THE DETECTION OF CORUNDUM IN SLAGS

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Abstract

The aim of the study was to determine the detection possibilities for corundum in slags. Corundum may be a harmful component in the secondary utilization of slag. To determine the occurrence and amount of corundum in slag, gravity concentration was used (using the specific weight differences) on tables. The first step of the partial work was detailed characterization of the material using mechanical and physical parameters, including, for example, particle size distribution or friction parameters. In the practical part, the material was first re-sorted. Subsequently, it was examined whether gravity concentration can be used to analyse corundum particles in slags. Individual tests were performed on water and pneumatic plate. Finally, the samples were floated. Some conclusions of the experiments suggest that gravity concentration can be used on plates to capture and analysis corundum minerals in these samples of slags. The quantity of the particles obtained and their size depended on the type of technological treatment. This method has been tested and applied in the laboratory of a company dealing with slag treatment.

Keywords: Slag, corundum, gravity concentration, vibrating table

1. INTRODUCTION

Slag originates as a secondary product during processing of ferrum and steel by means of melting, metal refining, firing of coal or various waste. Slag is considered a waste originating as a secondary product in metallurgical processes. It is divided into several groups according to its origin: blast furnace slag (during ferrum production), steel slag (during steel production) or eventually foundry slag. In **Table 1** it is possible to compare differences in average percent representation of individual elements that can be found in blast furnace and steel slag. The greatest differences are recorded within values SiO_2 a $FeO + Fe_2O_3$. [1, 2]

Table 1 Percent differences among basic elements contained in slags [2]

Slag	Element (wt. %)					
	MnO	MgO	CaO	Al_2O_3	SiO_2	$FeO+Fe_2O_3$
Blast furnace	0.5-2	10-14	35-38	6-9	34-38	0.5-1
Steel (carbonaceous steel)	3-8	5-15	35-60	2-9	9-20	15-30
Steel (alloyed steel)	0.4-2	8-15	39-45	3-8	24-32	1-6

Nowadays, slag is largely used as a secondary raw material mainly in the building industry. Within this branch, it can supply primary raw materials very well. It is thus advantageous from the ecological as well as economical point of view. [1, 3] It effectively cuts expenses for production of used building material (cement. dry mortar alloys. concrete. mortar. bricks. pavers and many other products) by 15 - 30 %. We can find many examples showing usage of slag for these purposes abroad, for example 100 % of the slag annual yield is utilized in

Germany or Denmark. Furthermore, up to 70 % of the annual yield is utilized in the United States. Great Britain. Poland etc. [4]

Corundum is a crystallic form of aluminium oxide (Al_2O_3) in the hexagonal structure. Corundum can be found in nature in colourless as well as in various coloured variations. The colour depends on contained trace element in the mineral. Next to diamond, corundum is one of the hardest minerals that can be found in nature and it is thus highly resistant to abrasion and corrosion. Due to its physical characteristics it is widely used as an abrasive element in industry. Furthermore, it can be found in refractory walling due to its high thermal endurance. Production of artificial corundum by modification of aluminium oxide from bauxite is easier than mining. This process is very demanding from energetic and production point of view. It is necessary to grind ore itself and mix it with calcite and sodium hydroxide. Such an alloy is then pumped over to high-pressure tubs where it is heated. Sodium hydroxide with aluminium oxide that precipitates from the dilution is then rinsed and heated by means of which superfluous water is removed. The aim of the process is to gain white powder that is similar to sugar. The alloys are often enriched by trace elements that colour the material and improve its physical and chemical characteristics. [5, 6, 7].

2. THE EXPERIMENT A METHODS

In the study we used and investigated blast furnace slag that was by basic conventing methods (sieving. milling. magnetic separation) modified to characteristics that would conform to its further utilization in industry. Samples of various charges and production dates were used in laboratory experiments. Within the samples we set their basic mechanical and physical characteristics with an evaluation of further possible utilization in particular technology.

2.1. Network analysis

The network analysis was carried out according to the norm ČSN EN 933-1 (721193). The norm complies with the European norm EN 933-1:2012. Part 1 was used: definition of granulity, screen analysis (content: *5 Test facility, 6 Preparation of test backfill, 7 Testing method, 8 Calculation and presentation of results).* [8]

2.2. Separation on weirs

The separation of material is carried out in the flow of the medium on a slightly reclined board which performs irregular oscillatory movement in the longitudinal direction. A sufficient difference of specific weight of separated components is a must. The boards can be in the form of a rectangle or a rhomboid. On the board there are ledges tied up. They slow down movement of the elements. Bigger or heavier elements have higher gravity center and thus within the board they move further than small or lighter elements. The board bent is usually between 2° and 10° in the cross direction. The elements are influenced by mass power (large elements in water), boundary shear of the medium, frictional force (kinetic friction) and oscillatory motion (length and number of vibrations). [9]

As for the medium we use water (a water weir) or air (a pneumatic weir). As far as the water weirs are concerned we make use of an effect of a thin level of water flowing along a slightly bent weir board. Due to the lean, the sludge tries to course down the board through the shortest way, i.e. vertically to the longitudinal axis of the weir. The grain is influenced by two powers - inertial force operates in the direction of the longitudinal axis (an attempt to shift grains to the opposite side of the weir). Then, the grain is influenced by a power of water flow that is vertical to the direction of inertial force operation. The work principle is rather complicated. it is mainly about the fact that the elements of higher density move along the surface of the weir board and by operation of the oscillatory motion in the weir they are drifted to the exit part. The elements with low density do not reach the end of the exit part due to the water flow operation that drifts the grains away from the board. Moreover, the heavier grains are protected against water operation through installed ledges. The pneumatic weirs use compressed air blown from the bottom of the board to float particles. Separation effectivity depends mainly on water speed, board bent and amount of supplied material within the input. Speed of sludge flow increases together with increase of the board bent angle and increasing specific weight of the fluid. The greater viscosity leads to the smaller the smaller is flow speed. If we take into account that the difference in friction factor is minimal, then a great grain of low density will move very quickly and a grain of high density will move slowly. [9, 10]

3. RESULTS AND DISCUSSION

There were two samples from another production period available. The first sample was marked as *a sample A*. the second one was marked as *a sample B*. The practical part of the study deals with the theme of separation in the pneumatic and water weir. Attention is paid to the screen analysis as well.

3.1. Granulometric Analysis

The graph below the text shows granulity curves of both analysed samples. In **Table 2** we can find values of parameters of element size, mean diameter of element size and specific surface. In order to compare the graphs of granulity curves with one another we can conclude that sample A is much more coarse grained than sample B. It is mainly indicated by parameters of the specific surface and the grain size. According to the shape of the curves of undersize and oversize we can evaluate that sample A has much more fluent transfer from softer grains to more coarse grained grains and contains much greater percentage representation of coarse elements. It is due to the usage of various sizes of net mesh in the sorting machine that was used for raw material sorting in the line form slag processing.

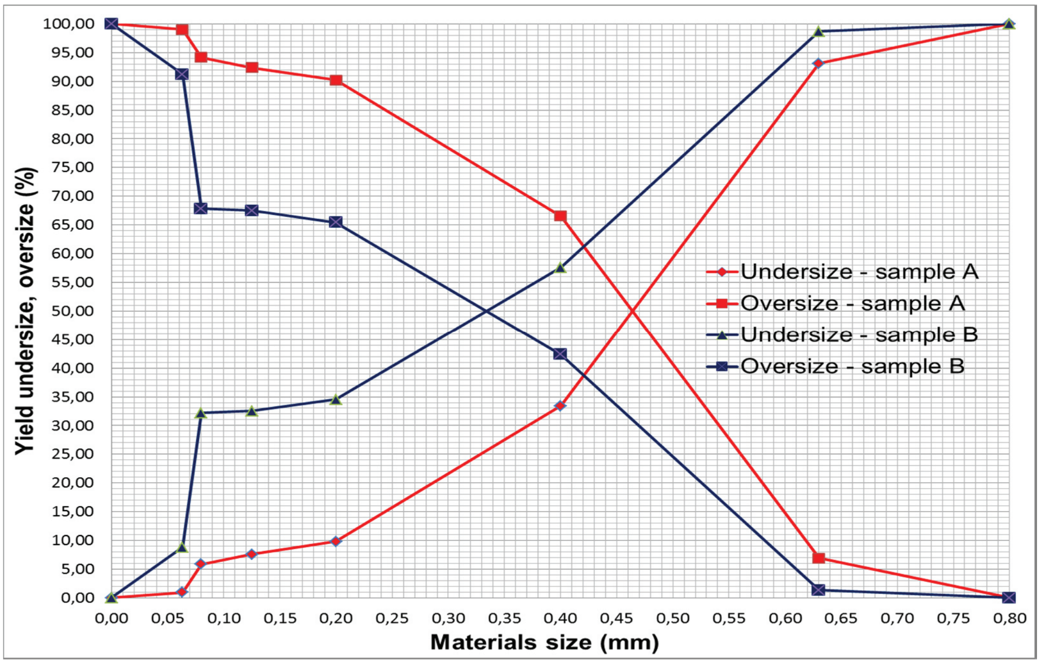

Figure 1 Granulometric Analysis - sample A and sample B

Table 2 Results of the experiment - Granulometric Analysis

Materials	Value of specific surface area	Grain size parameter	Size parameter of the particle mean diameter
Sample A	200.319	0.463	0.436
Sample B	468.342	0.336	0.313

3.2. Separation within the pneumatic weir

The study observes influence of setting of parameters and their overall technological efficiency on gravitational separation within the pneumatic weir where both samples, which were available for laboratory experiments, were analyzed. **Table 3** shows results of individual experiments for various types of setting for both samples. **Table 4** includes individual parameters for weir setting during the experiments.

Table 3 The separation results on the pneumatic weir (*A - before HCl, B - after HCl, C - after melting in borax*)

Laboratory experiments	Products	Return (%)	Number of minerals			Laboratory experiments	Products	Return (%)	Number of minerals		
			A	B	C				A	B	C
$1A_1$	$K1A_1$	**5.9**	66	17	**11**	*$1B_1$*	$K1B_1$	33.6	*28*	***4***	***1***
	$B1A_1$	94.1	5	2	0		$B1B_1$	66.4	4	0	0
$2A_1$	$K2A_1$	32.4	35	1	0	*$2B_1$*	$K2B_1$	**12.7**	*17*	***3***	***2***
	$B2A_1$	67.6	8	3	0		$B2B_1$	87.3	3	1	0
$3A_1$	$K3A_1$	**14.7**	6	0	0	*$3B_1$*	$K3B_1$	15.6	7	0	0
	$B3A_1$	85.3	1	0	0		$B3B_1$	84.4	1	0	0
$4A_1$	$K4A_1$	23.0	10	0	0	*$4B_1$*	$K4B_1$	61.2	7	0	0
	$B4A_1$	77.0	2	2	0		$B4B_1$	38.8	1	1	0
$5A_1$	$K5A_1$	18.7	17	2	**1**						
	$B5A_1$	81.3	3	1	**1**						
$6A_1$	$K6A_1$	24.9	27	7	**3**						
	$B6A_1$	75.1	7	2	0						

Table 4 Setting of parameters on the weir

	Separator setting				Separator setting				Separator setting				Separator setting				Separator setting		
$1A_1$	Oscillation	---	8	*$3A_1$*	Oscillation	---	8	*$5A_1$*	Oscillation	---	9	*$1B_1$*	Oscillation	---	8	*$3B_1$*	Oscillation	---	9
	Bent	↑	8		Bent	↑	8		Bent	↑	8		Bent	↑	4		Bent	↑	7
		→	10			→	6			→	9			→	10			→	6.5
	Flux	---	5		Flux	---	8		Flux	---	6		Flux	---	5		Flux	---	6
	Feed	---	4		Feed	---	4		Feed	---	4		Feed	---	4		Feed	---	4
	Separator setting				Separator setting				Separator setting				Separator setting				Separator setting		
$2A_1$	Oscillation	---	8	*$4A_1$*	Oscillation	---	7	*$6A_1$*	Oscillation	---	7	*$2B_1$*	Oscillation	---	9	*$4B_1$*	Oscillation	---	6.5
	Bent	↑	8		Bent	↑	8		Bent	↑	8		Bent	↑	9		Bent	↑	2
		→	8			→	9			→	9			→	9			→	6.5
	Flux	---	5		Flux	---	4.5		Flux	---	3.5		Flux	---	3.5		Flux	---	4.3
	Feed	---	4		Feed	---	4		Feed	---	4		Feed	---	4		Feed	---	3

Attained results imply that gravitational separation of the monitored raw material proceed in a very changeable way. Reached yields of concentrates vary between 8 % and 32 % at sample A and between 12 % and 60 % at sample B. There were great differences among the results. These differences are also monitored in the number of gained heavy minerals in the concentrate. The best results of the experiment are emphasized in the tables. The most important monitored parameter is the number of minerals that remain after decoction in

HCl and then after smelting in borax. The best results were examined for sample A within experiments $1A_1$. $5A_1$ a $6A_1$ and for sample B within experiments $1B_1$ a $2B_1$.

The greatest amount of minerals was obtained in the experiment 1 and sample A. During this experiment we managed to gain over 66 minerals. 17 minerals remained after decoction and 11 minerals remained after smelting in borax. In the experiment 6 we obtained 27 minerals. 7 minerals after decoction in HCl and 3 minerals after smelting. In the experiment $2A_1$ there were 3 heavy minerals after decoction and 2 minerals after smelting.

3.3. Separation within the water weir

In this part of the study there were two available samples analyzed again. The experiment was carried out on the water weir. We set 298 revolutions a minute on the electronic rotating device of the switching box. Such setting corresponds approximately with 100 board oscillations a minute, the board bent being 5 %. The separator setting was the same for all experiments. A weir board with bent ledges was used.

Table 5 Separation results on the pneumatic weir (*A - before HCl, B - after HCl, C - after smelting in borax*)

Laboratory experiments	Products	Return (%)	Number of minerals			Laboratory experiments	Products	Return (%)	Number of minerals		
			A	B	C				A	B	C
$1A_2$	$K1A_2$	**19.7**	45	20	**5**	*$1B_2$*	$K1B_2$	23.5	10	3	0
	$B1A_2$	80.3	8	3	**1**		$B1B_2$	76.5	2	0	0
$2A_2$	$K2A_2$	30.5	20	5	0	*$2B_2$*	$K2B_2$	25.5	6	1	0
	$B2A_2$	69.5	7	4	0		$B2B_2$	74.5	7	4	0
$3A_2$	$K3A_2$	27.2	36	10	**3**	*$3B_2$*	$K3B_2$	**21.9**	15	3	**1**
	$B3A_2$	72.8	10	2	0		$B3B_2$	78.1	2	2	**1**
$4A_2$	$K4A_2$	**22.6**	24	7	0	*$4B_2$*	$K4B_2$	**20.1**	19	5	**1**
	$B4A_2$	77.4	6	5	1		$B4B_2$	79.9	6	3	0

The results of the gravitational separation on the water weir are shown in the **Table 5**. Data in the above showed tables imply that efficiency of obtaining heavy minerals is similar to the separation on the pneumatic weir. Yields of obtained concentrate range from 20 % to 30 %. There are also differences in the amount of obtained heavy minerals in the concentrates. It was possible to gain the greatest amount of heavy minerals after smelting in borax within the experiments $1A_2$ a $3A_2$. In each of the experiments $3B_2$ a $4B_2$ we obtained a piece of mineral.

4. CONCLUSION

The study is dedicated to verification of possibility of applying physical modification process on the water and pneumatic weir in order to obtain heavy minerals from slag. The method should be a tool for basic knowledge about the particular material and amount of heavy minerals contained within it. Gravitational separation on the pneumatic and water weir was tested as the basic method of gaining heavy minerals during the course of experimental works. Refining separation on the pneumatic weir was applied as a supplementary possibility. The achieved results fully verify facticity of consideration about possible processing of the raw material. In laboratory conditions, all together there were 24 heavy minerals gained after smelting in borax out of approximately 15 kg of sample *A*. Within sample *B* we obtained 6 heavy minerals after smelting in borax out of approximately 13 kg of sample. However, we cannot average the data in order to be able to state exactly how many minerals are in the amount after conversion to a certain weight of product. Differences in the amount of found minerals vary substantially. It is due to the fact that sample *A* was processed by a different technological setting on the production line.

Based on the above mentioned facts we can say that the method on the pneumatic weir seems to be the best option as a factual modification scheme when comparing both methods. First, it is due to the results of individual experiments. Second, it is due to keeping basic conditions for a new methodic of better detection of heavy minerals. Cheaper operation of the device and easier manipulation with individual separation products are the main advantages of the pneumatic weir. As far as the water weir is concerned, it is necessary to assure a water source and thus also further equipment (drainage, drying etc.).

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