BIOGAS AS A PERSPECTIVE FUEL FOR AGRICULTURE TRACTORS

1. Introduction

At present, manure biogas is used on-farm for direct electricity generation and some of the waste heat is recovered for other uses. There are other potential uses of biogas on a farm besides combined heat and power, such as in agricultural pumps, refrigeration, and vehicles. The utilization of biogas as a fuel for agriculture vehicles is practically new area of research which would allow for its wider application because for now there is neither an existing demand for raw biogas as a vehicle fuel [1]. Biogas is one of the strongest candidates for on-farm production of renewable energy, but it could also have a future role as a tractor fuel for farmers seeking energy self-sufficiency and an escape from rising diesel costs [2].

2. Biogas as a fuel for dual fuel CI engine

Biogas consists of many components which are formed during oxygen-free fermentation process and the methane content depends on resources and conditions in which the biogas is created. Table 2 shows that the typical composition of raw (i.e., unprocessed) biogas does not meet the minimum CNG fuel specifications. In particular, water vapor and sulfur (as contained in H₂S) content in raw biogas is far too high for it to be used as a gaseous fuel for vehicles without additional processing.

Tab. 1 Compressed natural gas fuel specifications vs. typical raw biogas composition [3]

<table>
<thead>
<tr>
<th>Component</th>
<th>CNG Fuel Specification [% vol.]</th>
<th>Raw Biogas Composition [% vol.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane (CH₄)</td>
<td>&gt;88</td>
<td>&gt;48</td>
</tr>
<tr>
<td>Ethane (C₂H₆)</td>
<td>&lt;6</td>
<td>&lt;0,1</td>
</tr>
<tr>
<td>C₃+(Propane, etc.)</td>
<td>&lt;3</td>
<td>&lt;0,1</td>
</tr>
<tr>
<td>C₆+(Hexane, etc.)</td>
<td>&lt;0,2</td>
<td>&lt;0,1</td>
</tr>
<tr>
<td>Hydrogen (H₂)</td>
<td>&lt;0,1</td>
<td>&lt;0,1</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>&lt;0,1</td>
<td>&lt;0,1</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>&lt;1</td>
<td>&lt;0,1</td>
</tr>
<tr>
<td>Inert gases</td>
<td>1,5-4,5</td>
<td>&lt;40</td>
</tr>
<tr>
<td>Sulfur</td>
<td>16 ppm</td>
<td>50-2000 ppm</td>
</tr>
<tr>
<td>Dew Point</td>
<td>&lt;99%</td>
<td>Saturated</td>
</tr>
<tr>
<td>Particulate matters</td>
<td>Non-damaging to engines</td>
<td>Variable</td>
</tr>
<tr>
<td>Odorant</td>
<td>Easily detectable</td>
<td>Detectable</td>
</tr>
</tbody>
</table>

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From the point of view of utilization of biogas to power a vehicle it is very important to achieve possible high energy density of the gas fuel because of high weight of gas cylinder which should be mounted on it. Biogas which is purified form H\textsubscript{2}S, and water is much more cheaper than biomethane but includes less energy per mass unit. The lower heating value of biogas strongly depends on the content of CO\textsubscript{2} in it (Fig. 1a).

![Fig. 1](image)

**Fig. 1**  a) The calculated lower heating value of biogas (3% vol. H\textsubscript{2}, 3% vol. O\textsubscript{2}) vs. mass content of CO\textsubscript{2} in the biogas, b) Biodiesel and biogas consumption vs. the mass share of biogas in the dual fuel mixture /calculated/ [1]

### 2.1 The application of biogas as a fuel for agriculture tractor

The goal of research work in Warsaw University of Technology (Faculty of Automotive and Construction Machinery Technology, Institute of Vehicles, IC Engine Department) is to increase a direct on-farm use of slightly cleaned biogas that has been upgraded through the removal of H\textsubscript{2}S, and water. Low energy density of biogas with high content of CO\textsubscript{2} is one of the most important problem which is a barrier for application of this fuel for a vehicle. In order to partially eliminate the problem it was decided to use biogas together with biodiesel. For experiment the agriculture tractor type Case IH MX135 was chosen and adapted for dual fuelling. The results of the simulation of consumption of biodiesel and biogas are presented in Fig. 1b. From the practical point of view the biogas share in the dual fuel mixture should be confined to 20-30%. For this share of biogas in the dual fuel mixture and for the typical manure biogas composition (58% of methane in the biogas) the calculated biogas consumption exceeds 10-15 kg/h. It is sufficient for 4 hours run of fully loaded engine [1].
Fig. 2. The tractor type Case IH MX135 from Poldanor will be adopted for dual fuelling with biogas and biodiesel

3. BIOGAS POWERED TRACTORS

Two manufacturers, Steyr and Valtra, have already demonstrated tractors equipped to burn. Steyr and Valtra tractors are equipped with CI dual fuelled engines. The gas which is used as a fuel for both tractors is purified biogas with the high content of methane (biomethane).

3.1 Valtra

Two tractors have been built for Valtra's research program. The first was based on an N111 HiTech model powered by a 4.4 liter Sisu Power diesel engine adapted to run on both diesel and biogas.

Each fuel has its own injection system allowing the fuel balance to be varied on the move, and the engine can also run on diesel only. Power output is 110hp on diesel or with a gas/diesel mix, and the preferred operating mode is likely to be a 75/25 gas-to-diesel ratio. Valtra's second biogas research tractor was shown at last year's Agritechnica event and is a T133 model with a six-cylinder engine and SCR technology. The T133 has a dual-fuel engine starting on diesel and the main benefit, the makers claim, is a fuel cost saving of up to 40% on an optimum dual-fuel mix compared with a similar tractor using diesel only. The containers on Valtra's T133 experimental tractor hold 170 liters of biogas at 200 bar pressure, enough for a modest 3 to 5 working hours, but running out of fuel is unlikely because the standard 165-litre fuel tanks still carry diesel [2].

3.2 Steyr

The 2011 Agritechnica also saw the arrival of a biogas tractor from Steyr, described as a production model with a 2015 launch year. The Steyr tractor is the Profi 4135 Natural Power with a special gas burning engine from Fiat Powertrain Technologies. The 3 liter engine has 136hp rated output and burning biogas offers environmental benefits, the makers say. Steyr's Profi 4135 biogas tractor has nine gas tanks with capacity for 5 to 7 hours depending on the work load. The gas capacity is backed up by a 15-litre petrol tank to reduce the risk of being stranded with empty gas tanks [2].
4. THE ADAPTATION OF CASE IH MX135 FOR DUAL FUELING

As a result of analysis of biogas consumption and combustion of dual fuel mixture, the concept of dual fuelling of the agriculture tractor was elaborated. The standard turbocharged engine type CDC 6T-590 is equipped with injection pump. Additionally, the tractor is equipped with gas installation. In order to confine the biodiesel dose which must be replaced by biogas there is elaborated a special mechanism which reduce the dose of the injected biodiesel according to the planned strategy of fuelling of the engine. The strategy is similar to that which is described in [6]. The scheme of biogas installation is shown in Fig. 4.

![Biogas installation for CDC 6T-590 engine](image)

**Fig. 4. The biogas installation for CDC 6T-590 engine [1].**

5. Conclusions
The analysis of fuel consumption and the phenomena connected with filling of the engine cylinders as well as the analysis of dual mixture combustion show that it is possible to apply 30% mass share of biogas in the biodiesel-biogas mixture. The usage of biogas as a fuel for agriculture tractor is a practical realization of the idea of sustainable energy production and utilisation of renewable energy sources.

References:

BIOGAZU JAKO PERSPEKTYWICZNE PALIWO DO CIĄGNIKÓW ROLNICZYCH

Streszczenie
Artykuł przedstawia perspektywę zastosowania biogazu do zasilania maszyn pracujących w rolnictwie, a głównie ciągników rolniczych. Przedstawione są rozwiązania dostępne za granicą oraz schemat stanowiska budowanego w hamowni Instytutu Pojazdów.

Słowa kluczowe: biogaz, rolnictwo, ciągniki

Abstract
This paper presents the perspective of the application of biogas to power the machines working in agriculture, mainly agricultural tractors. The solutions are available abroad and chart positions built in bench Institute of Vehicles.

Keywords: biogas, tractors

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