Analysis of experimental researches of wood gasification process in a continuous layer

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Abstract – For today are known quite a bit methods redoing of wood and its wastes in energy, but one of the most perspective is gasification. The construction of the gazogene, on which the row of experiments is conducted with the aim of determination of conformity to law of influence of entrance factors which influence on the process of gasification and on quality of synthesis-gas, was worked out for this purpose. The statistical processing of experimental data enables to define the optimal parameters of work a gazogene.

Keywords: wood gasification, continuous layer, gazogene, synthesis-gas, optimal parameters, lower heating value.

I. Introduction

In many countries of the world biomass, as a source of making of energy today gets more ponderable value in the different sectors of economic activity, in particular: on the thermal and electric stations for the production of warmth and electric energy [1-3]. It is related first of all to exhausting of extractive block which results in the increase of price on them fuels. Except it an extractive fuel has a large influence on the state of environment, and it compelled world public to creation and introduction in an action of the program of the Kyoto agreement. It is necessary to notice that potential of biomass to ten one times exceeds possible requirements of humanity in energy, is ecologically clean and has a capacity for renewal.

Today the tendency of decentralization of energy takes place in the world, id est there is the use of cogeneration plant making of heat and electricity. Perspective cogeneration plant are engines of internal combustion, which work on the eider of synthesis gas.

II. Presentation of the main material

The impact of input parameters on the calorific value of the syngas is analyzed to find the optimal regime parameters of the gasification process and the gas generator operation. This is aimed at developing a gasification process technology and a constructive model of an industrial gas-generating unit.

The experiments were based on using the following materials: pine (Pinus sylvestris).

The problem was in finding the dependence of the lower heating value (LHV) (net calorific value (NCV) or lower calorific value (LCV)) of the synthesis gas on the size of the wood particles that are fed into the gasifier, as well as the dependence of the amounts of air and fuel on the total volume of the reactor during the gasification of the studied species of wood.

The experiments were conducted and the technological process for gas synthesis was developed on the basis of designing a gasifier with a continuous layer [4].

The known modern gas generators with continuous layers [2, 3] allow obtaining synthesis gas with a calorific value of 5-7.5 MJ/Nm^3; they are vulnerable to the gasified fuel quality and hard to maintain. The challenge is to develop a gas generator that would be easy to maintain and that would help obtain synthesis gas of a higher calorific value and gasify fuel at a higher humidity.

In the developed gas generator with a continuous layer, the problem is solved because the gasification chamber is made in the form of two truncated cones. The larger bases of the cones are placed opposite one another with a small gap between them, which excludes fuel bridging and facilitates its passing to the nozzle at the top of the gasifier. The device for air supply is made of a casing, with a tube inside to drain the synthesis gas from the top of the case to the consumer. This design allows heated air to be blown into the gasification chamber and helps cool the syngas. The truncated cones and the enclosure parts are bolted for easy maintenance.

The tests have showed that the use of gas generators of the proposed design helps improve efficiency by increasing the speed and intensity of the chopped wood gasification process. This is achieved because the gases that are formed during the gasification process repeatedly pass through a layer of hot fuel in the zone of oxidation and recovery. At high temperatures, there happen the heterogeneous recovery of carbon dioxide, i.e. $C+CO_2 \rightarrow 2CO_2$, and the formation of carbon monoxide as a combustible component of the synthesis gas. If the recovery area contains water vapor, a high temperature produces the reaction of its conversion, i.e. $C+H_2O \rightarrow CO+H_2$ and $CO+H_2O \rightarrow CO_2+H_2$. In this case, there appears a second combustible component of the synthesis gas, which is hydrogen. Thus, due to the high content of carbon monoxide and hydrogen in the synthesis gas, the lower heating value (LHV) is relatively quite high.

In a series of experiments, the task was to find the LHV dependence on the particle size of the chopped wood as well as the amount of air and the amount of fuel in the gasification chamber for each of the studied wood species. Besides, another task was to determine the dependence of the LHV of the synthesis gas on the species of wood that was gasified.

Entrance x_i factors of experimental researches:

- the dimensions of the particles of wood l : 10, 20, 30, 40, 50 mm;
- the amount of air, which is given in the gazogene G: 40, 65, 90 m^3/h;
- the amount of fuel in the gasifier reactor q: 50, 75, 100 %.

Output parameter y :

– lower heating value of synthesis gas, MJ/m^3.

The number of the tests that were duplicated in each series was n=6. The data of each experiment were subjected to statistical analysis to find gross errors; questionable results were checked by using the Student's t-test [5]. Any questionable result (y_i) was temporarily excluded from the sample, and the remaining data were used to calculate the arithmetic mean (y_{avg}) and the variance.

The regression equation, which can be obtained as a result of implementing plans of the second order, i.e. plans to obtain the mathematical description of objects in the second order [5], has the following form:

$$y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x_i^2 + \sum_{i,j=1}^{k} b_{ij} x_i x_j, \qquad (1)$$

where x – denotes the variable factors; b – stands for the regression coefficients; k – denotes the number of the variables.

Then the normalized values are associated with the natural values by the following relations:

$$x_1 = \frac{l - 30}{20}; \quad x_2 = \frac{G - 65}{25}; \text{ and } x_3 = \frac{q - 75}{25}; \qquad (2)$$

The accuracy, objectivity, and reliability of determining the actual value of the measured characteristics and, therefore, the correctness of all subsequent conclusions depend on the accuracy of processing the experimental results.

After processing the experimental data and obtaining the regression equations, there followed their statistical analysis. This solved two major problems: the significance of regression coefficients was evaluated and the adequacy of the mathematical model was verified.

III. The results of researching

The B_3 plan was used to obtain the mathematical description of the object in a second order polynomial, which is:

$$y = 9.73 + 0.87 \cdot x_1 + 0.14 \cdot x_2 + 0.11 \cdot x_3 - 1.50 \cdot x_1^2 - 0.52 \cdot x_2^2 - \qquad (3)$$
$$-0,27 \cdot x_3^2 - 0.02 \cdot x_1 \cdot x_2 - 0.01 \cdot x_1 \cdot x_3 + 0.02 \cdot x_2 \cdot x_3$$

The regression equation rationalization for pine wood produced important input parameters at which the lower heating value y reached the maximum in Table 1.

TABLE 1
THE REGRESSION EQUATION RATIONALIZATION

The coded values of the factors		The natural values of the factors	
x_1	0.287	l	35.74 mm
x_2	0.138	G	68.45 m^3/h
x_3	0.199	q	79.98 %
y	9.88 MJ/m^3		

This, the B_3 plan produced the mathematical description of the object in a second order polynomial for each of the wood species. The rationalization of the regression equations for the studied species of wood has specified important input parameters at which the lower heating value reached the maximum: Q_{pine}=9.9 MJ/Nm^3.

The use of gas generators of the proposed design can increase the efficiency of the thermal processing of solid fuel into gaseous fuel by increasing the speed and intensity of the fuel gasification process. It can also solve the problems of the ecological utilization of industrial and household waste as well as of obtaining cheap energy and securing ecologically-friendly industrial conditions for the environment.

The experimental findings have specified the regression dependence of the LHV of the synthesis gas during the gasification of pine wood. The resulting regression equation can be the basis for implementing the studied process and its rational management. The equations of the input factors' dependence on the original setting make it possible to determine every possible parameter of assessing the process under study at any value of the factors between the upper and lower levels.

Conclusion

The use of gas generators of the proposed design increases the efficiency of processing wood into gaseous fuel by increasing the speed and intensity of the process of gasifying fuel. It also can solve the problems of the ecological utilization of industrial and household waste as well as of obtaining cheap energy and improving industrial effects for the environment.

The heat from burning the syngas has been found to be dependent of the particle size of chopped wood, the amount of air and the amount of fuel supplied to the gasification chamber. The B_3 plan implementation has produced the mathematical description of the object in a second order polynomial. The rationalization of the results for the studied types of wood has specified the important input parameters for which the calorific value of the synthesis gas that is produced during the gasification peaks at y =9.9 MJ/Nm^3. The average values of the rational input parameters for the gasification process in a continuous layer are the following: l=36 mm, G=69 Nm^3/h, and q=80 %.

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