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Use of organic byproducts as binders in the roll compaction of caustic magnesia

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ABSTRACT

This paper presents an improvement of the roll compaction process of dusty caustic magnesia carried out by using vinasses and molasses from the sugar beet industry as organic binders. The objective of this industrial study is to verify the possibility of increasing the particle size of the powdery raw material by granulation. It involved an instrumented pilot scale roller press (corrugated surface) to set the operating parameters and control the agglomeration process assessing the quality of the product established on a lot of final granules. As result, the effect of the addition of 5% (w/w) of binder by a spray nozzle atomizer on the caustic magnesia and the intensive mixing in a high shear mixer reduces notably the proportion of fines (by 30%) and increases significantly the rate of granules greater than 2 mm formed when the “moist powders” are compacted in the subsequent pressure agglomeration unit. This furtherance represents a process optimization strategy which increases the productivity and achieves a significant reduction in the quantum of failures.

1. Introduction

The retrieval process of magnesite ($MgCO_3$) is performed by mining operations in selected quarries and requires full-scale grinding to achieve a fine particle size. Once crushed, it is introduced through metering scales in calcining kilns where it can reach temperatures between 950 and 1000 °C suffering an almost complete decarbonization (see Eq. (1) below). MgO dust is collected in cyclones and bag filters of the purification system of exhaust gases.

$$MgCO_3 \xrightarrow{\Delta} MgO + CO_2\uparrow. \quad (1)$$

Calcined MgO grades are widely used in applications such as high quality fertilizer production because of their high reactivity, pH control in chemical production processes, paper and pulp industry, production of magnesium salts, animals feed, and many other applications [1,2].

When the pulverized magnesium oxide (PMgO) is spread on a farm field, it improves drainage, infiltration and healthy growth of beneficial microorganisms and therefore plants can absorb the nutrients more readily.

For these reasons it is primarily used to control acidity in soils by making them more alkaline and, as a result, more productive by reducing the fertilizer addition and making it more available for the plant roots.

Despite being more reactive in powdered form, it presents limitations regarding handling operations, distribution and application, as well as reluctance by the main consumers (farmers) [3].

Size enlargement of particulate solids through agglomeration improves all the above characteristics without substantially reducing the active surface, and by extension, the reactivity necessary for the pursued purposes. In addition, a granulated product would also improve the direct application to the soil, the flow properties and the handling operations [4,5].

Roll compaction is a pressure agglomeration technique by which dense compacts are formed by applying external forces to particulate solids which results in densification by squeezing the loose feed between two identical rolls rotating countercurrently [6].

These dense compacts called tablets or briquettes are then milled through low-shear breakers and subsequently screened to separate the formed granules and to remove the excessive fines which are typically produced from the low densification yields.

It is widely known that compression behaviour of powders during roller compaction is dominated by an ample number of factors affecting the process variables as well as raw material properties [7–9]. Some of them are related in Table 1.

The roll compaction of the studied dusty magnesia presents notable problems during the operation because of the light deformation tendency of MgO and SiO_2 and, due to that, this powder is not cohesive and has a poor flowability.

In certain cases, successful agglomeration by a continuous dry granulation process can be limited because a maximum pressure cannot be kept and the force is suddenly released. In this context, high recirculation ratios appear due to the significant percentage of feed material which does not get compacted properly.

In general terms, there is no agreement about the use of liquid substances as binders mainly because of the reduction of the internal friction when the liquid content is high and also because the incompressible

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Table 1
Main factors affecting roll compaction.

Process variables	Raw material properties
Specific force	Particle shape
Roll surface	Particle size distribution
Roll gap	Water content
Roll speed	Flowability
Feeding conditions	Cohesion

nature of liquids renders serious drawbacks during feeding due to flow stoppages as well as during the consolidation phase of the compacting [10,11].

Several issues can be analyzed in order to ameliorate the global yield and, in consequence, the strength of the agglomerates formed. This will lead to results that meet the required quality standards supporting the applicability of liquid binders in low moisture content applications [12,13].

Fig. 1 depicts a typical flow diagram of a roll compaction process reflecting the collection of raw pulverized materials, the mixing stage, the binder addition line, the roll compaction system and the yield improving phases consisting of granulation, recycling and sieving.

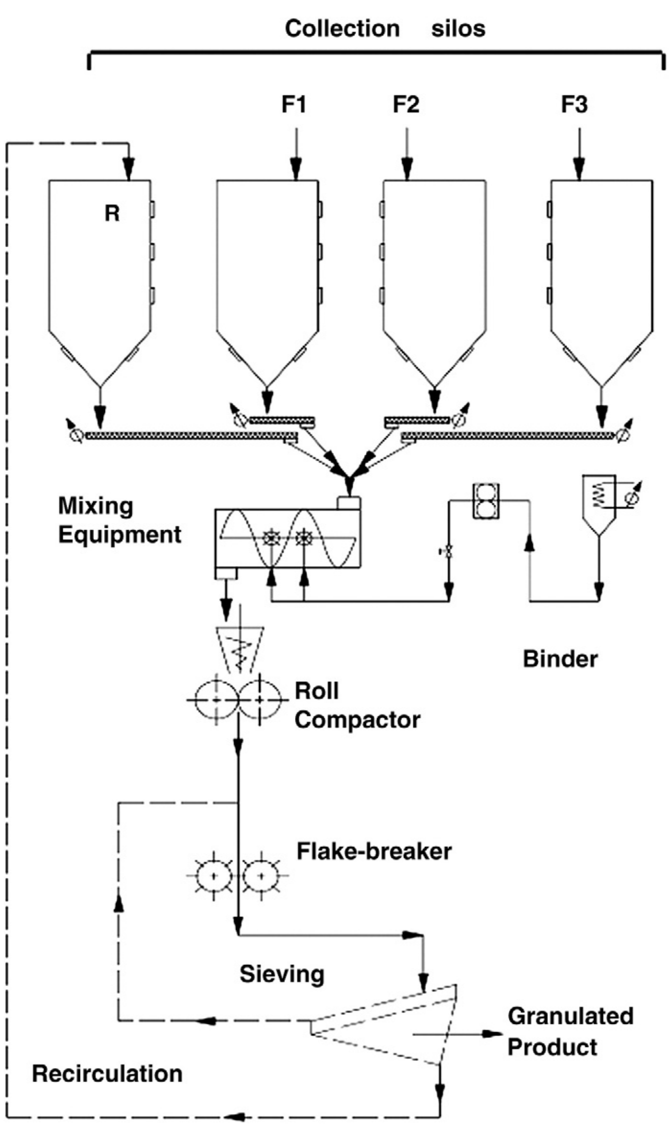

Fig. 1. Flow diagram in a typical roll compaction process.

In this kind of processes the distribution of the binder droplets along the surface of the pulverized material and its penetration inside the powder bed in the mixer represent a key factor because of the direct impact on relevant properties of the final granules such as porosity, size, structure and resistance [14–16].

The type of application will determine the appropriate nozzle flow rate, depending upon how much fluid is needed to achieve the desired goal, and other operating attributes of the nozzle.

Droplet size depends on the type of nozzle, flow rate, feed pressure and spray pattern. For instance, designing nozzles to distribute the liquid evenly is a key factor, since most nozzles do not present an even liquid distribution [17].

When a droplet impacts onto the solid surface, the liquid mass distribution determines the nucleation and the growth into larger agglomerates.

This assertion is examined along the present study postulating that molasses and vinasses can act as lubricants reducing the friction between the individual particles of magnesite and also increasing the attraction forces making the compaction process more effective.

2. Materials and methods

2.1. Characteristics of the raw material prior to agglomeration

The chemical composition of the raw material obtained by chemical analysis (Table 2) and X-ray diffraction spectra (Fig. 2) confirms the high proportion of MgO in the sample and a moderate part of $MgCO_3$ in the form of magnesite, dolomite ($CaMg(CO_3)_2$) and a slight presence of quartz (SiO_2).

The sample was measured on Philips type powder diffractometer fitted with the Philips "PW1710" control unit (Cu sealed tube, Lamda ($K_{\alpha 1}$) = 1.5406 Å operating at 40 kV and 30 mA). The pattern has been collected in the 3<2theta<60 range with a step size of 0.02° and counting time of 3 s per step. The sample has been spun during the data collection in order to get the best peak profile and to minimize the preferred orientation effect.

In line with the characterization, several relevant physical properties of the solid samples employed are listed in Table 3. All measurements were determined at least in triplicate.

The particle size distribution is given in Fig. 3 and it was obtained using a HELOS Laser Diffractometer (Sympatec GmbH).

According to the results it should be noted that the x_{50} is below of 15 μm and that 7% of the analyzed particles are below 2 μm.

2.2. Description of binders

Molasse is an organic by-product of sugar beet refining. It is a dark viscous syrup left after the extraction process (crystallization and centrifugation). It can provide energy for livestock in growing diets and it is a raw material in the production of citric acid and oxalic acid by fermentation.

With respect to vinasses it is a diluted waste of the distillery industry after the fermentation of molasses to produce alcohol which is very difficult to discard because of its high COD and BOD. Indeed its high content of organic carbon and nutrients makes this product ideal for use as amendment to agricultural soils.

In order to compare binders, different trials with molasses and vinasses were carried out fixing the dilution rate. Similar samples of the two binders were diluted in water to a weight ratio of 60/40. The physical properties of the diluted binders are listed in Table 4 at two different temperatures (25 and 40 °C).

M64 60/40 water solution of sugar beet molasses (initial dry matter 91.89%).
V64 60/40 water solution of sugar beet vinasses (initial dry matter 84.83%).