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STUDYING THE BINDER EFFECT ON THE PROPERTIES OF BRIQUETTES OF FERROALLOY PRODUCTION WASTE

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The paper shows the results of studies in searching for a binder for briquetting finely dispersed dust (FDD) of ferroalloy production of the Kazakhstan content. The fractional composition and shape of FDD particles were studied. Liquid glass and caustic soda were used as a binder. The research results showed the possibility of using liquid glass as a binder. Experimental briquettes have sufficiently high compressive strength and drop strength, which implies the possibility of their transportation and loading.

Keywords: ferroalloy production, ferrosilicon, finely dispersed dust, briquettes, strength

INTRODUCTION

The problem of utilization of finely dispersed dust (FDD) of ferroalloy production is not new but it has not nevertheless been resolved actually in the Republic of Kazakhstan.

In the process of ferroalloy production, among other anthropogenic wastes, finely dispersed dust (FDD) is necessarily formed.

This dust has a dual origin: firstly, it is formed as a result of implementing the technological process itself when discharging a ferroalloy product; secondly, it is formed as a product of gas cleaning systems [1].

Irrespective of the origin, FDD composition is close to that of the produced ferroalloy and can be used as a raw material for obtaining a conditioned product. At present, FDD of Kazakh ferroalloy production is actively exported abroad, in particular to Russia, and then imported to the Republic of Kazakhstan in the form of a briquetted product with a high added value.

FDD itself is an environmental hazard, because it requires significant storage space, it is a source of air pollution and has significant pyrophoricity due to the developed interaction surface [1].

These circumstances determine the relevance of the problem.

At present, there are a sufficient number of implemented technologies for FDD utilization in the world, but in our country such technologies are not widely used. The problem is exacerbated by the fact that simple transfer of the FDD utilization technology is impossible, because FDD of each production is characterized by certain features, such as the chemical and fractional composition, the presence of impurities, etc. This leads to the necessity to adapt even well-known technologies for a local product.

One of the promising areas for the utilization of FDD is producing briquettes, because the use of FDD in its original form, without preliminary agglomeration, is not possible [2, 3].

Finished briquettes produced on the FDD basis must meet the following requirements:

- correspond in chemical composition to SS 1415-93 for this ferroalloy;
- withstand the conditions of transportation, i.e. have sufficient mechanical strength;
- comply with the size factor according to the relevant SS.

One of the key points that arise during the FDD briquetting is the correct selection of the binder component. The binder component must provide certain plasticity for the formation of a briquette, mechanical strength after appropriate processing (for example, drying) and not make large changes in the chemical composition of the briquette, so that the composition of the briquette complies with the SS for a given ferroalloy.

Searching for a binder and developing the composition of the mixture for briquetting on the FDD basis are dealt with in a significant number of works [4-7]. In most studies, caustic soda, liquid glass, such minerals as fluorite or vermiculite, etc. are used as a binder. Depending on the binder, the post-treatment mode is selected to provide the necessary characteristics of the finished briquette.

EXPERIMENTAL

The purpose of this work is to determine the effect of some binders on the strength and hardness of the finished briquette produced on the basis of Kazakh raw materials. Finely dispersed dust (FDD) from the YDD Corporation LLP was used as the main raw material.

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Table 1 **Chemical composition of FS70 and FDD/wt. %**

Grade	Si	Fe	C	S	P	Al	Cr
FS70 (1415-93)	68,0-74,0	26-28	0,1	0,02	0,04	2	0,4
FDD	71,5	26,7	0,06	0,02	0,04	1,104	0,049

This enterprise specializes in the production of ferrosilicon (FeSi), in particular, FS70 grade (SS 1415-93). The mass of dust generated during the crushing of ferroalloys and dust that is the product of gas cleaning systems, currently amounts to tens of tons and is a real problem for this enterprise.

The chemical composition of the FS70 grade, according to SS 1415-93 and FDD (averaged, according to the enterprise certificate) are shown in Table 1.

It is seen from the data in Table 1 that the FDD composition corresponds to SS for FS70 and can accordingly be used as a raw material for producing a ferroalloy briquette. According to SS 1415-93, ferrosilicon can be supplied in the form of ingots weighing no more than 42 kg, pieces weighing no more than 25 kg, or in the form of crushed particles, the size of which depends on the size class.

To assess the fractional composition of the studied FDD, a sedimentation analysis of the product was carried out on an FSH-6K instrument. The results of the analysis are shown in Table 2.

It is seen from the data in Table 2 that the largest mass fraction falls on particles 0,2-1,0 mm in size, the total fraction of particles up to 1,0 mm in size is 78 %. It is known that the finer the powder particles, the greater their specific surface area and, as a rule, the worse its compressibility [8,9]. However, strength of compacts made using fine powder is often higher than that of compacts made using coarse powder of the same material. This is explained by the fact that with increasing the powder specific surface, mechanical adhesion of the particles increases, which, on the one hand, prevents compaction of the powder during pressing, and on the other hand, causes the particles to jam relative to each other, which leads to increasing strength of the compacts [9].

Table 2 **Particle size distribution / mm**

Particle size	≤ 0,05	0,05-0,2	0,2-1,0	1,0-3,0	≥3,0
Content	12 %	14 %	52 %	12 %	10 %

In addition to the fractional composition, the shape of powder particles also affects the process of briquette formation [9, 10].

The analysis of the FDD particles shape carried out using electron microscopy, shows that the shape of the particles is closer to equiaxed one (Figure 1) according to the classification [9] but not spherical. It is believed that spherical powder particles give the maximum bulk density, i.e., the most dense packing with free filling, but they are poorly pressed and high specific pressures are required to obtain compacts of sufficient strength [9]. In this case, taking into account the non-spherical shape of the particles, it is possible to start briquetting with relatively low pressures.

Liquid glass (an aqueous alkaline solution of sodium silicates $Na_2O(SiO_2)n$ and the 30 % aqueous solution of caustic soda NaOH were selected as a binder for producing briquettes using FDD.

The selection of binders is based on the results of studies [5–8], in which these substances were used as binders, however, the chemical and fractional composition of the FDD differed from that used in this work. Binders and moisture were added in excess of 100 %; the mass of pure FDD was taken as 100 %.

Table 3 shows the composition of the charge used.

All the components of the charge were thoroughly mixed within 5 minutes until a homogeneous mass was achieved. Then, samples with the diameter of 35 mm and the height of 10 mm were made using the prepared mixture, the pressure varied from 30 to 60 kN.

Table 3 **The composition of the charge used**

Charge designation	Amount of $Na_2O(SiO2)n$ / %	Amount of NaOH / %	Water / %
A	10	-	5
B	-	10	5

Raw briquettes were dried at the temperature of 60 ^{0}C within 2 hours. At the end of the drying process, the finished briquettes were tested for compressive strength and drop strength.

Compressive strength was determined on an Instron machine, and drop strength was determined according to the method specified in work [4].

The sample was 3 times dropped onto a steel plate 20 mm thick from the height of 2 meters. Then the test samples were sifted through 10 mm sieves. Sieves with smaller meshes were not used, because according to SS 1414-93, the smallest allowable particle size is 10 mm (size class 6), and the share of undersize product should be no more than 10 %.

The weight fraction of the undersize product was used as the indicator of the drop strength: the larger the

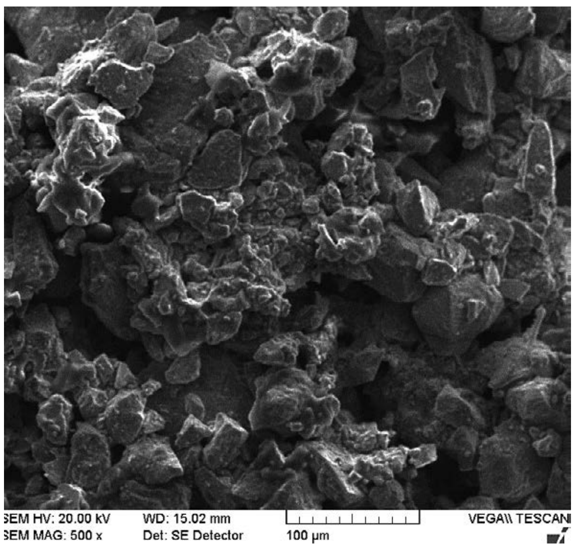

Figure 1 FDD particle shape

Table 4 **The results of the tests carried out**

Sample number	Charge	Pressure / kN	Compression strength / MPa	Share of the undersize product ≤ 10 mm / %
1	A	30	15	44
2		40	19	26
3		50	27	15
4		60	32	10
5	B	30	12	58
6		40	22	35
7		50	26	23
8		60	28	18

share of the undersize product, the lower the drop strength. Table 4 shows the results of the studies. Figure 2 shows the appearance of the samples before and after the drop test.

It is seen from the data in Table 4 that the samples of series A (the binder is liquid glass) in all the respects show higher characteristics than the samples of series B. Therefore, the use of caustic soda as a binder in the briquetting of this enterprise (the YDD Corporation LLP) FDD seems less appropriate.

If to consider the relationship between the pressure and the mass fraction of the undersize product (Table 4), then it can be concluded that the use of pressure below 50 kN is also inappropriate, because the output of the undersize product after discharge tests exceeds the allowable rate according to SS 1415-93. Such briquettes cannot be used in the future, because during transportation or loading, they will increase the amount of solids emitted into the atmosphere, which in turn will lead to deterioration in technical and economic indicators, environmental pollution, etc.

Among the studied samples, only samples No. 3 and No. 4 are of practical interest. For sample No. 3, the share of the undersize product slightly exceeds the permissible norm but there are prospects for improving pre-treatment (drying mode), which can improve this indicator.

Sample No. 4 has sufficient drop strength and meets the requirements for the dimensions of a conditioned product in accordance with SS.

It should also be noted that samples No. 3 and No. 4 have sufficient compressive strength: 27 and 32 MPa, respectively. According to study [7], for transportation of briquettes, it is necessary to provide mechanical strength of at least 25 MPa.

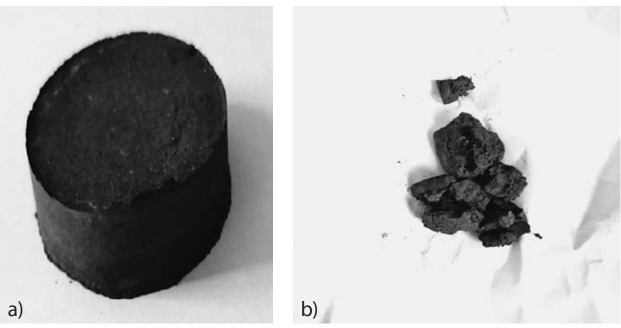

Figure 2 Sample: *a* – before testing; *b* – after testing

CONCLUSION

The studies carried out in searching for a binder for briquetting fine dispersed dust of ferroalloy production show the possibility of using liquid glass as a binder. The obtained results are the basis for carrying out more detailed studies for the development of pressing and drying modes of the Kazakhstan content FDD for producing a conditioned product.

In the future, it is necessary to study the chemical composition and such properties of briquettes, as porosity, pore size distribution, and specific surface area of pores, since these parameters of the porous structure determine electrical conductivity, thermal conductivity and interaction surface, which together with mechanical properties determine the quality of the final product.

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REFERENCES

[1] Kostikov V.I., Varenko A.N. Industrial and environmental safety of metallurgical industries. Ecomet (2006), 388-392.
[2] Ozhogin V.V. Fundamentals of the theory and technology of briquetting of crushed metallurgical raw materials // Mariupol: PSTU, 2012, 441p.Meghana A Patankar, Sandeep Td Experimental Investigations on Effect of Alccofines and Microsilica on Durability Properties of High Performance Cocrete//|International Journal of Advanced in Managment, Technology and Engineering Sciences (2018) 8, 1-8.
[3] Aubakirov D., Issagulov A., Kvon S., Kulikov V., Chsherbakova Y., Arinova S. Modifying Effect of a New Boron-Barium Ferroalloy on the Wear Resistance of Low-Chromium Cast Iron. Journal Metals 12 (2022) 7, 543–546.
[4] Fei Li, Zhibo Sun, Fegyun Yan The agglomeration of solid Wastes for Ferroalloy Production. Infacon XVI: Internationak Ferro-Alloys Congress? Trondheim 27029 (2021), 1-7.
[5] Patent RU 2398029 // Method of producing briquettes using industrial dispersed ferroalloys.
[6] Patent RU 2156814 // Method of producing briquettes using dispersed and powdery wastes of ferroalloy production.
[7] Protsenko E.L., Zhukovsky T.F. Experimental studies of the process of briquetting fine-grained dust produced by ferrosilicon. Vestnik of BSEU n.a. V.G. Shukhova (2014) 6. 187-191.
[8] Baisanov S., Tolokonnikova V., Narikbayeva G., Korsukova I., Mukhambetgaliyev Ye. Mathematical method of phase equilibrium of binary system Cr-Si based on Bjerrum-Guggenheim concept. Metalurgija 59 (2020) 1, 97-100.
[9] Aubakirov, D.R., Issagulov, A.Z., Akberdin, A.A., Kulikov V., et al. Influence of boron- and barium-containing modifiers on the structure of low-chromium cast iron. Heliyon 8 (2022) 11, 87-91.

Note: Responsible for the English language is Natalya Drak, Karaganda, Kazakhstan