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Development of the forest waste gasification system with electricity production

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Abstract. The aim of this work is development of a technological scheme of gasification of biomass to generate electricity, as well as development of efficient circulating fluidized bed gasifier with heat exchanger. The paper deals with the existing technology of biomass gasification and the influence of thermal parameters on the composition of gasification products.

Introduction

The total wood stock in Russia is more than 80 billion m³, our country is the leader in the area of forest resources and its amount per an inhabitant. The potential of biomass usage in Russia is the following: gross (467 million TOE/year), technical (129 million TOE/year), economic (69 million TOE/year), including agricultural waste, which is up to 80 million TOE/year; forest waste is more than 30 million m³ [1–7].

The volume of wood waste generation in the timber industry is 32% of the raw material. The amount of waste, for example, in a furniture factory reaches about 62% of all used wood.

In Russia at the enterprises, plants and factories wood waste is burned out or thrown into dumps and landfills. At present, energy-saving programs are being introduced, as well as that for reduction of harmful emissions into the atmosphere and optimization of primary resources usage [8–21].

Developed technological scheme

The area of application of generator gas is very wide. From the generator gas, electricity can be obtained by burning in a steam boiler, in gas engines or in steam and gas installations. We have investigated the scheme of the steam-gas installation (Fig.1), because the efficiency of a steam-gas installation is greater than for other schemes [22–24].



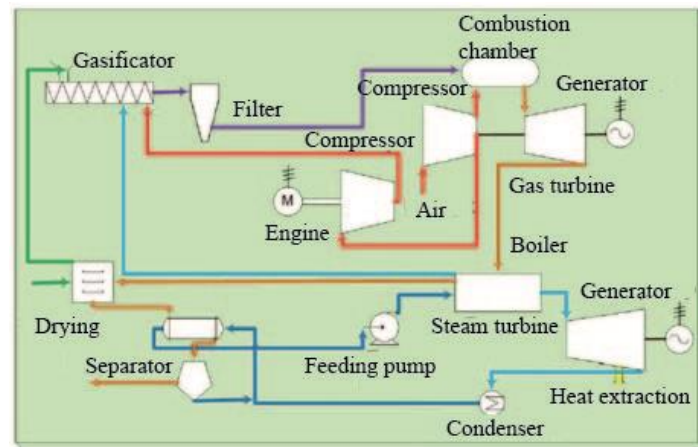


Fig. 1. The scheme of the steam-gas installation based on biomass gasification

The feedstock after drying is fed to the gas generator, where steam and air are pumped under pressure of 20 atmospheres for thermal conversion process. As a result of heat treatment, a generator gas is formed, which is purified from dust and ash in the filter. The purified gas is sent to a gas turbine that produces electricity. The exhaust gases after the gas turbine are sent to the waste heat boiler. In the boiler, the heat exchanger produces overheated steam. Part of the steam goes to the gas generator, and another part of the steam goes to a steam turbine, which generates electricity.

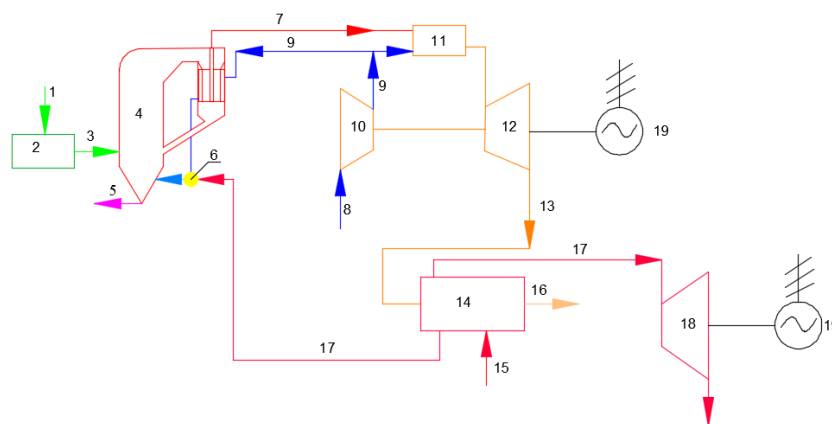


Fig. 2. Developed technological scheme of biomass gasification from steam-gas installation:
 1 – biomass; 2 – crusher; 3 – crushed biomass; 4 – circulating gas generator of boiled layer with heat exchanger; 5 – ash; 6 – ejector; 7 – gas of generator; 8 – cold air; 9 – compressed air; 10 – compressor; 11 – combustion chamber; 12 – gas turbine; 13 – wasted gases; 14 – utilizing boiler; 15 – feed water; 16 – output gases; 17 – overheated steam; 18 – steam turbine; 19 – generator.

In Fig. 2 the developed technological scheme of the steam-gas installation based on wooden wastes is presented. The principle is the same as in Fig. 1, but there are some distinctive features:

- Absence of drying installation for biomass;
- Usage of physical heat of the generator gas for heating the compressed air in the heat exchanger;
- No additional air compressor under the engine;
- Usage of an ejector to disperse compressed air using overheated steam.

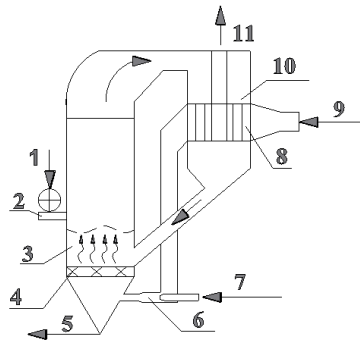


Fig. 3. The developed scheme of the circulating gas generator of boiling layer with heat exchanger. 1 – biomass; 2 – feeder; 3 — gasification zone; 4 — fuel layer; 5 – ash; 6 – ejector; 7 – overheated steam; 8 – heat exchanger; 9 – compressed air; 10 – cyclone dust collector; 11 – gas of generator

In the paper we present a circulating gas generator of boiled layer with heat exchanger, which is shown in Fig. 3. The heat exchanger 8 can increase the temperature of the compressed air 9 and raise the efficiency of gasification.

The main feature of the developed gas generator is the supply to the gasification zone 3 of the steam-air mixture from the ejector 6, dust purification in the vertical cyclone dust collector 10 and heating of the compressed air 9 in the heat exchanger 8.

The research of the dependency of the output parameters of the biomass gasification products

An output of biomass gasification products depends on the initial input parameters to the generator (ratio of the flow rate of the oxidant and amount of superheated steam) and on given parameters (gas temperature, pressure in the reactor). Calculations of dependency of output parameters were carried out in MathCad15 [25]. The air flow rate and the pressure in the generator were accepted as 0.3 and 2.5 MPa respectively [26].

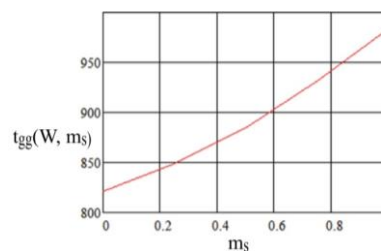


Fig. 4. Temperature change depending on the supply of superheated steam

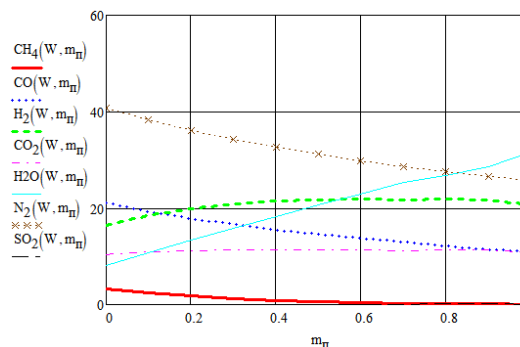


Fig. 5. Relation between the output of gasification biomass products and the steam amount

With an increase of the amount of overheated steam supplied to the ms, the temperature of the generator gas linearly increases (Fig. 4).

In general, the amount of overheated steam in the gas generator mostly influences on the output of H₂ and H₂O (Fig. 5). The maximum value of H₂ at the ms boundary varies from 0.2 to 0.8, but with increasing of ms the CO output decreases.

From Fig. 6 it can be seen that with the increase in the amount of overheated steam, the chemical heat of combustion of the generator gas decreases, but the physical heat increases. So, it is not effective to supply more steam to the gas generator, since an important role in thermal installations is played by the heat of combustion, and the use of physical heat can lead to pressure loss.

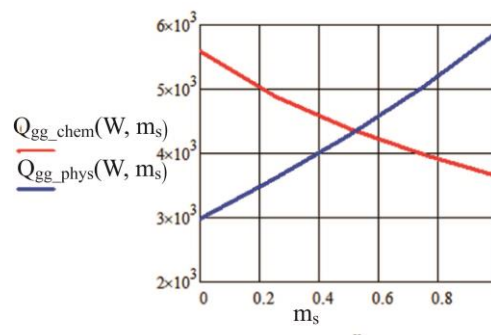


Fig. 6. Change in the heat of combustion and the physical heat of the generator gas depending on the amount of steam

Based on the research of the dependence of the heat of the gas on the amount of steam, the amount of overheated steam can be taken $m_s = 0.2$ kg/kg (biomass) to obtain a certain pressure in the gas generator.

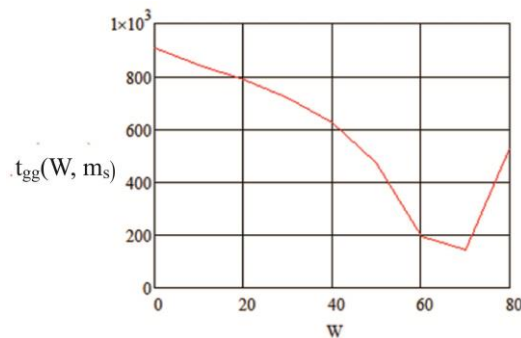


Fig. 7. Change of gas temperature in the dependency on biomass humidity.

Raw materials humidity W greatly affects the process of biomass gasification. So in fig. 7 it is displayed that the temperature of the gas of generator is reduced to 70 % with an increase in the humidity of the raw material, then increases sharply from 70 %. This is due to the fact that the heat is lost on the evaporation of moisture and the thermal conversion reaction of the evaporated moisture.

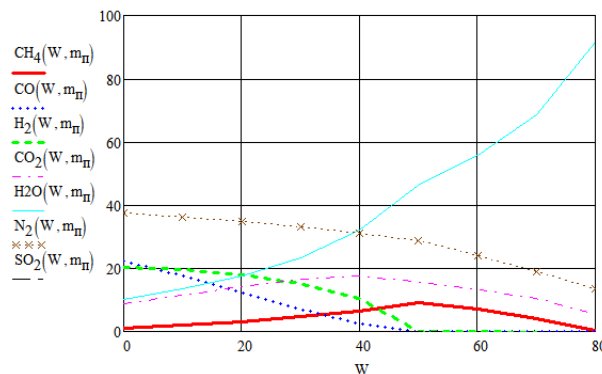


Fig. 8. Relation between composition of the generator gas and raw materials humidity.

The humidity of wood waste usually reaches 15 %. Based on the graph of the dependence of the amount of heat on humidity, it can be assumed that for biomass gasification it is enough to take raw materials with $W=10$ %, since the heat of combustion will be about 5 MJ/m³. The gas of generator with such chemical heat of combustion can be used in the steam-gas installation.

Conclusions

The new technological scheme of the steam-gas installation based on wood wastes was developed. It has a number of features in the comparison with a scheme in Fig. 1:

- Absence of drying installation for biomass;
- Usage of physical heat of the generator gas for heating the compressed air in the heat exchanger;
- No additional air compressor under the engine;
- Usage of an ejector to disperse compressed air using overheated steam.

Also we developed a new effective circulating gas generator of the boiling layer with heat exchanger, in which the efficiency of the biomass gasification increases due to heating of compressed air.

As the overheated steam and biomass humidity increase, the heat of combustion of the generator gas decreases. Based on this, it is enough to take the biomass moisture $W = 10\%$, and the amount of steam is 0.2 kg/kg (biomass) to disperse the compressed air to reach a certain pressure in the gas generator.

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