Water-coal fuel, coal, ash level, rheological characteristics, hidrotransport

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ECOLOGICAL ASPECTS OF WATER COAL FUEL TRANSPORTATION AND APPLICATION

Summary. This paper deals with the aspects of influence of transportation process and burning of water coal fuel on an ecological condition of environment. Also mathematical dependences between coal ash level and power consumption for transportation are presented.

ЭКОЛОГИЧЕСКИЕ АСПЕКТЫ ТРАНСПОРТИРОВАНИЯ И ИСПОЛЬЗОВАНИЯ ВОДОУГОЛЬНОГО ТОПЛИВА

Аннотация. В статье рассмотрены аспекты влияния процесса транспортирования и сжигания водоугольного топлива на экологическое состояние окружающей среды. Также представлены математические зависимости между зольностью угля и энергетическими затратами на транспортирование.

1. INTRODUCTION

Constantly growing prices for liquid fuel and natural gas causes constant growth of expenses for manufacture of thermal and electric energy. Besides, direct incineration of traditional firm, liquid and gaseous kinds of fuels is connected with high level of harmful emissions in the atmosphere. The combination of these factors makes actual problem of search and working out of technologies of use less expensive and more ecologically safe alternative kinds of fuel. One of such kinds of energy carriers is water coal fuel (WCF) which preparation is carried out from coals of various marks, and also froma cleaning rejects and conversion of the coal, using rather limited demand in the market in connection with their advanced humidity and regrinding. Besides, low technological provision of the enterprises does not allow to use effectively low-grade kinds of coal fuel in laminary and chamber fireboxes of various power installation.

2. THE CHARACTERISTICS OF WATER COAL FUEL

Water coal fuel (WCF) represents the disperse mix consisting from micronized coal, water and a reagent-softener. Receive WCF from coal, a carbonaceous waste and coal slimes (tab. 1). WCF possesses all technological properties of liquid fuel: it is transported in railway and auto tankers, on pipelines; it is stored in closed tanks; keeps the properties at long storage and transportation.

Table 1

Structure of WCF and its temperature characteristics

Components	Use volume
Coal (size 0-250 μm)	59-70%
Water	29-40%
Plasticizing agent	1%
Fire point	450-650 ^{0}C
Combustion temperature	950-1050 ^{0}C

In Fig. 1 the scheme of preparation of WCF by an one-phasic grinding is presented.

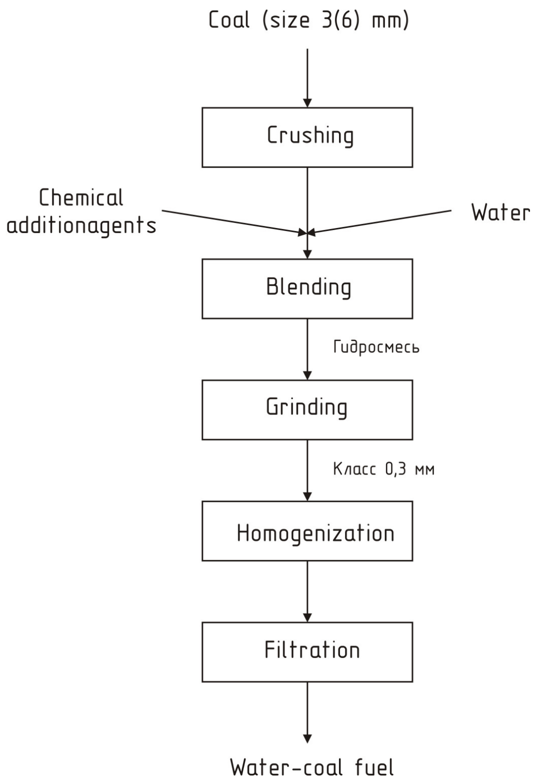


Fig. 1. The technological scheme of preparation WCF
Рис. 1. Технологическая схема приготовления ВУТ

As it indicated above, coal bimodal granule composition receives in connection with change granule composition of grinding bodies in a spherical mill. In table 1 data on loading of a drum of spherical mills by grinding bodies are shown.

The technology of preparation WCF is without waste and ecologically pure as allows to use cleaning rejects, a coal fines, slimes and other low-grade components.

Under physicomechanical characteristics WCF it is similar to liquid fuel, therefore processes of its transportation, storage, coal-conveying plant and burning also are similar. Realisation of production technique, storages, transport and power use of water coal fuel allows to reduce sharply unjustified losses of coal at its transport, storage and burning thanks to what ecological conditions in areas of its use improve.

3. ECOLOGICAL ASPECTS

Application of suspension coal fuel is real possibility of replacement not only "dirty" coal and ineffective methods of its burning in fireboxes, but also scarce liquid and gaseous kinds of fuel.

Especially sharply there is a problem in coal regions of Ukraine where round of the coal producer in the sludge ponds and sediment boxes a considerable quantity of the extracted coal presented in a kind fine coal slims are accumulates. The specified problem dares in the most primitive image. Colliery waters, technological waters of concentrating factories with small coal particles are dumped in superficial sediment boxes which are periodically cleaned by mechano-hydraulic way, and repeatedly extracted coal slimes or are dumped in the fulfilled developments of mines, or in the nearest ravines and reservoirs. Dehydration of a waste of flotation and their warehousing on the free areas is on occasion made.

One of technical decisions of this problem is introduction in power system of water coal fuel technology which is characterised by high efficiency and ecological cleanliness of burning. Water represents itself as the original catalyst which improves and accelerates burning process, promotes higher completeness of combustion at the smaller expense of air. The smaller quantity of fume is thus formed. In combustion products the quantity of soot, nitric oxides and sulfur considerably decreases.

Transfer slimes in transportable and technologically convenient suspension water coal fuel (WCF) will allow to receive essential economic benefit and sharply to improve ecological conditions in regions. Thus received fuel and technologies of its use should meet rigid requirements of the modern market: economic competitiveness and is minimum possible dangerous ecological influence on environment at its reception and use.

Quantity of slims and theirpower budget at humidity $W_t^r = 20\%$ are shown in Tab. 2 [1].

Table 2

The power budget of coal slimes

Slimes ash	Anthracitic coals		Power station and coking coal	
	Amount of slimes Q_d, mil ton	Power budget E_d, mil Gcal	Dirt quantity Q_d, mil ton	Power budget E_d, mil Gcal
$A^d < 45\%$	1721,7	6091,24	680,4	2267,25
$A^d = 45\% - 60\%$	5117,0	13922,89	30858,0	78668,43
$A^d > 60\%$	3000,0	6810,00	63303,0	119870,0
In all	9838,7	26624,13	94844,4	200805,68

Process of WCF burning in all cases is characterised by high completeness of burning out of fuel (98-99,7%), decrease in mechanical incompleteness of combustion and full absence of chemical incompleteness of combustion of fuel that allows to raise essentially efficiency of its use, especially in chambers with fuel-bed coal firing in which chamber coefficient of efficiency increases from 50-60% to 80-85%.

WCF burns down without emissions with combustion products of monoxide carbon, secondary hydrocarbons, soot and cancerogenic substances; thus sulfurs oxides formation is sharply reduced to 70-85% and nitrogen oxides on 80-90%. [2, 3]

At burning of water coal fuel flying ashes are agglomerated in the form of balls of the correct form owing to what emissions of firm particles also are reduced to 80-90%. It is reached without a construction of expensive and whimsical installations in operation on clearing of products of combustion.

4. RESEARCH OF WATER COAL FUEL TRANSPORTATION PROCESSES

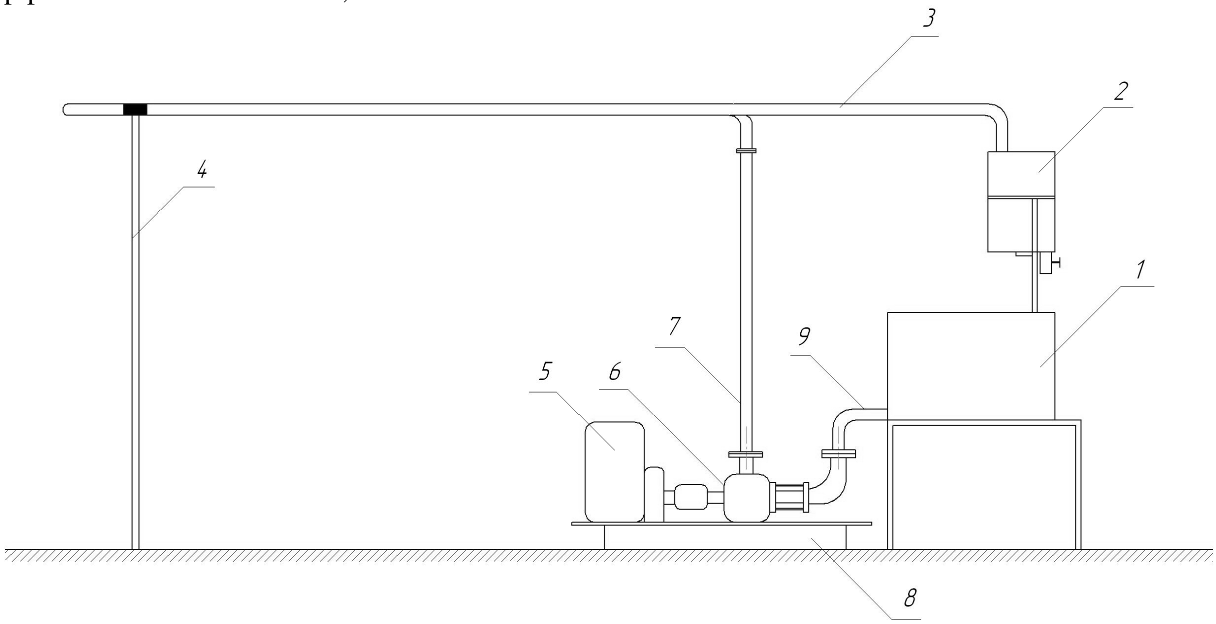
Earlier it was specified, that one of advantages WCF is possibility of its transportation by pipeline hydrotransport. Distinctive feature of hydrotransport is possibility of line and continuous giving of coal on considerable distances. At use of pipeline transport the sizes of the occupied earths are sharply reduced, the intensification of technological processes is observed, power and financial expenses for transportation decrease, and also improvement of conditions of a labour safety and ecological safety [2-5] is provided.

Therefore one of requirements is reception WCF with rational sedimentation and rheological characteristics which will allow to provide fluidity and transportability fuel.

For research of hydrotransportation processes of the water coal fuel prepared from various marks of coals, on the basis of laboratory of the Dal's East Ukrainian national university experimental installation has been created. In fig. 2 its scheme is presented.

Main objective of laboratory experimental researches is the mode substantiation of rheological models and formation conditions of WCF rheological properties at change of coal particles concentration, grain-size classification of a firm component, Reynolds's number for coals of marks G and A.

Experiments at the hydraulic stand consist in transfer of water coal fuel with various concentration of coal particles on the ring pipeline in diameter D_y=50 mm by means of the one-screw pump 1V-10. Regulation of pump productivity is made by spherical cranes on an input in the pipeline. The gage tank is built in a design by capacity of 35 liters which is used for definition of the valid productivity of the pump, expense and average speed of a fuel mix stream. The length direct a measuring site on the pipeline makes 3800 mm. As measuring devices 3 U-shaped manometres with which help pressure differences on a direct site of the pipeline are defined are used, and also at stream turn on 90^0 and 180^0.



1 - capacity for WCF; 2 - gage tank; 3 - ring pipeline; 4 - support; 5 - manometres; 6 - electromotor; 7 - one-screw pump; 8 - column; 9 - pass-by.

Fig. 2. The scheme of the experimental stand for research of water coal fuel rheological characteristics

Рис. 2. Схема экспериментального стенда для исследования реологических характеристик водоугольного топлива

Principle of work of the stand by the following. Water coal fuel by means of the one-screw pump 7 which is put in action by the electromotor 6, from a tank 1 arrives in the pipeline 3 which is supplied by pass-by 9 for regulation of speed of fuel movement. From the pipeline 3 WCF arrives in a gage tank 2, fuel from which arrives in a tank 1 at opening of the spherical crane located in the bottom of a gage tank 2, flow friction on pipeline sites are measured by U-shaped manometres 5.

At research of WCF as homogeneous liquid which possesses of non-newton properties most used rheological equations the condition equations of visco-plastic liquids defined by generalised Balkly-Hershel model and model of a sedate liquid (Osvald model) which usually write down in the following way [2, 6] are:

$$\tau = k \cdot \dot{\gamma}^n , \tag{1}$$

where: τ - shift voltage, the Pa·s; k - factor of thickness, Pa·s^n; $\dot{\gamma} = \frac{dv}{dr}$ - gradient of speed or shear rate, s^{-1}; n - stream index; τ_0 - initial shift voltage, Pa·s; μ_c - structural viscosity, Pa·s.

Key parameter defining rheological behaviour and ecological compatibility of water fuel coal use is viscosity which depends on physicochemical properties of feed stock. Definition of analytical dependences of rheological models parametres from viscosity and factors influencing it is one of the primary goals at research of WCF hydrotransport.

For the liquids described by the equation (1), usually define values of dynamic and effective viscosity. Dependence for dynamic viscosity has the following appearance [7]

$$\mu_\partial = \frac{d\tau}{d\dot{\gamma}} , \tag{2}$$

or proceeding from the equation (1)

$$\mu_\partial = k \cdot n \cdot \dot{\gamma}^{n-1} . \tag{3}$$

Value of effective viscosity is a consequence of the law of a viscous friction of Newton and is described by the equation [6, 7]

$$\mu_{эф} = \frac{\tau}{\dot{\gamma}} . \tag{4}$$

Considering the equation (2), expression for effective viscosity can be written down in the following way

$$\mu_{эф} = k \cdot \dot{\gamma}^{n-1} , \tag{5}$$

and consequently from the equations (3) and (5) communication between values of dynamic and effective viscosity can be resulted in a form

$$n = \frac{\mu_\partial}{\mu_{эф}} . \tag{6}$$

Earlier already it was said that WCF viscosity depends on many parameters including from properties of initial coal. One of key parameters characterising properties of a raw product and influencing viscosity of water coal fuel, is ash level (A^d). Ash level values variously for each concrete mark of coal.

On fig. 3 the approximated graphic of WCF effective viscosity dependence from ash level an row product, and on fig. 4 - the dependence of shear stress from a velocity gradient of shift is presented. Between the graphics presented in drawings there is a conformity.

The graphic presented on fig. 3 is described by the following function of effective viscosity from ash level dependence

$$\mu_{ef} = 0{,}17 + 0{,}12\left(\ln A^d\right)^2 . \tag{7}$$

Graphic differentiation of the dependences presented on fig. 4 allows to receive value of dynamic viscosity $\mu_\partial = C_{\mu_d}$ in the form of expression (2).

Then taking into account expression (7) dependence for an index of a stream from effective viscosity can be written down in a form

$$n = \frac{C_{\mu_d}}{0{,}17 + 0{,}12(\ln A^d)^2}. \qquad (8)$$

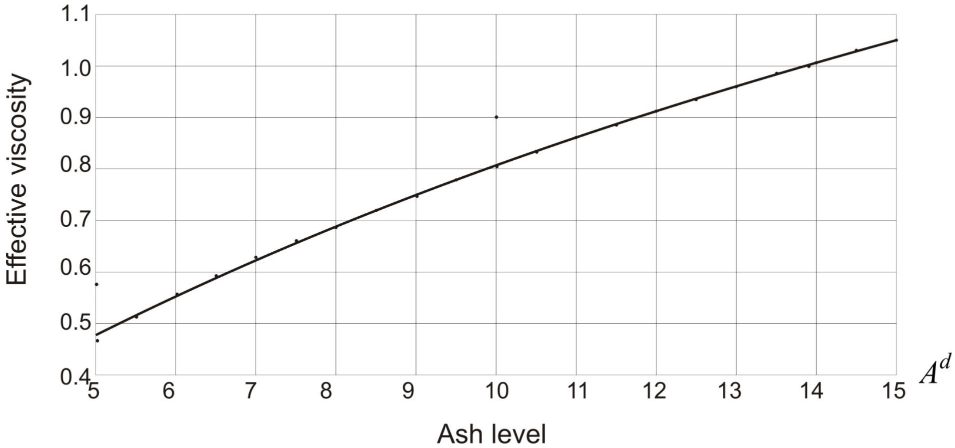
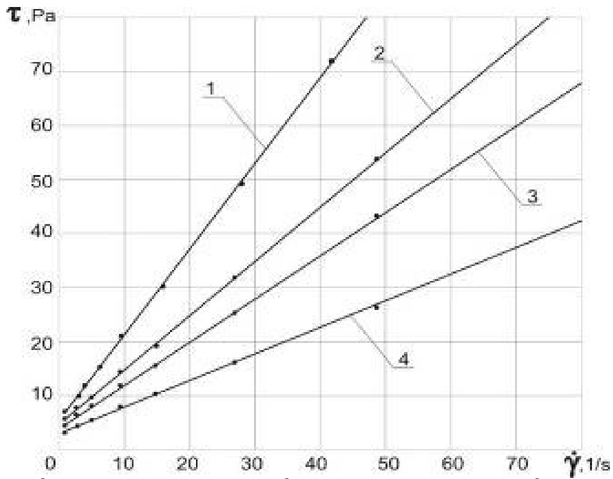


Fig. 3. Ash level effect on WCF effective viscosity
Рис. 3. Влияние зольности на эффективную вязкость ВУТ



1 - temperature 5 C^0; 2 - temperature 10 C^0 ; 3 - temperature 15 C^0; 4 - temperature 20 C^0

Fig. 4. Dependence of shear stress in WCF, prepared from coal mark «L, G» with concentration of 65 % from a gradient of shear rate at various temperature
Рис. 4. Зависимость касательных напряжений в ВУТ, приготовленном из угля марки «Д,Г» с концентрацией 65% от градиента скорости сдвига при различной температуре

Taking into account (1) dependence of thickness factor k from ash level of row coal can be found as follows

$$k = \frac{\tau}{\dot{\gamma}^n} = \frac{\tau}{\dot{\gamma}^{[C_{\mu_d}/0{,}17+0{,}12(\ln A^d)^2]}}. \qquad (9)$$

Having designated a denominator of expression (9) variables N, we will receive

$$k = \frac{\tau}{N}. \qquad (10)$$

From the graphic presented on fig. 4 and dependences (9) and (10) it is visible, that factor k is function from row product ash level $k = \left(A^d\right)$ and consequently depends on coal mark.

Possibility of WCF effective transportation essentially depends on power inputs which are characterised by specific pressure losses $\frac{\Delta p}{L}$.

Integration of the Newton law of a viscous friction leads to the known formula in a hydromechanics for the expense of liquid Gagena-Puajzelja:

$$Q = \frac{\pi R^4 \Delta p}{8\mu L} = \frac{\pi D^4 \Delta p}{128\mu L}, \tag{11}$$

where: R - internal radius of a pipe, Δp - pressure difference on a site of the pipeline long L, $D = 2R$ - internal diameter of a pipe.

From the formula (11) the factor of dynamic viscosity is expressed

$$\mu = \frac{\pi D^4 \Delta p}{128QL} = \frac{D\Delta p / 4L}{32Q / \pi D^3}. \tag{12}$$

In numerator of the formula (12) there is an expression for τ, and in a denominator for $\dot{\gamma}$, i.e.

$$\tau = \frac{D\Delta p}{4L}, \tag{13}$$

and

$$\dot{\gamma} = \frac{32Q}{\pi D^3}. \tag{14}$$

Taking into account expressions (10) and (13) it is possible to receive dependence for specific losses of pressure on length of the pipeline from initial product ash level

$$\frac{\Delta p}{L} = \frac{4kN}{D} = \frac{4k\dot{\gamma}^{[C_{\mu_d} / 0,17+0,12(\ln A^d)^2]}}{D}. \tag{15}$$

5. CONCLUSIONS

1) WCF is ecologically pure. It is especially actual for east regions of Ukraine which are the most polluted in the ecological plan. As the basic sources of pollution the enterprises coal act, power and an metallurgical industry which are concentrated in the east of the country and throw out in atmosphere about 86% of all harmful substances. The density of emissions across Donbass makes 59,9 t/km^2, that in 8,7 times more than on the average across Ukraine.
2) For WCF preparation it is possible to use industrial wastes.
3) Use of suspension fuels allows to use oil-gas boilers without their cardinal re-equipment.
4) Use of this kind of fuel will allow to release a railway transportation from expensive and labour-consuming transportations of coal, at the expense of use of pipeline hydrotransport.
5) Use of WCF is economic in high degree. It possesses high combustion heat that allows to organise burning process rather effectively, and application of the warmed-up air considerably raises technical and economic indicators of thermal units. Capital expenses at use of pipeline transport essentially more low, than at use railway, that reduces cost of coal transportation.
6) By means of the received dependence it is possible to define communication between power, rheological and ecological parametres of WCF.

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