ACTA TECHNICA CORVINIENSIS
– Bulletin of Engineering
Tome X [2017]
Fascicule 4 [October – December]
ISSN: 2067 – 3809

[1.]Radostin DIMITROV, [2.]Penka ZLATEVA, [3.]Siyka DEMIROVA

INVESTIGATION OF THE CHARACTERISTICS OF BIOGAS FUELS AND OPPORTUNITIES FOR THEIR DISTRIBUTION IN BULGARIA

[1.] Department of Automotive Engineering, Faculty of Machine Technology, Technical University of Varna, Varna, BULGARIA
[2.] Department of Thermal Engineering, Shipbuilding Faculty, Technical University of Varna, Varna, BULGARIA
[3.] Department of Industrial Management, Faculty of Machine Technology, Technical University of Varna, Varna, BULGARIA

Abstract: In the article examined the characteristics of biogas fuels and presented opportunities for distribution in Bulgaria. For this purpose have been made studies on the composition of the biogas fuels derived from various starting materials. Analyzed the possibilities for use of biogas fuel, depending on the content of the various concentrations of methane and carbon dioxide. An in-depth analysis of the possibility of distributing raw materials to finished filling stations in Bulgaria, according to the application. Consider the possibility of distribution of finished materials and comply with the requirements for the transport of dangerous goods.
Keywords: Biogas, Algorithm, Distribution, Lower calorific value, Gas generators stations

INTRODUCTION

Road transport is one of the main sources of air pollution. When the full and insufficient combustion of fuels to generate complex mixture of gaseous and solid pollutants, many of which are dangerous to human health.

In addition to carbon oxides, nitrogen oxides, sulfur dioxide, hydrocarbons, particulate matter, etc., are emitted and many toxic pollutants such as benzene - carcinogenic by the International Agency for Research of Cancer (IARC), polycyclic aromatic hydrocarbons (PAHs), especially benzo [a] pyrene, which is used as an indicator of the carcinogenic properties of PAHs [1,2]. It necessary to looking for alternative fuels and to implement short- and long-term measures to reduce emissions from road transport as: reducing the volume of motorized traffic, improved traffic flow, promoting public transport, transfer of highly polluting cars to less sensitive places and others [3,4].

Currently in Bulgaria there are numerous farms of biogas. The first biogas plants are made in India in 1859 currently is estimated in Germany there are 1000 installations in Austria - 200 in Switzerland - 100 in Korea - 30,000 in India - and 500,000 in China - seven million. Biogas is a product of fermentation processes in organic matter by the action of methane bacteria. These microorganisms are strictly anaerobic. Their working range is in the range of 0 to 70°C.

The rate of fermentation processes, and hence the quantity of the product gas depends strongly on the temperature regime. The most common feedstock for biogas production is taken excrement of livestock and poultry. Nature provides, however many, some even unexpected as resources [5-8].

This publication examines the possibility of using biogas as a fuel for internal combustion engines and its application in transport. It is also analyzed the possibility of distributing biogas fuel in Bulgaria.

RESEARCH OF THE CHARACTE-RISTICS OF BIOGAS FUELS

The main component of biogas is methane, which is characterized by the following properties: burning cleaner, cheaper, and its octane number is greater. Because of these properties, in recent years, methane is becoming more widespread.

It is mainly used for heating in industry and households, but the most valuable application is in transport. Using natural gas allows toxic substances, soot and smoke exhaust gases to reduce about 3-4 times. The use of methane in the internal combustion engine is environmentally the cleanest technology (after

© copyright Faculty of Engineering – Hunedoara, University POLITEHNICA Timisoara

hydrogen). Table 1 reflects the relationship between the consumption of 100 km compared to other fuels [11].

Table 1. Relationship between the consumption of 100 km compared to other fuels

Fuel	Expense (litres/100 km)	Price (BGN)	Price of 100 km (BGN/100 km)
GASOLINE	8	1.99	15.92
PROPANE-BUTANE	10	1.01	10.10
METHANE	4.8	1.19	5.71

Biogas is a fuel gas, which is obtained by fermentation in anaerobic (without presence of oxygen) environment of organic products. Let us mention that in nature biogas is obtained in a natural way (so-called marsh gas). The composition of biogas, most often in the range shown in Table 2 [5].

Table 2. Composition of biogas

№	Ingredients	Content, %
1	METHANE (CH_4)	45 - 75
2	CARBON DIOXIDE (CO_2)	25 - 50
3	NITROGEN (N_2)	0 - 7
4	OXYGEN (O_2)	0 - 2
5	HYDROGEN (H_2)	0 - 1
6	HYDROGEN SULFIDE (H_2S)	0 - 1

With these parameters the energy value of biogas is 4,5 to 7,5 kWh/m^3. For comparison, the energy value of diesel is approximately 12 kWh/kg, the wood - 4,5 kWh/kg, briquettes - 5,5 kWh/kg, natural gas - 8,3 kWh/m^3.

Reconstruction of the petrol engine to work on gaseous fuel is relatively easy, since the engines are designed to work with external mixture formation and spark ignition. The main change that is made to provide an adequate system for mixing gaseous fuel with air. The management of this type of engine is done by changing the supplied fuel-air mixture, i.e. depending on the change of the angle of the throttle opening.

There are several reasons why using biogas as an alternative fuel. For example, the combustion process is quiet, non-exhaust emissions are less even during cold start, CO_2 emissions are significantly smaller, has a high octane rating, allowing it to be used in gasoline engines turbocharging. Compared to gasoline methane fuels have the following disadvantages: lower density, consumes an additional energy for their thickening, loss of gas production and transportation, and relatively few charging stations at the time.

The majority of all gas engines are internal combustion engines with spark ignition and fuel injection in manifold. In the gas engine, especially when working with biogas with a high content of CO_2 may reduce the amount of air, in order to enrich the gas-air mixture. The range of power reduction by a large degree depends on the value of the net calorific value of the used biogas. If biogas contains 15% CO_2, a lower calorific value Hu decrease with 33% [(Q^d_i) Hu value is between 45670 to 30806 kJ/kg], and this contributes to reducing the effective power of the engine with approximately about 30%.

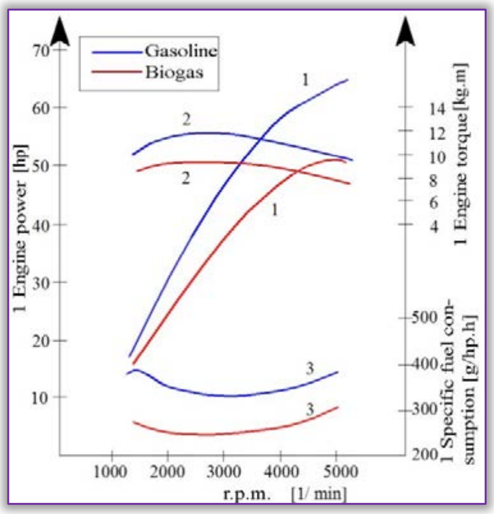

Figure 1. The change of engine power (1), torque (2) and specific fuel consumption (3) as a function of the rotational speed of the crankshaft for petrol and biogas

In comparison with the use of clean natural gas maximum power reduced by 20%, and LPG - 5%. The main conclusion from this is that you have well-considered choice of class power of the engine to cover the estimated needs. Figure 1 shows the change of engine power (1), torque (2) and specific fuel consumption (3) as a function of the rotational speed of the crankshaft for petrol and biogas.

The high content of H_2S in biogas is a major problem with the engines. During combustion it reacts and forms SO_2 and H_2O. After which SO_2 reacts with water to produce H_2SO_3 - sulfuric acid. SO_2 can also react with O_2 to obtain SO_3 and then with water to form H_2SO_4. The presence of these acids leading to severe corrosion and wear of parts in the engine. The presence of hydrogen sulphide in the biogas also leads to deterioration of the engine oil and to the destruction of the catalyst system of the vehicle. Siloxanes R_2SiO can form a thick layer of silica inside the combustion chamber and engine exhaust system. Are formed a large amount of silica particles responsible for the wear on the valve and valve seat.

Ammonia is another corrosive constituent element of the biogas. It reacts with water and forms NH_4OH, which has a corrosive effect on aluminum and copper parts (sliding bearings) of engine. The presence of a large amount of diluent in the biogas leads to a reduction of the calorific value. Some of the heat of combustion is taken from the diluent and this is the reason for a low flash point, which leads to a lower rate of combustion. CO_2 has a high heat capacity, which increases with increasing temperature. This means that at high combustion temperatures, large part of the heat is absorbed by CO_2, and as a result considerably reduces the temperature of combustion which is also shown in Figure 2. However, the heating of the gas-air mixture leads to an increase of the combustion temperature but then dissociates CO_2 (apart) and many of CO emissions are emitted from the exhaust system.

To maximize the efficiency of the gasoline engine, redesigned to work with Biogas fuel should increase the angle of start of ignition, because that biogas has a lower rate of combustion than gasoline.

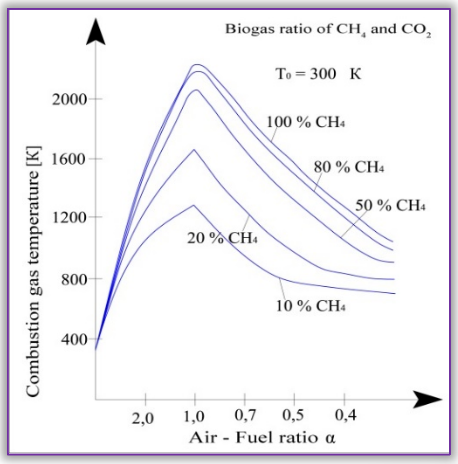

Figure 2. Temperature of combustion of biogas, depending on the concentration of CO_2

RESULTS AND ANALYSIS

To determine the appropriateness of the use of biogas as a fuel for internal combustion engines is an analysis of some parameters affecting work and a power-economic indices of the engines. The calculations were made for several Biogas fuel, depending on the raw material used to produce biogas. Calculated are: lower calorific value of fuel, the required amount of air for the combustion of 1 kg. fuel, the density of the gas at various rates of CH_4 and CO_2.

Table 3. Biogas from organic waste

CH_4 [%]	CO_2 [%]	CO [%]	N_2 [%]	O_2 [%]	H_2 [%]	H_2S [%]	C_6H_6 [%]
60	35.47	0.1	3.4	0.5	0.001	0.533	0.000066
65	30.47	0.1	3.4	0.5	0.001	0.533	0.000066
70	25.47	0.1	3.4	0.5	0.001	0.533	0.000066
75	20.47	0.1	3.4	0.5	0.001	0.533	0.000066
80	15.47	0.1	3.4	0.5	0.001	0.533	0.000066
85	10.47	0.1	3.4	0.5	0.001	0.533	0.000066
90	5.466	0.1	3.4	0.5	0.001	0.533	0.000066
95	0.466	0.1	3.4	0.5	0.001	0.533	0.000066
100	0	0	0	0	0	0	0

Hu [kJ/m^3]	ρ [kg/m^3]	M [kg/mol]	Hu [kJ/kg]	Air [kg]
21636	1.184	26.53	18278	10.3825
23427	1.122	25.14	20889	11.2122
25219	1.059	23.74	23806	12.042
27010	0.997	22.35	27088	12.8718
28802	0.935	20.95	30806	13.7016
30593	0.873	19.56	35055	14.5313
32385	0.811	18.17	39955	15.3611
34176	0.748	16.77	45670	16.1909
35830	0.716	16.05	50042	17.0954

Lower specific heat of combustion Hu is a quantity of heat which is removed by complete combustion of a unit of gas. The difference between the lower and upper limit of the calorific value of 1 m^3 gas is equal to the heat of vaporization (condensation) of the water which is produced by the combustion of the gas. Calculations were made according to the composition of the gas by the formulas shown in [9, 10] and the obtained results, with specialized software, are shown in Tables 3 to 5.

Table 4. Biogas from agricultural materials

CH_4 [%]	CO_2 [%]	CO [%]	N_2 [%]	O_2 [%]	H_2 [%]	H_2S [%]	C_6H_6 [%]
60	35.9	0.1	2.5	1	0.5	0	0
65	30.9	0.1	2.5	1	0.5	0	0
70	25.9	0.1	2.5	1	0.5	0	0
75	20.9	0.1	2.5	1	0.5	0	0
80	15.9	0.1	2.5	1	0.5	0	0
85	10.9	0.1	2.5	1	0.5	0	0
90	5.9	0.1	2.5	1	0.5	0	0
95	0.9	0.1	2.5	1	0.5	0	0
100	0	0	0	0	0	0	0

Hu [kJ/m^3]	ρ [kg/ m^3]	M [kg/mol]	Hu [kJ/kg]	Air [kg]
21565	1.18	26.46	18268	10.2166
23356	1.118	25.06	20886	11.0464
25148	1.056	23.67	23812	11.8762
26939	0.994	22.28	27105	12.7059
28731	0.932	20.88	30837	13.5357
30522	0.869	19.49	35104	14.3655
32314	0.807	18.09	40027	15.1952
34105	0.745	16.7	45773	16.025
35830	0.716	16.05	50042	17.0954

Table 5. Landfil biogas

CH_4 [%]	CO_2 [%]	CO [%]	N_2 [%]	O_2 [%]	H_2 [%]	H_2S [%]	C_6H_6 [%]
60	26.87	0.1	10	2.5	0	0.533	0.000066
65	21.87	0.1	10	2.5	0	0.533	0.000066
70	16.87	0.1	10	2.5	0	0.533	0.000066
75	11.87	0.1	10	2.5	0	0.533	0.000066
80	6.867	0.1	10	2.5	0	0.533	0.000066
85	1.867	0.1	10	2.5	0	0.533	0.000066
86.9	0	0.1	10	2.5	0	0.533	0.000066
86.9	0	0.1	10	2.5	0	0.533	0.000066
100	0	0	0	0	0	0	0

Hu [kJ/m^3]	ρ [kg/m^3]	M [kg/mol]	Hu [kJ/kg]	air [kg]
21636	1.126	25.24	19210	10.0507
23427	1.064	23.85	22016	10.8805
25219	1.002	22.46	25171	11.7103
27010	0.94	21.06	28744	12.54
28802	0.877	19.67	32823	13.3698
30593	0.815	18.27	37524	14.1996
31262	0.792	17.75	39469	14.5094
31262	0.792	17.75	39469	14.5094
35830	0.716	16.05	50042	17.0954

THE POSSIBILITY OF DISTRIBUTING RAW MATERIALS TO FINISHED FILLING STATIONS IN BULGARIA, ACCORDING TO THE APPLICATION

Currently in Bulgaria there are biogas plants producing raw biogas, but there is no built Methane stations using fuel - upgraded biogas. This raises the need to establish an algorithm that can be used as in the case where at the biogas plant has added a system to enrich produced biogas and a case where there is none. The resulting upgraded biogas can be used as fuel for internal combustion engines. There is also the possibility next to the biogas installation has a charging station. Also upgraded biogas can be distributed in the already existing network of charging stations for methane in Bulgaria. Raw biogas can be used for the gas-generating stations producing electrical energy.

Algorithm for distribution of finished materials to filling stations in Bulgaria, depending on their application.

In connection with the distribution of the finished raw materials to filling stations in Bulgaria, according to the application they proposed algorithm (see Fig.3).

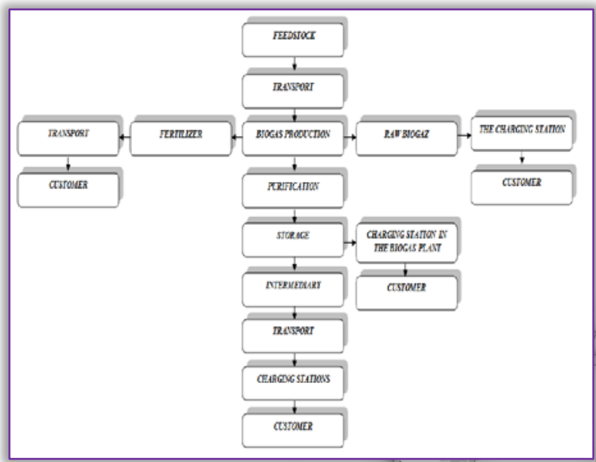

Figure 3. Algorithm for distribution of finished materials to filling stations in Bulgaria, depending on their application

The proposed algorithm enables full distribution of finished materials in various stages of production of biogas. It shows sample distribution capabilities biogas to filling stations and end users.

CONCLUSIONS

Based on the above study, and theoretical calculation can be made to the following conclusions:

- » Using non-upgraded biogas as a fuel for internal combustion engines is inefficient. CO_2 concentration in the composition from about 15% decreased the net calorific value of the fuel with up to 33% (Hu vary from 45 670 to 30 806 kJ / kg).
- » Vehicles using upgraded biogas have significant advantages over those with gasoline or diesel engines. Total CO_2 emissions are drastically reduced due to the use of gaseous fuel. Soot emissions are also drastically reduced, even compared with new diesel engines, which use appropriate filters. Emissions of NOx and non-methane hydrocarbons are also significantly reduced. It has been shown that upgraded biogas (biomethane) has the greatest potential as a fuel compared to other biofuels.
- » The proposed algorithm enables full distribution of finished materials in various stages of production of biogas. Shows sample distribution capabilities biogas to filling stations and end users.

The above conclusions are grounds to assert that unfortified biogas can be used as fuel for gas-generating stations. Upgraded biogas (biomethane) can be used in vehicles as it has the greatest potential as a biofuel. The application of the proposed algorithm will doprine for full and effective use and distribution of finished materials and waste products in various stages of production of biogas.

References

[1.] Chuturkova R. Air Pollution, Book, TU-Varna, pp. 309, 2015

[2.] Chuturkova R. Assessment of Air Pollution with Benzene and Benzo[A] Pyrene in Regions in North-East Bulgaria. International Journal of Inventive Engineering and Science, vol. 4, No 1, pp.1-8, 2016

[3.] Chuturkova R. Air Quality Management, Book, TU-Varna, pp. 248, 2014

[4.] Bakalov, I., Constructive solution to reduce the NOx and SOx in the marine boilers burners. Proceedings section II transport. Safety and ecology. Logistics and management. Education theory, pp.12-14, Trans & MOTAUTO Varna, 2016

[5.] Seadi, T., Rutz, D., Prassl, H., Köttner, M., Finsterwalder, T., Volk, S., Janssen, R., Dimitrova, D., Cheriyska, I., Georgiev, K., Marinova, S., Kolev, N., Biogas Handbook, University of Southern Denmark Esbjerg, Niels Bohrs Vej 9-10,DK-6700 Esbjerg, Denmark, 2009

[6.] Seadi T., Dimitrova D., Cheriiska I., Biogas – Handbook, Sofia, 2009

[7.] Bakalov, I., Stoqnov, R.: Study the combustion products of diesel engines using diesel and biodiesel, Scientific and technical conference with international participation, vol. XX: pp. 14 – 18, ECO Varna 2014

[8.] Dimitrov R., Zlateva P., A study of the environmental characteristics of a gasoline engine operating on upgraded biogas; Eastern Academic Journal; Volume 2, July, 2015

[9.] Dimitrov 1. R., Investigate the influence of upgraded biogas on combustion processes in engine with external mixture formation, PhD thesis, TU-Varna, 2015

[10.] Heywood J., Internal combustion engine – fundamentals, USA, McGraw – Hill Inc., 1988

[11.] http://www.globalpetrolprices.com/Bulgaria/gasoline_prices/, (accessed 05.07.2017)

copyright ©
University POLITEHNICA Timisoara,
Faculty of Engineering Hunedoara,
5, Revolutiei, 331128, Hunedoara, ROMANIA
http://acta.fih.upt.ro