Processing of biomass in order to obtain energy components

O A Kolenchukov¹, E A Petrovsky¹, K A Bashmur¹, A Ye Sinitskaya¹ and Ya A Tynchenko¹,²

¹Laboratory of Biofuel Compositions, Department of Technological Machines and Equipment of the Oil and Gas Complex, Siberian Federal University, 82/6, Svobodny Av., Krasnoyarsk, 660041, Russia
²Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarskiy rabochiy pr., Krasnoyarsk, 660037, Russia

E-mail: olegandrenalin.ru@mail.ru

Abstract. This article presents a classification of existing types of biofuels obtained from biomass. Pyrolytic methods of biomass processing are characterized. An experimental setup for producing hydrogen and carbon nanomaterials is presented. The purpose of the experiment was to determine the amount (liters) of produced biohydrogen per unit of time (hour). With an increase in the temperature of the process, the yield of finished products increased. The choice of the appropriate catalyst also plays an important role.

1. Introduction
Annually increasing consumption of environmental management products leads to the emergence of urgency in the transition to non-traditional types of production of fuel components and various valuable materials. The greatest interest in this direction is the use of the potential of animals and plant organisms called biomass. Biomass also includes products of processing of various industries of the national economy (agricultural waste, waste from the forest and oil industries, etc.). The presence of organic compounds in its composition unites all types of biomasses. It should be noted that the transition to alternative sources will lead to a reduction in the environmental burden by reducing the generation of waste from human activities.

2. Classification of biofuel production methods
It is possible to classify all known types of biofuels obtained from biomass as follows [1–3]:

- Solid. They are obtained from plant raw materials, from raw materials of microbial origin, from human waste, as well as raw materials of animal origin.
- Liquid. They are formed from carbon dioxide and water, from raw materials of animal and vegetable origin, as well as raw materials of microbial origin.
- Gaseous. They are obtained from raw materials of animal and plant origin, waste products of human activity, as well as from raw materials of microbial origin.

More detailed information about the types of fuels obtained from biomass is presented in table 1.
Table 1. Classification of biofuels.

| Fuel class | Type of fuel | Product |
|------------|--------------|---------|
| Solid      | From vegetable raw materials | Firewood |
|            |               | Sawdust briquettes |
|            |               | Charcoal |
|            |               | Sunflower husk |
|            | From human waste | Household waste |
|            | From raw materials of microbial origin | Mechanically dehydrated sewage sludge |
|            | From raw materials of animal origin | Mechanically dehydrated sewage sludge |
| Liquid     | From vegetable raw materials | Biobutanol |
|            | From carbon dioxide and water | Bioneft |
|            | From raw materials of microbial origin | Bioneft |
|            | From raw materials of animal origin | Bioethanol |
|            | From vegetable raw materials | Biobenzine |
|            | From human waste | Vegetable oils |

As can be seen from table 1, the nomenclature of biofuels is quite wide, therefore, the amount of resources for obtaining a particular type of biofuel is also different. Unfortunately, the importance and usefulness of this type of resources has not been fully appreciated in the Russian Federation until today. Therefore, it is important to create an effective technology for producing biofuels from biomass with the maximum possible reduction in the cost of production of final products. One of the types of biomass are products obtained from petroleum feedstock (plastic, rubber, etc.), as well as the hydrocarbons of petroleum feedstock themselves in the form of various spills and accidents that are not suitable for further processing.

3. Pyrolytic methods of biomass processing and an experimental plant for the production of biohydrogen

The most common pyrolytic biomass processing methods can be classified into the following three types [4–6]:

- Torefication. The preliminary drying of the feedstock is carried out with further thermal destruction of the organic component of the biomass. As a result of such manipulations, a solid hydrophobic product is formed, the specific heat of which exceeds the specific heat of the feedstock.
- Pyrolytic conversion. Allows to obtain gas with high calorific value. High values of the calorific value are due to a decrease in the proportion of non-combustible components in it, which occurs due to the reduction of carbon dioxide to carbon monoxide.
- Pyrolysis. The classic method of processing the organic part of many substances. Pyrolysis products are light hydrocarbons, solid carbon residue, high molecular weight hydrocarbon compounds (saturated, unsaturated, aromatic, etc.), as well as non-condensing gases (CO₂, CO, H₂, N₂). With the repeated pyrolysis of light hydrocarbons in the presence of a catalyst, it is possible to obtain biohydrogen and carbon nanomaterials.

At the current moment in time, the technology for processing biomass should be complex. Combine two or more stages of biomass processing in order to maximize the conversion of feedstock into useful raw materials. So, the complex technology proposed by the authors of the article [7] includes pyrolysis in two stages, while at the first stage liquid and gaseous products are formed, at the second stage part of the gaseous products is converted into biohydrogen and carbon nanomaterials. In order to study the second stage of pyrolysis, an experimental setup was developed (figure 1) [7]. The principle of operation of the experimental setup can be described as follows. The required amount of catalyst for one cycle of operation of the reactor is introduced through the branch pipe for introducing the catalyst 8, then through the inlet pipe 5, incandescent thermal gases are supplied to heat the reaction zone of the reactor, through the heating circuit 3, and they are removed through the outlet pipe 6, thereby carrying out a continuous flow of gas through the heated loop, then the required amount of hydrocarbon gas is fed into the reactor vessel 1, which, acquiring additional acceleration inside the reaction zone, due to its design features, reacts with the catalyst, stirring is carried out using a vibration stirring device 2. The hydrogen formed during the reaction and unreacted hydrocarbons are discharged through the outlet branch pipe 9. All branch pipes of the experimental setup are equipped with shut-off valves (not shown in the figure). At the beginning of the reactor operation, the shut-off valves of the branch pipes 7, 8 and 9 are closed, and the valves of the branch pipes 5 and 6 are open. After reaching the specified temperature, open the nozzles 7 and 9 and carry out a cyclic injection of hydrocarbon gases through the nozzle 7 and the output of pyrolysis products through the nozzle 9, while the valve of the nozzle 8 is opened at the beginning of the reactor operation, when the catalyst is required. The hatch 4 is designed for unloading solid pyrolysis products, and the hatch 10 is for transferring the experimental setup and for moving the reactor zone along the mixing device 2 in order to select a more optimal position.

The initial product for loading into the reactor was gas - methane, obtained by pyrolysis of biomass (oil sludge) at the first stage.

Figure 1. Perspective view of an experimental setup for producing biohydrogen and carbon nanofibers.
The hydrogen yield was different depending on the process temperature and the type of catalyst. When using the catalyst 90% Ni + 10% Al2O3, the hydrogen yield at 550°C was 55 l/h, and at 650°C - 110 l/h. The 70% Ni + 20% Cu + 10% Al2O3 catalyst gave the following results: at 550°C - 44 l/h, at 650°C - 115 l/h. The highest product yield was observed on the catalyst 70% Ni + 20% Cu + 10% SiO2, at 550°C the yield was 89 l/h, at 650°C - 118 l/h.

4. Conclusion
Having analyzed the types of biofuels obtained, it is possible to make a brief description that the following types of biofuels are the most in demand. Among liquid biofuels, bioethanol and biodiesel are widely used in production. The first is a component of motor fuels, the second is self-firing fuel. Among solid biofuels, the most widespread are the so-called pellets or wood pellets, as well as charcoal, characterized by its slow gorenje and smokelessness. The main gas biofuel produced is biogas.

Biomass processing should be of a complex nature. For the complete transformation of the feedstock, it is necessary to carry out pyrolysis in several stages, with the possibility of obtaining not one, but several types of biofuels. For example, the production of gas compositions from solid and liquid biomass with subsequent processing at the first stage, to obtain biobenzine and biodiesel, at the second - the production of hydrogen and nanomaterials.

Experimental studies show that an increase in temperature from 550°C to 650°C leads to an average increase in hydrogen yield by 95% (from 30 to 160%), depending on the catalyst. At the same time, it is necessary to keep in mind the possible increase in energy consumption, which may affect the efficiency of the process.

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