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Research paper

Compressive strength of manganese fine-grained material and molasses briquettes regarding binder content and curing time

Dhaffiny Rondon Gonçalves [1], Leandro Gustavo Mendes de Jesu [1] *

[1] *Department of Metallurgy, Federal Institute of Science and Technology Mato Grosso do Sul, Corumbá, Brazil*
**Corresponding author E-mail: leandro.mendes@ifms.edu.br*

Abstract

In the production of raw materials for the manufacture of ferroalloys, up to 50% of the material mined is discarded as fine-grained tailings. Those tailings are deposited in dams, which are considered an environmental liability. To avoid this, an alternative would be to agglomerate the tailing dam materials using the briquetting process. Therefore, this work aims to evaluate the compressive strength of briquettes made of manganese fine-grained material (with particle size < 2.00 mm) and molasses regarding curing time and percentage of binder. To achieve the objective, 45 briquettes were made with fine-grained manganese ore, with 3 different molasses content (binder), these were put into 3 weeks of curing, to analyze the impact of binder content and curing time. The result was that the longer the curing time, the better the compressive strength and that increasing binder content reduces its compressive strength. Finally, the best results were obtained with 5 % binder and 3 weeks of curing time, in which the agglomerate produced had a compressive strength of 9,0 MPa.

Keywords: *Briquettes; Compressive Strength; Manganese Fines.*

1. Introduction

Manganese is considered one of the most important metals in the world. Its main application is in steel production, which is added as ferroalloys [1]. The main ferroalloys are high carbon ferro-manganese (FeMnHC) and silicomanganese (SiMn). Manganese-based ferroalloys are produced in submerged arc furnaces (SAF) and their main inputs are metallic charge (ore and agglomerates), reductant (coke and/or charcoal), fluxes (mainly limestone) and electrical energy [1].
The furnace is equipped with three electrodes positioned at the vertices of an imaginary triangle located in the center of the furnace through which the electric current flows, promoting heating and charge reactions (Figure 1).

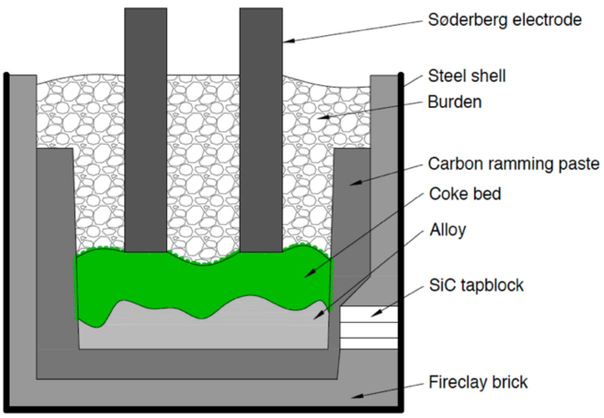

Fig. 1: Schematic Diagram of the Submerged Arc Furnace [2].

In the manganese ore production, the ore is taken to processing stages, with the aim of adjust its grain size, that is, it aims to ensure that the ore has a suitable size for the reduction process [2]. The processing of manganese ores aims to ensure that the ore has a chemical composition (high Mn content and adequate particle size and ratio) [1]. Thus, during the processing stages, up to 50% of the material mined is discarded as waste [1]. The waste, as observed in several studies, has as its main characteristics high manganese content (similar to those

required for SAF raw materials) with an excessively low particle size (< 9.5 mm) for use in the reduction process for production of ferroalloys [2].
The low particle size tailings materials have as main characteristic its size and are disposed in dams, which are considered an environmental issue with a high associated risk. The Corumbá dams have a high risk with them due to being located in the Pantanal biome [3].
An alternative to reduce the deposition of fines in tailing dams is the use of agglomeration processes [2]. Among the processes, briquetting, which is based on the densification of fine-grained solids using external pressure, presents itself as a possibility due to its low capital and operating costs [4]. To use it, it is necessary to assess the mechanical behavior of the briquettes, since if they do not have proper strength, they may crumble, making the material behave as a fine-grained material.
When these materials are charged in the SAF, they face a reducing atmosphere and progressive increase in temperature [1]. The load descends towards the bottom of the furnace and the gases produced by the reduction rise towards the top; thus, the SAF is divided into two zones (Figure 2). The pre-production zone (located in the upper part of the furnace) where manganese oxides undergo throughout reduction up to MnO by rising gases [1]. The coke bed zone (located in the lower part of the furnace, at high temperature) where MnO and other compounds melt in the form of slag and MnO is reduced by solid carbon [1]. Reactions in the coke bed zone produce CO that promotes the reduction of manganese oxides that are present in the pre-reduction zone.

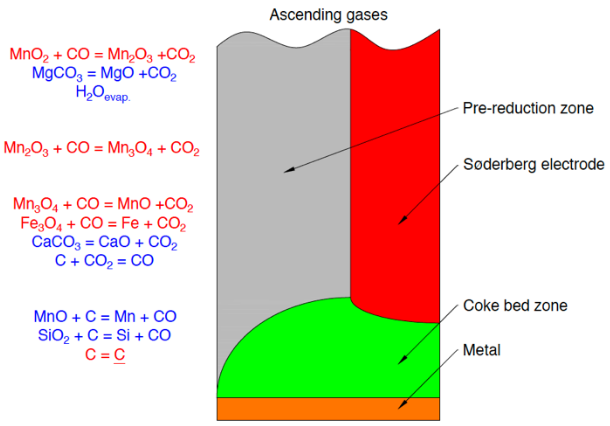

Fig. 2: Main Reactions Within the Submerged Arc Furnace [1].

Therefore, loading fines inside the furnace (or materials that behave as fines) would result in the deposit of such materials in the interstices of the coarser particles. This would prevent ideal gas flow causing obstruction to the gas path.
Thus, the subject of this work is to study the compressive strength of fine manganese ore tailings briquettes as a function of curing time and binder content. The work is based on the hypothesis that there is an optimal binder percentage and curing time for briquettes with raw materials of particle size lower than 2.00 mm that increases the compression resistance of briquettes to the maximum.
The aim of this work is to evaluate the compressive strength of briquettes made from manganese ore fines as a function of molasses content (binder) and the curing time of the materials.

2. Materials and methods

The experimental procedure was carried out in the Laboratory of Metallurgy of the Federal Institute of Mato Grosso do Sul located in Corumbá/Brazil. The fine-grained material was sieved at a particle size of 2.00 mm. Three batches of 15 briquettes of fine-grained manganese ore tailings were made with 3 different mass content (5, 10 and 15 %) of the binder (molasses). The specimens were cured for different time range (5 specimens of each batch) for 1, 2 and 3 weeks. After curing time, the agglomerates were submitted to compression tests.
To manufacture the briquettes, the manganese tailing dam material was mixed with, three mixtures of three different percentages (mass percentages) were made, 5, 10 and 15 %. The mixture was placed in a beaker and then homogenized in a mechanical propeller stirrer for 40 seconds.
The briquettes were produced in a cylindrical die and punch, with an internal cavity of 10 mm, where the pressing of the material placed inside the die was carried out using a hydraulic press. To facilitate the removal of the specimens from the matrix, it was lubricated with engine oil. The pressing pressure was 1 ton and the pressing time was set to 30 seconds.
After manufacturing, the briquettes were stored for curing. After the curing time (which was determined weekly, for 3 weeks), 5 specimens of each composition were tested. The axial compression resistance analysis was carried out on the EMIC multipurpose mechanical testing machine.

3. Results and discussion

Table 1 presents the data obtained through the experimental procedure previously described.

Table 1: Experimental Results

Time [weeks]	Rupture force [N]			Compressive strength [MPa]		
	5 %	10 %	15 %	5 %	10 %	15 %
1	464,8	304,8	62,4	5,9	3,9	0,8
2	482,4	309,8	166,8	6,1	3,9	2,1
3	707,2	571,0	251,6	9,0	7,3	3,2

Figure 3 shows the relation between the binder content and compressive strength. The curves presented that the strength of the briquettes decreased with the increase in the binder content. Furthermore, the data showed similar compressive strength values in the first two weeks, followed by a sharp increase in the third week.

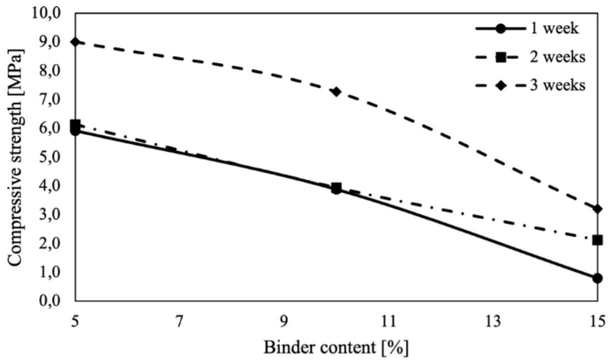

Fig. 3: Influence of Binder Content in the Compressive Strength.

From the data on the influence of binder content on compressive strength, it is possible to note the decrease in the compressive strength with the raise in the molasses content. This decrease is reported by other authors [5, 6] who presented reviews on the binding mechanism between ligand and particles. According to the authors, the binder acts at the particle interfaces, ideally, there should be an amount of binder that connect the particles together, ensuring cohesion between them. However, once the surface is filled, a binder film will form on the surface of the particles, giving the briquette a plastic character, resulting in decrease of strength of the specimen due to binder saturation. This was observed in the briquettes produced in the present study, as shown in Figure 4.

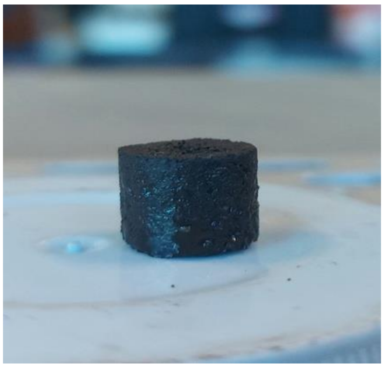

Fig. 4: Briquette Made with 15 % of Molasses.

Figure 6 shows the relation between compressive strength and curing time. The results an increase in the compressive strength as the curing time of the specimens increased. Furthermore, for all binder percentages, the growth of the compressive strength is higher in the third week of curing time, which has already been previously observed.

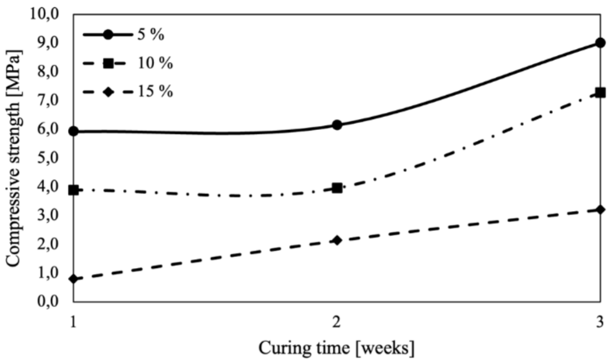

Fig. 5: Influence of Curing Time in the Compressive Strength.

The increase in compressive strength due to the increase in curing time may be related to sugar crystallization. The phenomenon of crystallization of sugar-rich solutions has been previously reported by Hartel and Shartry [7], in addition, the phenomenon was reported in sugar cane molasses by Hebeda [8]. Thus, the main hypothesis for this effect is that the formation of sugar crystals promotes greater cohesion to the specimens and, consequently, higher compressive strength.

4. Conclusion

The main conclusions of the presented work are:

1) The compressive strength of briquettes decreases with increasing binder content.
2) The compressive strength of briquettes increases with increasing curing time.

Acknowledgement

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