

TECHNOLOGY FOR LOW-TEMPERATURE THERMOCHEMICAL CONVERSION OF BIOMASS

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The paper describes a modern technology of biomass low-temperature thermochemical conversion for production of biogenic fuels in gaseous, liquid and solid phases. The equipment which was acquired during the life of the project "Building Research Centre AgroBioTech", ITMS code: 26220220180, allows carrying out long-term experiments in pilot conditions. As an example of the high efficiency of the biomass conversion we present results of experiments with the use of agro pellets, while using the dose input of 63 kg/h a highly energy valuable synthesis gas with the average flow rate of 10 m³/h, liquid component - reactor oil in the volume of 20 l/h, and the solids - carbon in the amount of 21 kg/h was obtained.

KEYWORDS

biomass, low-temperature thermochemical conversion, biogenic fuel, renewable energy sources

1 INTRODUCTION

Biomass is one of the most universal and most widely used energy sources in the world. It is the biodegradable fraction of a product, or residue from plant and animal substances from agriculture and forestry, or biodegradable fraction of industrial and municipal waste. Compared with other forms of renewables, such as wind, water or solar energy, the significant advantage of biomass is that it can be used anywhere in the world. The total mass of biomass on the Earth, including moisture, is 2,000 billion tons, while the weight of the biomass converted to one person is 400 tons.

The fossil fuels, which are currently heavily used, negatively affect the environment: when combusted, the atmosphere is receiving substances that have been stored for millions of years beneath the earth's surface. Unlike that the energy use of biomass is from the point of view of greenhouse gas emissions neutral.

The most widely used fuel from the category of biomass is wood that may be used as a single-piece, in the form of waste (scraps, shavings, sawdust, etc.), or it may be purpose-grown as energy plants (e.g. willow, poplar) or grasses (Miscanthus grass species: Mishkan huge, silver grass, sugar Mishkan).

Among other sources, which play an increasingly important role in the economies of the world, it is in particular the agricultural biomass. It is suitable for the production of heat by combustion (e.g. grain, rape, maize, sunflower straw), or for the production of biogas (from the excrements of livestock, waste from food establishments, from the green mass and silage). Agricultural biomass is used in the acquisition of the first generation liquid biofuels in order to produce RME (rape seed oil methyl ester) or bioethanol (maize, corn, sugar beet). Biofuels - most often

bioethanol, biobutanol and biodiesel - are considered to be future alternative energy sources in transport. The European Commission considers biomass to be an important part of Europe's energy future.

In the National Action Plan for Renewable Energy, designed by the Ministry of Economy and Construction of the SR, which was approved 6. 10. 2010, it is stated:

Increasing the share of renewables in electricity and heat production in order to create adequate additional resources needed to cover domestic demand is one of the main priorities of the Energy Policy that was approved already in 2006.

It becomes evident that the use of renewable energy sources, as domestic energy sources, increases to some extent the security and partially diversifies energy supply while reducing economic dependence on unstable oil and gas prices. Their use is based on advanced and environmentally friendly technologies and contributes to reducing greenhouse gases and other pollutants.

Energy utilization of biomass in Slovakia has great potential, which is based primarily on geographic landscape features: the whole territory of the Republic is covered by about 47 % of agricultural and approximately 41 % of forest land. It is a challenge for Slovak farmers - in addition to food production and ensuring the population has enough to eat, also possibilities in the field of energy and energy carriers are being created, which in the future could bring 25-30 % of revenue.

In this paper we present the first results of experiments with the use of technology of low-temperature thermochemical conversion of biomass into biogenic fuels, which were implemented in pilot conditions at the Laboratory for Biomass Gasification in Research Center AgroBioTech at Slovak University of Agriculture in Nitra.

2 MATERIAL AND METHODS

Creation of a 'Laboratory for biomass gasification' has been defined as one of the outcomes of the activity 1.6 Applied research in bioenergy and economic studies in the project "Building Research Centre AgroBioTech", ITMS code: 26220220180, which was run during the period of 2013 - 2015.

The aim of the designed laboratory with its key equipment was to allow to conduct applied research in the field of the efficient use of renewable energy in real terms with the use of modern instruments, laboratory equipment, hardware and software, which should be followed by immediate transfer of knowledge into practice with a view of initiating other similar operation plants oriented on efficient conversion of biomass into valuable energy carriers - 1st and 2nd generation biofuels.

Biomass in the conditions of the EU represents one of the most promising renewable energy sources. Speaking about the biomass, under this term we understand the organic material of plant or animal origin, either as a result of productive activity or as waste from agricultural, food and forestry production, or from municipal services.

Efficient and clean use of biomass in energy production has the least negative impacts on the environment. Due to the possibility of regional production it is well suited for the use in small and medium-sized energy sources.

Different principles of thermochemical conversion of biomass has recently appeared as a very interesting phenomenon which enable comprehensive utilization of biomass feedstock for its conversion into biofuels in gas, liquid and solid state.

Gasification is a thermochemical process allowing transforming poorly maneuverable and low-grade fuel - biomass waste, sorted organic waste, which significantly contributes to the reduction of harmful emissions, such as sulfur, chlorine and nitrogen compounds.

'Laboratory for biomass gasification' consists of 4 main buildings:

- control room,
- room with gasification technology,
- storage of biomass feedstock and biofuels, external gas tank,
- cogeneration room.

Gasification unit of the type UNIPYR SPU-1, consists of a set of equipment for the production of syngas and biogenic fuels.

Heating of the pre-reactor and the reactor is ensured by ceramic heating mantle with a max. wattage heating of jackets 20 kW. Power consumption of motor assembly is 8.8 kW (assembly total is $P = 28.8$ kW). The principle of the device operation is a continuous thermal decomposition of biomass and woody biomass, or other materials of organic origin (paper, textile) free of inert impurities (metal, glass, soil, sand), with a processing capacity of raw materials up to 20 kg/h. Heat treatment of organic material in the reactor assembly causes decomposition of input materials into three main output components, namely: synthesis gas (gaseous phase), reactor oil (liquid phase) and the remaining part of the processed inputs is charred portion of input materials - carbon (solid phase).

The technological assembly (Fig. 1, Fig.2) consists of a pre-reactor (3), the raw material is pre-heated to the temperature 100 up to 180°C and subsequently passed to the reactor (5), where the degradation process (depolymerization) of the raw material into the gas phase (synthesis gas) occurs at temperatures up to 600°C and the rest of the raw material remains in the solid phase in the form of ash or carbon that is transported out of the reactor on the conveyor (7), wherein at the same time the cooling is provided. The gas phase of the degraded mass is distributed to a condenser (9), where it is cooled, and this involves its partial precipitation into the liquid phase (so called reactor oil). The precipitated reactor oil is collected in the oil collection container (10) from where it is further drained through the distillation apparatus (11) to a condenser tank (12) where the modification of its quality parameters happens. The synthesis gas produced in the technological process of low temperature biomass decomposition is removed through the gas pipeline into the distribution biogas blower (14) through which it is transported for treatment (drainage and desulphurization) into the biogas treatment unit (15) out of which it is further conveyed into the gas tank (16) and further into the cogeneration unit (17) with an electrical output of 30 kWel (Fig. 3).

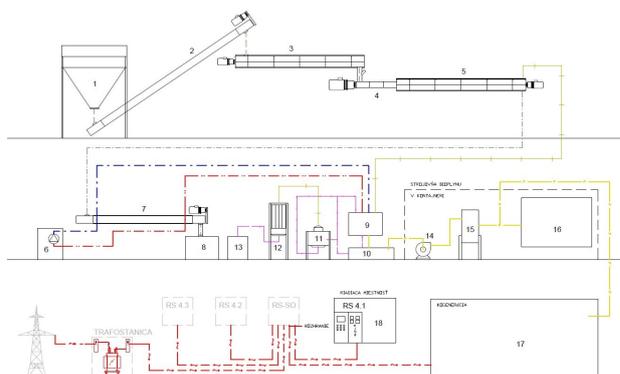


Figure 1. Technological scheme of the gasification unit of the type UNIPYR SPU-1



Figure 2. View of the gasification unit



Figure 3. Cogeneration unit

3 OBJECTIVES OF THE RESEARCH IN 'LABORATORY FOR BIOMASS GASIFICATION'

The assembly of the gasification unit is used for the research of energy efficiency of alternatives and variants of synthesis gas, liquid and solid biofuels production emerging in the process of thermochemical catalytic conversion of biomass in gasification reactor. The interim product of the composition is the synthesis gas, which is then further used as fuel for powering

cogeneration units and solid biofuels (mostly pure carbon), which can be further energetically utilized as fuel for boilers.

The object of the experiments is to find suitable mixtures of biomass feedstock and monitor their impact on the quantity and quality of emerging gaseous, liquid (2nd generation biofuels) and solid biogenic fuels. The process parameters (reactor temperature, feed pace of the material in a bioreactor) are experimentally verified in order to find the optimal settings for each combination of input materials with the purpose of achieving the highest quality of the produced biogenic fuels.

While carrying out comparative measurements using gasification technology of input materials composed of various types of biomass the same methodology is used for determining the following starting parameters:

- biomass weight, including the weight fractions of the different components of mixed mass materials using precise weighing,
 - dry substance content, using automatic dry substance weight,
 - the content of the organic dry substance, using a muffle furnace, and standard procedures,
 - pH value.

The research subject includes also process parameters:

- process temperature measured electronically, online,
- feed speed of the material in the reactor, measured by electronically, on-line,
- volume of produced synthesis gas, measured online.

Measured are:

- amount of liquid and solid fractions outgoing from the reactor,
- composition of syngas - portable gas analyzer and more precise analyzes - chromatography.

4 RESULTS OF EXPERIMENTS

To document the functionality and efficiency of the technology of biomass thermochemical conversion we provide as an example the results of experiments with agro-pellets thermochemical conversion (Fig. 4) made of the mixture of agricultural biomass waste.



Figure 4. Input material - agro pellets

The following parameters were used for the experiment Tab.1:

Biomass feedstock	Value
Biomass feedstock dose (agro-pellets)	63 kg/h
Dry substance content	86 %

Table 1. Parameters used for the experiment

From experiments with stated biomass feedstock - agro-pellets, the following average amounts of biogenic fuels were generated Tab.2.:

Produced biogenic fuels	Value
Carbon (charcoal)	21 kg/h
Reactor oil	20 l/h
Synthesis gas (mean)	10 m3/h

Table 2. Produced biogenic fuels

Average composition of synthesis gas showing in Tab.3.

Component of synthesis gas	Value
CH ₄ + higher hydrocarbons	57 % vol.
CO ₂	25 % vol.
H ₂ S	0,18 % vol.
O ₂	0,5 % vol.
CO	17 % vol.

Table 3. Average composition of synthesis gas

During the thermochemical conversion of agro-pellets the gasification process was very stable and generated very valuable synthesis gas that was burned in the engine of cogeneration unit; a solid component - pure carbon (Fig. 5) is also a high-quality fuel and generated reactor oil (Fig. 6) requires further distillation to achieve better quality parameters.



Figure 5. Output solid fuel – carbon



Figure 5. Output liquid component - reactor oil

5 CONCLUSION

The laboratory for biomass gasification with its unique pilot plant for low temperature decomposition of biomass, followed by immediate use of synthesis gas and the part of the liquid phase produced second-generation biofuels in cogeneration unit enables carrying out of a large number of experiments with different composition of biomass feedstock, but also with different operational parameters for the reactor itself (search for optimal conditions, in particular the process temperature and the feed speed of the material).

The device is conceptually designed for continuous operation in two control modes: manual and automatic, while critical process parameters are controlled and protected under both operation systems.

Contribution of this experimental work is determining the optimal parameters of input materials composition for achieving desired parameters and characteristics in all three emerging phases of biogenic fuels, namely gaseous, liquid and solid.

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