Combined environmentally friendly technology for recycling of coal-water slurries in coal mining

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Abstract. The article shows that coal mining enterprises has environmental problems and energy losses in recycling process. Expediency of heat sources use in order to protect the environment and increasing the efficiency of secondary energy sources use is described in the research. The ways of recycling energy sources in processing plants, as well as prospects for the improvement of modern power plants are investigated. The methods of recycling are presented in the article. The technology of co-combustion of coal-water slurry and biogas is described and developed. It is one of the proposed solutions for recycling of used dispersed materials at processing plants. The results of cluster analysis in determining the basic fossil fuels for the developed installation are given. The prospects for industry development are shown. These prospects are based on the recovery methods at coal preparation plants.

1. Introduction

An extracted coal is the most important product for the modern enterprises. However, while receiving energy by fuel combustion, enterprises negatively affect the environment and exceed the permissible pollution limits. That points to the necessity of secondary energy sources, which allow reducing emissions, as well as increasing power plant efficiency and reducing fuel consumption. This article proposes to consider the option of two types of fuel combustion. M. Lauer and others show economic assessment of power generation from biogas in the article [1]. Use and development of new improved installations for the recycling of power plants are described in the same article [1]. Implementation of recycling projects in the future power plants is an opportunity for development of power energy industry in Russia.

2. Statement of the problem

The calculation of efficiency allows assessing the prospects for the development of energy industry and the environmental protection against emissions. Therefore, the aim of this work is to analyze the methods of waste recovery at processing plants and the development of an energy-efficient method of waste recovery. Researchers, like as S. Gao, C. Bo wrote about water cleanup under the biogas-induced pressure [2]. The practical significance of the idea is to increase the efficiency of a thermal power plant and to improve the environmental situation.

3. Waste recovery at processing plants

The mineral products are used in industrial manufacturing. The one should admit that deep-seated mineral deposits come with high ore costs. Waste recovery or recycling at mining and processing plants is the solution to this problem. The procedure of primary processing is to manufacture secondary

products used as a secondary source of energy or completely recycled. Another problem in this field is low efficiency of using materials. In addition, wastes can be separated and disposed in case of inexpedience of recycling. E. Murko, V. Kalashnikov wrote about slag dehydration [3]. Nowadays, the secondary processing of the materials and its use as the secondary source to get the raw materials needed for construction companies are essential. For example, M. R. Konduri, P. Fatehi described the properties of coal-water slurry obtained from these wastes in their article [4].

4. Evaluation of waste recovery methods at processing plants

The remaining solid is meant to be raw materials for the production of construction materials. With the growth of recycling proposals, the efficiency of waste recovery is increasing. That problem is shown in research of A.V. Minakov, A.A. Shebeleva [5]. The negative impact on the environment will decrease significantly. There is an increased amount of toxic elements in the storehouses of some processing plants and those elements can badly influence human health. However, with significant production volumes, the level of recycling still remains low. This leads to the idea of creating a more promising waste management system. Analysis of the structure of the flow of coal-water fuel was given in the articles by A.V. Zenkov, M. Kurgankina [6, 7]. Thus, the best option from the point of view of ecology, economics and expediency of the resource use is to increase the number of efficient installations in processing plants. G.S. Nyashina, K.Y. Vershinina, N.E. Shlegel and others wrote in detail about this decision [8].

5. The waste storage problem

The waste recovery level remains low while waste volumes are significant. That is connected with an increasing waste volumes and their placement within one or more storehouse and their capacity is limited. This method of storing raw materials significantly affects the environment. The problems created are the air pollution with dust, the ingress of minerals into the soil and the impact on the health of population. However, there is a way to get rid of these problems. For example, the suggested method of waste recovery at coal processing plants and agricultural complexes by burning water-coal fuel and biogas received from installations. B. Mohseni-Gharyehsafa and others wrote about the thermodynamic properties and economical evaluation of biogas [9, 10]. The article about biological innovations by M. Tabatabaei, M. Aghbashlo and others [11] is well known. The process scheme of water and steam heating using the technology of co-combustion is shown in the Figures 1, 2.

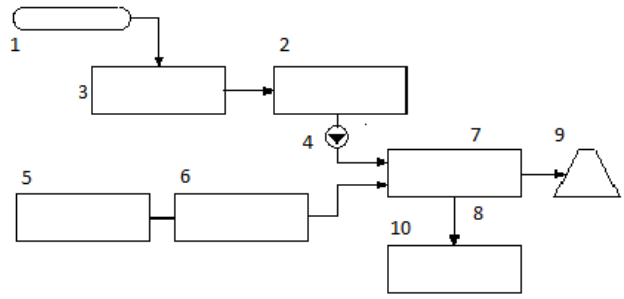

Figure 1. The process scheme of co-combustion of coal-water slurry and biogas in a boiler: 1 – conveyor; 2 – coal-water slurry producing unit; 3 – secondary raw material source; 4 – pulp pump; 5 – agricultural complex; 6 – biogas production unit; 7 – boiler unit; 8 – heat network; 9 – cooling tower; 10 – heat consumer

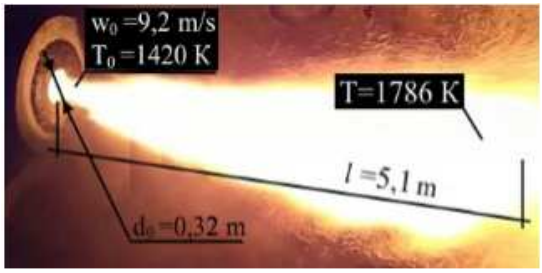

Figure 2. Experimental study co-combustion of coal-water slurry and biogas in a boiler

The concept of heating water and steam in a boiler unit is in co-combustion of two types of fuel. In the first case, it is a unit for the production of coal-water slurry from wastes received from coal processing plants. H.-Y. Lu, X.-F. Li, C.-Q. Zhang and others wrote about using coal slurry [12]. Y.

Zhang, H. Wang, K. V. Osintsev, K. Vershinina and others [13–15] wrote about preparation of coal-water slurry.

In the second case, it is a unit for biogas production in the processing of secondary materials of the agricultural complex. K.B. Prajapati and R. Singh wrote about improvement of biogas using [16]. The combustion process takes place with air supply. Biomass-based gas use in Swedish iron and steel industry is supplied from process integration. That is shown in the article of C. M. Nwachukwu and others [17]. A. Can studied the statistical modeling of potential biogas production capacity from solid waste disposal sites in Turkey [18].

Nowadays, the technology use is critical in some power engineering systems. For example, new technologies can improve existing wastewater treatment systems as well as micro algal biogas processing units. Hegab, Akker and others wrote about domestic wastewater treatment [19]. I. Wiesberg, J. Pinto and others [20] wrote about processing of micro algal biogas.

6. Methodology of research investigation. Cluster analysis

The applied method implements a hierarchical agglomerate algorithm. Before starting clustering, all objects are considered as separate clusters, which are combined in the course of the algorithm. At first, N objects are taken and distances are computed in pairs. Then let us select a pair of objects that are closest to each other. These objects are combined into one cluster. As a result, the number of clusters becomes equal to N-1. More details about cluster analysis in paper of K. V. Osintsev, I. S. Prikhodko, T. A. Pshenitsyna [21].

7. Scientific novelty

This technology innovation is to improve the technology of modern use of resources. The significance of the environmental factor in the country's metallurgical regions is shown in terms of this idea. This unit includes a number of facilities for processing wastes in the heat power system. The method guarantees an increase in the ecological level and an increase in the efficiency of industrial enterprises. That will not only protect the health of the citizens, but also will improve the results in the economy of the country.

8. Practical significance. Experimental study

Such kind of development will play a significant role in the future, as the efficiency of the enterprise will increase. Heated water can be supplied to heat supply areas through heating networks. The advantage of this method is the serious cost savings of enterprises, despite the costs of additional installation construction. J. P. Singh, S. Kumar, S. K. Mohapatra wrote about that [22]. Thanks to this technology, the necessary amount of additional energy will be obtained at the minimum costs through the processing of secondary resources.

The implementation of new waste recycling installation is possible even in the territory of the plant itself. This processing structure will give the possibility to observe the process of successful development of the country's energy sector and enterprises in general. In addition, the data are given when burning coal with a heat of combustion of 27,820 kJ / kg. Analysis of the calculated and experimental data showed a discrepancy between them of 4-5%, which could be explained by some error in conducting experiments at high temperatures in boiler installations, for example, re-radiation and high dust plume in the combustion space [23, 24].

9. Conclusion

The undertaken research study has shown that the use of wastes as a potential energy source is a really effective way in terms of industrial development, as well as the energy and economic level of the country in general. The highest efficiency will be obtained with the complete waste recovery at coal processing plants. Furthermore, researchers showed that in case of co-combustion could use woody pellets with dispersed materials [25, 26]. Forecasting of using materials in coal mining and combustion is shown in

some research [27–29]. In total, development of dispersed materials is necessary in cases aimed at achievement of high efficiency.

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References
[1] Lauer M, Leprich U and Thrän D 2020 Economic assessment of flexible power generation from biogas plants in Germany's future electricity system *Renewable Energy* **146** 1471-1485
[2] Gao S, Bo C, Li J, Niu C and Lu X 2020 Multi-objective optimization and dynamic control of biogas pressurized water scrubbing process *Renewable Energy* **147** 2335-2344
[3] Murko E, Kalashnikov V, Gorbachev A and Mukhomedzyanov I 2019 Using of shell filtering constructions for concentrating plant's coal slurry dewatering *E3S* **105** 02029
[4] Konduri M and Fatehi P 2019 Alteration in interfacial properties and stability of coal water slurry by lignosulfonate *Powder Technology* **356** 920-929
[5] Minakov A, Shebeleva A, Strizhak P, Chernetskiy M and Volkov R 2019 Study of the Weber number impact on secondary breakup of droplets of coal water slurries containing petrochemicals *Fuel* **254** 115606
[6] Zenkov A, Gvozdyakov D and Gubin V 2019 Analysis of coal-water fuel flow structure in the process of coaxial spraying *AIP* **2135** 020064
[7] Kurgankina M, Nyashina G and Strizhak P 2018 Advantages of switching coal-burning power plants to coal-water slurries containing petrochemicals *Applied Thermal Engineering* **147** 998-1008
[8] Nyashina G, Vershinina K, Shlegel N and Strizhak P 2019 Effective incineration of fuel-waste slurries from several related industries *Environmental Research* **176** 108559
[9] Farzaneh-Gord M, Mohseni-Gharyehsafa B, Arabkoohsar A, Ahmadi M and Sheremet M 2020 Precise prediction of biogas thermodynamic properties by using ANN algorithm *Renewable Energy* **147** 179-191
[10] Kang J, Kang D, Kim T and Hur K 2014 Economic evaluation of biogas and natural gas co-firing in gas turbine combined heat and power systems *Applied Thermal Engineering* **70** 723-731
[11] Tabatabaei M, Aghbashlo M, Valijanian E, Nizami A, Ghanavati H, Sulaiman A and Karimi K 2018 Biogas production systems *Biofuel and Biorefinery Technologies* **6** 1204-1220
[12] Lu H, Li X, Zhang C, Li W and Xu D 2019 β-Cyclodextrin grafted on alkali lignin as a dispersant for coal water slurry *Energy sources, part A: recovery, utilization and environmental effects* **41** 1716-1724
[13] Yu Y, Liu J and Cen K 2014 Properties of coal water slurry prepared with the solid and liquid products of hydrothermal dewatering of brown coal *Industrial and Engineering Chemistry Research* **53** 4511-4517
[14] Zhao Z, Wang R, Ge L, Wu J, Yin Q and Wang C 2019 Energy utilization of coal-coking wastes via coal slurry preparation: the characteristics of slurrying, combustion, and pollutant emission *Energy* **168** 609-618
[15] Vershinina K, Glushkov D and Strizhak P 2017 Characteristics of the ignition of the drops of organic coal-water fuels based on waste oils and industrial oils *Solid Fuel Chemistry* **51** 188-194
[16] Prajapati K and Singh R 2020 Enhancement of biogas production in bio-electrochemical digester from agricultural waste mixed with wastewater *Renewable Energy* **146** 460-468
[17] Nwachukwu C, Toffolo A and Wetterlund E 2020 Biomass-based gas use in Swedish iron and steel industry: supply chain and process integration considerations *Renewable Energy* **146** 2797-2811
[18] Can A 2020 The statistical modeling of potential biogas production capacity from solid waste disposal sites in Turkey *Journal of Cleaner Production* **243** 118501

[19] Hegab H, Akker B, Ginic-Markovic M and Saint C 2018 Innovative graphene microbial platforms for domestic wastewater treatment *Reviews in Environmental Science and BioTechnology* **17** 147-158
[20] Brigagao G, Wiesberg I and Pinto J 2019 Upstream and downstream processing of microalgal biogas: Emissions, energy and economic performances under carbon taxation *Renewable and Sustainable Energy Reviews* **112** 508-520
[21] Osintsev K, Prikhodko I and Pshenitsyna T 2018 Choice of Chelyabinsk and Kuznetsk coals as main fuel for steam generator PK-14 using elements of cluster analysis *IOP Conference Series: Earth and Environmental Science* **194** 052018
[22] Singh J, Kumar S and Mohapatra S 2019 Experimental design-based analysis on process parameters for head loss in pipe bend *Journal of Process Mechanical Engineering* **233** 1151-1161
[23] Toropov E V, Osintsev K V and Aliukov S V 2018 Analysis of the calculated and experimental dependencies of the combustion of coal dust on the basis of a new methodological base of theoretical studies of heat exchange processes *International Journal of Heat and Technology* **36(4)** 1240–1248
[24] Guo J, Yan H, Liu Y and Li S 2019 Preventing spontaneous combustion of coal from damaging ecological environment based on thermogravimetric analysis *Applied Ecology and Environmental Research* **17(4)** 9051-9064
[25] Miranda T, Roman S, Montero I, Nogales-Delgado S, Arranz J, Rojas C and Gonzalez J 2012 Study of the emissions and kinetic parameters during combustion of grape pomace: Dilution as an effective way to reduce pollution *Fuel Processing Technology* **103** 160-165
[26] Saidur R, Abdelaziz E, Demirbas A, Hossain M and Mekhilef S 2011 A review on biomass as a fuel for boilers *Renewable and Sustainable Energy Reviews* **15(5)** 2262-2289
[27] Boman C, Nordin A and Thaning L 2003 Effects of increased biomass pellet combustion on ambient air quality in residential areas - A parametric dispersion modeling study *Biomass and Bioenergy* **24(6)** 465-474
[28] Nussbaumer T 2003 Combustion and co-combustion of biomass: fundamentals, technologies, and primary measures for emission reduction *Energy and Fuels* **17(6)** 1510-1521
[29] Qiu G 2013 Testing of flue gas emissions of a biomass pellet boiler and abatement of particle emissions *Renewable Energy* **50** 94-102