Gasification of Wood and Non-wood Waste of Timber Production as Perspectives for Development of Bioenergy

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Abstract. The article deals with biomass gasification technology using the gasification plant running on wood chips and pellets, produced from essential oils waste (waste of coniferous boughs). During the study, the authors solved the process task of improving the quality of the product gas derived from non-wood waste of timber production (coniferous boughs) due to the extraction of essential oils and the subsequent thermal processing of spent coniferous boughs at a temperature of 250-300°C degrees without oxygen immediately before pelleting. The paper provides the improved biomass gasification process scheme including the grinding of coniferous boughs, essential oil distillation and thermal treatment of coniferous boughs waste and pelletizing.

1. Introduction

Social and economic development of modern society and the dynamic growth of world industrial production led to an inevitable increase in the consumption of energy and fuel. The raw material for the production of electricity and heat, as well as gasoline and diesel fuels for internal combustion engines are mainly hydrocarbon resources whose value is currently high enough and will continue to increase due to the rapid depletion of deposits with readily recoverable resources and the increase of their production costs.

In addition, an important problem is the pollution of the environment which is both a consequence of accidents, arising from the development of oil and gas wells, and the usage of hazardous production technologies (such as hydraulic fracturing technology) that could affect the stability of ecosystems, and the consequence of the usage of the derived products of hydrocarbon feed (including atmospheric pollution by exhausted gases from internal combustion engines which comprise more than two hundred kinds of harmful substances and compounds including carcinogenic).

All these factors actualize the problem of the development of alternative energy technologies and fuel production. In industrialized countries, one of the priorities of industrial production is the search for clean, renewable energy sources. Today these sources are bioresources as well as agricultural waste and household waste.

Gasification of biomass is one of the most cost effective and environmentally friendly methods for producing electricity and heat.

In Russia the gasification technology of biological raw materials have not yet received wide distribution as well as other methods of recycling industrial and household waste. According to
various estimates 300 million tons of organic waste of which up to 50 million tons of household waste are accumulated in our country annually.

For gasification, timber industry can give a large number of biological cheap raw materials such as low-grade wood, waste timber (vertices, branches, stubs, bark, slabs, shavings, sawdust, etc.), furniture manufacturing waste and wood housing waste. The presence of a significant amount of waste in the timber production is a consequence of the low level of automation of the production process and the usage of integrated forest utilization [1; 2].

Let us consider the gasification technology of wood and non-wood waste of timber production.

2. Methods

*Gasification of wood* - is the process of converting it to a gaseous fuel. It has a number of advantages such as the ability to transport over long distances, high temperature of combustion and easy adjustment of this process [3].

Furthermore, the advantages of this type of fuel are relatively low cost of production and the usage of renewable (wood) resources.

Gasification technology is known for a long time. First gasification of solid fuel for the production of combustible gas was used in approximately 1805-1815 in the UK, Germany and France. Initially, producer gas was used for street and house lighting by means of gas street lamps and lamps; then it was used as fuel. The Russian equipment for artificial gas was first introduced in 1865. According to Mosgaz, Moscow has 215 versts of gas networks, 8735 gas street lamps and 3720 private gas consumers by 1905.

According to Russian experts, "History shows Russian independent development of gasification technology and refutes recently emerging statements that gasification plants had been borrowed abroad. Such assertions are untenable even because of the fact that the illuminating gas has never been received from wood in Europe and America, while it was the Russian forestry that was the cradle not only of the natural gas industry but also of the Russian energy sector generally” [4].

In the twentieth century, gas-generating technologies were widely used in the Soviet Union. Thus, in the 1920-1930s wood gas generators were installed on cars, buses, tractors and other machinery manufactured in series (for example, Russian GAZ-42, ZIS-21). In the forest industry logging vehicles and skidders were equipped with gas generator.

According to the SSC (State Statistic Service) up to 1958 in the USSR, 350 gas-operated power stations with capacity from 200 kW to 3 MW used biomass and peat, and 47 gas-stations with the capacity of 1 to 5 MW used coal and shale as the fuel. Such stations produced over 400 bln. m³ of the produced gas. In addition, the national economy had more than 250 thousand gas plants of the transport type with the capacity from 1 to 200 kW; they are actively used in the automotive, agricultural and forestry sectors, on the railroad and in navigation. However, "after the relevant decision of the Government” the use of gas plants and the gas plants of the transport type has been gradually phased out, even where their operation was economically justified. As a result, the gas plants in Russia are not constructed for over 50 years, and the experience of their design and operation is largely lost "[4].

The biomass gasification problem currently remains rather complex, and the experience accumulated in 1940-1960 years of the last century, can not be always useful because the advanced technical solutions are often based on different approaches.

Today, many Russian and foreign institutions and companies, scientific research institutes are engaged in the development of gas plants for wood and other solid fuels. Gas plants are vary in power capacity: small - up to 100 kW, an average - from 100 to 1000 kW and high power - more than 1000 kW. There are many types of gas plants used for the gasification of wood waste and other biomass. The most popular of these plants are of the forward and reverse combustion, as well as the fluid bed ones.

The modern gas plants involve the use of wood in form of the industrial chips [5] or the fuel pellets - pellets [6], instead of the firewood (as at the old gas plants). This allows increasing the combustion
temperature of the produced gas, which in turn leads to an increase in productivity of gas consumers (hearts, glass melting and other furnaces) and to a decrease in gas consumption rates per unit of production. In addition, modern gas plants have a higher performance, a high level of mechanization of the process, low capital costs (basic equipment can be placed outside the building, which reduces the cost of capital construction, the cost of plumbing, electrical and other types of work), and ease of use.

The authors give some parameters for comparing the operation of the industrial gas plants using spruce wood in the form of billets and the industrial chips with a relative humidity of 38% (Table 1)[7].

Table 1. Comparative wood gasification indicators (W = 38%) of various grinding

| Indicators                                                                 | Billets gasification | Chips gasification |
|---------------------------------------------------------------------------|----------------------|------------------|
| 1. Wood size, mm                                                         | 1000                 | 80               |
| 2. Gas temperature at the gas plant outlet, °C                            | 180                  | 78               |
| 3. Yield of dry gas vs. the weight of the oven-dry wood, Nm³/kg           | 1.94                 | 1.6              |
| 4. Heat of the combustion gas, kcal / Nm³                                 | 1350                 | 1680             |
| 5. The yield of liquid products from the weight of the bone dry wood, %  |                      |                  |
|   – resin                                                                 | 8.4                  | 16.0             |
|   – volatile acids (converted to acetic);                                 | 2.1                  | 3.5              |
|   – methyl alcohol;                                                       | 0.9                  | 0.7              |
| 6. The intensity of the gasification to the unit of shaft section in terms of the oven-dry wood, kg / m²h | 85                   | 190              |
| 7. The residence time of the wood in the shaft of the gas generator, h     | 28                   | 3                |

However, studies show that an increase in the content of the pine needles in the outcome of chips reduces the yield of resin and other products. This was confirmed by conducted experiment of the clean needles gasification (free of bark and wood). Thus, the output of the gasification products vs the weight of oven-dry pine needles as a percentage of:

- volatile acids (converted to acetic) – 3.5;
- methyl alcohol – 0.32;
- ester (converted to methyl acetate) – 0.54;
- settled resin – 8.7;
- soluble resin – 5.3;
- reaction water – 28.

The yield of the most valuable settled resin while needles gasification is substantially different from the stem wood resin yield. Herewith the quantity of soluble resin (5.3%) is significantly higher than the corresponding index of the wood chips gasification, constituting 0.4 - 1.5%, indicating that no quite satisfactory degumming of the gas in tar extractor occurred. The settled resin analysis without fractional distillation reveals a large number of neutral substances (39%) in the resin due to the presence in the feedstock (needles) the essential oils and other neutral organic substances soluble in organic solvents.

The authors believe that the technology of gasification of non-wood waste of the wood production (needles) economically and technologically suitable for use in combination with essential oils production technology - fir, cedar and others.

Fir oil is essential oil extracted from the needles and thin branches of the fir, and represents a transparent light yellow or greenish liquid with a characteristic odor. Fir oil contains 30-43% of bornyl
acetate, 18-20% of camphene, 3-5% of borneol and other substances. The raw material for the production of oil is the coniferous boughs with the length of 26-30 cm, comprising (by weight) of 70% needles, 18% of bark, and 12% of wood. This bough gives the highest yield of fir oil. Fir oil is used in medicine, perfumery, cine technique soap making, in the manufacturing of camphor, etc.

Production waste (coniferous boughs waste) remaining after getting of the essential oil were processed into pellets - pellets of a cylindrical shape 10-30 mm long and 8 m in diameter produced without bounding chemical under the high pressure. Pelletizing is necessary to increase the energy density of non-wood waste and ensure stable operation of gas plants at their subsequent gasification.

At this, the pelletizing process has been improved: raw material (coniferous boughs waste) subjected to preliminary heat treatment at a temperature of 250-300°C without access of oxygen. In experimental studies, it has been found that carrying out the heat treatment of raw material can increase the hydrogen and carbon monoxide content in the composition of the product gas while reducing the carbon dioxide that contribute to increasing of the generated energy while the producer gas consumption.

3. Results
As a result of the wood and non-wood waste gasification process, the purified producer gas was obtained and used in the internal combustion engines and for the power generation, as well as a number of chemical products, such as resin, volatile acids, methyl alcohol.

Analysis of the producer gas resulting from gasification of pellets made of the essential oils waste production (coniferous boughs waste) with the preliminary heat treatment, in comparison with the results of the pelleted needles gasification not subjected to a heat treatment are shown in Table 2.

Table 2. Composition of the producer gas produced by the gasification of the pelleted biomass, %

| Gas components | Pelleted waste of the essential oils production, passed through the thermal treatment | Pelleted needles |
|----------------|----------------------------------------------------------------------------------------|----------------|
| CO₂            | 2.8                                                                                    | 4              |
| CO             | 32.4                                                                                   | 29.4           |
| CH₄            | 2                                                                                      | 1.3            |
| H₂             | 8                                                                                      | 6              |
| N₂             | 48                                                                                     | 59             |

The process of biomass gasification involves the use of processing facility equipment comprising the distillation of the essential oil and the production of pellets as well as the gas plant of the forward gasification (Figure 1).

Coniferous boughs lay into crusher 1, where it is ground on a helical grinder to pieces 5-7 mm in length and then fed via belt conveyor 2 in the lower part of lifting column 3. The coniferous boughs moves upward the lifting column by means of the lifting screw and straight through processed at a temperature 110-115° C by steam coming from boiler 4, which is heated by means of fuel burning (wood / coal) in furnace 5. From the top of the lifting column the biomass is dropped to unloading column 6, where it descends in the opposite flow of steam. At the top of unloading column the oil vapor comes out on steam line 7 to cyclone 8, wherein the raw material particles are trapped, and further purified oil vapors are directed into refrigerator 9, then - in oil separator 10, from which the essential oil enters oil receiver 11.

At the bottom of the unloading column by means of the unloading screw the coniferous boughs waste removed and on the belt conveyor enters heat treatment chamber 12 where it is heated to 250-300°C. without access of oxygen. Thermally treated biomass enters the hopper of pelleting 13, where the fuel pellets are made under pressure.
Finished pellets come into feed hopper 14 on the belt conveyor and then - into gas producer plant 15 which is also connected with a hopper for loading industrial chips 16. Using of the gas producer plant operating both with pellets, and the industrial chips, allows creation of the technological complex for the development of the producer gas more efficient and convenient in operation.

Figure 1. The scheme of the process for the production of complex gas from wood and non-wood waste timber production

4. Discussion
The product gas as a fuel has undoubted advantages over direct combustion of wood and other biomass. The product gas, like natural gas, may be transported over long distances through pipes in the cylinders; it is convenient to use it in the home cooking, facility heating and water heating, as well as in industrial and power plants. Gas combustion is easy to automate; combustion products are less toxic than the direct products of the combustion of wood and other biomass.

The producer gas is used as raw material for further chemical processing and as a convenient and efficient fuel for burner’s dryers, ovens, boilers and gas turbines but more often for piston units. Thus, it is similar in properties to the natural gas and may be used instead of the latter.
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