Original Article

Evaluation of density as a parameter to act in the quality control of the coating solution (anti-sticking) applied to iron ore pellets

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Abstract

Iron ore pellets used in direct reduction reactors must receive the application of a solution on their surface to avoid sticking during the production process in the steel plants. There are several studies regarding the types of solute, its characteristics and the specific target consumption to obtain the optimal mixture for application in the pellets. Through the specific "standardized" consumption, sets points of the industrial plants defined to allow the proper addition of the solute to the solvent occurs. An important process variable should be checked is density. However, density as control variable is few disseminated in studies in the literature. This article aims to show the results obtained in the industrial tests considering the density as an additional control variable in the preparation of the solution for application of the coating in iron ore pellets.

Keywords: Coating; Iron ore pellets; Density.

1 Introduction

According to Lopes [1], the process of forming clusters in pellets is a superficial phenomenon resulting from the sintering of iron particles, which occurs in the direct reduction process in steel plants. The clustering formation is extremely undesirable in reactors, as it can result in loss of production, process interruptions and, above all, increase operational risk.

To minimize the formation of *clusters* in the reactors, Viotti [2] highlights some alternatives: reducing the Fe content in the pellets, reducing the melting temperature, adding coke or coating the pellets with inert materials for the reduction process. To coat the pellets, a solution called *coating* is used. The *coating* solution acts as a physical barrier, preventing the formation of fibrous iron and the sticking of the pellets.

The effectiveness of coating the pellets is verified through various tests, among the main ones we can mention the metallurgical test of clustering index, according to the ISO 11256 [3] norm and the evaluation of the percentage of coating in pellets.

Simões et al. [4] developed a method for analyzing the percentage of coating from the *coating agent* through an automatic image processing system, where it was possible to perform a correlation between the percentage of coating and the pellets clustering index. This image analysis method can provide valuable data and adequate time for decisions to be taken in order to adjust the process parameters of the coating *plants*.

In addition to the chemical composition of the coating agent, another factor that must be considered during the application of the *coating* to avoid the effect of sticking the pellets is the dosage of the input, which has already been discussed in previously published works.

Collins and Norrman [5] investigated the efficiency of different materials as coating agents for pellets in order to mitigate the effects of sticking under reduction. Quartzite, silica, talc, dolomite, olivine, lime, bentonite/olivine, bentonite/dolomite, dolomite/cement and olivine/cement mixtures were evaluated. The best clustering index results were obtained with the use of olivine, bentonite, magnesite, cement, and mixtures.

Lopes [1] stated that, for use at high temperatures, even above 1000 °C, clustering index values between 60 and 100% are common. The results obtained by different authors evaluated the efficiency of the type of *coating* to avoid clustering, considering the input dosage in kg/t.

The input can't be dosed in solid form. In order to spray *coating* on the pellets, it is necessary to prepare a solution of this agent with water. However, in the literature there is little information regarding the density of the solution and its use as a process variable.

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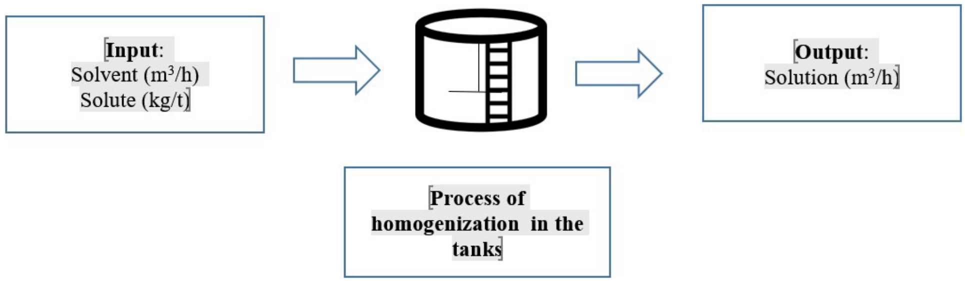

Figure 1. Solute homogenization process with solvent in *coating plants*.

This paper evaluated the density of the *coating* solution, which is determinant for adjusting the specific consumption, transporting the solution in pipes and the efficiency of the adhesion of the raw material on the surface of the pellet. All these parameters affect the pellet clustering index, regardless of the type of *coating* used.

2 Materials and methods

The addition of *coating* on iron ore pellets is considered an extremely critical and crucial process to avoid the formation of "clusters" in direct reduction reactors. The preparation of the solution is performed in industrial plants, where it is possible to add a solute to the solvent, homogenize the solution and apply it on the surface of the pellets, as shown in Figure 1.

The reference value for parameterization of the solute (in kg/t) is easily found in the literature. However, the parameterization of the solvent and the solution (in m^3/h) must be evaluated individually in each industrial plant. This peculiarity is due to the fact that the industrial plants have different characteristics, such as the capacity of the homogenization tanks and the necessary flow to guarantee a good spraying of the coating in the sprays that direct the solution to the pellets, as shown in Figure 2.

Coating plant process parameters in which this work was developed, the minimum and maximum solution flows (in m^3/h) were defined to avoid solution shortages at the *coating application points* and also avoid an excess that could characterize waste.

The development of the ideal operating parameters was carried out together with the teams that operate the plant remotely and locally. All information was entered into the supervisory by the team that operates remotely, but field verification and fine adjustments can only be carried out with feedback *from* field operators.

In Figure 3, it is possible to visualize the configuration of the plant (remote activity) and the other items verified by the field team (solute dosage, homogenization and flow in the sprays in the application of the coating solution on pellets).

2.1 Measurement of the density of the *coating* solution

Density measurement is a parameter that must be considered to indicate the quality of the *coating solution*.

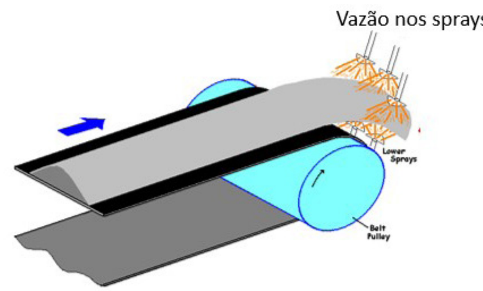

Figure 2. Application of *coating* on pellets.

Density is a relationship between mass and volume. For the *coating* solution, the density of the solution can be represented by Equation 1:

$$\textit{Density of the Solution} = \frac{m1 + m2}{v1 + v2} \quad (1)$$

Being:
m1: mass of the solute;
m2: mass of the solvent;
v1: solute volume;
v2: solvent volume.

According to Ribas et al. [6], a saturated solution is one that is in equilibrium with excess of solute.

The excess of solute (when detected) may represent an excessive/abnormal consumption of the input (according to Equation 2) or a shortage of water in the preparation of the solution (according to Equation 3).

$$\uparrow d = \uparrow m1 \quad (2)$$

$$\uparrow d = \frac{1}{\downarrow v2} \quad (3)$$

The scarcity of water in the preparation of the solution can be quickly identified by reducing the levels of solvent in the tank, however the identification of the solution saturation caused by the addition of the solute takes longer and, in many cases, is not even detected due to the lack of feedbacks parameterized by measured density values.

Figure 3. Preparation of the solution and application pellets.

3 Results and discussions

3.1 Evaluation of solution density

In 28 productive batches, considering the addition of solute as the only variable to feed the control loop, 12 density measurements were detected, that is, 43% of the measurements were higher than the control limit. In contrast, 7 measurements (25%) were below the lower limit. Figure 4 shows the density measurements of the productive lost analyzed. To ensure the confidentiality of the information, the data were transformed to base 100.

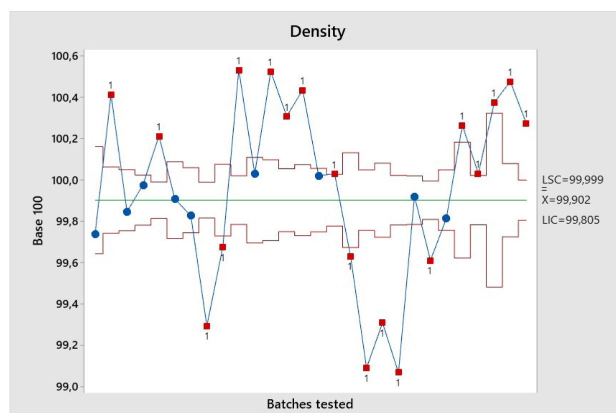

Figure 4. Control chart for density of the *coating solution*.

With the density measurements presented in the Figure 4, it was possible to see opportunities for optimizing the process to reduce the specific consumption of the solute. In this way, experiments were planned that aimed the modification of the *set points* of the solute dosage and the volumes of the solvent in the tank, in case the density measurements were outside the established limits.

To ensure that the quality of the *coating* solution was not deteriorated due to the experiments, it was necessary to define "checkpoints" for validation of the tests. For this, we adopted the following test protocol, shown in Figure 5:

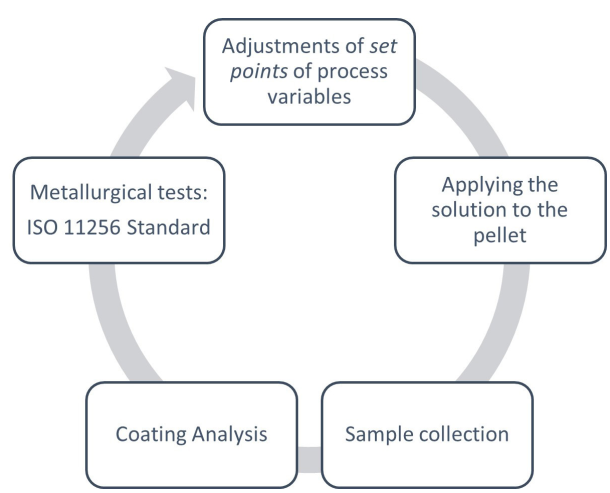

Figure 5. Check points defined for carrying out industrial tests.

After defining the protocol, tests were performed on 21 production batches. Because it is an experiment, the dosing control logic was not changed. With this, the *setpoint adjustments* were configured manually, that is, for each event considered as a "trigger", the operational team would enter the new desired set point.

To confirm if the results obtained were satisfactory, sample collections and quality analyzes of the *coating* applied to the pellet were carried out. In Figure 6, it is possible to visualize the sample collections and the results of the coating analysis of one of the productive batches.

Figure 6. Stages of industrial tests to control the solution considering the density.

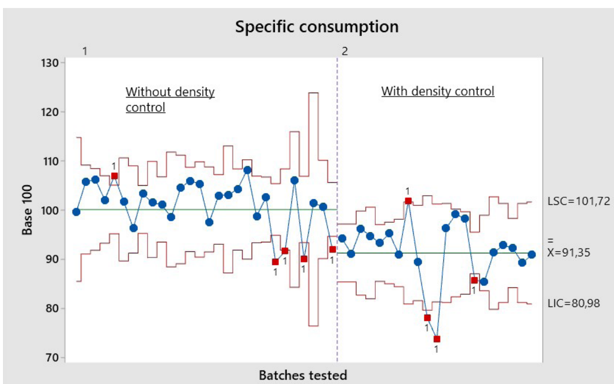

Figure 7. Comparison between the specific consumption of the solute.

3.2 Evaluation of specific consumption in the operation considering density control

Measurements of specific solute consumption are performed in real time during input dosing (before mixing with the solvent in the tanks) and density measurements are performed while pumping the solution to the application points in the pellets.

The specific consumption (in kg/t) was compared between the productive batches tested, divided into group "1" and group "2": being group "1" the productive batches in which the control loop was guided by the consumption of the solute and, group "2" the productive batches in which the setpoints *were* changed manually in function of the density values of the solution.

It is observed that the specific consumption obtained during the production of group "2" was lower by approximately 8% in relation to the specific consumption of group "1", as shown in Figure 7. To ensure the confidentiality of the information, the data were transformed to base 100.

These results reinforce the opportunities for adapting the control loop of the industrial plant which the tests were performed. In addition, opportunities are visualized for the academy to explore more about the subject according to each type of approved solute.

4 Conclusion

Dosing and *coating* agents are widely discussed in the literature as an alternative to avoid clustering in iron ore pellets. The processes for preparing the solutions in the industrial plants are parameterized in order to guarantee the quality of the solution (*coating agent* and water), considering a fixed dosage of the coating agent in kg/t.

Considerations about the density (in kg/m^3) of the solution are scarce and/or non-existent in the literature, which is why industrial tests were carried out considering the density of the solution as a process variable. During the tests, samples of pellets were collected to assess the quality of the coating and measure the clustering index, according to ISO 11256.

When evaluating the solution density considering a fixed dosage of the coating agent (in kg/t), it was observed in certain cases the existence of unnecessary or insufficient consumption of the coating agent.

By modifying the plant's control logic to obtain the density parameters in kg/m^3 (instead of a fixed dosage of the coating agent in kg/t), it was possible to identify that the density control method allowed guaranteeing the quality of the coating, clustering index. In addition, this method contributed positively with 8% to the reduction of the specific consumption of the *coating agent*.

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