DOI *10.18454/PMI.2016.4.538*

УДК 662.8.052

COAL-PEAT COMPOSITIONS FOR CO-COMBUSTION IN LOCAL BOILERS

A.V.MIKHAILOV
Saint-Petersburg Mining University, *Russia*

In article results of experiments on creation of coal and peat fuel compositions for burning in solid-fuel boilers are described. The main objective of research consisted in development of combination of coal dust and natural peat without binding additives. The role of peat consists that it increases efficiency of process of granulation, being natural binding. The method of granulation allows to utilize waste of the coal industry. Joint burning of two types of fuel – coal dust and peat reduces emission of sulfur dioxides. The cost of peat raw materials is lower, than artificial binding, applied to briquetting of coal dust. The composition of mix of coal dust and peat varied in the ratio 2:1, 1:1 and 1:2 in volume ratio at humidity of mix before extrusion of 65 %. In the course of preparatory operations of coal raw materials its crushing and sifting through sieve of 24 mesh (0,707 mm) was carried out. Procedure of hashing of samples of coal and peat was carried out before receiving homogeneous mixture. After hashing mix was located in piston press for receiving granules. Coal dust and wet peat pass semifixed extrusion on piston press with formation of cylindrical granules with a diameter of 16 mm. After extrusion of granule are dried to operational humidity of 25 %. Coal and peat fuel granules showed sufficient mechanical strength for transportation and power feed in solid-fuel boilers. Burning of coal and peat fuel granules in vitro at temperature of 800 °C does not lead to ashes agglomeration. The conducted preliminary researches showed prospects of utilization of coal waste by granulation method in mix with natural peat.

Key words: coal fines, peat fuel, mixing, pelletizing, granular product.

***How to cite this article*:** Mikhailov A.V. Coal-peat compositions for co-combustion in local boilers. Zapiski Gornogo instituta. 2016. Vol.220, p.538-544. DOI 10.18454/PMI.2016.4.538

Introduction. Fuel balance development of the distributed power in the Russian Federation, it is necessary to consider need of local fuel wide use. Peat can be regarded as a slowly renewable biomass and carbon neutral fuel [13, 15].

Besides, analytical tests show that peat deposits, which can potentially fuel several existing power plants have low sulphur and ash content, and virtually no mercury [1, 13]. Accordingly, the co-firing can also reduce emissions of SO_2, particulates and mercury. Co-firing peat can reduce CO_2 emission from existing coal-fired power plants and local boilers.

Peat is generally regarded as a low quality fuel source because of its high water content in addition to lower fuel efficiency. On average, peat contain up to about 80 % moisture by weight, which causes a substantial percentage of the energy produced by these peat being used to dry them prior to full combustion. Compared with some low rank coal such as lignite, peat contains higher carbon contents, lower sulfur contents, and virtually no mercury [10, 7].

Peat fuel has an energy-content similar to lignite coal, which makes it a potential alternative fuel to coal for power generation in existing coal-fired boilers through co-firing. Minor engineering retrofit is needed for combustor system when co-firing peat and coal [14].

Coal material handling, crushing operations, air tables, drying, and storage is by far the most polluting in terms of emissions, releasing high levels of coal fines and dust. In coal mining processing and handling, enormous tonnages of coal fines are created. Coal fines whether cleaned or reclaimed from waste ponds, are typically in the form of a wet cake that is difficult to handle, store and transport [4].

Typically, after handling and cleaning is completed, about fifteen to twenty percent of the tonnage mined consists of fines ranging in size from powder to small granules. For the most part, these fines are not directly usable, thereby leaving great quantities of material that is wasted and represents a hazardous and expensive disposal problem. Accordingly, coal-fines handling, storage and disposal operations represent a significant and unproductive expense for the industry.

Even when blended with cleaned coarse coal product, the fines can cause plugging in chutes and hang-ups in transport systems. If stored in piles, contamination of water runoff is possible. Thermal drying of fines is prohibitively expensive, and the product can create a dust problem or even an explosion hazard. Perhaps of greater significance is the loss of fines that may occur during rail transport, and the resulting environmental damage that affects areas near these transport systems. One solution

DOI 10.18454/PMI.2016.4.538

to problems associated with coal fines is reconstitution via granulation. It has been shown that binders such as corn starch, lignosulfonates, asphalt emulsions, and lignocellulosics, can be employed to produce a strong and durable final product [3]. Granulation is a method to utilize coal fines, as a byproduct of mining, to decrease loss of this energy source [6].

The granulation improves such important physico-mechanical parameters of any disperse product as flowability, decrease in dusting and caking due to giving to particles of a form and the necessary size. The granulation is applied practically in all industries. The received granules from powdered fractions can be utilized effectively by burning methods.

As a result of these problems, as well as of strict customer demands with respect of coal quality and of increasingly stringent regulation of mine waste disposal practices to satisfy environmental standards, coal fines utilization has been recently reexamined by the industry. In the past, fines have been used mostly for manufacturing briquettes for home and commercial heating. Coal briquetting technology focused on low pressure agglomeration of coal fines, using a binder, typically of coal tar origin, to hold individual particles together. The fines material containing between about twenty and thirty percent moisture, depending upon its size distribution and ash content. In a dry state, the fines are generally predominantly passable through a 28-mesh screen, a size that may be used for pelletizing or briquetting purposes. As used in this disclosure, the terms pellet, briquette, log and block are used interchangeably and are intended to refer to all forms of pellets, briquettes, logs, blocks and other coal agglomerates produced by binding coal fines into a concrete material [5].

However, most binders studied to date significantly increase the cost of coal reconstitution, thus limiting the use of this technology. Therefore, a low-cost, or even negative cost, binder and pelletization process is needed [17]. The positive properties of the granules, such as stability during transport, high bulk density, low dust formation etc., at minimum costs for process. On the other hand, peat derived from peat deposit is using as a local fuel [9].

It is economically attractive to use peat in the existing power plants by co-firing. Peat is particularly interesting due to its excellent binding properties, which makes a combination with all materials possible. The primary goal of this report is the development of the combination of coal fines with peat without additives and binders for producing a more stable and cohesive granules. Another objective is a peat that to reduce the emission of sulfur dioxide during the coal peat fuel combustion and increasing the efficiency of the pelletizing process. Finally, an objective of the report is a peat that can be produce inexpensively. Therefore, according to these and other objectives, the present report consists of the combination of coal fines with peat. The coal fines with peat are mix and the resulting well mixed mass is then pelletizing by the application of pressure in conventional equipment – stiff extrusion. The coal fines and peat was conditioned at various moisture contents to observe the effects on the finished product. The material then agglomerated into a granular product.

Materials and methods. Materials used in the research were low-caking coal taken from Kuzbass and peat that used as binder were found in Karelia Republic. Peat decomposition degree is H4 on the von Post scale. Why peat used as a binder is supported by the fact that peat contains a bitumen's and humus that is possible to act as the binder, besides, the peat itself is renewable energy source. Generally, peat has proximate analysis of 70 % volatile matter and 57 % fixed carbon (moisture free and ash free basis), whereas low-caking coal has 84 % fixed carbon and Just 40 % volatile matter. The proximate and ultimate analyses of these two fuels are given in Table 1.

Table 1

Characteristics of the coal and peat

Sample	Calorific value, kJ/kg	Moisture, %	Volatile matter, %	Ash, %	Elemental analysis, %				
					C	H	N	O	S
Low-caking coal	23.4	10.2	40.9	16.3	84.6	5.1	2.1	8.2	0.60
Grass moss peat	12.8	76.2	70.0	6.5	57.4	6.0	1.4	35.1	0.14

Study was performed at the following conditions. Product coal/peat graniles have a cylindrical form with diameter 16 mm and height 25 mm, extrusion pressure was 40 MPa. In experiments on the

DOI 10.18454/PMI.2016.4.538

piston press force of replacement of weight was registered as function of time and movement of the piston. The test of replacement lasted 10 seconds for steady formation. Ratios of the coal/peat was 1:2; 1:1 and 2:1 (V/V).

The peat sample was thoroughly mixed by hand and placed in a plastic bag for granulating experiments. After preliminary separation were removed large wood inclusions from peat samples. Preliminary dewatering of peat was carried out on a fabric filter press. The separated and dehydrated peat were subjected to mechanical processing – attrition. Attrition of peat raw materials is carried out for the purpose of preliminary mechanical processing on laboratory chopper for a further extrusion.

In the raw material preparation step, coal was crushed and sieved with passing the sample through a 24-mesh sieve (0.707 mm) a size that may be used for pelletizing purposes. The procedure begins with passing the sample through a 24-mesh sieve (0.707 mm) and then mixing the minus 20 mesh material with peat for produce homogenous mixture. After stirred the mixture then put into the piston press to produce the granules. Figure 1 presents the steps of the granules preparation.

Stiff extrusion technology for coal waste recycling combines high torque and high pressure to process coal fines with low moisture content, requiring no additives and fewer processing steps.

Extrusion of coal-peat mix was carry out on a piston press with a diameter of 32 mm and 300 mm long, established by universal Zwick/Roell Z100 Machine. Breakdown of mix via dies with a length of calibrating part of 60 mm and with a diameter of 15 mm at a speed of 0.0125 m/s and ambient temperature +20 °C. The experimental installation is submitted in figure 2.

Experiment on drying of granules was make on experimental drying installation in a motionless layer with a constant speed and air temperature (+35 °C) with an atmospheric pressure. Air in a drying chamber moved an electric fan heater.

The drying chamber 300 mm high and with a diameter of 85 mm was also isolated 10 mm by a layer of mineral wool and wrapped up by aluminum foil, for elimination of radial temperature gradients. Air temperature in a drying chamber was taken by the thermometer with an accuracy of ±1 °C. Experiments on drying were made at relative humidity of air of 30% and atmospheric pressure of 758 mm of mercury column and temperature of air of +23 °C.

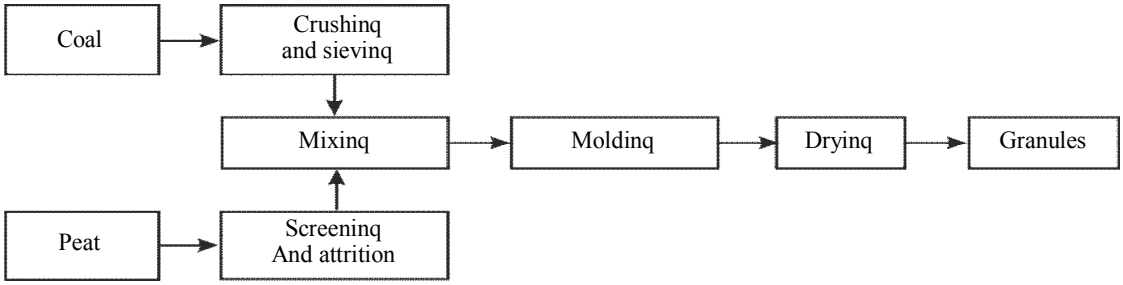


Fig.1 Steps of granules preparation

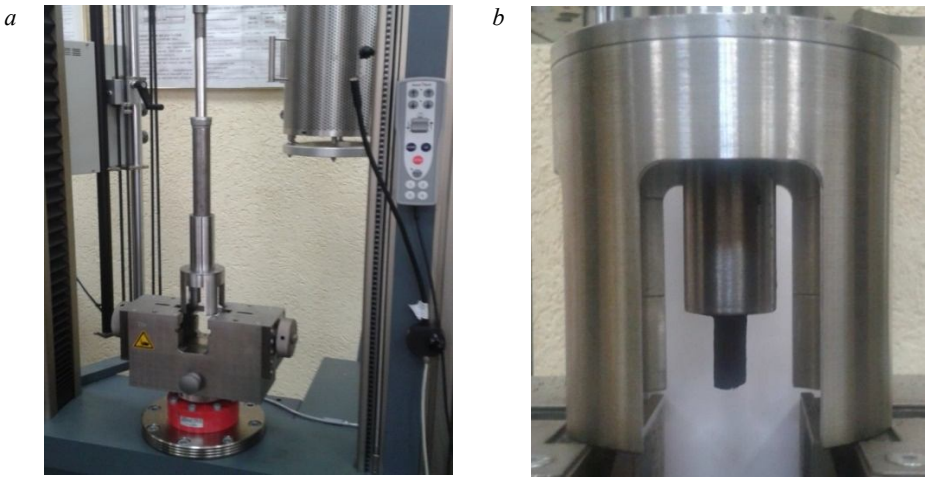


Fig.2. Experimental installation on universal Zwick/Roell Z100 machine (*a*) and granulation process (*b*)

DOI 10.18454/PMI.2016.4.538

Damp granules kept within the cartridge, which was suspended in a drying chamber at the height of 100 mm from an output nozzle of a fan heater. The area of the cartridge is 0.08 m^2.

The mass of granules before drying, and also the mass of container decided on laboratory scales of VLKT-500 on accuracy ± 0.01 g.

Mechanical tests of composite fuel samples provided determination of strength at monoaxial compression. Determination of samples strength were made by universal test equipment Zwick/Roell Z100 at a speed of compression of 0.1 m/min. Tests on a mechanical durability (DU) included measurement of a mechanical durability at tenfold dropping a sample from height of 2 m on a concrete floor.



Fig.3. Experimental coal/peat granules (moisture content 25 %)

Fixation of the loading operating on a sample and the deformation arising thus was carried out in the automatic mode. At an assessment of physic mechanical properties of granules determined the sizes, density, durability in accordance with Russian Standard GOST 54248-2010.

Results. The final goal is to conclude, on qualitative basis, which pre-treatment options for coal dust are the most promising with regard to co-firing with peat as a binder. Based on the theory of binding, binding force is the sum of physical and mechanical binding mostly is the mechanical binding, also the results of mechanical combination when the binder comes into the internal void of the binding substance [2]. Peat as a binder is to use such ways to process natural high polymer organic compound raw material. Peat is with the property of high surface activity lowered tension strong capability of dispersion.

Fine colloidal particles of peat promotes process of granules consolidation. From factors of group composition of peat, the humic acids (HA) and the highly hydrolyzable (HH) have the greatest impact on strength of granules (Fig.3).

In the process, a mixture of peat and coal is extruded into pellets, which are dried and cured to a durable form. The key element in the process is peat that is composed of bitumens humus, cellulose fiber and lignins.

These components give peat special characteristics for binding materials. Components of organic matter of peat, %: bitumens – 7.3; water soluble matter, easily hydrolyzed matter – 33.7; humic acids – 26.1; fulvic acids – 16.3; cellulose – 6.2; lignin – 9.2.

The presence of peat natural binders decrease sulfur and residual ash of granules, while they make a negligible decrease in calorific value. Advantages of peat-based materials include low sulfur content, and lower NOx production.

The main functional components in humic substances, including bitumens, humic acids and fulvic acids, could provide sufficient strength for the wet and dry granules [18]. Content of humic acids is higher than 15 % and bitumens more than 3-4 % increase the inhibiting and consolidating abilities of peat binding. Strengthening of rheological, structural and mechanical properties of mix is observed.

The jointing and density which in turn depend on extent of mechanical processing of material, and also technological indicators of processes of formation and drying has essential impact on strength properties of fuel granules. Table 2 shows the parameters of cylindrical granules.

Table 2

Parameters of cylindrical composition granules

Sample coal:peat (volume)	Average (wet granules)					Average (dry granules)					
	diameter, mm	length, mm	volume, $m^3 \cdot 10^{-6}$	moisture, %	mass, g	diameter, mm	length, mm	mass, g	volume, $m^3 \cdot 10^{-6}$	density, kg/m^3	shrinkage, %
2:1	16.0	25.0	5.026	34,4	6.14	15.5	24.0	4.18	4.54	922	9.73
1:1	16.0	25.0	5.026	49,7	7.24	14.9	22.8	3.23	3.98	812	20.81
1:2	16.0	25.0	5.026	60,5	8.14	14.3	20.3	2.48	3.26	761	35.07

DOI 10.18454/PMI.2016.4.538

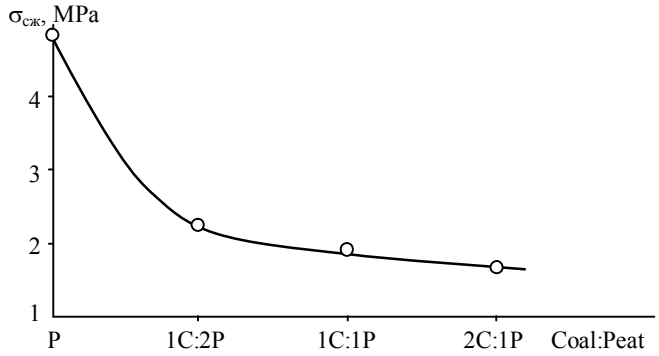


Fig.4. Coal/peat granules ultimate crushing strength

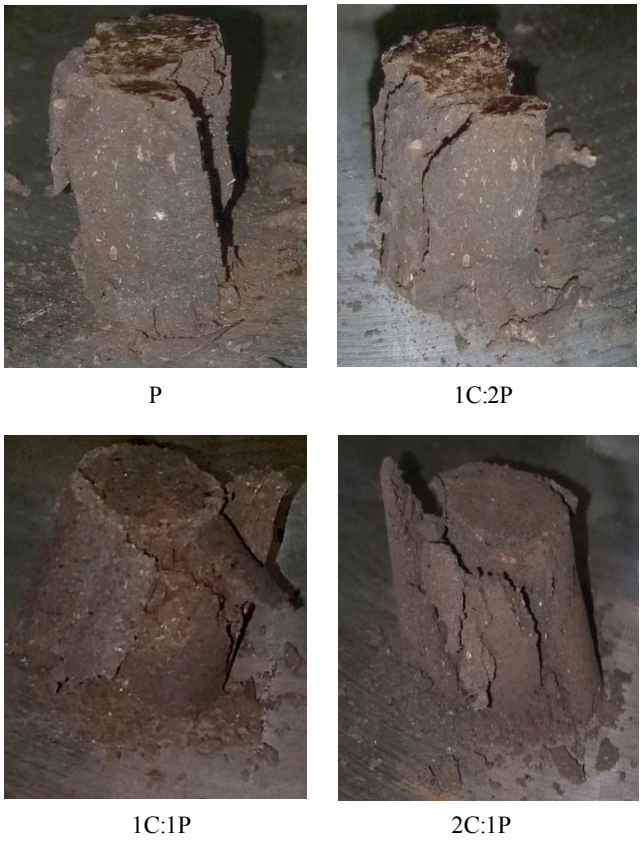


Fig.5. Splitting of fuel samples at uniaxial compression

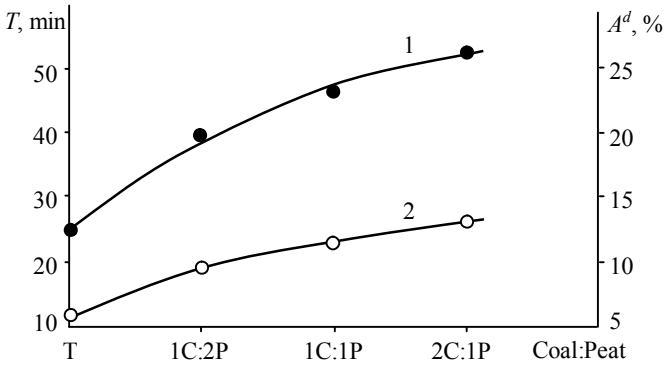


Fig.6. Coal/peat granules burning time (1) and ash content after burning (2)

The organic functional components in peat are chemically adsorbed onto surfaces of coal particles so that the granules strength is improved.

A suite of tests, which showed, characterized these granules:

• Researches showed that, coal-peat granules have sufficient mechanical durability. In a dry state strength on compression changes from 1.15-1.63 MPa. The limit durability at compression decreases with increase in amount of coal dust in final mix (Fig. 4, 5).

• Designation for mechanical durability (DU) of granules were make, when granules could be dropped from a height of 2.0 m on a concrete floor and survive. The mechanical durability of cylindrical granules made 96.5 % [8]. For normal pellets DU95.0 ≥ 95.0 % [11].

Granulated fuel conversion and ash formation is tested in a laboratory stove SNOL 7.2/1100 at a temperature of 800 °C. Co-firing of the coal/peat blends resulted in the low relative ash deposition rate (RDA) and melting points [12].

The compositions of the ashes are generally similar, but the peat contains relatively lower contents of SiO_2 and Al_2O_3, and higher concentrations of CaO and MgO [12]. The ash deposition rate in co-firing the coal and peat decreases with increasing fraction of the peat (Fig.6). This can lead to decreased ash cleaning and removal requirements.

Direct co-firing involves firing the coal and peat in the same boiler. This is the simplest and most widely applied technology for co-firing. As all the constituents of the peat enter the coal boiler, several technical issues arise depending on the boiler type. Direct co-firing has been undertaken in stoker boilers (Fig.7).

In a stoker – or grate-fired boiler, the fuel is fed onto a continuously moving grate while air is blown through the bed of fuel. The two main types of grate are the chain or travelling grate or a vibrating, inclined grate. The smaller particles burn in suspension above the grate while the larger particles burn on the grate as the fuel moves from the back to the front of the boiler. Stoker boilers are capable of firing a wide range of fuels including fairly large pieces, though generally less than 3 cm in length. Stoker boilers are restricted to a maximum capacity of about 20 MWe. Stoker boilers are capable of firing a wide range of

DOI 10.18454/PMI.2016.4.538

fuels including coal, wood, waste fuels, peat. The boiler can be designed to fire even fairly moist fuels of varying sizes but not with too much dust. [16].

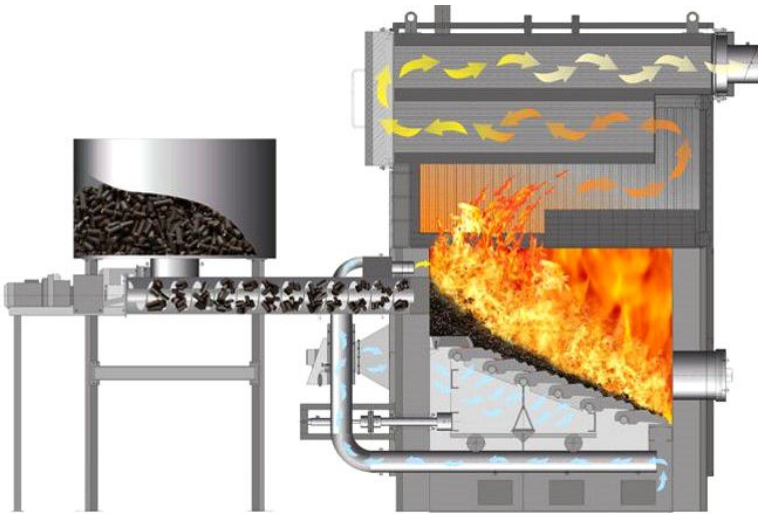


Fig.7. Combustion of the granulated fuel in layered fire chamber with an inclined pushing grid-iron lattice

Conclusion. This research focused on the evaluation the feasibility of coal fines with peat granulation. Fuel granules were prepared using coal and peat, as main components. The complex researches showed a possibility of receiving the granulated fuel compositions by an extrusion method. The results showed that the best composition and process condition to achieve high physical stability of granules would be coal to peat content ratio 1/1. The organic functional components in peat are chemically adsorbed onto surfaces of coal particles so that the granules strength is improved. Mechanical durability decreases with increase in amount of coal dust in final mix. Increase in amount of coal dust in composition allows to increase fuel burning time.

The granulated composition of two types of fuel: coal dust and peat provides burning in in layered fire chamber with an inclined pushing grid-iron lattice. Coal and peat granules have sufficient mechanical durability for transportation and mechanical giving in a boiler. Burning of coal-peat compositions does not lead to ashes agglomeration.

The commercialization of pelletizing technology that incorporates coal fines should sufficiently prove the economics and emissions reduction potential of coal/peat fuels to justify continued research into alternative pelletized fuel feedstocks such as peat. The equipment and the technology of the stiff-extrusion make it possible to produce the extrusion granules having high strength.

Thus, the conducted preliminary researches showed prospects of coal fines with peat granulation method. Further study is being undertaken to analyze coal/peat granules in an evaluating the combustion and emissions of coal/peat granules tests and of the water resistance defined as the time required for fuel destruction and dispersion in the water medium.

REFERENCES

1. Biopact. Canadian researchers study co-firing of peat and biomass with coal. URL:http://news.mongabay.com/bioenergy/2007/12/canadian-researchers-study-co-firingof.html (accessed on April 2016).

2. Briquette Binder Products. URL:http://www.humicacidcn.com/ PRODUCTS/ ShowArticle.asp ArticleID=71 (accessed on April 2016).

3. *Conkle H.N.* et al. Pelletizing/Reslurrying as a Means of Distributing and Firing Clean Coal. Proceeding from the Eighth Annual Coal Preparation Utilization, and Environmental Control Contractors Conference. July 27-30. 1992.

4. *Cooper M.* et al. Research and Development for Storage, Transport and Handling of Coal-Based Fuels, Proceedings of the Sixth Annual Coal Preparation. Utilization and Environmental Control Contractors Conference. August 6-9. 1990, p.26-34.

5. *Donald H.* White, Pelletizing and briquetting of coal fines using binders produced by liquefaction of biomass. U.S. Patent 5916826 A. June 29. 1999.

6. *Gholipour Zanjani N.*, *Zarringhalam Moghaddam A.*, *Dorosti S.* Physical and chemical properties of coal briquettes from biomass-bituminous blends. Petroleum & Coal. 2014. 56(2), p.188-195.

7. *Hupa M.* Interaction of fuels in co-firing in FBC. Fuel; 2005. 84, p 312-1319.

8. *John T. Kelly*, *George Miller*, *Mehdi Namazian*. A Low Cost and High Quality Solid Fuel From Biomass and Coal Fines. Final Report DOE Contract No. DE-AC26-99FT40157. July 2001. URL:http://www.osti.gov/scitech/servlets/purl/795777 (accessed on April 2016).

9. *Mikhailov A.*, *Bolshunov A.*, *Kremcheev E.*, *Epifantsev K.* Requirements to peat raw materials for production of granulating fuel. Mining Informational and Analytical Bulletin. Vol.4, 2012. p.59-63.

10. *Orjala M.*, *Ingalsuo R.* Sulphur dioxide reduction in co-firing of peat and wood in fluidized bed boilers. 5th International Conference on Technologies and Combustion for a Clean Environment. 1990. Is.12(15), p.685-689.

11. Quality guidelines for fuel peat: fuel classification and quality assurance, sampling and analysis of properties. NT Envir. 009, Nordic Innovation Centre, Approved 2005-11, p.24.

DOI *10.18454/PMI.2016.4.538*

12. *Shao Yuanyuan*. Investigation of Ash Deposition During Co-Firing Biomass/Peat with Coal in a Pilot-Scale Fluidized-Bed Reactor. Electronic Thesis and Dissertation Repository. 2011, p.108.

13. *Sudol S.* Peat Fuel – A Clean Solution to Northwestern Ontario's Energy Crisis. INORD Commentary. 2005. http://inord.laurentian.ca/commentaries.htm. (accessed on April 2016).

14. *Telford P.G*. Peat fuel – a sustainable bioenergy resource. IASTED International Conference Environmental Management and Engineering (EME 2009), Banff, Canada, July 7-8, 2009, p.6-10.

15. *Theis M*., *Skrifvars B.J*., *Hupa M*., *Tran H*. Fouling tendency of ash resulting from burning mixtures of biofuels. Part 1. Deposition rates. Fuel. 2006. 85(7-8), p.1125-1130.

16. *Van Loo S*, *Koppejan J*. Handbook of biomass combustion and co-firing. London, UK, Earthscan, 2008, p.442.

17. *Woodworth R*., *Kelly J*., *Namazian M*., *Miller G*. Biobinder process for reconstitution of fine coal. URL: http://www.netl.doe.gov/publications/proceedings/96/96jpfs/jpfs_pdf/biofuel.pdf (accessed on April 2016).

18. *You-lian Zhou*, *Yuan-bo Zhang*, *Bing-bing Liu*, *Guang-hui Li*, *Tao Jiang*. Effect of modified humic acid binder on pelletisation of specularite concentrates. Journal of Central South University. April 2015. Vol.22. Is.4, p.1247-1255.

Author **A.V.Mikhailov,** *Dr. of Engineering Sciences*, *Professor*, *epc68@mail.ru* (*Saint-Petersburg Mining University*, *Russia*).

The paper was accepted for publication on 25 May, *2016*.