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A STUDY ON THE PROCESS OF FINE-GRAINED PLUMBIFEROUS MATERIAL AGGLOMERATION

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In the paper, results of a study on the agglomeration process of fine-grained plumbiferous materials, belonging to basic resources for lead recovery, are presented. For the agglomeration tests, a laboratory drum granulator and a balling disc were utilized. The obtained granules were tested for compression strength with the use of a so-called Michaelis testing device as well as for drop strength, determined per the standards. The results allowed for evaluating the effects of the composition of the blend of materials subjected to agglomeration on the quality of obtained granules.

Key words: metallurgy, plumbiferous materials, agglomeration, grains

INTRODUCTION

Currently, there are significantly higher amounts of generated fine-grained carboniferous and plumbiferous materials. Their sources are results of the activity of coal mines, coking plants and metallurgical companies. Management of these materials in their primary form, either for energy or metallurgical industries, is very difficult due to a high level of refinement, various chemical compositions and, frequently, high water content. One of the solutions aimed at reusing these materials for specific technological purposes is their pre-treatment – briquetting. Certain technologies have already been developed, including granulation of coal slurry-biomass blends, granulation of converter sludge, briquetting of various types of ferriferous waste or EAF dust agglomeration [1 - 9].

For pyrometallurgical processes, briquetting is even more important as its product becomes a charge material containing metalliferous components and, necessary for the process, carbon. In this case, as carboniferous materials, fine-grained waste from e.g. a coal-enrichment process, coke dust, anthracite dust or coal soot can be used for briquetting. Loading these materials into a metallurgical unit as direct substitutes for e.g. coke is not possible due to a high level of their refinement, but they can be used in the forms of briquettes or agglomerates. By utilization of fine-grained carboniferous waste as alternative fuel in a metallurgical process, a considerable cost reduction may be expected. However, it should be noted that such a replacement may result in a harmful increase in CO_2 emission [10]. In the paper, results of the study on waste agglomeration processes with the use of carboniferous materials and a plumbiferous sludge fraction (generated during lead-acid accumulator scrap treatment) are presented.

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MATERIALS AND RESEARCH EQUIPMENT

For the tests, three types of carboniferous materials, i.e. coke dust, anthracite dust and coal slurry, were used. Their properties are presented in Table 1.

The plumbiferous material, used in the study, was sludge generated during lead-acid accumulator scrap treatment. Plumbiferous material used in the researches contained 78,6 % mass of Pb.

Table 1 **The analysis of investigated fine-grained carboniferous materials**

Parameter	Coke dust	Anthracite dust	Coal slurry
Humidity content / %mass	0,3	5,1	27,3
Carbon content / %mass	88,5	82,3	ND
Sulphur content / %mass	0,66	1,51	0,95
Ash content / %mass	10,35	10,7	32,56
Volatile matter content / %mass	0,8	185	ND
Calorific value / kJ/kg	28 500	27 875	10 633

The agglomeration tests were performed with the use of a laboratory drum granulator and a balling disc. Preliminary tests, aimed at selecting granulation conditions, were conducted in the drum granulator, while semi-technical tests – by means of the balling disc (the efficiency of 3 Mg/h).

The compression strength tests were performed with the use of a so-called Michaelis testing device, while the drop strength values were determined, per the standards, based on the results of sample drops from the height of 2 metres onto a steel sheet.

RESULTS

For the agglomeration tests, 15 variants of blends were prepared according to the study schedule. Their compositions are presented in Table 2. The post-agglomeration granules were subjected to the strength tests.

Due to the fact that under industrial conditions, processing of the metalliferous fraction generated during acid-lead accumulator scrap treatment is performed mainly in rotary-rocking and rotary-tilting furnaces, these properties of charge material are of high importance. As the technology of accumulator scrap treatment is a continuous process that requires large supplies of charge materials, the obtained granulates were also subjected to seasoning.

Table 2 **Component fractions with regard to plumbiferous sludge in pre-granulation blends / % mass**

No.	Na_2CO_3	Reducers			Ferrum source		Binder
		Coke dust	Anthracite dust	Coal slurry	Mill scale	Steel filings	Hydrated lime
1	-	6	-	-	-	-	-
2	8	6	-	-	-	-	-
3	8	6	-	-	8	-	-
4	8	6	-	-	-	-	5
5	8	6	-	-	8	-	5
6	8	6	-	-	-	8	5
7	8	-	-	6	8	-	5
8	8	-	-	6	-	8	5
9	8	-	6	-	-	8	5
10	8	-	6	-	8	-	5
11	8	-	-	6	-	8	-
12	8	-	-	6	8	-	-
13	8	-	6	-	8	-	-
14	8	-	6	-	-	8	-
15	8	6	-	-	-	8	-

The compression strength test results for the granulates obtained from various blends are listed in Tables 3 and 4. It is known that the acceptable charge material grain sizes in the technology of plumbiferous sludge treatment should not be smaller than 3 mm. Therefore, the granulates containing grains sized over 10 mm and 3 – 5 mm were included in the tests.

The analysis of data presented in Tables 3 and 4 revealed that for the granulates with grains sized 3 ÷ 5 mm, compression strength values were frequently over two-fold smaller than the values obtained for the grains sized over 10 mm. It should be noted, however, that the strength reduction vs time during the seasoning period was less rapid than that observed for bigger grains. In both cases, the post-granulation material showed plastic properties.

After a 24-hour seasoning period, the compression strength values for the granulates were 9 ÷ 10,3 daN/granule for the smaller grains and 17,1 ÷ 26,7 daN/gran-

Table 3 **Compression strength values for the granulates with grains sized > 10 mm, obtained from selected blends after a seasoning period**

No.	Compression strength / daN/granule			Water content in the blend / %mass	Water content in the granulate / %mass
	After 24 h	After 3 days	After 6 days		
1	24,1	19,0	15,1	7,8	19,7
2	26,2	22,0	18,3	7,6	16,9
3	25,7	21,6	18,8	7,1	15,4
4	26,7	18,2	14,1	7,3	18,5
5	24,1	21,3	17,7	6,9	17,8
6	24,9	18,8	14,3	6,9	18,3
7	25,5	18,3	13,5	7,8	21,7
8	20,8	18,6	17,7	7,8	20,0
9	19,4	14,8	12,2	7,8	21,1
10	24,2	15,2	11,0	7,8	21,0
11	24,8	18,8	14,4	8,1	17,1
12	24,3	16,7	11,8	8,1	15,3
13	18,5	11,2	10,0	8,1	16,5
14	17,1	13,6	11,5	8,1	16,8
15	26,0	20,4	13,8	7,2	15,3

Table 4 **Compression strength values for the granulates with grains sized 3–5 mm, obtained from selected blends after a seasoning period**

No.	Compression strength / daN/granule			Water content in the blend / %mass	Water content in the granulate / %mass
	After 24 h	After 3 days	After 6 days		
1	10,2	9,4	8,4	7,8	19,7
2	9,9	9,2	8,8	7,6	16,9
3	9,8	9,1	8,8	7,1	15,4
4	10,0	9,4	8,9	7,3	18,5
5	10,3	9,6	8,9	6,9	17,8
6	9,1	8,9	8,6	6,9	18,3
7	9,4	9,0	8,7	7,8	21,7
8	9,8	9,1	8,5	7,8	20,0
9	10,2	9,7	8,8	7,8	21,1
10	9,2	8,9	8,4	7,8	21,0
11	10,0	9,2	8,5	8,1	17,1
12	9,0	8,8	8,6	8,1	15,3
13	9,5	9,0	8,5	8,1	16,5
14	9,2	8,9	8,5	8,1	16,8
15	9,9	9,0	8,4	7,2	15,3

ule for the grains sized > 10 mm. After 3 days of seasoning, the compression strength values for the granulates slightly decreased and they were 8,8 ÷ 9,4 daN/granule for the smaller grains and 11,2 ÷ 22,0 daN/granule for the grains sized >10 mm, while after the 6-day seasoning period, the values were 8,4 ÷ 8,9 daN/granule and 10,0 ÷ 18,8 daN/granule, respectively.

The results of drop shatter tests for the obtained granulates (Tables 5 and 6) showed that the seasoning process resulted in drop strength reduction. For the > 10 mm agglomerates, over 90 % of grains remained intact after one drop regardless of the seasoning duration, while after three drops, granulate degradation was observed. After the 6 - day seasoning period, large amounts of subgrains sized <10 mm were seen (up to 80 ÷ 85 %). It should be noted, however, that the granulate did not crumble into dust but into a few pieces with grains sized 3 ÷ 5 mm which can be successfully utilized for further processing.

Table 5 **Drop strength values for the granulates with grains sized > 10 mm, obtained from selected blends**

No.	After a 24-hour seasoning period		After 6 days of seasoning	
	1 drop	1 drop	1 drop	3 drops
1	96,5	95,2	95,2	34,4
2	97,2	97,5	97,5	38,5
3	100	95,8	95,8	27,4
4	98,1	96,0	96,0	40,0
5	99,0	98,7	98,7	35,4
6	96,8	100	100	20,3
7	97,9	100	100	44,3
8	96,1	85,2	85,2	38,4
9	97,3	97,6	97,6	26,9
10	98,5	98,9	98,9	34,9
11	99,6	90,3	90,3	35,8
12	95,4	99,0	99,0	40,1
13	97,5	99,6	99,6	22,8
14	98,9	100	100	37,4
15	100	98,8	98,8	15,2

Table 6 **Drop strength values of the granulates with grains sized 3 ÷ 5 mm, obtained from selected blends**

No.	After a 24-hour seasoning period		After 6 days of seasoning	
	1 drop	3 drops	1 drop	3 drops
1	96,5	90,2	97,8	79,3
2	97,9	89,9	97,9	83,2
3	98,0	92,3	98,0	81,4
4	98,1	87,4	98,2	84,4
5	99,1	88,4	98,4	80,6
6	96,2	90,5	98,6	85,3
7	97,8	90,0	96,8	77,4
8	98,0	92,3	95,7	70,4
9	97,9	88,9	97,3	80,1
10	99,0	93,5	97,5	73,7
11	99,1	91,1	92,6	70,2
12	98,0	89,2	97,9	81,6
13	97,5	91,0	96,8	78,5
14	98,1	87,9	97,3	83,2
15	97,9	92,0	99,2	80,1

For the agglomerates with grains sized 3 ÷ 5 mm, 1 drop yielded 97 % of grains >3 mm in practically all cases. A very important property was the amount of granulate with > 3 mm grains: 90 ÷ 95 % immediately after the granulation process. During the seasoning period, the drop strength of granulates decreased, but not as rapidly as it was observed for the granulates with grains sized over 10 mm. Immediately after the granulation process and after 3 drops, the fractions of >3 mm grains were 90 ÷ 95 % and slightly decreased to 87 ÷ 93 %, 85 ÷ 90 % and 70 ÷ 85 % after 24 hours, three days and six days of seasoning, respectively, which means that the granulates with smaller grains, due to their lower mass, get broken to a lesser extent.

A comparison of the analyses of strength values for granulates with various grain sizes shows that the granulates with grains sized 3 ÷ 5 mm demonstrated better drop strength properties but worse compression strength parameters compared to the granulates with grains sized 10 ÷ 12,5 mm. The compression strength is a very important property if granulate is meant to be processed in a shaft furnace where a high compression strength of the charge column is required. If granulate is processed in rotary-rocking or rotary-tilting furnaces, the compression strength parameter does not seem to be of such importance.

Here, the drop strength is an essential parameter. As mentioned above, immediately after the granulation process, the material was plastic and did not crumble. It is a very important property which enables transportation of granulate to the seasoning site or directly to the production process. Particularly good drop strength values were observed for the granulates with grains sized 3 ÷ 5 mm; however, the granulates with grains sized over 10 mm should not be neglected as they did not crumble into dust after the drops but into a few pieces with grains sized 3 ÷ 5 mm which can be successfully utilized for further processing.

In the case of granulate treatment, seasoning duration should also be considered. Raw granules contained about 15 ÷ 21 % mass of water which must be eliminated during the production process. That means additional consumption of energy necessary for its evaporation. After three days of seasoning, the granules contained about 2 ÷ 5 % mass of water and their mechanical properties were good enough to use the granules in the production process.

Furthermore, the tests showed that the obtained granulates broke down in water, which means that if they are meant for temporary seasoning and storing, this must be performed in sheltered sites that are resistant to atmospheric conditions. Depending on technological parameters, granulates with grains of various sizes can be produced with an optimal seasoning period aimed at efficient processing of the material.

SUMMARY

Based on the results of tests with the use of plumbiferous sludge obtained from accumulator scrap, performed by means of the granulation method with various reducers and ferrum sources, it was demonstrated that:

- Blends of plumbiferous material and various reducers (coke dust, anthracite dust, coal slurry) as well as ferriferous materials (mill scale, filings) showed very good agglomeration abilities. An efficient granulation process required previous crushing and sieving of the plumbiferous material and coal slurry as they tend to cake rapidly.
- The water content in all blends before briquetting was 7 ÷ 8 %, i.e. too small for the granulation process. During blend granulation, the water content in the final product should be supplemented to about 15 ÷ 21 % – such water content yielded a granulate with proper parameters.
- A characteristic property of the granulated blends was reduction in strength during seasoning, which decreased with time.
- Hydrated lime, added as a binder, did not affect the granule strength properties, which means that if lime is not required for the technological process, its usage may be unjustified.
- Immediately after briquetting, the granulates were plastic and did not crumble, which enables transportation of the granulate to the seasoning site or directly to the production process.
- In the case of granulate treatment, seasoning duration should be considered. Raw granules contained about 15÷21 % mass of water which must be eliminated during the production process. That means additional consumption of energy necessary for its evaporation. After three days of seasoning, the granules contained about 2 ÷ 5 % mass of water and their mechanical properties were good enough to use the granules in the production process.
- If granulate is meant for temporary seasoning and storing, this must be performed in sheltered sites because humidity is a cause of its crumbling.

REFERENCES

[1] H. Giemza, G. Gruszka, J. Hycnar, T. Józefiak, K. Kiermaszek: Technologie odzysku drobnoziarnistych materiałów i odpadów węglowych na potrzeby produkcji paliw. Materiały konferencji „Zagospodarowanie surowców energetycznych i energii w gospodarce krajowej". Zakopane (2009), 51-59.

[2] A. Lutyński., J. Szczypka: Zagospodarowanie drobnoziarnistych odpadów ze wzbogacaniem węgla kamiennego, Górnictwo i Geoinżynieria, 34 (2010), 4/1, 155-163.

[3] J. Łabaj, M. Słowikowski, W. Żymła, J. Lipart: The research on reactivity of alternative carbon reducers, Metalurgija 52 (2013), 1, 68-70.

[4] G. Borowski: Produkty odpadowe jako surowce wtórne, Inżynieria ekologiczna (2009), 21, 85-96.

[5] N. El-Hussiny, M. Shalabi: Effect of recycling blest furnace Flue Dust on the sintering Performance, Science of Sintering 42 (2010), 269-281.

[6] M. Nakano, T. Okada, H. Hasegawa, M. Sakakibara: JSIJ International vol. 40 (2000), 3, 238-243.

[7] D. Senk, H. Gudenau, S. Geimer, E. Gorbunova: JSIJ International vol. 46 (2006), 12, 1745-1751.

[8] D. Senk, A. Babich, H. Gudenau: Rev. Metal. Madrid (2005), 284-288.

[9] F. Su, H. Lampinen, R. Robinson: JSIJ International vol. 44 (2004), 4, 770-776.

[10] V. Roubiček, P. Pustějovska, J. Bilik, J. Janik: Decveasing CO_2 emission in metallurgy, Metalurgija 46 (2007), 1, 53-59.

Note: The responsible for English language is the lecturer of Silesian University of Technology