BLAST FURNACE SLAG, PROCESSING AND UTILIZATION

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VYSOKOPECNÁ TROSKA, JEJ SPRACOVANIE A ZUŽITKOVANIE

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Abstrakt

V technologickom procese výroby surového železa vznikajú súbežne s výrobou hlavného produktu surového železa, aj produkty vedľajšie, majúce charakter druhotných surovín a priemyselných odpadov. Medzi najzastúpenejší vedľajší produkt vznikajúci v procese výroby surového železa zaraďujeme vysokopecnú trosku. Na každú tonu vyrobeného surového železa je potrebných približne 1,6 tony vstupných surovín, z toho približne 330 kg koksu, 150 kg prachového uhlia, 900 m^3 horúceho vzduchu. Objem vzniknutej vysokopecnej trosky pri tom predstavuje približne 230-400 kg na jednu tonu surového železa. Podľa katalógu odpadov (zbierka zákonov 284/ 2001) trosky z procesov výroby surového železa zaraďujeme do skupiny ostatných odpadov. Táto skupina odpadov nepredstavuje veľké riziko pre životné prostredie svojim chemickým zložením, je však problematická najmä svojim veľkým výskytom.

Vysokopecná troska vzniká roztavením hlušiny kovonosnej časti, troskotvorných prísad a popola koksu. Jej chemické a mineralogické zloženie, ako aj fyzikálno-chemické vlastnosti ju predurčujú k zužitkovaniu v rôznych oblastiach priemyslu. Chemické zloženie trosky, ako aj spôsob ochladzovania sú faktory, ktoré významným spôsobom ovplyvňujú možnosti jej ďalšieho zužitkovania. Z hľadiska jej maximálneho zužitkovania je preto dôležité detailne poznať trosky ako také, a to od ich vzniku, chemického a mineralogického zloženia, fyzikálnych vlastností, ktoré v kombinácií s rôznym spôsobom spracovania môžu poskytnúť rôzne výsledné vlastnosti produktu. V tomto príspevku sú popísané spôsoby spracovania jednotlivých druhov trosiek spoločnosťou Vulkmont, a.s.. Detaile sa zaoberá problematikou technologického zabezpečenia spracovania vysokopecnej trosky vo forme granulovannej vysokopecnej trosky, vysokopecného štrku a vysokopecnej pemzy, ako aj možnosťami zužitkovania finálnych produktov.

Abstract

During the pig iron technology process, by-products are generated along with pig iron production as a main product, having nature of secondary raw material and industrial waste. Blast furnace slag (hereinafter „BF slag“) ranks among the most frequent by-product generated within pig iron production process. Approx. 1,6 t of input raw material is required per a ton of produced pig iron; hereof approx. 330 kg of coke, 150 kg of dust coal and 900 m^3 of hot air. Amount of generated BF slag refers to approx. 230-400 kg per a ton of pig iron. According to the Waste Catalogue (The Act No. 284/ 2001 Coll.) slag generated in the pig iron production process is classified in the category „Other Waste“. This waste category doesn´t impose a high environmental hazard with regard to its composition but excessive occurrence.

BF gas is generated through metal-bearing waste rock, flux and coke ash melting. BF slag chemical and mineralogy composition as well as physical-chemical properties predetermine it to utilization in various industrial branches. BF slag chemical composition and cooling-down method refer to the factors that significantly affect its further utilization possibilities. With regard to BF slag maximum utilization, it is therefore important to know slag types in detail beginning from slag generation, chemical and mineral composition up to physical properties that in combination with various processing methods can result in various final product properties. This document describes various methods of particular slag type processing at company Vulkmont, a.s.. The material deals in detail with technology provision of BF slag processing in the form of granulated BF slag, BF gravel and BF pumice as well as with possibilities of final products utilization.

Keywords: blast furnace slag, processing of slag, granulated blast furnace slag, blast furnace gravel and blast furnace pumice, utilization of blast furnace slag

Introduction

Blast furnace slag is generated during pig iron production in blast furnaces and consists of melted metal-bearing waste rock, fluxes and coke ash. Slag is tapped from the Blast Furnace together with pig iron at temperature approx. 1540 °C. In general, we can state that BF slag is generated from non-metallic parts of BF charge during iron ore reduction. BF slag final properties depend on chemical composition of input raw material, technology of BF process control and method of slag processing after tapping. Basic components of BF slag refer to: SiO_2, Al_2O_3 and CaO, MgO coming from fluxes. These four majority components represent 95% of BF slag composition. Sulfur and ash as minority components of BF slag are coal-based. Moreover, up to 1% of metal iron can be separated from slag. BF slag alkalinity should exceed 1 in order to ensure good desulfurizing ability of slag. Thus, BF slag belongs to category of acidic slag.

Very important factors that affect possibility of BF slag utilization include: nature of main mineralogy components, crystallization rate, size and form of crystals, occurrence of hyaline stage and distribution of crystalline and hyaline stages. Method of BF slag processing after tapping as well as molten slag cooling down rate affect and determine the product physical properties. Slag that is fast cooled down solidifies in the form of hyaline/ glass – amorphous material. Slow cooling-down process results in simple oxides changing to more complicated bonds and further crystallizing during cooling down to various minerals, mainly silicates. Based on their mineralogy and chemical composition, BF slag is suitable to various utilization purposes mainly in civil-engineering industry. To be able to utilize BF slag, it is necessary to ensure slag integrity through observance of prescribed BF slag composition. In case of inadequate slag chemical composition and thermal processing gradient, BF slag could disintegrate. Slag with content of basic oxides within range specified in the table No. 1 is considered the stable BF slag suitable to utilization in civil engineering industry.

Table 1 Content of basic oxides ensuring stability of BF slag

Oxides content	Minimum amount of [%] wt	Maximum amount of [%] wt
CaO	-	43
MgO	-	16
SiO_2	30	-
Al_2O_3	4	-
FeO	-	3
S		1

Depending on method of processing the melted BF slag – cooling down and solidification, the following types of products can be produced at conditions of company Vulkmont, a.s.: granulated BF slag, BF gravel and BF pumice.

Blast furnace slag processing

Granulated blast furnace slag

Granulation process includes pouring of molten slag through high-pressure water jets in the granulation equipment. During granulation, the slag falls into the water basin and is subsequently dehydrated. At conditions of company Vulkmont a.s., slag granulation is performed at two granulation stations, each of them containing six granulation aggregates. Particular aggregates are separated one from another at distance of slag car length that allows for granulation in six, four or two runners simultaneously at one station, as required. Granulation aggregate consists of the following parts: pouring runners, granulation runners, granulation field, granulation water supply ensured from the pumping station. The granulation process is controlled from the control cabins. The operations are following: slag shell ramming in the ladles, slag ladles emptying, granulation process monitoring. The pouring begins immediately after water supply activation when water flow is stabilized in the granulation runner. Pouring is performed slowly and continuously so as granulation runner flooding or technology accident is avoided – explosion caused by poured excessive amount of slag in the granulation runner. Pouring is completed through slag car straightening. Afterwards, the cars are disconnected from power supply and instruction is given to carry the slag cars away.

Blast furnace gravel

Pits serve to BF gravel production that are gradually filled in with thin slag layers. Following slag solidification, slag cooling down can be speeded up through slight water addition. Solidified and completely crystallized slag is removed from the pit with dredging shovel. Pig iron is magnetically removed from the slag and slag is then sorted out to required granulation fractions. At conditions of company Vulkmont, slag is carried to Gravel Plant in the slag cars after granulation processing. BF slag must have suitable chemical composition – see table No. 1. Slag is carried in slag cars to emptying rail section specified in advance where the cars are emptied through emptying panels and portal crane with ramming out ball. It is inefficient to empty slush, freeze and slag cars with slag that isn´t suitable to production. Emptied BF slag is cooled down with water and disintegrated with portal crane iron ball. During concurrent dredging, pig iron is separated from BF slag by portal crane magnet. Such prepared and adequately soaked slag is loaded with dredger into feeding car to further processing. Proper soaking is important for two reasons: to avoid excessive dust generation and to avoid excessive soaking that could cause reduced sorting-out preciseness through glued-up sorting-out surfaces. Optimum soaking is up to experience. Operation of crushing and sorting-out line begins with primary crushing at jaw crusher with getting out granule fraction up to 150 mm, further sorted out at Gravel Plant sorting-out station according to required fractions. Particular fractions are stored in the tanks or on loose heaps. BF slag is shipped according to requirements either by trucks or by RR cars.

Blast furnace pumice

In the slag cars, BF slag is carried to the pumicing station. It is necessary to ensure horizontal position of pumicing bathes and circulation of cooling water through cooling shell.

Water pressure should refer to 4 - 6 MPa. Quality of carried slag is checked up visually as well as thickness of cooled down slag in the ladles. Afterwards, emptying cable is connected to slag car, the pump is activated and slag ladle emptying is commenced. After commenced emptying of slag ladle and slag pouring, approx. 2 – 3 cm of cooling water is required on the bath bottom. Following pouring the slag into the bath, slag foaming begins followed with slag cooling down. After slag maturing, the ladle content is emptied into pumicing pits where it is removed from by dredging shovel onto cooling heap where pumice is allowed for maturing. Technology duration of pumicing: molten slag pouring into pumicing - 30 - 45 sec., foaming process - 40 – 55 sec., cooling down in the bath/ maturing - 2,50 – 4,00 min..

Blast furnace slag utilization

BF slag cannot be used in metallurgy works and is to be treated for use outside these facilities. Company Vulkmont, a.s. has been dealing with possibilities of slag products utilization in cooperation with the Faculty of Metallurgy, the Technical University in Košice [1].

Possibilities of BF gravel utilization as a concrete filling instead of natural stoneware were analyzed by the authors of Article [2]. 100 % BF gravel was used to concrete production with gravel fractions 0-4 mm, 4-8 mm and 8-16 mm. The mixture composition: BF gravel (stoneware), cement, water, plasticizers and aerating additives. The concrete analysis revealed strength properties of the concrete suitable to most demanding road concrete.

Further possibilities of BF gravel and granulate use are in preparation of slag-alkali cements and concrete [3]. Grinded BF granulated slag 300 – 500 m^2 was used to preparation of cement-free concrete mixtures (blaine) and BF gravel with fraction 0-4 mm, 4-8 mm. Water hyaline was used as a solidification activator. Resulting strength properties of concrete not only met but significantly exceeded the strength requirements of road concrete, thus this concrete type could be used a road building or production of concrete panels.

Chemical similarity of BF slag with certain natural stoneware resulted in attempts for obtaining usable technical ceramics through adequate cooling down process [4]. Composition of BF slag used during the experiments: 38.9 % SiO_2, 1.67 % Fe, 42.56 % CaO, 6.8 % MgO, 2.29 % Al_2O_3, 0.69 % MnO, 0.63 % S, 0.023 % P. In case of poured melted slag of the above composition into the forms for relatively thin ceramic materials, the slag is fast cooled down and hyaline-like material is created with cracking tendency. On the contrary, slowly cooled down molten BF slag develops a crystalline structure. Crystallization of the hyaline stages can be supported with additions of nucleators – nucleating speeding up agents. TiO_2 in the form of titanic iron ore was used in the experiments as a nucleator. Cooling down process was affected at BF slag in such manner that resulted in obtained crystalline structure similar to technical ceramics structure.

Conclusion

At BF slag processing conditions of company Vulkmont a.s., BF granulate, gravel and pumice represent the final product. Annual processing capacity depends on amount of produced pig iron, input material quality and product types and currently varies around 1 – 1,6 million of ton per year. Nowadays, BF slag and its products represent modern industrial products that are effectively utilized and create profit. To optimize this process, it is necessary to thoroughly know the slag properties. Using various cooling-down process, processing and quality control regulation systems, it is possible to optimize slag products properties. If metallurgy slag is properly handled with, the slag properties can be even better than those of natural materials.

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