M. NIESLER, J. STECKO, J. ŁABAJ, A. SMAGÓR, L. BLACHA

ISSN 0543-5846
METABK 61(1) 273-276 (2022)
UDC / UDK 669.3:66.082:622.335-621.775:662.81:620.18=111

APPLICATION OF WASTE ANTHRACITE DUST IN THE PROCESS OF COPPER MATTE SMELTING

Received – Primljeno: 2021-04-20
Accepted – Prihvaćeno: 2021-07-29
Preliminary Note – Prethodno priopćenje

This study presents the results of research on the process of smelting of copper matte with the use of anthracite waste dust as fuel. A method of introducing this carbon-bearing waste into the technological process carried out in a shaft furnace in the form of an additive to briquettes with copper concentrate was developed. These briquettes were tested for the required strength properties.

Keywords: copper matte, concentrate, anthracite dust, briquettes, structure

INTRODUCTION

The significant increase in the production of various types of materials for applications in many fields of technology, observed for many years, resulted in a relatively quick depletion of natural resource deposits. This also applies to fuels, used in large quantities in many pyrometallurgical processes, for which less expensive alternative carbon-bearing materials are sought [1-8]. An example of a technology that uses coke as fuel is the production of copper matte in a shaft furnace. In this process, coke constitutes about 10 % of the total mass of the input processed with this technology [9-14]. When looking for alternative fuels, it should be remembered that they must ensure the proper course of a given technological process and thus not disturb its heat balance, do not cause additional consumption of fluxes or the formation of increased amounts of slags. In the case of metallurgical aggregates such as shaft furnaces the strength properties of the fuel also play a very important role, which clearly affect, for example, gas permeability of the charge.

This study presents the results of research on the smelting of copper matte with the use of fine-grained anthracite waste dust. The proposed solution reduces the costs of the discussed technology and at the same time is a method of managing waste generated in another production process.

MATERIALS FOR TESTING

A mixture of copper concentrates with the composition given in Table 1 was used in this research. Waste anthracite dust was used as fuel in the process. This material has a similar calorific value compared to the coke used in the analysed process of smelting copper matte in a shaft furnace.

Table 1 **Chemical composition of copper concentrates used in the tests**

Content / wt %						
Cu	Al	Ca	C	Fe	SiO_2	S
17,5	3,43	3,42	10,5	7,81	19,7	12,06

METHODOLOGY

Shaft furnaces are metallurgical units where input materials require appropriate preliminary preparation. This applies to the necessity to form them into pieces, ensuring adequate air circulation of the input column and preventing the input material from being lifted by waste gases. Therefore, it was assumed that a fine-grained carbon-bearing material would be introduced into the shaft furnace in the form of an additive to the briquette made of copper concentrate. Taking this into account, a programme consisting of the following two stages was adopted:

- Research on briquetting of copper concentrate – anthracite dust mixtures
- Smelting of copper matte from the obtained agglomerates.

The research on agglomeration conducted in the first stage was carried out after the initial homogenisation of the compacted materials with the use of a modern rotary mixer. The agglomeration was carried out using a punching machine with a pressing force of up to 30 tonnes. As a binder, sodium lignosulphonate was also used as a component of the agglomeration mixtures. The selection of this binder resulted from the fact that it is used for briquetting metal concentrates in industrial conditions. The obtained briquettes were subjected to drop strength tests and a quasi-static compression test.

M. Niesler (e-mail: Marian.Niesler@imz.pl) - Łukasiewicz Research Network – Institute for Ferrous Metallurgy, Gliwice, Poland, J. Stecko - Łukasiewicz Research Network – Institute for Ferrous Metallurgy, Gliwice, Poland, J. Łabaj Silesian University of Technology, Gliwice, Poland, A. Smagór Silesian University of Technology, Gliwice, Poland, L. Blacha Silesian University of Technology, Gliwice, Poland.

The latter was carried out with the use of an INSTRON universal testing machine. In addition, the briquettes were subjected to homogeneity assessment, which was performed based on the analysis of the image obtained from the briquette cross-section. The analysis of the geometrical structure of the surface images was performed using the MountasMap version 7 software. The smelting of the copper matte from the prepared briquettes was carried out in a shaft furnace with air blast [7]. The basic parameters of this device are presented in Table 2.

Table 2 **Technical characteristics of a shaft furnace used for smelting copper matte**

No.	Parameter	Value
1	Diameter	350 mm
2	Productivity	0,6 Mg/h
3	Useful height	2,45 m
4	Number of nozzles	1

RESEARCH RESULTS AND DISCUSSION - INVESTIGATION OF THE PROPERTIES OF BRIQUETTES

The briquetting process was performed on a Cu concentrate-anthracite dust mixture. Table 3 shows the determined values of compressive strength of briquettes obtained from these mixtures. The obtained compression curve is shown in Figure 1.

The data presented above show that the obtained briquettes are characterised by very good strength properties. This means that during processing in a shaft furnace there should be no disadvantageous phenomenon of their crushing and thus their removal along with the dust. As previously mentioned, the briquettes were also subjected to a drop strength test. Figure 2 shows examples of test results of drop tests for briquettes from the tested mixture obtained for samples after the maturing period. This strength was presented as the fraction of briquettes with a diameter greater than 10 mm in the total mass of briquettes. The presented results relate to the strength after 3 drops, because this number of drops was adopted as an illustration of the briquette transport process from the moment of production to the moment of loading into the shaft furnace (in industrial conditions).

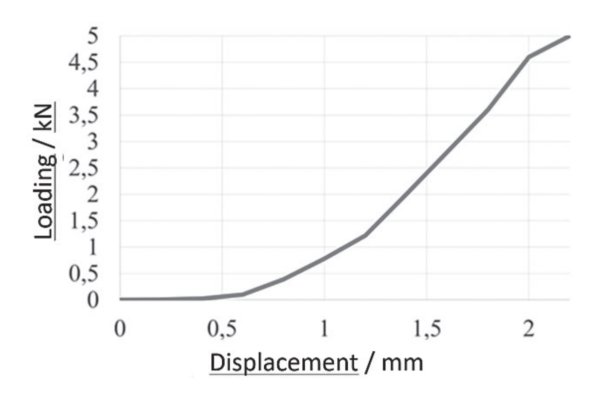


Figure 1 Compression curve of briquettes made of concentrate – anthracite dust mixtures

Table 3 **Arbitrary compressive strength of Cu concentrate – anthracite dust briquettes**

Mixture type	Mixture ingredients	Content / wt %	Max force / N	Arbitrary compressive strength / MPa
fresh	Cu concentrate	87	5000	3,88
	lignosulphonate	3		
	anthracite dust	10		
matured	Cu concentrate	87	8466	6,58
	lignosulphonate	3		
	anthracite dust	10		

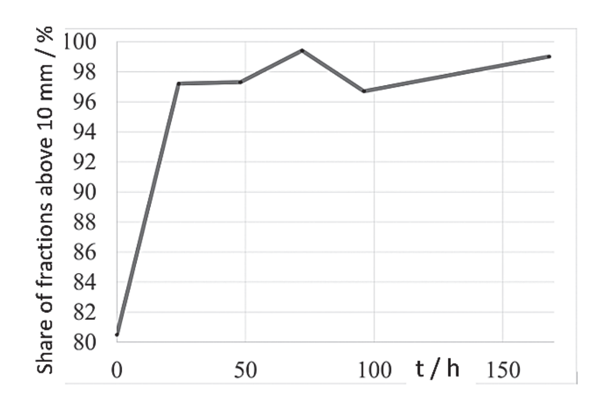


Figure 2 Results of drop strength tests for briquettes with the addition of anthracite dust for specific maturation times

The briquettes were also subjected to homogeneity assessment, which was performed based on the analysis of the image obtained from the briquette cross-section. Examples of the results of structure examination for the manufactured briquettes are shown in Figures 3-6.

No significant porosity was observed when analysing the results of structural examination of briquettes. No cracks or discontinuities were found on the cross-sectional surface of these briquettes, both in their origi-

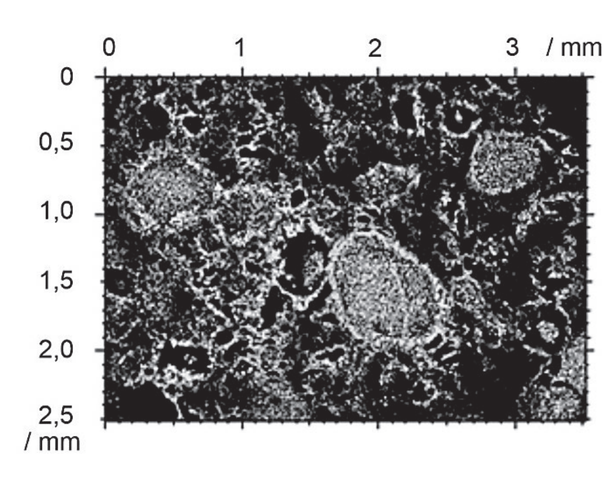


Figure 3 Macrostructure of the Cu concentrate – anthracite dust briquette cross-section

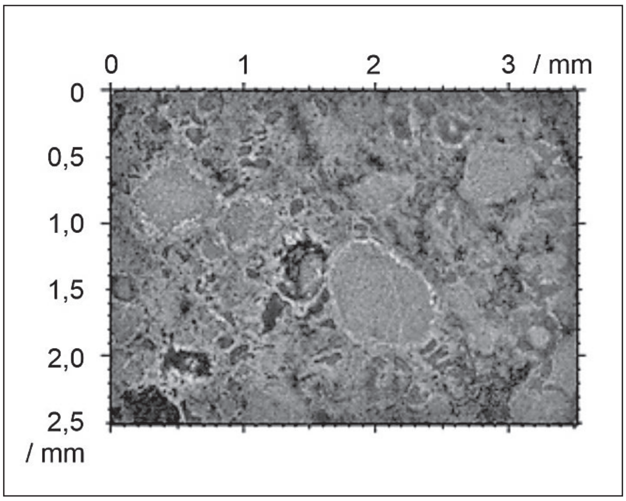
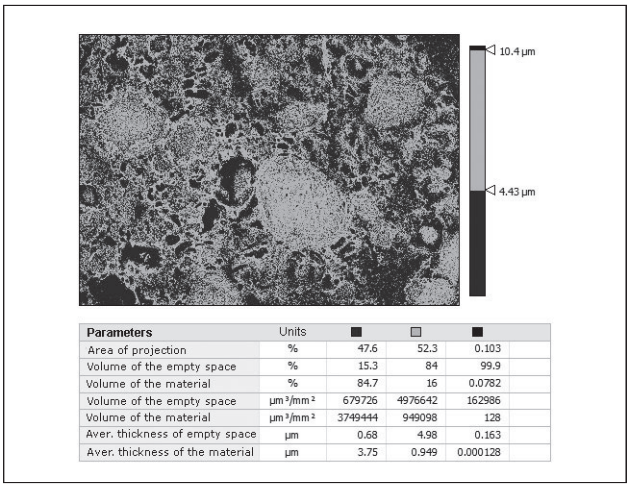


Figure 4 Binary image of the Cu concentrate – anthracite dust briquette cross-section



Parameters	Units	■	□	■
Area of projection	%	47.6	52.3	0.103
Volume of the empty space	%	15.3	84	99.9
Volume of the material	%	84.7	16	0.0782
Volume of the empty space	µm³/mm²	679726	4976642	162986
Volume of the material	µm³/mm²	3749444	949098	128
Aver. thickness of empty space	µm	0.68	4.98	0.163
Aver. thickness of the material	µm	3.75	0.949	0.000128

Figure 5 Grain distribution in the Cu concentrate – anthracite dust briquette cross-section

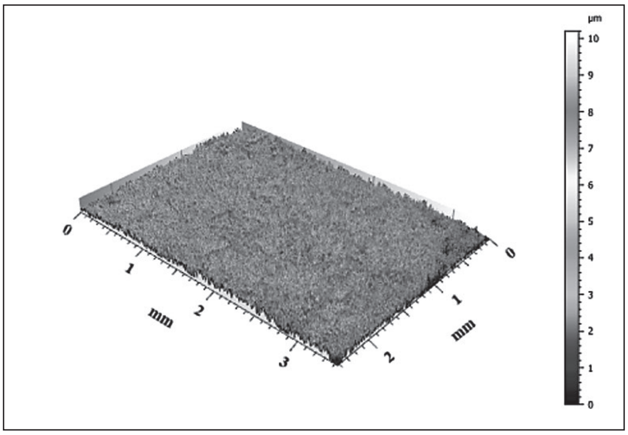


Figure 6 Distribution of agglomerate boundaries in the Cu concentrate – coal flotoconcentrate briquette cross-section, 3D view

nal state and after maturation. The results of research on the surface structure of briquettes Cu concentrate – carbon-bearing additive – confirmed that anthracite dust is a beneficial carbon-bearing additive in the copper matte smelting process.

Table 4 **Averaged chemical composition of obtained copper mattes**

Concentrate + anthracite dust				
Content of ingredients / wt %				
Cu	Fe	Pb	SiO_2	S
60,6	12,1	2,1	0,88	19,2
Copper matte, industrial data				
Content of ingredients / wt %				
Cu	Fe	Pb	SiO_2	S
58 - 63	10,5 - 11,5	3 - 4	up to 1 %	20,5 - 21,5

COPPER MATTE MELTS

In order to confirm the metallurgical quality of the obtained briquettes from the tested mixtures, copper matte melts from these charge materials were verified. The chemical composition of the obtained copper mattes is presented in Table 4. For comparison, the table also shows the average chemical composition of copper matte obtained under industrial conditions.

The data presented in Table 4 show that a satisfactory degree of transition of the components of the copper concentrate to the smelted copper matte was obtained. The Cu content in the copper matte is within the range of values obtained in industrial conditions.

CONCLUSIONS

Based on the results of the conducted investigations it was concluded that:

- It is possible to introduce waste anthracite dust to the process of copper matte smelting in a shaft furnace in the form of briquettes with copper concentrate. Thus, it can be a partial replacement for the coke breeze used in this process as a fuel.
- The maturing process does not reduce the compressive strength of the obtained briquettes.
- The introduction of anthracite dust in the mixture into the briquetting process in the amount of up to 10 wt% allows obtaining briquettes with the technologically required drop strength and compressive strength.
- The maturing process does not reduce the strength properties of the obtained briquettes.
- The content of Cu in the copper matte obtained in the process of remelting briquettes containing Cu concentrate and anthracite dust is within the range of values obtained in industrial conditions.

REFERENCES

[1] J. Legemza, M. Fröhlichova, R. Findorak, Thermodynamic study of utilization of charcoal in the iron-ore sintering process, International Multidisciplinary Scientific Geo-Conference (2013), 649-659.

[2] L. Liu, X. Li, M. Mahoney, Z. Zang, Biomass Materials for Metallurgical Advances in Materials Science and Engineering, (2018), doi.org/10.1155 /2018/7297136

[3] R. Findorak, J. Legemza, M. Fröhlichova, G. Fabriciová, M. Džupková, New utilization of specific biomass: Lignin in the iron ore sintering process, Metals, 10 (2020), 1170, 1-17, doi:10.3390 /met10091170.

[4] M. Alwaeli, J. Golaszewski, M. Niesler, J. Pizoń, M. Golaszewska, Recycle option for metallurgical sludge waste as a partial replacement for natural sand in mortars containing CSA cement to save the environment and natural resources, Journal of Hazardous Materials, 398(2020), 123101, 1-14, doi.org/10.1016 /j.jhazmat.2020.123101

[5] C. Hillmann, K.Sassen, Solutions for dusts and sludges from the BOF process Stahl und Eisen, 126 (2006), 11, 149-156.

[6] M. Alwaeli, The implementation of scale and steel chips waste as a replacement for raw sand in concrete manufacturing. Journal of Cleaner Production 137 (2016), 1038-1044. doi.org/10.1016 /j.jclepro.2016.07.211.

[7] J. Łabaj, L. Blacha, A. Smalcerz, R. Findorak, M. Niesler. Utilization of waste coal flotation concentrate for copper matte smelting, Engineering Science and Technology, an International Journal (2021), https://doi.org/10.1016/j.jestch.2021.01.003

[8] A. Babich, D. Senk, M. Knepper, S. Benkert, Conversion of injected waste plastics in blast furnace, Ironmak Steelmak, (2015), 11-21 doi.org /10.1179/1743281215Y.0000000042

[9] V. Trinkel, N. Kieberger N, T. Bürgler, H. Rechberger, J. Fellner, Influence of waste plastic utilisation in blast furnace on heavy metal emissions, Journal of Cleaner Production, 94 (2015), 312-320, doi.org/10.1016/j.mset.2019.08.002

[10] C. Wang, P. Mellin, L. Nilsson, M. Larsson, Injecting different types of biomass products to the blast furnace and their impacts on the CO_2 emission reduction, AISTech, 1 (2015), 1525-1534.

[11] M. Niesler, Method of testing of reactivity of coke with different grain sizes and its verification under industrial conditions, Archives of Metallurgy, 48 (2003), 1, 87-103.

[12] K. W. Ng, L. Giroux, T. Macphee, T. Todoschuk, Combustibility of charcoal for direct injection in blast furnace ironmaking, Iron and Steel technology, 9 (2012), 3, 1-7.

[13] G. Hanniker, J.C. Davidson. Toward 300 kg/thm coke rate with granular coal. Ironmaking Conference Proceedings, Glasgow, UK, 50 (1991), 503-516.

[14] M. Kucharski, Pirometalurgia miedzi, Wydawnictwo AGH Kraków, 2003.

Note: The responsible translator for English language is Ling House, Poland