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Interactions about Pneumatic Conveying Systems on the characteristics of Calcitic Limestone

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***Abstract*— *Pneumatic conveying is one of the most important techniques for the manipulation of particulate or powdered materials in the industry. This method has many advantages such as greater flexibility, simplicity of operation and lower cost if compared to other techniques of particulate handling. The objective of this work is to check the modification of the characteristics (particle size, angle of repose and apparent density) of calcitic limestone in an industrial scale pneumatic conveying system. It was verified by means of standard tests that the characteristics such as apparent density and effective diameter decreased by 22% and 7%, respectively, from the cycles with the material through the line of the pneumatic conveying system, and the angle of repose, even after abrasion of the material in the system, there were no significant changes.*
***Keywords*— pneumatic conveying, material characterization, calcitic limestone.**

I. INTRODUCTION

Pneumatic conveyance is the term used for moving different types of materials from the suspension and mixing in a gas flow through a pipe. Because it presents advantages such as flexibility and low maintenance cost, it is one of the most important materials transfer techniques in a huge variety of industries (LOPES, 2007).

The design of a pneumatic conveying system for a solid material is strongly dependent on its physical properties, in particular, those ones involving interaction with air and with the pipeline. Typically, these interactions are a function of basic particles properties such as size, density, and shape.

The study of these properties and its correlation with their macroscopic characteristics is what defines the material for its proper application. If there is any change in these properties, the material may lose its applicability.

In a pneumatic transfer, intense friction can occur due to the interactions of the material with the air, the pipe and between particles, entailing changes in the characteristics of the material transported such as granulometry, apparent density, and angle of repose, which can lead to losses for industries.

In the mineral industry pneumatic convey is highly used, one of the materials widely used is the limestone. The limestone presents a wide variety of uses, from material for construction, material for aggregates, material for the manufacture of lime (calcium oxide), source of hydraulic binder in the manufacture of cement, and even as ornamental stones (MINISTÉRIO DE MINAS E ENERGIA, 2008). The applicability is associated with the size of the limestone granule, size grains of 40 to 100 mm are used in cement kilns and steel kilns, as small grains of about 100 μm are used in animal feed (FEECO, 2008). For each industrial branch, the size of the limestone affects its application.

The present work deals with the analysis of calcitic limestone characteristics by sieving granulometry, apparent density through a known volume and angle of repose by the funnel method, before and after being transported in a pneumatic system by means of pressurized feeders, in order to compare the changes in their characteristics, validating or invalidating its applications.

II. THEORETICAL FRAMEWORK

This work presents and discusses the results of calcitic limestone characterization in terms of its angle of repose, bulk density, and granulometry. The angle of repose, among other applications, is relevant to determine the amount of volume loss in collecting equipment, such as a silo or hopper, due to the angle formed on the surface. This test gives directions for deciding the best solution for the material handling required in the company and to make

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coherent projects for the installation of this chosen solution (ANDRADE, 2016).

Apparent density is the bulk density of the powder. It provides the mass per unit volume of loose-packed powders. This value is a first, low-cost evaluation of powder to determine consistency from lot to lot. A low apparent density can be an indication of fine particles and a high apparent density can be an indication of large particles. A change in apparent density can also indicate a change in the surface roughness of the powder.

The granulometry is important to predict characteristics of the material transport, depending on the granulometry the material may have a greater facility to be transported, the granulometry also influences the fluidization capacity of this particular material, besides its applicability. Some definitions (VARELA, 2017) should be presented for a better analysis of the material:

- Fineness module: The sum of the percentages accumulated in all the sieves of the series used, divided by 100. The larger the modulus of fineness, the thicker the soil will be;

- Maximum diameter: Corresponds to the number of the sieve of the series used in which the cumulative percentage is less than or equal to 5%, provided that this percentage is greater than 5% in the sieve immediately below;

- Effective diameter: the opening of the sieve for which we have 10% in the total mass of all particles smaller than it (10% of the particles are thinner than the effective diameter) and presented by equation 1; this parameter provides an indication of the permeability of the sand;

$$d_{ef} = d_{10} \quad (1)$$

- Coefficient of non-uniformity: is the ratio between the diameters corresponding to 60% and 10%, taken in the particle size curve and presented by equation 2. This relation indicates the lack of uniformity since its value decreases when the material is more uniform;

$$c_{nu} = \frac{d_{60}}{d_{ef}} \quad (2)$$

$c_{nu} < 5$ uniform

$5 < c_{nu} < 15$partially uniformity

$c_{nu} > 15$not uniform

For the comparison between the limestone before and after transports, the first characterizations were carried out on samples of virgin calcitic limestone. After this data collection, the material was submitted to pneumatic transport in a cyclic system and then the same characterization procedures were performed. The pneumatic conveying system used is described in the next section.

III. MATERIAL AND METHODS

The mentioned material characterization, as well as the pneumatic conveying process, were performed at the facilities of the Zeppelin Systems Latin America Test Center, located in São Bernardo do Campo.

The system in question consists of two hoppers MG-02 and MG-04, two pneumatic guillotine valves (VGP-01 and VGP-02), one manual guillotine valve VGM-01, two butterfly valves for dosing -35) and a butterfly valve for air control (V-28), the blow tank (VP0100), a standard 3"pipe of about 130m, having a 5m height difference between the hoppers, an RT conveyor -01 and flexible for interconnection.

In order to control this system a flow meter (FL-01) and two pressure transmitters (PT-01 and PT-09) were used. The transport cycle consists of dosing material into the blow tank by means of butterfly valves, opening of valve V-28 and its subsequent closing.

Due to the limited availability of material to perform the tests, it was necessary to recirculate the material in batches through the system. It was defined that at a certain set mass value measured in the upper hopper the system would enter into the lower hopper feedback stage, preventing the opening of the air supply valve V-28, opening the pneumatic valve VGP-02 and RT-01 thread until a certain set value was reached, thus returning the system to its initial operation.

Each feedback loop was defined as "mass cycle". The system is shown in Figure 1.

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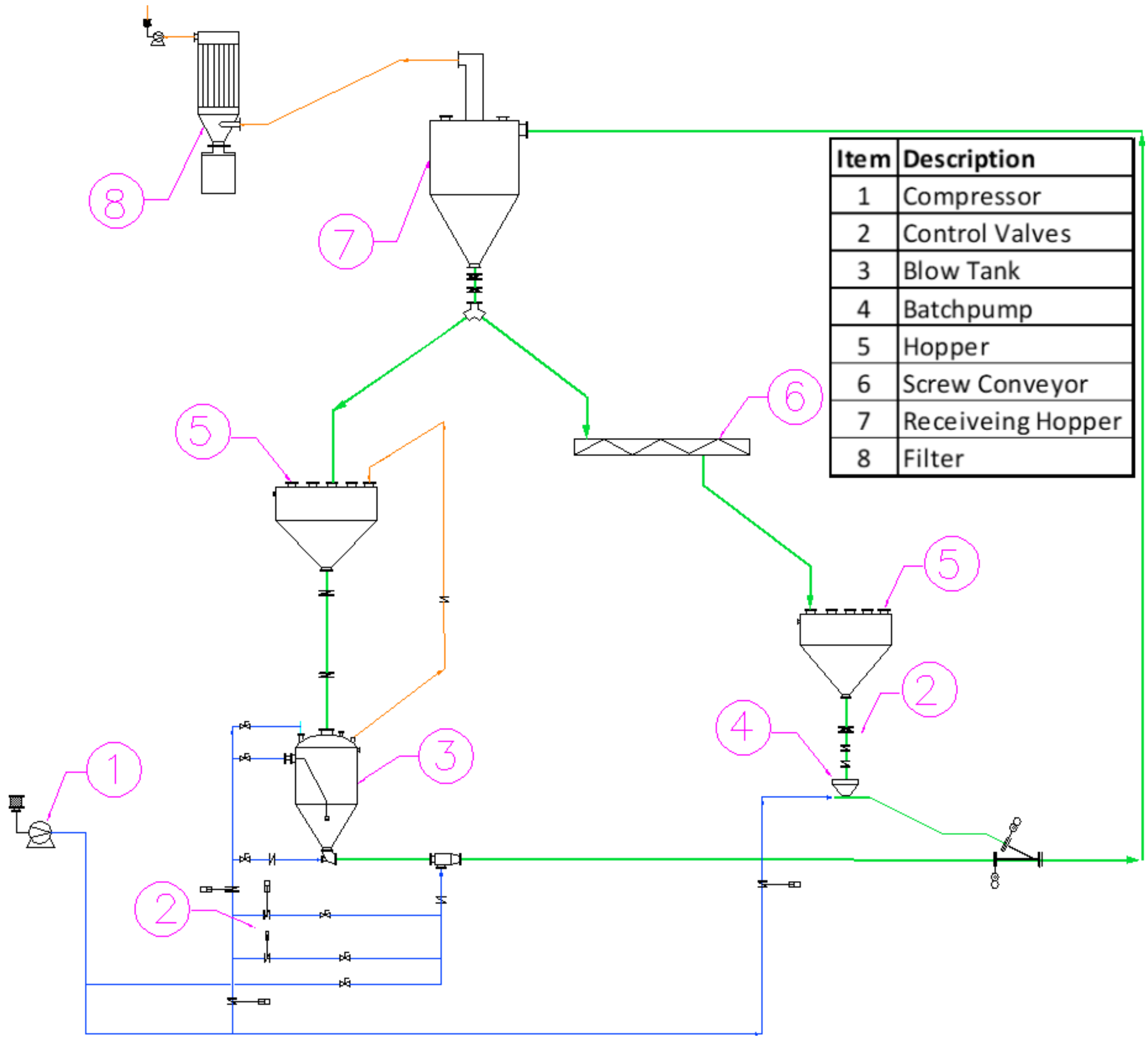

Fig.1: Schematic representation of the pneumatic conveying system.

The funnel method was used in the evaluation of the angle of repose. This method consists of filling a cylinder with a diameter at the exit of at least five times the diameter of the particle (GUZMAN, PELAEZ, 2008). The work makes use of a PVC tube filling up to approximately half its capacity, pouring the material contained in the container slowly and avoiding any vibrations in the cylinder and its bearing surface. The material is then deposited on the surface forming a cone as shown in figure 2, whose angle was measured by using a goniometer positioned at the straightest region of the cone and corresponds to the angle of repose.

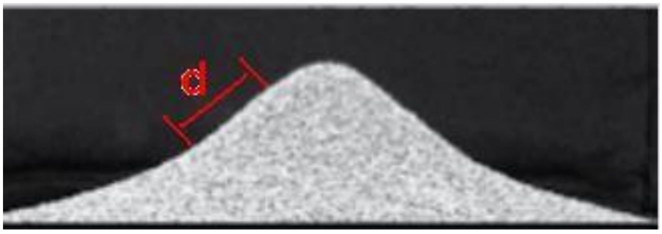

Fig.2: Material deposition and the region of the cone (d) that must be used to evaluate the angle of response.

The method used in the work to determine the apparent density followed the experimental procedure: the material was added in a cylinder of known volume (152 cm^3) until it was completely filled slowly so that there was compaction of the material, so as not to leave empty spaces which interfered in the density calculation, and then the mass of that material was measured by repeating this procedure ten times for the minimization of instrumental uncertainties. After these measurements, the obtained value of mass was recorded, and thus the density was calculated dividing the mass contained into the recipient by its volume. The mean value of the bulk density was considered.

The granulometric test carried out in this work was done through the sieving method (SAMPAIO, 2007), where a series of sieves with different openings and previously known masses are stacked and the material is deposited into the top sieve. After submitting the ensemble to ten minutes of vibration, using for this purpose a sieves agitator, the sieve masses were evaluated again. The mass difference corresponds to the amount of material retained at each sieve.

IV. RESULTS AND DISCUSSION

Before the passage in the pneumatic transport, the sampled material showed an average apparent density of 970 kg/m³. In terms of the angle of repose, it was obtained a mean value of 44 °. Through the granulometric test it was possible to obtain the values of fineness module, maximum diameter, effective diameter and coefficient of non-uniformity, for future comparison with the limestone that passed through pneumatic transport. After characterization of the blank sample, the material was inserted into the transport line presented in figure1and then a sample was drawn for characterization. Its apparent density was 757 kg/m³. The mean value of the angle of repose at this stage resulted in 45 °.

From the granulometric test after the transport, it was possible to analyze the fineness module, maximum diameter, effective diameter and the coefficient of non-uniformity. These results are presented in table 1 comparing the limestone characterization before and after the pneumatic transport. The coefficient of non-uniformity revealed that limestone before the transport process did vary significantly, with an increase of 43%, but remained lower than 5, which corresponds to a considerably uniform material. The maximum diameter increased as well, which means that there was a greater mass accumulation in the sieves of greater aperture if compared to the test gauged out before the conveyance.

Table 1. Comparison of the material properties after and before the pneumatic conveyance process.

Property	Before transport	After transport
Angle of repose (°)	44	45
Bulk density (kg/m³)	970	757
Effective diameter (um)	42	39
Maximum diameter (um)	180	300
Coefficient of non-uniformity	2,14	3,07
Fineness module	0,05147	0,03500

When comparing the obtained values of the tests with the applicability of the limestone (FEECO, 2018), one can verify that, considering only the particle size, the material continues in the same range of application even being submitted to cycles of pneumatic conveyance which are not common in industries, that is, the material is usually transported from a storage device to a destination only once. The influence of the pneumatic transport, by the system used, was that of degradation of the calcareous limestone grain. What can be concluded is that the material conveyance can change the analyzed characteristics of materials and, depending on the particularities of the system and number of cycles, can influence the application.

V. CONCLUSION

It can be concluded from FEECO, 2018, that limestone after passage through the pneumatic conveying systems did not show a change in its angle of repose. Already analyzing the densities and the fineness modulus we can see that there was a significant decrease. In the apparent density, there was a decrease of 22% after transport and in the fineness module a decrease of 32%. The effective diameter decreased by 7%. This shows that the limestone has become thinner because of the intense particle-particle, particle-air and particle-pipe interaction that occurs in a pneumatic convey. These interactions cause wear on the material and can cause a decrease in grain diameter.

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