DOI 10.52209/2706-977X_2025_1_43 IRSTI 53.39.25 UDC 628.477.6:669

Effect of Binder Composition on Briquettes from Dust-Like Ball Bearing Steel ShKh15

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Abstract. In the work, it was studied how the composition of the binder affects the characteristics of briquettes from ball bearing waste, steel. The goal is to find an efficient way of recycling metal waste, in order to reduce the damage to nature and better use resources.

The briquettes were pressed in the laboratory, choosing optimal conditions. The influence of different binders on the strength of briquettes, important for metal melting and recovery was investigated. It was found that the binder composition greatly affects the strength, gas permeability and heat resistance of briquettes, which determines the recycling efficiency.

This work is important for the creation of new technologies for metal recycling, improvement of product quality and increase of profitability of steel processing.

The study will help to optimize the choice of binders, reducing costs and improving the performance of the briquettes. More durable and resilient briquettes will extend the life of metal smelting and recovery equipment. In the future, the results can be used to introduce technology in enterprises that will increase recycling opportunities and reduce waste. Developments can be widely applied in metallurgy.

Keywords: industrial waste, briquettes, chips, metal chips, components, drying, complex compositions.

Introduction

Increased competition, increasing environmental requirements, as well as the complexity of extraction and pre-preparation of raw materials - these and other factors impose higher demands on the country's metallurgical industry. Therefore, the improvement of traditional and development of new technologies is a necessary condition for sustainable development of metallurgy. New intensive technologies and processes not only place high demands on the quality of raw materials, but also demand new types of them. With the increasing shortage of low-carbon coking coals and the intensification of processes, complex ore-fuel materials will become increasingly important, and pre-partial recovery processes will be applied more widely in raw material preparation. Traditional methods of raw material canning by agglomeration and crushing have largely exhausted their reserves and capabilities. Thus, at the current technical level it is difficult to obtain a metallized agglomerate or solid pellets with high free carbon content. At the same time, such materials are obtained by briquetting.

At present, waste is generated in the processing of castings made from ShKh15 ball bearing steel. Pulverized wastes from milling and drilling lose their productive and material value as opposed to bulk products, and are usually waste. The recycling of industrial wastes generated by mechanical processing is becoming increasingly important. One of the tasks at such enterprises of the Karaganda region as a KMZ Parchomenko, LLC «Maker» is the production of briquettes from scrap of bearing steel ShKh15. For the briquettes, one of the main indicators of quality is durability. In turn, one of the important factors ensuring strength performance, along with technological regimes of pressing and sintering, is the choice of optimal binder. Liquid glass is commonly used as a binder, however, there are a number of experiments to investigate the use of various components as a binder.

For example, the paper [1-3] presents studies on the technological properties of briquettes with peat, bentonite and marshall as binders.

The use of hot pressing when liquid glass is used as a binder is also addressed in work [3-5].

It is known that briquetting is a technological process of interaction of different solid components and is based on the property of loose material to be compacted and strengthened under the influence of applied pressure. In this case, the resulting adhesion forces between the close particles ensure the formation of a briquette. Therefore, the formation of a briquette is the result of compaction and hardening of loose material under the influence of pressing. The main technological parameters of the briquette as a component of metal scrap are: strength, bulk mass, content of harmful impurities [6-7].

In the work [8-10], it is proposed to use sludge from steelworks as a binder additive. This increases briquetting performance and reduces the cost of briquette production.

The key points related to the control of particle formation, particle crushing, cleaning and briquetting are discussed in this paper [11-13].

In the proposed study used a mixture of the following composition: S15 steel waste - 85%, liquid glass - 5%, bentonite clay - 10%. Briquette manufacturing regimes: drying temperature - 90 0C for 90 minutes, pressing pressure 50-70 kN.

1. Materials and Methods

The object of research was used pulverized chips, arising from machining parts of steel ShKh15 in the plant of KMZ IT. Parchomenko» (Karaganda). Chemical composition of steel chips ShKh15 is given in table 1.

After machining of steel parts from ShKh15 steel on the grinding machines, chips are formed. This chip is sent to the retention system and then to the engineering networks for disposal through pipelines. In the engineering network, the chip undergoes a filtration process, after which it is collected into special containers and transported to the retention area for storage. In order to obtain high-quality bars, samples of chips are taken from the storage areas for briquetting and subsequent processing of fusing modes. The chemical analysis carried out on the spectrometer revealed an increased content of carbon and sulphur in the powder of the chip compared to the original steel ShKh15. This is due to the contamination of the chip with the residual coolant used in the grinding process [14, 15].

Table 1. Chemical composition of powder chips ShKh15

Element	C	Cr	Si	Mn	Ni	S	P	Fe
Content	1,01	1,52	0,24	0,25	0,12	0,01	0,02	96,83

Retsch analytical sieving machine was used to analyze the fraction composition of the swarf sludge, which showed that the bulk of the particles (70%) refers to the fraction 0-0.6 mkm. The fraction 0.7-3.0 µm constituted 25% of all particles. The particle content >1 mm was less than 5%. The bentonite clay analysis showed that the bulk of the particles is 0-0.7 µm, the fraction 0.7-1.0 µm was 20% of all the particles.

To determine the feasibility of manufacturing briquettes from Table 1 - Chemical Composition of Powder Chips steel chip processing in industrial conditions, identical laboratory studies of briquettes with different binder composition were carried out. The criterion of conditioning of such briquettes was their strength and chemical composition of carbon and chromium.

The briquette components (Table 2) were mixed in laboratory roller-type runners. The compound of liquid glass and bentonite clay is proposed as a binder. Various ratios of these additives were investigated.

Table 2. Complex Briquette sample compositions

Component	Content of sample					
	№ 1	№ 2	№ 3	№ 4	№ 5	№ 6
Steel Chip S15	84,5	84,5	84,5	89,5	89,5	89,5
Water	0,5	0,5	0,5	0,5	0,5	0,5
Liquid glass	10	8	5	7	5	3
Bentonite clay	5	7	10	3	5	7

The pressing was carried out in a press (Figure 1) with a diameter of 20 mm, using a laboratory press at a pressure of up to 500 kN.

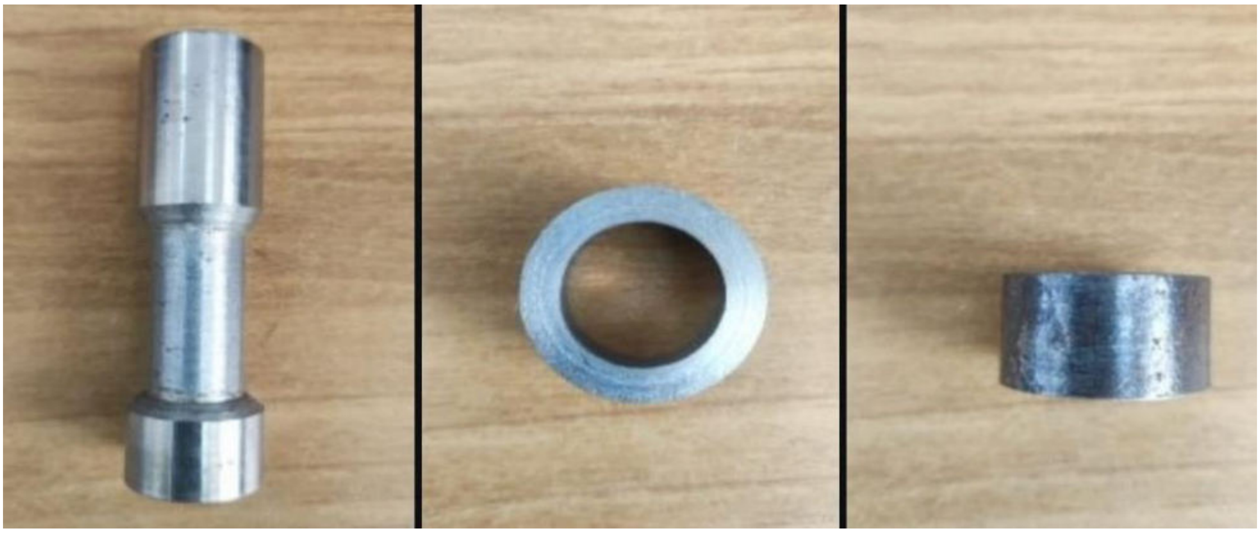

Fig. 1. - Punch and press prepared for briquette production

Briquettes sintering was carried out in the drying cabinet SNOL-67/350. In order to determine the optimal briquette drying regime, a briquette drying was carried out - 3 briquettes at each selected temperature in the Snol-67/350 oven, with the mass of the briquettes being determined every half hour to determine the amount of water evaporation. The most optimal briquette drying regime was found to be sample 4 (table 3), where at an initial temperature of 600C, the briquette is heated up to 60 minutes and dried out to 900C for 90 minutes.

Table 3. Selection of the optimal time and drying modes for briquettes

Sample briquettes	Drying time, min		Drying temperature, ^{0}C		Evaporation of water, g	
	primary	final	primary	final	primary	final
sample № 1	40	80	50	100	0,3	0,39
sample № 2	45	75	65	80	0,26	0,3
sample № 3	50	75	55	90	0,3	0,35
sample № 4	60	90	60	80	0,2	0,25
sample № 5	45	65	65	85	0,27	0,32
sample № 6	40	70	60	80	0,28	0,31

Briquette drying speed depends on the surface area as well as the briquette drying temperature. Also due to the evaporation of water during drying changes drying time. That is, the drying time is reduced at a higher temperature. We conclude that the optimum time for drying briquettes is 90 minutes and the drying temperature 80 ^{0}C (table 3). Because these modes show more optimal strength properties of the briquettes, which promote safe transportation and further loyal melting of the briquettes in induction furnaces.

Fig. 2. - Samples after drying

The briquettes were produced in two modes with the same temperature and different pressure (Table 4).

Table 4. Briquette modes

Type of binder	Mode	Temperature drying, ^{0}C	Duration drying, min	Pressure, kN
sample № 1	A	90	90	50
	B	90	90	60
	C	90	90	70
sample № 2	A	90	90	50
	B	90	90	60
	C	90	90	70
sample № 3	A	90	90	50
	B	90	90	60
	C	90	90	70
sample № 4	A	90	90	50
	B	90	90	60
	C	90	90	70
sample № 5	A	90	90	50
	B	90	90	60
	C	90	90	70
sample № 6	A	90	90	50
	B	90	90	60
	C	90	90	70

Strength was determined on the floor installation to determine the tensile strength of the Instron-100. The chemical composition was evaluated using an Olympus Vanta Element-S metal analyzer. The gas permeability of samples (Figure 3) was determined on a gas permeability measuring instrument type 04315M.

Fig. 3. - Samples of briquettes made from CH15 steel dust chips

2. Research results

The strength and gas permeability characteristics of the manufactured briquettes (Figure 2) are shown in table 5. The strength characteristics are affected by the oxide inclusions and the content of some blanks.

Table 5. Results of sample studies

Sample/mode	Characteristic			
	Compressive strength, MPa	Compressive strength, MPa	Content, %	
			C	Cr
№ 1 A	492	76	1,03	1,48
№ 1 B	504	74	1,04	1,47
№ 1 C	509	72	1,02	1,47
№ 2 A	514	78	1,01	1,46
№ 2 B	518	77	1,03	1,44
№ 2 C	521	74	1,00	1,45
№ 3 A	526	82	1,01	1,49
№ 3 B	537	80	1,02	1,47
№ 3 C	539	78	1,02	1,47
№ 4 A	517	73	1,00	1,51
№ 4 B	524	72	1,03	1,50
№ 4 C	526	71	0,99	1,50
№ 5 A	519	75	1,02	1,49
№ 5 B	526	71	1,00	1,48
№ 5 C	527	69	0,98	1,50
№ 6 A	524	75	1,01	1,50
№ 6 B	527	72	1,00	1,51
№ 6 C	529	70	1,01	1,52

Thus, it has been determined that the use of bentonite clay in a mixture together with liquid glass increases the strength of ShKh15 ball bearing steel briquette while maintaining the pressing and sintering modes. It is obvious that the partial use of bentonite clay in volume 10% with application of liquid glass in volume 5%. Probable mechanism of strengthening is wrapping (plating) the dispersed particles of clay dust and their good adhesion bond in liquid glass medium. The optimum total is a binder content of about 15%, but exceeding it is not advisable, as this results in a thicker binder layer between the particles which can be subject to brittle destruction as a result of loading. In addition, the increase of the binder content negatively affects the silicon content in the briquette. With increasing content of liquid glass in the mixture, gas permeability of briquette is reduced. Also the increase of pressure leads to a decrease in gas penetration [16-17].

The content of chromium and carbon in the briquettes is comparable to that of ShKh15 steel casting, which means that the binder components used do not have a significant effect on the chemical composition of the briquette.

The optimum pressing pressure for briquettes with complex binder composition has been determined to be 60 kN. Further pressure increase is not advisable, because at increased energy costs, almost does not affect the strength of the briquette.

In the study of the microstructure of a briquette, we concluded that fine grain gives the best mechanical properties at output (Figure 4).

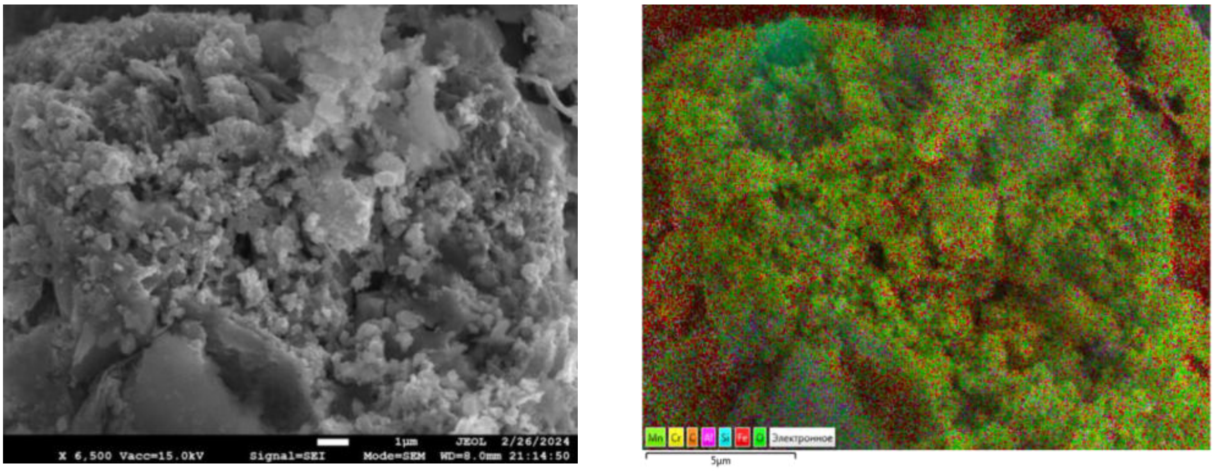

Fig. 4. - Microstructure of the briquette and multi-layer chemical element distribution map, 6500

Studies have shown that the distribution of chromium and carbon along the briquette volume is uniform.

Multiclo on the distribution map of chemical elements is obtained from the surface of the sample briquette. The distribution of carbon and chromium is uneven due to the briquette sintering processes, so they are more concentrated in the upper layers. The oxides are also less localized in certain areas of the briquette, which improves the strength and wear resistance of the briquettes.

Conclusion

The metal dust chip as a component of the metal sheet for the introduction of the further smelting process requires prior preparation at the expense of low strength. As a result, cold briquetting with binder components was used to improve the process properties.

According to the results of experimental studies, it was determined that the most optimal composition of briquettes obtained is: ShKh15 steel slag - 85%, liquid glass - 5%, bentonite clay - 10%. Briquette manufacturing regimes: drying temperature - 90 ^{0}C for 90 minutes, Press pressure 60 kN.

It was determined that the chemical composition of the briquette corresponds to the chemical composition of the main material according to GOST 801-78 «Ball bearing steel».

This briquetting method allows to obtain briquettes with chromium and carbon content comparable to the content of the main product and to produce a technologically necessary strength of the briquette (about 540 MPa). Based on the studies carried out, it can be concluded that the production of high-quality briquettes from scrap ShKh15 steel metal chips is the initial stage on the way to the production of high-quality steel ingot.

The study gives the start to the rational recycling of chip waste and its reuse in production, which allows to actualize complex activities aimed at reducing material losses and including involving it in a new technological cycle, and also provides ways to reduce pollution.

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