ANNOTATION
of the dissertation work of PhD doctoral candidate
on specialty 6D070200 - "Automation and control" Zhirnova O.V.
on the theme: "Development of an automated system for biogas combustion process diagnostics and control "

The dissertation work on the theme "Development of an automated system for biogas combustion process diagnostics and control" is devoted to the study of actual problems in the field of biogas development as a source of renewable energy.

The relevance of the work is shown by the increasing of the role of energy resources at the present stage of human development. The limitation and high cost of the currently used hydrocarbon raw materials (oil, gas, coal) lead to the need to search for alternative and mainly renewable energy sources - wind, solar energy and others. One of the important ways to solve this problem is the use of biofuel (agricultural wastes, timber producing and timber processing industry). At the same time, the use of installations for direct burning of such wastes is ineffective and, therefore, the most promising is the use of the biofuel gasification process to produce "generator" or "synthesis" gas, which can be further used in both energy and chemical industries. At the same time, the heterogeneity of the used raw materials, the complexity and variety of chemical reactions of gasification, the need to increase the calorific value of the resulting generator gas (synthesis gas) makes it necessary to create an effective system of process diagnostics and control.

The relevance of the biomass gasification process research is due to the fact that this technology allows to solve a set of problems associated firstly with the use of low-quality and renewable resources for the production of heat and energy. Secondly, this technology makes it possible to obtain synthesis gas, which is a valuable initial material for the production of such substances as methanol, synthetic liquid fuel, higher alcohols and others. Thirdly, the process of steam gasification can be used as a mean of fuel saving (in comparison with other technologies of gasification) and therefore is a resource-saving technology. The use of biomass for energy purposes is also relevant from the ecological point of view, because it will lead to a reduction of greenhouse gas emissions in conjunction with the disposal of domestic, industrial, wood and agricultural wastes. The transition to the proposed type of fuel to solve the problems of energy supply of the industry should be accompanied by the use of advanced energy-efficient technologies based on pyrolysis or gasification of initial raw material and subsequent combined generation of electrical and thermal energy in the installation cycle.

The purpose of the work is to create an automation system of the biofuel gasification process, with the development of algorithms for process diagnostics and control. The aim of the work is to study and develop the biomass gasification process diagnostics and control: in the research of the determining parameters influence on the kinetic regularities of the biomass gasification process; experimental researches of the influence of biomass composition on the

composition of synthesis gas, in the development of a mathematical model and methodology for calculating the technological biomass gasification process, the establishment of optimal parameters of the biomass gasification process, as well as in system analysis and in a synthesis of an automated installation, in the development of a system for biomass gasification processes diagnostics and control. One of the main objectives of the given aims was to create a universal demonstration installation capable to produce fuel from biomass for carrying out researches of gasification processes. This aim has been fully achieved.

Main tasks:

In order to achieve the given aims the following tasks were set and solved:

1. Analysis of the technological complex as an object of automation, formalization of the task formulation of the process control system development;

2. Development of a mathematical model of the biomass gasification process on the basis of analysis of physicochemical, thermal and hydrodynamic regularities of the process;

3. There were carried out experimental researches of the technological modes of the process and was made a parametrical identification of mathematical model;

4. There was developed a structure of the process control system taking into account the distribution of process parameters along the height of the reactor;

5. In order to estimate the dynamic characteristics of the control channels there was studied the process by statistical methods with the use of auto- and inter-correlation functions and the corresponding spectral densities;

6. Were developed algorithms for process diagnostics and control;

7. Designed and tested the automation system of the biofuel gasification process;

8. Conducted the comparative analysis of the biomass gasification control process, analyzed the physicochemical processes of biomass gasification, were identified the main parameters that determine the biomass gasification process and the development of new control methods;

9. Studied the gasification technology of the regularity of interaction of various gasifying agents with carbon-containing materials;

10. Studied the influence of temperature and raw material type at biomass gasification with the stream of superheated water vapor of atmospheric pressure on the characteristics of the resulting synthesis gas for the development of new approaches for the creation of systems that provide the production of thermal, electric energy and synthesis gas;

11. Was carried out a mathematical modeling and description of the gasification process with obtaining kinetic parameters responsible for this process;

12. Calculated an estimation of favorable operating parameters of the biomass gasification installation;

13. Developed a schematic diagram of the installation with a biomass gasifier;

14. Determined the parameters of the control system model and checked the control algorithm efficiency using simulation;

15. Defined the control strategy and developed the structure of the control system.

The idea of the work. The task of efficient biofuel gasification process control was considered in the class of multi-level control systems for objects with distributed parameters, at the upper level the desired temperature distribution was calculated, at the lower level - the stabilization of the calculated regimes. Statistical methods were used to estimate the dynamic characteristics of stabilization channels.

The object of the research is the biomass gasification process control system.

The subjects of the study are construction methods, modeling and optimization of biomass gasification process diagnostics and control.

Methods of the research. The methodological base of the dissertation research is the methods of mathematical modeling, methods of synthesis and structural analysis of systems, the system control theory by the distributed parameters, methods of statistical dynamics. As modeling tools there are used modern application software packages: Math Lab. MR Lab. Mathcad. Coinzol. Fluent.

Scientific novelty. The novelty of the dissertation work consists in the construction of an analytical mathematical model of a complex technological process of gasification, the application of control methods for systems with distributed parameters and statistical dynamics for the synthesis of structures and control algorithms and process diagnostics.

There was calculated the composition of the biomass based on the analysis in order to obtain universal kinetic parameters responsible for gasification.

The scientific results of the dissertation work are relevant and have a practical interest. The carried out researches and the received results of dissertation work are applied in the laboratory of the university for studying and for the analysis of modern technologies of combined generation of thermal and electric energy on the basis of continuous pyrolysis or gasification of initial fuel.

In the process of the work the following studies were carried out: the investigation of the kinetic regularities of the formation of gaseous substances and a solid residue at the biomass gasification on the raw materials base of coal mining wastes and coal enrichment; the construction of a methodology for calculating the technological biomass gasification process in a water vapor environment (in the one-dimensional approximation); the development of a mathematical model and methodology for the technological calculation of the biomass gasification process; determination of optimal parameters of the biomass gasification process; the development of a program for the introduction of research results into the educational process. Performing the experimental work there were used thermodynamic methods of measuring the water vapor consumption and a hydrogen-oxygen mixture on the basis of differential manometers, methods of contact and non-contact temperature measurement in a superheater, in a permeable biomass layer, carried out standard techniques for synthesis gas analyzing on a chromatograph and on a flow gas analyzer. At mathematical modeling there were used the approbated mathematical models and the checked reliable methods.

Research methods include experimental studies on the effect of gasification temperature conditions, of the properties of the initial raw material on the qualitative composition and on the quantitative output of synthesis gas; modeling of the gasification process of carbon-containing substances with the solution of the obtained model by iteration-interpolation method.

The practical value of the work is following:

1. There was created methodical support for the construction of control systems for the biomass gasification process that meets the necessary requirements.

2. There was developed a system for biomass gasification process diagnostics and control.

The dissertation work was carried out in accordance with the thematic plan of research works, the laboratory of the Lublin Scientific Research Institute (with the technical procedure Q/ZK/R/15/04/A).

As a result of the research of the kinetic regularities of the formation of gaseous substances and solid residue in the biomass gasification there was established the influence of the biomass composition on the output of oxide and carbon dioxide, as well as hydrogen and methane. The presence of biomass in steam conversion at the same temperature increases the output of hydrogen compared to the conversion of carbonized coal, and with the content of wood in the charge of 30% - the amount of hydrogen in the synthesis gas remains constant and corresponds to its output - in the biomass gasification.

The presence of wood in the charge at all other equal things has a decreasing effect on the output of carbon monoxide and an increase one on the proportion of carbon dioxide.

Developing the methodology for calculating the technological process of coal industry wastes gasification there was proposed a draft version of a continuous countercurrent gasifier. Developing the model of the technological process, the model of autothermal layer gasification in the one-dimensional approximation was adopted as a basis. The layer is a monofractional coal backfilling, through which the stream moves. The difference from autothermal steam-gasification is in the absence of an oxidation zone. The system of equations of the model includes the equations of the gas phase components transportation, the equation of the energy of the gas phase, the equations of the solid phase components transportation and the equation of the energy of the solid phase. The set problem was solved numerically. In order to test the model there was used an analytical solution at the initial vapor temperature less than 300°C. In this case, the problem of inert heating has an analytical solution.

Establishing the optimal parameters of the gasification process, the choice of the initial parameters of the layered countercurrent gasifier was made due to the thermal power of the steam flow, which is 50 kW. The choice of optimality criteria is due to: 1) the output of gasified organic raw material from the reactor with a carbon content not more than 1% from the initial content at the reactor inlet varying geometric dimensions of the apparatus, consumption and thermodynamic parameters of the vapor and solid phases; 2) the maximum heat of product gas

combustion. As a result of the numerical calculation there was developed a methodology for determining the optimal parameters for the process of organic raw materials gasification on the model of a countercurrent mine layered gasifier.

Studying the kinetic regularities of the formation of gaseous substances and solid residues at the biomass gasification the obtained results show that the formation of gasification products under the process conditions begins on the surface of a particle and, as the carbon is removed, the gas evolution front moves inward, exposing the mineral framework. This is indicated by the change in the relief and structure of the particle surface during the process.

The study of the solid residue gasification was carried out by raster electron microscopy using a scanning electron microscope JEOLJSM6390 $EM with a console for the microanalysis JED 2300.

One of the main areas of application of the research results can be the creation of an original technology for the biomass processing in mobile gasification reactors on a high-temperature superheated steam of atmospheric pressure in order to produce high-calorific fuel, synthesis gas, synthetic liquid fuels and coke. There was constructed a model and was developed a methodology for calculating the technological process of steam biomass gasification of the enterprises using the example of a continuous countercurrent gasifier. At an initial vapor temperature less than 300°C the problem of inert heating has an analytical solution. As a result of the numerical calculation there was developed a methodology for determining the optimal parameters for the biomass gasification process in a model of a countercurrent layered gasifier of 50 kW on two optimality criteria: the highest calorific value of the product gas and the degree of conversion of the organic part not less than 99%. The change of the relief and structure of the particle surface during the process, the result of the analysis of the particles composition after gasification allows to state that with the use of the proposed method of slurry processing almost complete conversion of carbon can be achieved, which is difficult to achieve even in gasification processes. In the educational process for students under the direction "5B070200-Automation and Control" the section "Automation of Biomass Gasification Processes" is presented taking into account the results obtained in this research work.

There was developed a physico-mathematical model of the biomass gasification process in an experimental horizontal reactor.

Approbation of work. The main provisions and results of the work were reported and discussed: at the International Satpaev Readings "Competitiveness of Engineering Science and Education" dedicated to the 25th anniversary of independence of the Republic of Kazakhstan, 2016, International Scientific and Practical Conference "Information and Telecommunication Technologies: Education, Science, Practice" Almaty city, Kazakhstan, December 3-4, 2015, All-Russian scientific-practical conference (with international participation) December 5, 2014, Neftekamsk, the Republic of Bashkortostan, International scientific and practical conference "Innovative technologies in the construction industry" (Almaty, KazGASA, 2014), International scientific - practical conference "actual problems and prospects of development, modernization and energy efficiency"

2013. Materials of the iv international conference 'global science and innovation', 12-13march, USA, Chicago. 2015.

Publications. On the theme of the dissertation work there were published 17 printed works, including 5 articles in journals recommended by the Committee of the CSES, 7 reports at the International Conferences, 2 articles in the database (Scopus), 3 articles in the database (Tomson).