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RESEARCH PAPER

Remelting ferrochrome-crushing dust

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ABSTRACT

This article discusses the practical implications of remelting briquettes from ferrochrome dust after crushing. The formation of corrosion-resistant electrically conductive powder (CRP) and its fractional compositions are described, shedding light on the potential applications of this research. The partially described briquetting method used is explained, along with the equipment in detail, providing valuable insights for future research and industrial applications. A literature review on lignosulfonate-based binders provides a comprehensive understanding of this aspect. The work compares the remelt of briquettes in the base and experimental periods, where in the base period, dust is remelted in bulk (in the initial dusty state) and in the experimental period, in a briquette state. The article also characterizes the weighing of charge materials and their comparison; the tables indicate the electricity costs and electrodes spent on remelting, providing practical data for industrial operations. The chemical compositions of the charge materials for remelting and technical and economic indicators (referred to as TEI from now on) are given in the tables, offering practical guidance for future research and operations. The comparison results with standard melting modes are briefly touched upon, providing a valuable benchmark for the research. In the end, the results and conclusions of the work are written, summarizing the study's practical implications.

Keywords: remelting; briquetting; lignosulfonate; corrosion-resistant electrically conductive powder (CRP); dispersed metal dust

INTRODUCTION

Metallurgy is one of the most material-intensive industries and is characterised by significant production volumes on a planetary scale. Effective operation of huge production capacities is possible only by using high-quality metallurgical raw materials, the reserves of which are quickly depleted. This gives rise to a general raw materials problem [3].

Industrial waste, from the enrichment of raw materials or waste from its processing, is not only a source of environmental hazard but is also of interest in extracting valuable components to obtain marketable products [2].

As time passes, rich natural chromium raw materials exhaust their proven reserves. In modern production, the use of low-grade chromium ores and industrial wastes, such as dust, sludge, tailings, slag, overburden rocks, etc., into enrichment and metallurgical processes is becoming increasingly acute.

Modern industrial production requires processing larger quantities of raw materials from various minerals, which leads to the depletion of its reserves [4]. At the same time, as a result of enterprises' activities, a huge amount of man-made waste is generated, which, accumulating in dumps, sludge storage facilities, and landfills, exposes the environment to significant anthropogenic impact. In this regard, developing and implementing technologies that produce valuable products from waste is an urgent task.

When crushing high-carbon ferrochrome, aspiration dust is formed, in which the content of metallic chromium fluctuates within 70%; the market value of this dust is much lower than that of commercial ferrochrome, and in its original form, it has found practically no application in metallurgy.

Aspiration dust is dust-like waste from crushing and fractionating high-carbon ferrochrome (HCF). Its metallic chromium content ranges from 60-70% (**Table 1**). Due to their specificity, fine dust classes increase the likelihood of irretrievable losses of the target metal during storage and various movements [1].

Table 1 Chemical composition of aspiration dust, in %

Cr	Si	C	S	P
60-70	1,5-2,5	8-10	0,04	0,01

Briquette remelting is when briquettes of ore and other materials are melted down in metallurgical furnaces. This method is widely used in the metallurgical industry to produce various metals and alloys [5].

At first, briquettes are loaded into a furnace and heated to the melting point, where they begin to melt and form a liquid metal. The metal is then released from the furnace and poured into moulds for further processing.

One of the main advantages of briquette remelt is its efficiency. The use of briquettes reduces the amount of dust and increases the process's productivity [6].

The final stages of ferrochrome production are the crushing and sifting of metal ingots. These processes are carried out on crushing and screening complexes (after this, referred to as CSC) or lines that include crushers, screens and transport conveyors. Technological operations for crushing and fractionation are invariably accompanied by the formation of a certain amount of fine fraction and dispersed metal dust, which are captured by the dry aspiration system, which is also part of the CSC.

Technological operations for crushing and fractionation are invariably accompanied (in addition to commercial fractions) by forming a certain amount of screenings and dispersed metal dust. The latter is captured by a dry aspiration system, which is also part of the crushing and screening complex. Dispersed metal dust or the so-called corrosion-resistant electrically conductive powder at the Aktobe Ferroalloy Plant (after this AktFP) is disposed of by remelt. The primary and significant disadvantage of the method used at the plant is the high proportion of mechanical losses of corrosion-resistant electrically conductive powder when loading into the furnace and the actual dust removal from the furnace itself during the remelting process. To reduce the loss of corrosion-resistant electrically conductive powder during remelting, options and solutions for briquetting in several ways based on increasing the strength of the briquettes were studied in detail.

MATERIAL AND METHODS

Due to its dispersion, metal dust cannot be treated like screenings. More than 96% of the material is powder with a particle size of less than 0.071 mm, as **Table 2** clearly demonstrates.

Table 2 Fractional composition of CRP

Fraction, mm	Content, %
+0,2	0,07
-0,2 – 0 ,16	0,14
-0,16 – 0,125	0,31
-0,125 – 0,071	2,75
-0,071	96,73

CRP is dusty waste from crushing and fractionation of high-carbon ferrochrome (HFC) with a size class of 1 mm or less. Processing this dust into marketable products is an urgent task in the metallurgical processing of technogenic raw materials. An open issue is the effective utilisation of aspiration dust from crushing

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HFC. The annual volume of its formation at two ferroalloy plants (Aktobe and Aksu) is about 4500 tons.

Alluvial processing of CRP by remelting is associated with significant mechanical losses during loading into the furnace and oxidation and dust carryover into the gas cleaning system. According to estimates, the losses amount to 15-20% of the total annual volume of CRP formation. Taking this into account, rational recycling methods are needed to minimize or exclude such losses. One relatively simple and widespread way of dispersed materials utilization is briquetting by semi-dry pressing and further remelting of the obtained briquettes.

Considering CRP's physical characteristics, such as dispersion, low wettability, and needle-shaped metal particles, briquetting is the optimal option for agglomeration.

Briquetting

CRP was briquetted using a semi-dry hydraulic press. The binder material was an organic polymer based on lignosulfonate “lingo.” Ligno is a yellow-brown powder with a specific odour. **Fig. 1** shows the appearance of the hydraulic press and the resulting briquettes.

Fig. 1 Semi-dry hydraulic press and CRP briquettes

Briquettes Remelting

Pilot tests on remelting briquette CRP were conducted in an ore recovery furnace. According to the technology, during the smelting of ferrochrome in a furnace, several types of metal concentrate (after this - MC) from the production of HCFCh and refined ferrochrome metal concentrate (after this - FMC) are used. It was decided to use only one type of MC to reduce the error in assessing TEI. In the base period, the composition of the charge was as follows:

- CRP (in bulk) - 1 ton;
- MC fraction 0-5 mm (Cr not less than 45%) - 8 tons;
- Chrome ore - 1 ton;
- Ferrosilicochrome (hereinafter - FSH) – 0,4 tons;
- Lime- 0,8 tons.

Data on the chemical composition of the charge materials used during the testing period are presented in **Table 3**.

The mentioned above sample of the charge was taken as the base version, and we had been working on it for three days, conducting 27 heats. The process of loading CRP into the furnace was accompanied by heavy dusting, which made it difficult to distribute it evenly in the furnace bath. Dust was also carried into the workshop atmosphere, bypassing the gas treatment plant. In addition, emissions of CRP from the furnace are periodically observed during its remelt, heating of pipes and furnace pockets. The release and casting of the melt are carried out following the current regulations for conducting remelt processes in the furnace. Metal and slag samples were taken from each heat. After each release, weighing the resulting volume of slag and metal ingots was mandatory.

At the end of the base period, we switched to using briquettes instead of alluvial CRP. During the experimental period, the furnace operated according to the following blending:

- CRP briquettes – 1,3 tons;
- MC fraction 0-5 mm (Cr not less than 45%) - 8 tons;
- Chrome ore – 0,9 tons;
- FSH – 0,4 tons;
- Lime- 0,8 tons.

During the experimental period, 48 heats were conducted over 5,5 days. The furnace personnel noted the absence of dust and ease of loading, which allowed briquettes to be evenly distributed throughout the entire furnace bath. During the

Table 3 Chemical composition of charge materials, %

Material	Cr/ Cr_2O_3	Cr_{met}	Si/ SiO_2	CaO	MgO	FeO	C	P
MC	48.2	45.1	6.5	-	-	-	-	0.029
Chrome ore	-/50.7	-	-/7.2	0.8	11.6	17.5	6.9	0.007
CRP	56	51.2	-	-	-	-	-	-
Briquette	-	42.5	-	-	-	-	-	-
Lime	-	-	-	91.3	-	-	-	0.004
FSH	32.3	-	44.0	-	-	-	0.03	-

Table 4 TEI for smelting HCFCh in a furnace using CRP

№	Base period		Experimental period	
1	Specified batch, kg:		Specified batch, kg:	
	MC	213000	MC	374000
	CRP	30340	Briquette	61937
	Cr ore	27200	Cr ore	44000
	FSH	10800	FSH	19200
	Lime	21600	Lime	41600
2	Received metal, physical. kg:	120040	Received metal, physical. kg:	246370
3	Received slag, physical. kg:	97732	Received slag, physical. kg:	174766
4	Slag ratio	0,81	Slag ratio	0,71
5	Metal composition, %		Metal composition, %	
	Cr	67,69	Cr	68,24
	Si	0,68	Si	0,68
	C	6,69	C	6,71
	S	0,02	S	0,03
	P	0,03	P	0,03
6	Average heat weight in Cr met, kg	3012	Average heat weight in Cr met, kg	3503
7	Volume of dust from gas purification, kg	4220	Volume of dust from gas purification, kg	3960
8	Cr met in dust from gas purification, kg	1208	Cr met in dust from gas purification, kg	144
9	Specific electricity consumption, kW hour/t (physical weight)	2732	Specific electricity consumption, kW hour/t (physical weight)	2368

Table 5 Comparison of dust from gas purification and experimental periods

Material	**Base period**			**Experimental period**		
	Physical Weight, kg	Cr_{met}, %	Weight in $Cr_{\text{мет}}$, kg	Physical Weight, kg	$Cr_{\text{мет}}$, %	Weight in $Cr_{\text{мет}}$, kg
Dust from gas purification	4220	28,67	1210	3960	3,63	144

experimental period, emissions from the smelting process and the heating of furnace pockets and pipes stopped. All technological operations for smelting and casting followed the current regulations for conducting remelt processes in the furnace.
Technical and economic indicators of the base and experimental periods are presented in **Table 4**.

The test results show that the volume of smelted metal increased by 16% during the experimental period. The specific reduction in losses of metal chromium with dust was in the primary mode, from 10 kg/t to 0.58 kg/t. At the same time, specific energy consumption decreased by 13.3% and electrodes by 5% (per 1 ton of smelted ferrochrome).

RESULTS AND DISCUSSION

At the end of the primary and experimental periods of pilot testing, dust was unloaded from the gas purification dust collection bunker and weighed on truck scales. A weight comparison showed that the dust generated in gas purification using CRP briquettes decreased. Dust samples for chromium metal were taken during the base and experimental periods of the pilot test. The results show that gas purification captures most specified dust, including metallic chromium, when using alluvial CRP. **Table 5** compares the captured dust from gas purification in the base and experimental periods.

CONCLUSION

As can be seen from the presented data, the use of briquettes made from CRP dust allowed:

- increase the yield of commercial metal by 16%;
- reduce the specific formation and loss of metallic chromium with dust from gas purification from 10 kg/t to 0,58 kg/t;
- reduce specific energy consumption by 13,3%;
- reduce the specific consumption of electrodes by 5%;

Thus, the successful use of briquettes provides an opportunity to introduce the technology for producing briquettes from CRP according to the proposed technology using a vibrocompression method followed by remelting in a furnace.

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