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UTILIZATION OF BIOGAS IN GAS ENGINES

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ABSTRACT

In the operation of heat engines, as well as in their maintenance beyond the technical formation of machines, equipment, the composition and quality of the used fuel exceedingly have a great role, which directly effect and endanger the cleanliness of our environment. The preservation of the state of our environment and the effective, economical expectations of the energy needs can be solved with the harmonized application of the traditional and renewable energy sources. Biogas fuel can meet the needs of the users and the runners in the most comprehensive ways. The utilization possibilities can be grouped into three main alternative circles: thermal utilization, mechanical utilization and complex utilization. The quantity of the daily biogas produce is of primary importance at the decision of the usage method of biogas utilization. The gas utilization in every case can be linked with the local circumstances. Various solutions offer themselves in the combustion of the biogas. One of the possible alternatives in the biogas internal combustion engines is the utilization taking place in Otto-gas engines if the biogas is able to meet the criteria of the engine combustion. The most important condition is that in the biogas $CH_4 > 45\%$, but in practice it is required that the methane content be over 60%. The application of biogas in the gas engines affects the operation of the engine and the compound of the combustion products too, i.e. biogases significantly differ from natural gas in compounds, specific energy content, and in the pollutants. The combustion products are important to be analysed indeed, because one of the basic pillars of the view of energetic equipment is the influence exerted on the environment. Of these influences the most important is the quantity of the released pollutants. With the aid of the built in catalysers the gas engines ensure the biogas as the utilization of chemical energy of energy carriers besides the smallest possible emission.

Keywords: *Biogas, Renewable energy, Gas engines, Combustion, Environment.*

I. INTRODUCTION

The reduce of fossil energy carrier supplies, the lightening of damages from air pollution necessitate the drawing of a greater extent of renewable, environment friendly energy sources into energy production. The search for alternative energy sources for Hungary is certainly important because our country is well-known to be poor at energy carriers of mineral origin. Several other reasons account for the use of energy carriers that can be produced from biomass. The two most important are: the energy policy and the environment policy. The utilization of biogas energetics practically promotes the realisation of each strategic objective.

Biogas in similarity to the natural gas is extremely utilizable gaseous matter in several fields; heat and electrical energy take form on the course of its combustion. The scientific literature sources and the results of the laboratory experiments of the increased scale mini fermenters reveal that how much and what kind of composite biogas is produced from various basic materials. On the course of utilization happening in the internal combustion engine (in the biogas engine) we can gather information on what effects the biogases from various basic materials have on the running of the gas engines, with special regards to combustion and emission, while taking into account the operational conditions, the compounds of biogas and the biogas output.

II. BIOGAS UTILIZATION IN THE CONNECTED HEAT AND ELECTRIC POWER PRODUCING AGGREGATES

The fundamental requirement at the choosing of energy producing unit is that the biogas utilization at disposal should be realized with good energetic efficiency. The energy quantity utilizable by us fundamentally depends on two factors, on the one hand on the quantity of fuel varieties obtainable and utilizable from the unit biomass quantity, on the other hand on the efficiency of the energy converting equipment.

The present gas engine aggregates can characteristically be applied in the 0.05 – 25 MW mechanical power domain. The gas engine is a traditional four-stroke Otto-engine, which has been designed for the utilization of gas state engine propellant. *[4]* The engine actuates the generator, which supplies electrical power. The engine is furnished with several heat exchangers (smoke gas, lubricant, coolant) for the purpose of producing/utilizing heat energy.

In *Figure 1* we can follow the simplified process of energy production or the possibilities of increasing the effectiveness in the gas engine equipment.

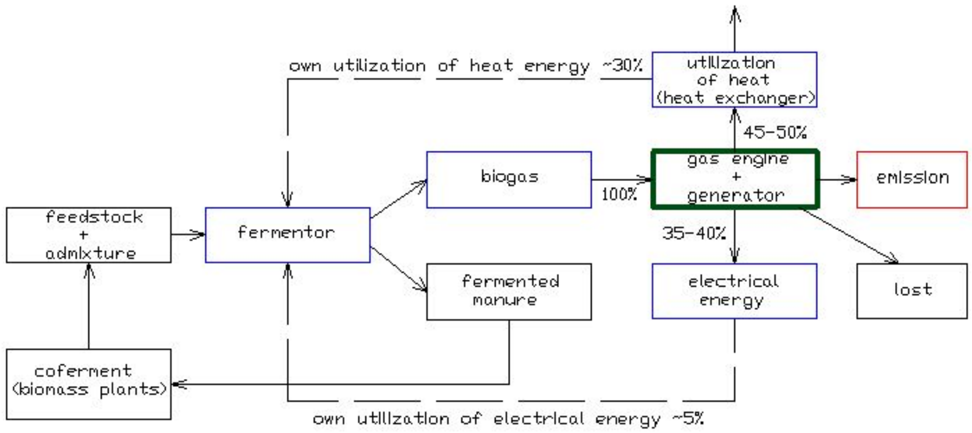

Figure 1 The process and efficiency of energy production

In the case of gas engine utilization we also gain 45-50 % heat energy besides 35-40 % electrical power on the course of the combustion of biogas. The connected electrical power producing projects belong to the limited group of environment friendly, and at the same time economical solutions. Before the combustion of biogas in gas engines it is advisable to enrich (removing carbon-dioxide), as well as cleaning it from polluting particles and materials. That is to say the position of the utilization of biogas is improved if the heat values are increased. Delivery, storage and not the least from the point of view of utilization it is advantageous to increase the energy density of biogas. When improving the quality, the removal of gases (carbon-dioxide, sulphur) apart from the methane should be solved. *[2]* The combustion of methane is slower and more perfect than the combustion of petrol. Owing to the slower combustion the running of gas engines is perceptibly quieter than the petrol engines. During the combustion of petrol heavier elements do not combust perfectly, the incombustible fuel-apart from the remains deposits in the cylinder block, the other part gets into the oil. Gas fuel contains quite much less heavy carbon-hydrogen; therefore the combustion area of engines operating with gas is much cleaner than those ones operating with petrol. According to experience the wear of the engine is smaller than in the petrol operation. *[5]*

There are two solutions during the utilization of biogas taking place in gas engines as fuel:

- the fitting of the fuel to the engine (industrial solution) or
- the fitting of the engine to the fuel (local solution)

The gas engine the crucial element of the technology and the choice of suitable gas engines need precise care. When choose the size of the gas engine we have to take the following necessary viewpoints into consideration:

- The parameters and quantity of the biogas at disposal, its state changes in the course of time. The gas engine is sensitive to the change of the composition and heat values of gas. The change of methane content cannot be greater than ± 7 % as prescribed.
- The utilization of heat energy, the changing of heat needs daily and seasonal will influence the choice of the engine.
- The gas engine is applicable to sectional operation, but it is advisable to provide continuous running for many hours after the switch on.
- The best possible utilization – the nominal maximum running power – for the gas engine should be provided.
- The emission of air pollutant should comply with the actual regulation of environment protection. Nowadays this is indispensable in the interest of protecting our environment.

III. GAS ENGINES IN BIOGAS OPERATION

The composition and quality of biogases used as fuel have a determining role in the operation of gas engines. The quantity and composition of the produced and collected biogas depend on the characteristics of the basic and additive agents, or on the fermentation conditions. Thus we can utilize the biogas effectively as the propellant of the gas engines if we remove CO_2 from the originating biogas or mixed with natural gas we secure the greater proportioned combustible gas concentration. By this the operation of the gas engine can easily be stabilized and the thermal efficiency can be higher than in the case of raw biogas operation.

The industrial-like continuous methane production enables the continuous operation of the gas engine; and the production of heat energy and electrical energy by this. Gas engines are fundamentally natural gas engines, but with partial adjustments we can make them combust biogases with changing characteristics or with the greater carbon-dioxide content. Biogas engines operate with great air excess just as they are made from corrosion-proof materials. *[11]* Out of an average power gas engine ~ 2.16 kWh of electrical energy and ~ 2.78 kWh of heat energy can be gained besides the 22.2 MJ/m^3 heat value in relation to 1 m^3 of biogas. We can prevent methane from getting into the atmosphere during the energetic utilization. That is to say, on the one hand methane is combustible gas with great energy content, on the other hand it is also a climatic gas, the greenhouse effect of which is 21 … 22 times as the carbon-dioxide. Energy production from the biomass (biogas burning connected with electrical energy production) is a future orient technology, which help us – to a certain extent – while we burden our environments minimally. *[1]*

These equipments greatly fit into the requirements of the environmental protection. During their life duration they burden our environment the least possible (noise reduction, monitoring of emission values etc).

IV. BIOGAS EFFECT ON ENGINER PARAMETERS

The application of renewable fuels has spread indeed; however, several limit values should be kept. In general ~ 50 % methane is needed for reliable operation. In the case of pre-combustion chamber lower methane than the above-mentioned is permissible. In *Diagram 2* and *Diagram 3* in the case of various methane, we can see low fundamental burning characteristics change, for example, the adiabatic flame temperature, or the laminar flame spreading speed.

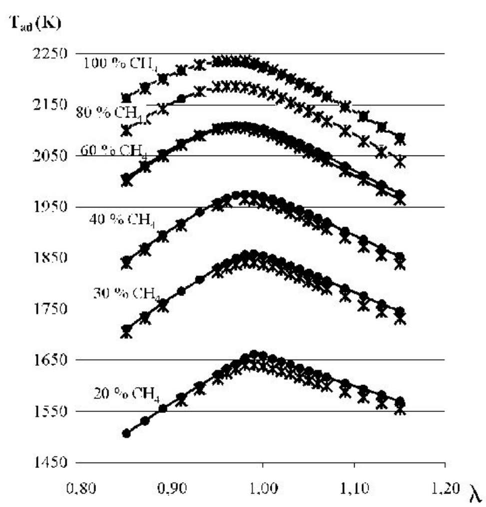

Diagram 2

Adiabatic flame temperature

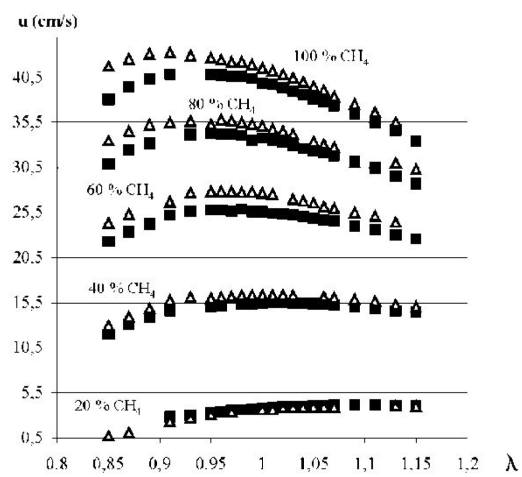

Diagram 3

Laminar flame spreading

in the air excess factor function *[6]*

The increasing CO_2 content significantly reduces the adiabatic flame temperature, and the laminar flame spreading speed respectively. The adiabatic flame temperature in the case of 60 % CH_4 content is 10 % lower, while the laminar flame spreading speed is about 40 % lower. To its effect lower maximum and average temperature takes form in the combustion block of the engine, just as the combustion process significantly draw away, which is coupled with power reduction and efficiency degradation. The drawing of combustion results in the increase of the heat quantity given to the walls and of the emerging smoke gas temperature.

From the point of view of operating gas engines it is important to keep – the value stipulated by the manufacturer – the methane number of fuel on constant value. The methane number of biogas is relatively high, which owes to the high CO_2 content, however, the significant CO_2 content can be crucial from the viewpoint of the ignition of the biogas-air mixture.

In *Figure 4* the diagram shows that the output reduces by the increase of CO_2 content, in the case of 45 % CO_2 it is with more than 16 %. The reason for this on the one hand is that the combustion temperature reduces, the specific heat changes, on the other hand the combustion speed reduces as well. In the interest of comparison on the course of the measurements the ratio of fuel-air mixture is such that the O_2 content of the smoke gas is 7 V/V % in every case, besides this the pressure of the suction area is of (0.8 bar) constant value. The CO_2 mixture modifies the flame spreading speed; that is why the ignition had to be optimised to output before the measurements at each measuring point.

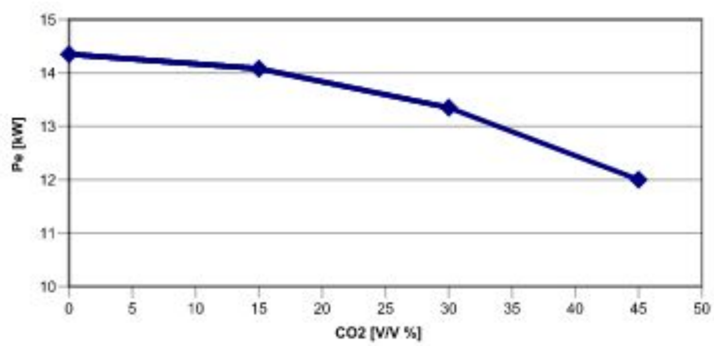

Figure 4 **CO_2 content effect on output** *[7]*

The parameters of gas engines significantly change in the case of the utilization of biogases taking place in the gas engine. The comparison in every case was natural gas operation.

In *Figure 5* momentary pressure trace can be seen in the function of the crank angle. In the case of 13.3:1 compression ratio the air excess factor changes between 1.57 and 1.61, and in the case of 12:1 compression ratio it is between 1.54 and 1.55 (operation with great air excess), the line of the indicator diagram in the case of natural gas fuel or in the case of ~ 40% CO_2 fuel is similar if we increase the compression ratio. The higher pressure relates to quicker combustion (besides similar ignition times).

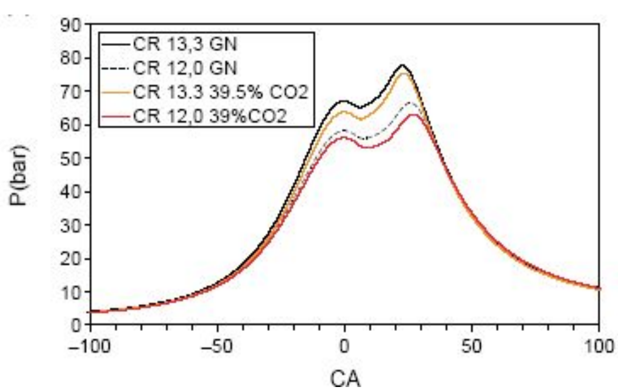

Figure 5 **Indicator diagram** *[9]*

V. BIOGAS EFFECT ON EMISSION

The application of biogas in the gas engines beyond the operation of the engine also influences the composition of the combustion products, i.e. biogases significantly differ from the natural gas in composition, specific energy content and in pollutant all the same. It is important to analyse the combustion products, because one of the basic pillars of deciding the energetic equipments is the effect exerted on the environment. Of these effects the quantity of the emitted pollutants is the most important, there is indeed a short time available towards the chemical oxidation process in the cylinder, just as the temperature is heterogenic distributed and quickly changes in the mixture. However, the gas engines with the help of the built in catalyser besides the least possible emission ensures the utilization of the chemical energy of energy carriers.

In the interest of realising the energetic utilization of biogas several problems need to be solved. The most important to-be-solved problem on the basis of the theoretical counting is the fuel need increasing to nearly two times, ensuring the necessary various pre-ignition angle towards the optimum operation, furthermore the corrosion-proof of the applied materials in the system supplying the fuel. Further problems are the fuel and the oxidation tendency (condensed down) of the combustion products.

Nitrogen (N_2) and nitrogen compounds (NO_x), oxygen (O_2), carbon-dioxide (CO_2), water vapour (H_2O), carbon hydrogen (C_nH_m), carbon monoxide (CO) or particles can be found in the exhaust gas of the engine, in concentration depending on the operation state. *[8]* From the point of view of emission air excess is the most important factor. The CO emission in the case of the increasing air absence rises suddenly. The partial oxidation in the case of C_nH_m emission and air absence rises; even in the case of greater air excess owing to the drawing off of combustion. The air excess reduced under theoretical values makes NO_x emission decrease suddenly. Further parameters apart from the air excess (ignition time, formation of combustion area, density ratio etc) influence the values of other emissions.

The fundamental requirement of the secured, economical and environment friendly energy supply is the more thorough knowledge of the main constituents of smoke gas, the mapping of the quantitative and qualitative characteristics of the constituents. The measurement of the methane of smoke gas serves as a starting point for the goodness of the combustion process, the factor value of air excess and the smoke gas emission values, however, gives information on the mixture forming.

Figure 6 shows the changes of efficiency in the function of NO_x emission in the case of 13.3:1 and 12:1 compression ratio. The measured efficiency is between 36.6% and 37.7% as well as 35.7% and 36.6%.

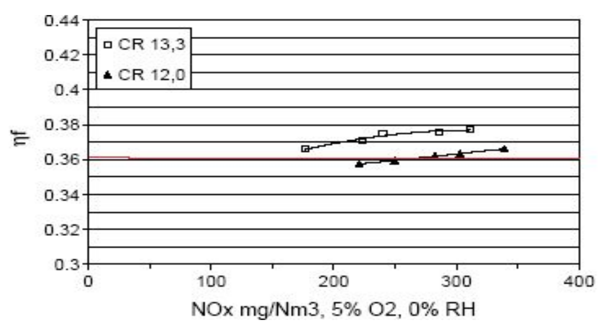

Figure 6 **Measured efficiency in the function of NO_x** *[9]*

Figure 7 shows the NO_x emission in the function of the relative air-fuel ratio. It can be concluded that the increasing CO_2 ratio produces a reducing NO_x emission, which can be accounted for the decrease of combustion peak temperature and the combustion speed. The compression ratio can be traced as it exerts effect on NO_x emission in the function of the relative air-fuel ratio: by increasing the compression ratio an increase is present near the theoretical air-fuel ratio, which can be reduced by increasing the CO_2 ratio and mixing N_2.

Figure 8 shows that by increasing the CO_2 ratio the combustion conditions degradate, which produce an increasing CO emission or higher incombustible carbon hydrogen quantity.

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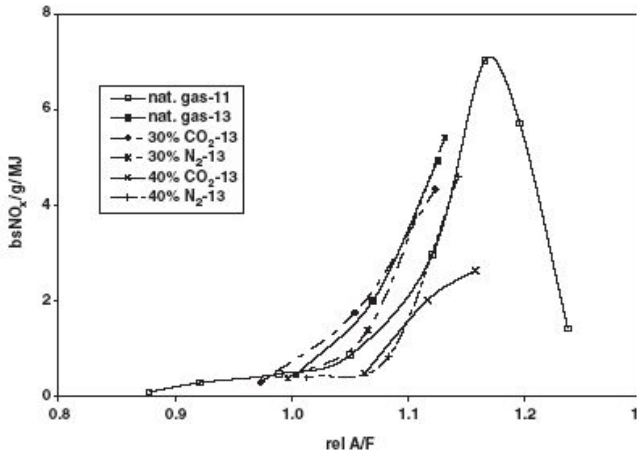

Figure 7

NO_x emission to different CO_2 content *[3]*

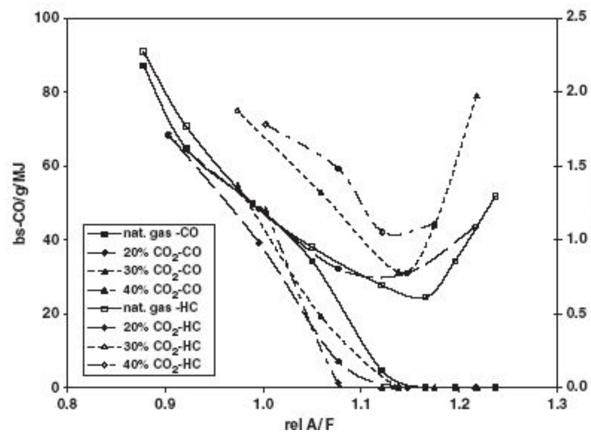

Figure 8

CO és HC emission *[3]*

The gas engines ensure the utilization of chemical energy of energy carrier with the help of the built in catalysers besides the least possible emission, the environment is burdened less with 35% CO_2, as if the electrical energy was produced in the thermal plant, and heat energy in parallel to this was produced in different furnace.

Biogas as fuel for gas engines can be utilized with low emission besides the high efficiency which can be attributed to the proper compression ratio and the structural design of the pre-combustion chamber of the biogas engines, as well. Finally, it may be said that biogas is the ideal energy for the environment, and however, gas engines are ideal environment for biogas.

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