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DUAL-FUEL LOW POWER GENERATOR WITH DIESEL ENGINE USING ALTERNATIVE FUELS

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Abstract

At the moment, there is a growing interest in low-power generating units in dispersed system. The production of energy in small units located in the vicinity of the energy recipients offers considerable benefits. First and foremost, it lowers the cost of energy production and the cost of its transfer and also makes the recipient independent from the domestic supplier. Small cogeneration aggregates will facilitate the use of energy from dispersed renewable resources. Gas self-ignition engines in cogeneration system powered with biofuels can be used in construction industry as ecological sources of heat and electrical energy, limiting the need for fossil fuels. This paper presents the possibility of using alternative fuels for internal combustion engines. It describes the possibility of using liquid biofuels separately or natural gas fuel to power diesel engines in dual fuel system. The conception of supplying low-power generator with diesel engine with natural gas to a dose of liquid biofuels test case. Pointed to the factors determining the desirability of a particular concept. Indicated the modification of the engine power to supply the natural gas generator with a dose of liquid biofuels. New technologies of extracting and using biofuels and alternative fuels are being introduced and developed for generating heat and electric energy. Studies on the use of gas and liquid alternative fuels are directly linked to research on the production of renewable and alternative energy as well as environment protection by minimizing emissions of toxic substances into the atmosphere.

Keywords: *alternative fuels, diesel engine, dual fuel engine, bio-fuels*

1. Introduction

In the time of ever-growing standard of living and increasing production of goods and energy the energy security of the country needs to be guaranteed. The limited resources of fossil fuels and their increasing prices as well as growing pollution of the atmosphere emphasize the necessity of pursuing alternative and ecological sources of energy to produce electric and heat energy. These sources are mainly sought for in gas fuels (biogas, natural gas) and liquid biofuels extracted from vegetable and animal products as well as in manufacturing waste. Therefore, new efficient methods of energy production are being developed to exploit these fuels. At the moment, there is a growing interest in low-power generating units in dispersed system. The production of energy in small units located in the vicinity of the energy recipients offers considerable benefits. First and foremost, it lowers the cost of energy production and the cost of its transfer and also makes the recipient independent from the domestic supplier. Additionally, such solutions improve the energy security in emergency situations. At present, the production and application of biofuels is seen as an energy factor, and the expansion of the agricultural land for energetic purposes may improve the overall situation of agriculture in the country. Small cogeneration aggregates will facilitate the use of energy from dispersed renewable resources. Gas self-ignition engines in cogeneration system powered with biofuels can be used in construction industry as ecological sources of heat and electrical energy, limiting the need for fossil fuels. The authors believe that a gas self-ignition engine with a pilot sample of liquid biofuel in the system with electricity generator can constitute a primary ecological source of electrical and heat energy.

2. Potential use of alternative and ecological gas and liquid fuels

The production of energy from renewable and alternative resources has been playing a more important role because of the increase in environment pollution and the growth in demand for energy. Biofuels are believed to increase the use of energy from renewable and alternative resources, decrease the deterioration of natural environment and help fulfil the obligations imposed on Poland in the EU accession to increase the share of renewable energy in the total consumption.

The Biocomponents and Liquid Biofuels Act of 25 August 2006, in force in Poland since August 2006, defines the following as biofuels [1]:

a) Engine petroleum containing over 5.0% of biocomponents or over 15% esters in the total volume,
b) Diesel oil containing over 7% of biocomponents in the total volume,
c) Esters, bioethanol, biomethanol, dimethyl ether and pure vegetable oil – constituting self-contained fuels,
d) Biogas - gas extracted from biomass,
e) Biohydrogen – hydrogen extracted from biomass,
f) Synthetic biofuels – synthetic hydrocarbons or blends of synthetic hydrocarbons, extracted from biomass, – constituting self-contained fuels.

The Act defined the agricultural raw products intended for biocomponents and biomass production, which, according to the Act, is defines as solid or liquid vegetable or animal substances, which undergo biodegradation, originating from products, waste and remains of agriculture and forestry, or from product processing industry, as well as some other products, which undergo biodegradation, agricultural products in particular. The sources of liquid biofuels and their possible applications are shown in Tab. 1.

Tab. 1. Sources of biofuel and their possible applications. Source: EC BREC/IBMER 2003

Biofuel	Plant	Conversion process	Application
Bioethanol	Grains, potatoes, topinambur etc.	Hydrolysis and fermentation	Substitute and/or petroleum additive
Bioethanol	White beets, etc.	Fermentation	Substitute and/or petroleum additive
Bioethanol	Energy crops, straw, grasses	Preliminary processing, hydrolysis and fermentation	Substitute and/or petroleum additive
Biomethanol	Energy crops	Gasification or methane synthesis	Fuel cells
Vegetable oil	Rapeseed, sunflower, etc.	-	Substitute and/or diesel oil additive
Biodiesel	Rapeseed, sunflower, etc.	Esterification	Substitute and/or diesel oil additive
Biooil	Energy crops	Pirolysis	Substitute for diesel oil or petroleum

In terms of practical potential, two of liquid biofuels seem to be particularly well suited – biodiesel extracted from vegetable oils and bioethanol added to petroleum. Biodiesel is a fuel for self-ignition engines, which is or contains a biological component in the form of vegetable oil esters. In Europe, it is mainly methyl ester of rapeseed, which can be used as pure fuel in certain vehicles or blended with conventional diesel oil. Bioethanol is a dehydrated ethyl alcohol extracted from vegetable products (grains, potato, white beet, sugar cane). Bioethanol can be used as a self-contained vehicle fuel in specially designed engines or blended with petroleum.

New technologies of extracting and using biofuels and alternative fuels are being introduced and developed for generating heat and electric energy. Studies on the use of gas and liquid alternative fuels are directly linked to research on the production of renewable and alternative energy as well as environment protection by minimizing emissions of toxic substances into the atmosphere.

The solution discussed here with regard to biofuels and alternative fuels for powering the engine can lead to, in conjunction with electricity generator, the creation of highly efficient, ecological source of heat and electric energy. Such a solution will lower the cost of produced energy and make its production possible with the use of alternative gas fuels such as natural gas and ecological fuels such as biogas, extracted in local gas generators. Studies prove that feeding the self-ignition engine with natural gas is more beneficial than using conventional diesel oil. Self-ignition engines meet the mandatory standards with respect to emissions of toxic substances. At the moment, gas fuels in which methane constitutes the main component are the most commonly used ecological fuel.

It is then advisable to use vegetable and animal products as well as broadly defined biomass and manufacturing waste to produce biogas and cogenerate heat, electric energy and cold (trigeneration) with the use of a system powered with gas engine.

Prior to its refining, biogas contains, except methane and carbon dioxide, some unwanted components, such as hydrogen sulfide, water vapor and other substances. The content of biogas, biomethane and natural gas is compared in Tab. 2.

Tab. 2. Comparison of biogas, biomethane and natural gas content. Source: (Rapp M. 2010)

Parameter	Biogas	Biomethane	Natural gas
Methane	45-75%	94-99%	93-98%
Carbon dioxide	28-45%	0.1-4%	1%
Nitrogen	<3%	<3%	1%
Oxygen	<2%	<1%	-
Hydrogen	negligible amount	negligible amount	-
Hydrogen sulfide	<10 ppm	<10 ppm	-
Ammonia	negligible amount	negligible amount	-
Ethane	-	-	<3%
Propane	-	-	<2%
Caloric	6 kW/m^3 on average, but depending on the input to biogas plant 5.5-7.7 kW/m^3	10.2-10.9 kW/m^3	Ok. 9-11 kW/m^3

Technologies of refining biogas have made it possible to use biomethane for powering internal-combustion engines. The concentration of methane in raw biogas is 45-57% of the volume, depending on the substrate used. This amount can increase to 99% of the total volume in the refinement of biogas. To enlarge the calorific value of biomethane and make its content quality similar to those of natural gas, liquified propane-butane (LPG) or air is added [2]. It is also necessary to adjust biomethane pressure as required in the recipient system. In biogas refinement, the following are eliminated from its content: hydrogen sulfide, ammone, water, oxygen and nitrogen compounds. However, the most demanding in terms of applied technology and the most expensive is the process of separating carbon dioxide from methane. The energetic end product, according to installation settings in biogas plant, is biogas – a gas of the content and parameters similar to those of natural gas.

The results of research on the use of alternative and ecological gas and liquid fuels for powering self-ignition engines may have an essential influence on:

- the use of bi-fuel gas self-ignition engines in power transmission systems,
- the use of alternative and ecological gas fuels for producing energy in electricity generators, cogeneration and trigeneration systems,
- the decrease in the level of toxic emissions into the atmosphere by replacing conventionally powered engines with gas self-ignition engines,
- the reduction in the reliance on fossil fuels in energy production,
- the reduction in the cost of energy production, which will lower the overall cost of production,
- the creation of local, dispersed energy sources independent from the domestic distributor (energy generation in a dispersed system).

The results of research on powering self-ignition engines in low-power generators may find a direct application in:

- highly efficient heat and electrical energy production from biogas extracted in fermentation from manufacturing waste, as well as the possibility of using gas fuel to power fleets of vehicles with engines adapted to gas fuelling,
- highly efficient heat and electrical energy production for household needs and for additional profit from the sale of surplus electric energy produced, for fuelling agricultural machines – from gas generated in local biogas plants from fuels extracted from vegetable and animal products with the use of generators of self-ignition gas engines,
- the use of manufacturing waste, generating heat, cold and electric energy, fuelling vehicle engines with gas extracted from manufacturing waste in furniture industry and broadly defined biomass in woodworking industry, with the use of highly efficient electricity generator of gas engine,
- for self-ignition gas engines in cogeneration systems as an ecological, local source of heat and electric energy, in particular in farm buildings and plants utilizing own gas generators,
- for the reduction in toxic emission into the atmosphere from heat and electric energy production and from vehicles and machines through the use of self-ignition gas engines fuelled with natural gas, biogas and generator gas.

Currently in many research centres in Poland and abroad studies are conducted on creating and implementing new, highly efficient technologies of ecological and alternative production of heat and electric energy. Cogeneration of heat and electric energy is now the most common method of using biogas immediately in the biogas plant. The energy produced in cogeneration systems is used for the processing needs of the plant and the surplus is sold as electric energy. The surplus of heat may be sold locally, but electric energy is mainly transferred to the national grid. The diagram of the system of cogenerated heat and electricity production is shown in Fig. 1.

Trigeneration creates opportunities with regard to the expansion of cogeneration and the increase in the association quotient. It consists in cogenerated production of heat, electric energy and utility cold. It considerably improves the economy of energy production in heating systems in summer in cogeneration with heat when the demand for heat is low and the demand for utility cold is steady.

3. Generator fuelling with CNG and B100 in a bi-fuel system

The research conducted by the authors of this paper pertains to fuelling of low-power electricity generators fitted with self-ignition engines with gas fuel with a pilot dose of diesel oil [4-6]. The subject of the study is a FOGO electricity generator of SI HATZ 1B40 bi-fuelled engine, cogenerated with electricity generator. Originally, the engine was fuelled with diesel oil, which was then replaced with an accumulator injection system of electromagnetic injector. A detailed description of the injection system of the engine fuelled with natural gas and diesel oil can be found in [7].

To facilitate the research an IS engine fuelled with compressed natural gas with a pilot dose of diesel oil was modernized to be fuelled with compressed natural gas with a pilot dose of liquid fuel

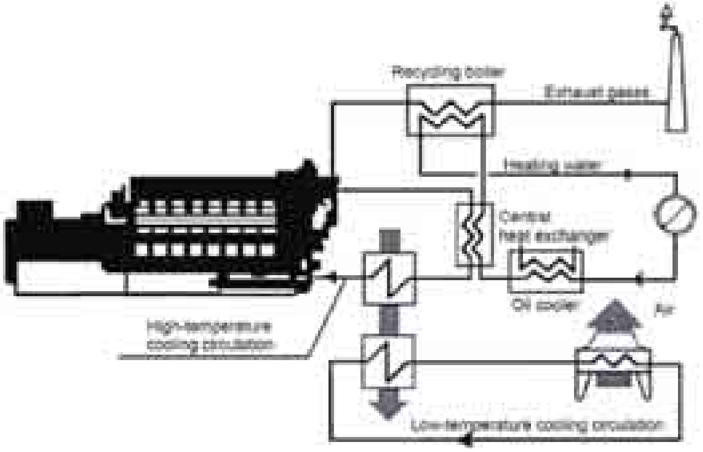

Fig. 1. The system of cogenerated electricity and heat production with the use of the Wärtsilä NSD combustion engine [3]

B100. In the research, a sample of liquid biofuel was used to trigger a self-ignition and gas ignition effect. The sample was charged into the combustion chamber during compression stroke. The parameters of the liquid biofuel sample were adjusted to account for the liquid biofuel used, the actual engine workload and performance parameters of the engine. The liquid biofuel sample had defined injection parameters – injection pressure, injection angle, and injection length (period).

The fuelling method and the diagram of the research station are shown in Fig. 2.

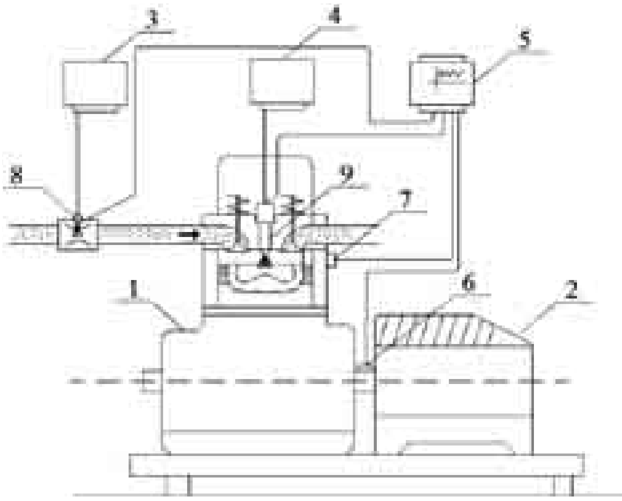

Fig. 2. The method of fuelling an IS engine with natural gas CNG with a pilot dose of liquid biofuel B100, constituting a self-contained fuel of the FAME methyl esters of fatty acids content of minimum 96.5% (m/m), 1- engine, 2 – generator, 3 – CNG fuelling system, 4 – B100 fuelling system, 5 – control system, 6 – torque sensor, 7 – pinking sensor, 8 – CNG injector, 9 – B100 injector

An IS engine powers the electricity generator. The engine is fuelled with compressed natural gas and liquid biofuel. During compression stroke a pilot dose of liquid biofuel B100, a self-contained contained fuel of the FAME methyl esters of fatty acids content of minimum 96.5% (m/m) is charged into the combustion chamber. Following the signals from the torque sensor, pinking sensor and other sensors, a steady torque is maintained as required for the generator, regardless of the actual workload to the system.

The gas fuel is fed into the mixer located in the intake passage where it mixes with the aspirated air to form a fuel-air blend. The sample of liquid biofuel is injected under high pressure into the combustion chamber. At the moment of change in the workload, following signals from the sensors, the quantity of the sample is set in order to maintain a steady torque. In keeping with signals from the sensors, the beginning of the injection, the injection pressure and the injection period for the biofuel sample are determined to obtain and maintain optimal performance of the system. A connection to the source of gas fuel and liquid biofuel is constantly maintained as the engine is in operation. In case the gas fuel is disconnected, the engine can work on the B100 liquid biofuel alone.

The following were used to fuel the engine during the research:

- Compressed natural gas CNG of the methane content of 98.195%mol according to PN-C-04752:2011,
- Ekodiesel Ultra D 6.8 diesel oil according to PN-EN 590+A1:2011,
- B100 liquid fuel, a self-contained fuel of the FAME methyl esters of fatty acids content of minimum 96.5% (m/m) according to PN-EN 14214+A1:2011.

4. Conclusions

The research has confirmed that fuelling an IS engine with natural gas and B100 liquid biofuel in a bi-fuel system makes economical sense as it lowers the cost of fuel and offers engine performance comparable to that of generators fuelled with diesel oil alone or with a mix of diesel oil and natural gas. Selected results of the study have been presented in Boruta and Imiołek, "A comparison of selected operating parameters of the diesel engine powered by blends of diesel oil or liquid bio-fuel with natural gas for low-power generators". A comparison of selected operating parameters has been presented of HATZ engine 1B40 fuelled with blends of diesel oil or liquid biofuel with natural gas. Indicator charts, exhaust content and chattering signals registered on the engine block have been analyzed.

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DEVELOPMENT OF INTEGRATED TECHNOLOGY OF FUELS AND ENERGY FROM BIOMASS, AGRICULTURAL WASTE AND OTHER