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DETERMINATION OF THE INTENSITY OF ABRASIVE CHAFE BY DIFFERENT CHAFEING MATERIALS

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Preliminary Note – Prethodno priopćenje

The article presents preliminary results of determining the coefficient of relative abrasiveness of various bulk materials. Comparative analysis of the early works of famous scientists devoted to the determination of the intensity of abrasive chafe by coal particles, crushed in mills to a size of 100 microns and less, or formed during their combustion by ash particles (the same or smaller size), usually moving in an air stream or smoke gases. It should be noted that in these studies, the abrasiveness of the material was determined indirectly - through the intensity of erosive chafe, without directly determining the abrasiveness of the material itself. There were practically no data on chafe by particles with sizes corresponding to crushing, interacting with the surface of elements, in the absence of carrier air or other gaseous substance.

Keywords: abrasion coefficient, bulk solids, coal, fly ash, Kazakhstan

INTRODUCTION

The state and development of the energy sector of each country has its own characteristics, due to the specifics of the resources of its primary energy carriers. In the most general case, the choice of the main source of primary energy for a particular country is a multi-parameter task, in solving which the influence of a number of factors should be taken into account. First of all, it is the availability and availability of resources, the possibility of their processing and transportation. For example, the countries of the Persian Gulf built their electricity and heat power industry on the use of oil and oil products. Kyrgyzstan and Tajikistan focused on the development of hydropower. An important role in choosing the energy policy of a particular country is played by the possibility of accumulating and / or storing the prevailing primary and processed resources. You should also take into account the demand for a specific type of energy in foreign markets. Such a comprehensive analysis makes it possible to determine a strategy for the development of the country's energy sector that is close to optimal. If we evaluate various types of primary energy resources in terms of the listed parameters, then coal should be considered as the main type of primary energy for Kazakhstan. Kazakhstan is one of the few countries that, in terms of the availability of fuel resources, fully meets the domestic demand and can export many energy resources in significant quantities.

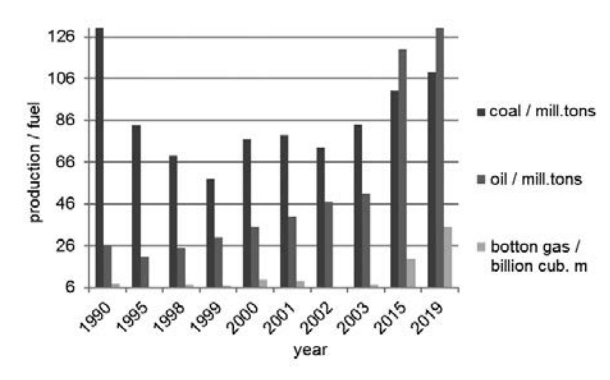

Figure 1 Fuel balance of the Republic of Kazakhstan in 1990 - 2019 (excluding nuclear energy)

Kazakhstan fully meets its needs for all types of energy (see Figure 1), except for the supply of natural gas [1]. The situation with the supply of natural gas is largely due to and is a vivid example of the legacy of the development of the fuel - energy complex of Kazakhstan as a component of the fuel and energy complex of the Soviet Union. With a general surplus of natural gas in Kazakhstan, a significant part of the gas consumed comes from Uzbekistan and Russia.

This significantly reduces energy independence and worsens the country's energy security for this type of energy. Under certain external conditions, this dependence can be a source of reducing the sustainability of the development of the energy sector in Kazakhstan.

RELEVANCE OF PLANNED RESEARCH

Coal in the world in its reserves is tens of times higher than other types of fossil fuels (oil, gas); therefore it

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Table 1 **Reserves and volumes of coal production in the regions of Kazakhstan / million tons**

economic region, embayment, mineral assets	geological reserves	balance reserves	recoverable reserves	production	forecast fuel production
Eastern Kazakhstan	4 500	3 040			
Kendyrlyk / field	586	191	77		total 1,0 - 2,0
	1 033	400	169		
	4 075	698	53		
Belokamen / field	957	914			up to 1,0
Iubilei / field	1 536			1,4	30,0
Western Kazakhstan	2 900	1 790			
Ural Caspian embayment	378	108	96		5,0
Mamyt / field	1 426	1 320	598		3,0
Northern Kazakhstan	81 800	18 520			
Yekibastuz embayment	12 500	9 700	7 700	62,2	up to 105
Maikiuben / field	5 700	1 805	1 767	0,3	15,0 - 25,0
Torgai embayment	61 910	6 564	5 933		2,0
Central Kazakhstan	54 500	14 800			
Karagandy embayment	51 300	15 800	7 500	14,4	up to 25,0
Kuuchen / field	600	150	150		1,8 - 3,0
Borlin / field	490	314		3,1	10,0
Shubarkol / field	2 100	1 700		1,8	22,0 - 28,0
Southern Kazakhstan	33 000	480			
Oikaragai / field	74	53,4	40,2		0,3 - 0,5
Nizhmii Ili / field	9 878				80,0
Alakol / field	130	50			0,3
Lenger / field	2 109	751	355		
Whole Kazakhstan	176 700	38 630	34 100	83,2	

can be considered as the fuel of the future. In addition, coal is undoubtedly a technological raw material. In particular, about 3,3 % of the world's industrial coal reserves are concentrated in Kazakhstan (see Table 1).

This Table shows that coal (as opposed to oil and gas), in one or another quantity, is present in almost all regions of Kazakhstan. In terms of reserves to the volume of coal production achieved by 2015, Kazakhstan can be considered as a country with unlimited reserves.

One of the physical characteristics of coal, the definition of which is required for use in power engineering, is its abrasiveness. Coal moving from the cars to the furnace will chafe out many elements of the station's fuel economy. The most common chafe out is the grinding elements of crushers and mills, bunker walls, feeders, dumpers on conveyors and others. However, until recently, there are no studies necessary to determine their abrasive chafe, including the abrasiveness of coal particles.

ANALYSIS OF ASH CHAFE AND ABRASIVENESS OF SOLIDS AND FORMULAS FOR THE ABRASIVENESS COEFFICIENT

Early work was characterized by the experimental study of external effects of collision of solid particles with a surface. So Syrkin [2], based on the analysis of surfaces exposed to the impact of particles, came to the conclusion that chafe is mainly due to the knocking out of material from the surfaces with the formation of craters. On the other hand, Welinger investigated the effect of the angle of attack on chafe for mild steel (relatively soft and tough) and for hardened high-carbon (relatively brittle) steel [3]. At the same time, he found that hard brittle steel exhibits greater chafe resistance at low angles of attack compared to mild steel. The problem of ash chafe has arisen in the last thirty years in connection with the pulverized method of burning polyline coals. Sheldon taking relatively large particles for experiments [4], in order to more accurately observe the effects of particle impact on the surface, found that both soft tempered and hardened cold-rolled steel is not worn out by cutting, but due to indentation and hardening of the material. Moreover, the volume of material carried away is proportional to the volume of the crater. From here, based on the experimental relationship established by Meyer between the geometric parameters of the embedded part of the particle and the penetration force, he derived a formula linking the volume of the eroded material with the size and velocity of the particle, as well as with such a mechanical property of the material being worn as Vickers Hardness [4]:

$$V = \frac{D^3 \cdot \vartheta^3 \cdot p^{3/2}}{H_V^{3/2}} \quad (1)$$

here, D - is the particle size, ϑ - is the particle velocity at the moment of impact on the surface, V - is the amount of material carried away from the surface during a single impact p - is the density of the particle, H - is the Hardness of material.

Sheldon explains some excess of the chafe data obtained from this expression over the experimental data

Table 2 **Test results comparative analysis**

example	abrasiveness / mm					
	coal (Yekibastuz)		white stone		sand	
	experiment	calculations	experiment	calculations	experiment	calculations
Steel 20	0,0129	0,0141	0,0119	0,0123	0,0365	0,0379

by the fact that not all the material displaced by the particle is carried away from the surface. The influence of the hardness of the Chafeing material on erosion was studied by M. M. Khrushchev and M. A. Babichev. They established a direct proportionality between the chafe resistance of the material and it's Brunel Hardness HB [4]:

$$\varepsilon = K \cdot HB \tag{2}$$

However, the K coefficient strongly depends on both the composition of the metal and the method of its processing. Taking into account the above factors, a number of empirical formulas were proposed in due time, linking linear chafe h / mm with parameters taking into account certain influencing factors. The most typical for this type of relationship is the empirical formula of S. N. Syrkin [2]:

$$h = k \cdot A \cdot M \cdot K_{\sigma}\left(\beta_C \cdot C\right)\left(\beta_W \cdot W\right)^3 \cdot \tau \tag{3}$$

where k is the coefficient taking into account the difference in chafe of the 1st and 2nd rows of pipes, A is the coefficient of ash abrasion, M is the coefficient of relative abrasion of the metal during impact chafe, K_{σ} is the experimental coefficient that takes into account the effect of the ash size, β_C is the peak concentration of particles in the incident flow, C is the concentration of particles, β_W is the velocity peak in the incident flow, W is the flow velocity, τ is the time.

Known studies are devoted to determining the intensity of abrasive chafe by coal particles, ground in mills to a size of 100 microns or less, or formed during their combustion by ash particles (of the same or smaller size), usually moving in a stream of air or flue gases. It should be noted that in these studies, the abrasiveness of the material was determined indirectly - through the intensity of erosional chafe, without directly determining the abrasiveness of the material itself [5]. There were practically no data on chafe by particles with sizes corresponding to crushing, interacting with the surface of elements, in the absence of carrier air or other gaseous substance. The analysis shows that the abrasiveness of a particular granular body significantly depends on many parameters: size, shape, formed edges. In this regard, as a result of the research, a kind of nomogram of the abrasiveness of bulk solids will be drawn up, which will make it possible to reliably predict the intensity of future abrasive chafe. The calculation of chafe by bulk solids is determined by a formula similar to that used to predict abrasive chafe by fly ash [7]:

$$K_{af} = \frac{h \cdot g}{E \cdot C \cdot W^{-3} \cdot \tau} \tag{4}$$

here, h - is the amount of change in the sample weight during the experiment (grams); g - is the acceleration of free fall on the Earth's surface / m / s^2;

E - is the coefficient of impacts of particles on the sample (in the considered installation is excluded from consideration); C – is the concentration of bulk solids (possibly, it will be replaced by the level of filling the installation with a test sample) / kg / m^3; W – is the relative velocity of particles and sample / m / s; τ – is the time / hour;

The calculated equation derived using the similarity method is a generalized expression of the previously obtained empirical formulas [6]:

$$K_{af} = \frac{0{,}0141 \cdot 10^{-3} \cdot 9{,}8}{1{,}10 \cdot 10^{-3} \cdot 53{,}5^3 \cdot 344} = 0{,}262 \cdot 10^{-10}$$

$$K_{af} = \frac{0{,}0123 \cdot 10^{-3} \cdot 9{,}8}{1{,}10 \cdot 10^{-3} \cdot 53{,}5^3 \cdot 344} = 0{,}193 \cdot 10^{-10}$$

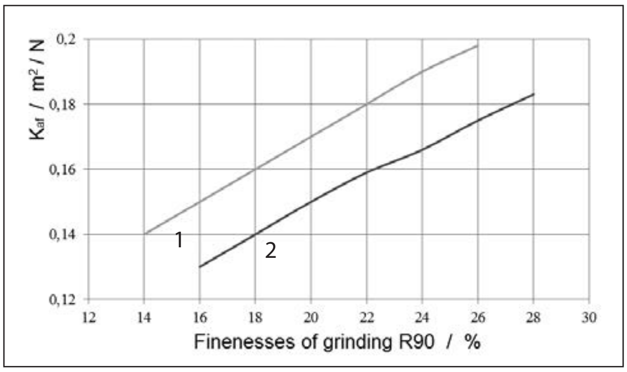
$$K_{af} = \frac{0{,}0379 \cdot 10^{-3} \cdot 9{,}8}{1{,}10 \cdot 10^{-3} \cdot 53{,}5^3 \cdot 344} = 0{,}190 \cdot 10^{-10}$$

The results of the experiments are shown in Table 2

A different approach to the study of the abrasiveness of bulk solids leads to different interpretations of its size, shape, hardness, strength, speed, etc.

CONCLUSIONS

The analysis of works on chafe in the list, carried out in the work, showed that all of them, as a rule, are mainly of an empirical nature, which, due to the complexity and multiparametric nature of the processes, does not allow them to be used for a wide analysis. It should be noted that in these studies, the abrasiveness of the mate-



1: Coal fraction at (R_{90} = 14 – 26) / %
2: Coal fraction at (R_{90} = 14 – 28) / %
Figure 2 Dependence of the abrasiveness coefficient of fly ash from Ekibastuz coal on the fineness of grinding

rial was determined indirectly - through the intensity of erosional chafe, without directly determining the abrasiveness of the material itself. There were practically no data on chafe by particles with sizes corresponding to crushing, interacting with the surface of elements, in the absence of carrier air or other gaseous substance. In one work, it is very difficult to investigate the influence of all factors on the abrasiveness of bulk solids. So far, preliminary results of the influence of the interaction rate on the intensity of chafe by bulk solids are given. In the future, we will experiment precisely with the abrasiveness of the material itself. Since, the abrasiveness of the material under study is determined by the relative material recognized as the reference.

REFERENCES

[1] L. Liu, D. Yin, Determination of material optical properties from diffusive reflection light intensity profiles at multiple distances, Mater. Res. Express 7 (2020) 025403, 1-7.

[2] Syrkin S. N. Sovet, Kotloturbostroenie 3 (1945), 7-13. (in Russian)

[3] Wellinger R. Testing of metallic materials at low temperatures. Z. Metallk. 40 (1949) 361-366.

[4] Sheldon G. L. Similarities and differences in the erosion behavior of materials. Journal of Basic Engineering 92 (1970) 3, 619-629.

[5] N. Heeren and T. Fishman, A database seed for a community-driven material intensity research platform, Scientific data, (2019) 6, 23 1-10.

[6] Augiseau V., Barles S., Studying construction materials fows and stock, A review: Resour. Conserv. Recycl. (2017) 123, 153-164.

[7] Akimbek G., Aliyarov B., Akimbekova Sh., The Development of the Method and Determination of the Relative Abrasiveness of Bulk Substances, E3S Web of Conferences 207(2020) 05003, 1-5.

Note: The responsible for England language is L. D. Sergeeva, Almaty, Kazakhstan