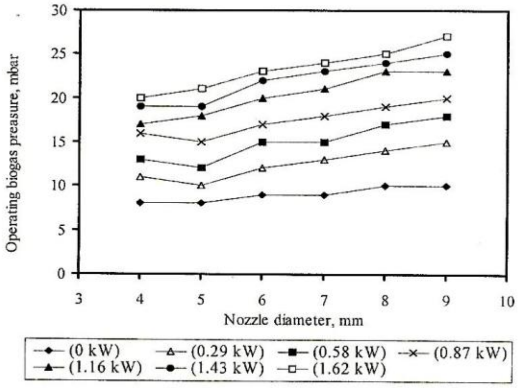

Fig. 3. Effect of nozzle diameters on operating biogas pressure at different loads.

Effect of electric loads and biogas nozzles diameter on biogas consumption

Fig. (4) revealed that there was no significant difference in biogas consumption for the two nozzle diameters of 4 and 5 mm at any electric load. Because of the operating biogas pressure gauge was almost about the same and it was affected the biogas consumption rather than nozzle diameter. The nozzle diameters of 6, 7, 8 and 9 mm at any electric load, strongly affected the biogas consumption. For the six different nozzle diameters of 4, 5, 6, 7, 8 and 9 mm with maximum load of 1.62 kW the biogas consumption rate was 1.028, 1.033, 1.091, 1.206, 1.261 and 1.359 m^3/hr, respectively. While at the rated output of 1.43 kW it was 0.935, 0.937, 0.997, 1.119, 1.148 and 1.258 m^3/hr, respectively. This means that the nozzle diameters above 5 mm gave higher biogas consumption and is not recommended for engine-generator unit operation.

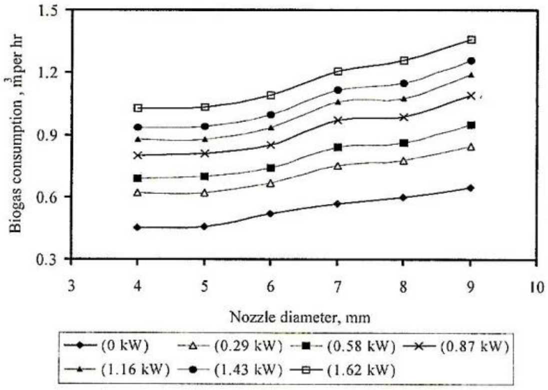

Fig. 4. Effect of nozzle diameters on biogas consumption.

Engine powers:

As the electric load increases the engine brake power is increased. Moreover, the brake power ranged from 0.744 to 2.106 kW at electric loads ranging from 0 to 1.62 kW with kerosene and biogas. However, the lowest values of frictional power were obtained with kerosene using nozzles diameter of 4 and 5 mm, respectively and the higher values were obtained with the other nozzles.

Effect of electric load on specific biogas consumption (SBC)

Fig. (5) shows the effect of different electric loads on specific biogas consumption with different nozzle diameters. It can be observed that increasing nozzle diameter results in increasing the specific biogas consumption, this increasing was higher with nozzle diameters greater than 5 mm at any electric load. The lower value of SBC occurred at rated and maximum electric loads (1.43 and 1.62 kW) for all the nozzle diameters. Moreover, it can be indicated that there was no difference between nozzle diameters of 4 and 5 mm for SBC at different electric loads. These nozzles gave the least values of SBC (0.489 and 0.488 m^3/kWh with nozzle diameter of 4 mm and 0.491 m^3/kWh with nozzle diameter of 5 mm) at rated and maximum electric loads (1.43 and 1.62 kW), and these values were lower than those obtained by Mitslaff (1988) (0.5 - 0.8 m^3/kWh for gasoline engine operated with biogas), 0.604 m3/kWh (Mahin, 1984) and 0.65 m^3/kWh (Sathianathan, 1975). While, the SBC obtained with other nozzle diameters (6, 7, 8 and 9 mm) are in agreement with the data published by the same researchers. When the generator was operated at maximum load (1.62 kW), the lowest SBC occurred with nozzles diameter of 4 and 5 mm (0.488 and 0.491 m^3/kWh).These two nozzles (4 and 5 mm) gave the best rate of SBC as compared with other nozzle diameters. They are, therefore, recommended for operating engine with biogas fuel.

Engine Efficiencies:

Brake thermal efficiency (ηb):

The effect of electric load and nozzle diameter on brake thermal efficiency of engine operated by kerosene and biogas fuels are illustrated in Fig. (6). The obtained results indicated that, as the electric load increased, the brake thermal efficiency using biogas or kerosene fuel is increased. Meanwhile, for biogas fuel increasing nozzles diameter led to decrease the brake thermal efficiency. The brake thermal efficiency for engine during operation with biogas fuel was lower at any load as compared with operating by kerosene fuel. These results are in agreement with Mitslaff (1988), and Mitslaff and Mkumbwa (1984), who mentioned that the reduction of brake thermal efficiency may be due to the incomplete combustion. Ortiz *et al.* (1981) indicated that the biogas burns slower than the kerosene fuel, therefore at higher speeds the gas doesn't have time to burn completely inside the cylinder before the exhaust valve opens allowing the biogas to burn in the exhaust manifold. The nozzle diameters 4 and 5 mm gave the higher values of brake thermal efficiency (28.09 and 28.17% with 4 mm and 28.03% with 5 mm diameter) at rated and maximum electric loads, respectively as compared with the other nozzle diameters. The corresponding values when using kerosene fuel were 28.82 and 28.85% at the same electric loads, respectively. The brake thermal efficiency values using kerosene and biogas fuels with nozzle diameters of 4 and 5 mm are in agreement with the values obtained by El-Ashry (2003) who reported that the brake thermal efficiency for gasoline engines ranged from 25 to 33%. The reduction ratios of brake thermal efficiency with 4 mm nozzle diameter were 2.78 and 2.36% (at 1.43 and 1.62 kW electric load), while they were 1.99 and 2.84% with 5 mm nozzle diameter as compared with that obtained with kerosene. The maximum reduction of brake thermal efficiency with nozzle diameters of 4 and 5 mm were 6.04 and 7.07% at 0 kW electric load, respectively. The obtained results are better than those reported by Jones and Evans (1985) who mentioned that reduction of efficiency was about 10 to 15% when changing operating engine from gasoline to biogas. Consequently, the nozzle diameters of 4 and 5 mm gave the least reduction in brake thermal efficiency as compared with other nozzles and kerosene fuel at different electric loads.

Mechanical efficiency (η_m):

The effect of electric load and nozzle diameters on mechanical efficiency of engine operated by kerosene and biogas fuels are plotted in Fig. (7). The obtained results indicated that increasing electric load led to increase the mechanical efficiency for the engine using kerosene or biogas fuel. While increasing biogas nozzle diameter resulted in decreasing the mechanical efficiency. Moreover, the mechanical efficiency of the engine was 83.21%, and 84.63% at rated and maximum output of generator during operation with kerosene fuel. The nozzle diameters of 4 and 5 mm achieved the higher mechanical efficiency (80.9, 82.4 and 80.3, 81.9%, at rated and maximum output, respectively) as compared with the other nozzles. Meanwhile, with increasing the nozzles diameter the mechanical efficiency decreased reaching the minimum values with nozzle diameter of 9 mm (75.84 and 77.71%) at rated and maximum electric loads, respectively. These results are in agreement with the data published by El-Ashry (2003) who reported that the mechanical efficiency for gasoline engines ranged from 70 to 90%.

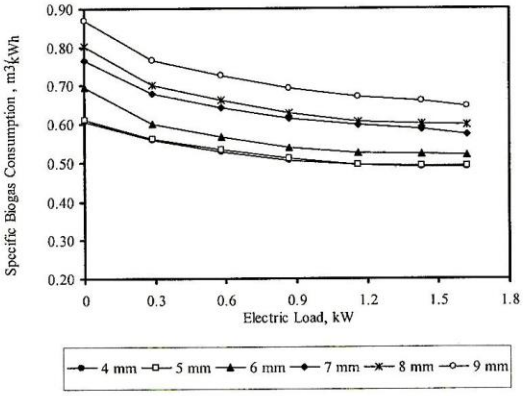

Fig. 5. Effect of electric load on specific biogas consumption.

The results also, showed that the minimum reduction in mechanical efficiency occurred with nozzles 4 mm (from 2.6 to 5.74%) and 5 mm (from 3.19 to 6.99%).

These are in agreement with Jones and Evans (1985) who mentioned that the efficiency loss up to 5% when changing from gasoline to natural gas fuel. They attributed the efficiency loss to the low burning velocity of natural gas as compared with gasoline fuel.

Generator performance:

The results indicated that every 1 m^3 of biogas is needed to operate the generator for one hour in order to produce the following quantity of electricity: 1.529, 1.527, 1.434, 1.277, 1.245 and 1.136 kW at rated output 1.43 kW with nozzles diameter of 4, 5, 6, 7, 8 and 9 mm, respectively. While at the maximum output of generator these values were 1.575, 1.567, 1.486, 1.344, 1.285 and 1.190 kW for the same nozzles diameter, respectively. These results revealed that nozzles diameter of 4 and 5 mm were the best option to operate the generator since it gave the higher production of electricity (1.529 and 1.575 kW at rated and maximum output with nozzle 4 mm and 1.527 and 1.567 kW at the same output with nozzle 5 mm) as compared with other nozzles. However, the maximum values of generator thermal efficiency from combustion of biogas were 21.7, 21.6, 20.4, 18.5, 17.7, and 16.4% at 1.62 kW electric load and 4, 5, 6, 7, 8 and 9 mm nozzles diameter, respectively. Meanwhile for kerosene fuel, this value was 22.2% at the same electric load. The electric generation efficiencies were 26. 2, 44.4, 55.2, 65.3, 74.9 and 76.9% at 0.29, 0.58, 0.87, 1.16, 1.43 and 1.62 kW electric load, respectively. The increasing rate was rapidly increased from 0 kW electric load until reached 1.43 kW then it was slightly increased.

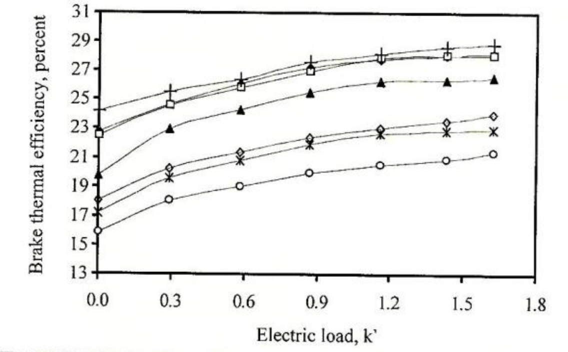

Fig. 6. Effect of electric load and nozzle diameters on brake thermal efficiency using biogas and kerosene fuels.

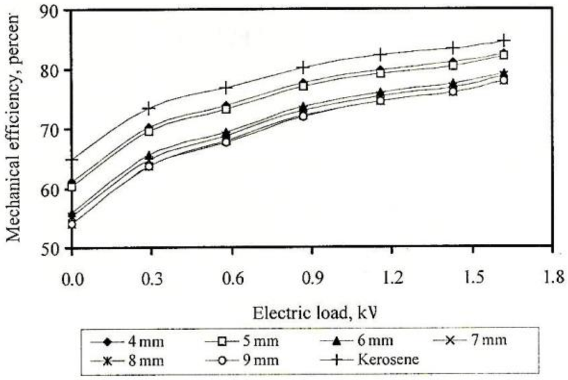

Fig. 7. Effect of electric load and nozzle diameters on mechanical efficiency using biogas and kerosene fuels.

CONCLUSION

The obtained results of this research can be summarized and listed in the following conclusions:

1- It is imperative to compress the biogas inside a cylinder in order to achieve a constant pressure which may be suitable for continuous applications and to easy transport the compressed biogas from the production area to the location of utilization.

2- The biogas can be used as a new fuel for operating the engine-generator unit. The best nozzle diameter of 5 mm for supplying biogas with the operating biogas pressure ranging from 19 to 21 mbar. At these conditions, high brake thermal efficiency, mechanical efficiency and combustion efficiency of the engine and high generator thermal efficiency and electric generation efficiency can be achieved. This nozzle also led to reduce the biogas consumption and specific biogas consumption rates.

3- The generator thermal efficiency was 21.67% and 21.56% but the electric generation efficiency was constant for all the experiments (76.9%).

4- The cost of mechanical energy unit was 0.079 L.E./ kWh with reduction ratio of 45.52% as compared with the kerosene fuel, while it was 0.158 L.E. / kWh for the electric energy unit, with reduction percentage of 46.4%.

5- Further experimental work is required to test and the utilize the biogas compression in order to operate different types of engines specially diesel engines in different agricultural applications to maximize the benefits of utilizing biogas as a new energy source.

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تطوير وتحسين محرك احتراق داخلى يعمل بالكيروسين للعمل بالبيوجاز

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أجرى هذا البحث فى معمل البيوجاز التابع لقسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة. و كان الهدف من هذا البحث هو تعديل مولد كهرباء يعمل عن طريق محرك احتراق داخلي يدار أساسا بالكيروسين للعمل بالبيوجاز بعد ضغطه فى اسطوانات لتوفير مدى من ضغوط التشغيل المختلفة. ويمكن من خلال هذا المولد توفير الطاقة الكهربائية اللازمة لشتى الأغراض. ولتحقيق هذا الهدف استخدم ضاغط هواء (١ حصان) تم تعديله ليقوم بسحب الغاز بدلا من الهواء وضغطه فى اسطوانات الغاز عن طريق صمامات عدم رجوع، صمام تحكم فى الضغط ، مبينات ضغط و صمامات تحكم يدوية.

تم إستخدام مولد كهرباء (١,٧ كيلووات) يعمل عن طريق محرك احتراق داخلي (٣,٢ كيلووات) يدار أساسا بالكيروسين ، تم تعديل المحرك ليناسب التشغيل مع البيوجاز. وذلك من خلال إضافة غرفة خلط البيوجاز مع الهواء متصلة مع الكاربراتير ، استخدمت أحمال كهربائية مختلفة لتوليد حمل متغير على المحرك (٠، ٠,٢٩، ٠,٥٨، ٠,٧٨،١,١٦، ١,٤٣ ، ١,٦٢ كيلووات) هذه الأحمال تولدت من توفيقات لسعات مختلفة من اللمبات الكهربائية ذات السعات ٦٠، ١٠٠،٢٠٠ واط.

تم تحليل الخواص الكيميائية والطبيعية لغاز البيوجاز الناتج واستخدمت معايير الكفاءة واستهلاك الوقود كمعايير لتقييم أداء المحرك–المولد عند التشغيل بالكيروسين و البيوجاز

عوامل الدراسة:

العوامل الرئيسية المؤثرة على أداء و كفاءة المحرك و المولد أثناء التشغيل بالبيوجاز تلخصت فى: قطر فوانى إضافة البيوجاز (عدد ٦ فونية) تشمل ٤ ، ٥ و ٦ و ٧ و ٨ مم بالإضافة الى القطر الداخلى لماسورة الغاز (٩ مم). الأحمال الكهربية للمولد (عدد ٧ أحمال) تشمل صفر ، ٠,٢٩ و ٠,٥٨ ، ٠,٨٧ ، ١,١٦ ، ١,٤٣ و ١,٦٢ كيلووات). بينما أخذت الأحمال الكهربية كعامل رئيسى لتقييم الأداء والكفاءة أثناء التشغيل بالكيروسين

أهم النتائج المتحصل عليها:

يتكون البيوجاز الناتج من المخمر (الطراز الصينى) من : ميثان بنسبة ٧٧,٢٩% ، ثاني أكسيد الكربون بنسبة ١٨,٨٣% ، نيتروجين بنسبة ٣,٨٨% و لا يوجد كبرتيد هيدروجين. كانت القيمة الحرارية الكلية والصافية للبيوجاز ٢٩,٠٨ ميجاجول/م^{٣} و ٢٦,١٨١ ميجاجول/م^{٣} أما كثافة البيوجاز فكانت ٠,٩٢١ كجم/م٣. كما أن المتر المكعب من الغاز الحيوى يعادل حوالى ٠,٦١ لتر من الكيروسين.

كان اقصى ضغط للغاز داخل الاسطوانة ١٥ بار وبلغ حجم الغاز عند هذا الضغط ٨٩٤,٩ لتر و كانت الطاقة الكلية المخزنة داخل الاسطوانة ٦,٥٠٨ كيلووات وبلغت نسبة الطاقة المستهلكة فى عملية الانضغاط ٣,٣ % من اجمالى الطاقة المخزنة. كما كانت الطاقة المخزنة الصافية ٦,٢٩٥ كيلو وات.

يتضح من النتائج أنه يمكن تشغيل وحدة محرك –مولد كهرباء لتوليد الكهرباء التي تستخدم في الأغراض المختلفة بكفاءة عالية وذلك عند تشغيل المحرك بوقود البيوجاز المضغوط داخل اسطوانات عند أقصى حمل (١,٦٢) كيلوواط أو عند الحمل المقرر حوالي (١,٤٣) كيلوواط وعند استخدام فونية البيوجاز ذات قُطر ٤ مم أو ٥ مم عند ضغط.تشغيل من ١٩ الى ٢١ ملى بار.حيث كان الاستهلاك النوعي لوقود البيوجاز ما بين ٠,٤٨٨ إلى ٠,٤٩١ م٣/كيلووات.س، و كانت الكفاءة الحرارية الفرملية للمحرك ٢٨,٢ و ٢٨%، و الكفاءة الميكانيكية الفرملية للمحرك ٨٢,٤ و ٨١,٩%. أما الكفاءة الحرارية للمولد فكانت ٢١,٦٧ و ٢١,٥٦%. وذلك عند أقصى حمل وعند الحمل المقرر على التوالى.