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EXPERIMENTAL STUDIES OF THE DISCHARGE BEHAVIOR OF AGRO-FOOD BULK SOLIDS EXTRACTED FROM STORAGE BINS WITH SCREW FEEDERS

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Abstract: *Screw feeders are devices suitable for handling a wide variety of bulk solids materials that have good flow ability characteristics and are often used as dosing feeders in food industry and agriculture. The manner in which material flows into the screw affects the flow characteristics of the feeding hopper, the residence periods of the material in various locations of the bunker and thus the properties of the dosed products. The present paper will present some experimental results regarding the discharging profile of the mass flow screw feeders with variable geometrical design.*

Key words: *discharging profile, mass flow, screw feeder.*

1. Introduction

Screw feeders are devices suitable for handling a wide variety of bulk solids materials that have good flow ability characteristics and are often used as dosing feeders in food industry and agriculture. The manner in which material flows into the screw affects the flow characteristics of the feeding hopper, the residence periods of the material in various locations of the bunker and thus the properties of the dosed products. The present paper will present some experimental results regarding the discharging profile of the mass flow screw feeders with variable geometrical design.

Dosing screw feeders are commonly used to extract bulk solids from the outlet slots of hoppers. The manner in which material flows into the screw affects the flow characteristics of the hopper, residence periods of the contents in various locations, segregation, attrition and torque requirements of the screw. Motion regimes of the bulk solids in various sections of the equipment are hard to be analysed and so most of the screw feeders used are not designed in concordance with the flow regime required.

In short, the advantages of the horizontal screw devices are: reduced risk of environmental pollution, the transported material is protected from exterior contamination, flexibility of use, functional reliability, easy to install, easy to clean, can control very well the flow of free flowing materials [1].

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The disadvantage is mainly linked to the poor mechanical transport efficiency and the low protection of the screw flight against objects that can be tapered in the screw clearance with the chamber.

There are 4 major types of dosing screw feeders according to their constructional characteristics: screws with uniform pitch and diameter; screws with gradual pitch; screws with gradual diameter (taper diameter screw); screws with taper shaft.

2. Flow Pattern of the Dosing Screw Feeders

Constant pitch and diameter dosing screw feeders are considered to be the most economical screws to manufacture and they are widely used in systems that run at low rotational speeds. This type of screw will fill with material only the first one or two pitches, the rest of the feeder length will not extract material developing above it a region of static material so called a stagnant flow [1].

The quality of the materials being extracted for food industry, this systems does not provide similar fed material properties, as the material in the stagnant region will change its properties as it requires a longer time to be extracted and is under greater consolidation forces due to the movement of the screw feeder and of the bulk pressure [1].

The construction parameters often are constant pitch in the feed section, different from the constant one in the conveying section typically the pitch will be two thirds of the diameter value in the feed section, and equal with the diameter in the conveying section.

Tapered diameter screw feeder is another way to provide a continuous increment in the extraction of bulk materials, it is to taper the screw flight diameter, starting with a small diameter and increasing it to a maximum value (Figure 1a). The pitch of the screw flights is constant throughout the length. This is not a very used method as it is not recommended for most materials because the narrow back end is prone to have arches over it, besides it is difficult to properly fabricate the screw [1].

Variable pitch screw feeders can provide increasing extraction capacity by starting with a short pitch of the flights and progressively increase the pitch to the maximum capacity (Figure 1 b, c). For short distances they can achieve a continuous bulk

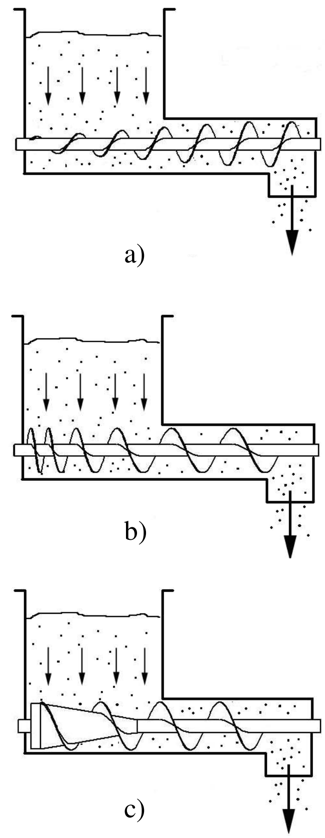

Fig. 1. *Schematic representation of the uniform material extraction by variable geometry screw feeders: a) extraction using a tapered diameter screw feeder; b) extraction using a variable pitch screw feeder; c) extraction using a tapered shaft screw feeder*

solids flow though the capacity of each increment depends on the transfer capacity. The minimum pitch must be no less than one-half the screw diameter (logging), the maximum pitch approx. one screw diameter [1].

Tapered shaft screw feeders tend to generate a progressive increase of extraction along the axis whilst this is an adequate method for producing a mass flow of the material extracted but the level will not be even (Figure 1c). Poor fabrication tolerances are a frequent problem and the consequence is high power consumption and poor flow. Also, it is a quite expensive configuration [1].

3. Experimental Study Method

For the experimental analysis of the flow profile of the mass flow screw feeders with variable geometrical design, an experimental dosing stand (Figure 2) was developed which provided the monitoring [2], [3] of the free bulk solids surface that was discharged from the feeding bin of the dosing stand according to the characteristics of each screw feeder.

The monitoring of the free surface of the bulk solid was made using distance measuring ultrasound sensors that were positioned on 9 different points in 3 different regions at the feeding bunker.

By graphic representation of each set of measurements the experimental stand allowed the representation through the surface measurements of the material free surface during the discharge, providing in this way a comprehensive insight of the way the screw geometry affects the flow of the material.

The dosing stand is powered by a three phase electric motor with 1.5 kW power. The driving of the screw feeder is made through a chain transmission with a transmission ratio of $i = 2.28$.

The dosing chamber is made of a steel tube with an internal diameter of 140 mm and a length of 830 mm and is custom made in accordance with the German standard DIN 15262. The inlet and outlet areas of the bulk solid are of rectangular section in order to study the most commonly used situation in industry. At both ends of the dosing chamber there are easily changeable ball bearing flanges that allow for a quick access for changing the screw feeders.

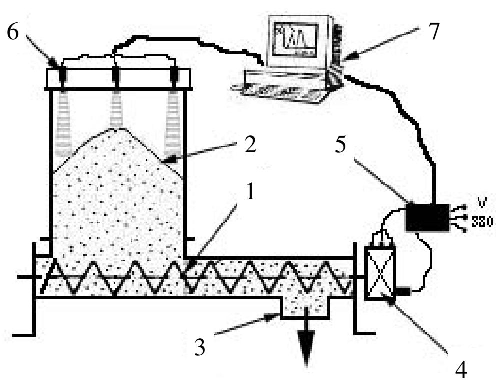

Fig. 2. *Experimental stand with horizontal screw feeders with variable geometry*: 1 - *interchangeable dosing screw feeder;* 2 - *feeding bin for material in bulk solids;* 3 - *evacuation area;* 4 - *driving group with sensor of rotating speed;* 5 - *frequency invertor for automatic adjustment of the rotating speed of the electric motor;* 6 - *ultrasound level sensors*

The feeding bin is made out of steel sheets that are coated with a wear resistant paint, has a 0.2 m^3 capacity and a rectangular cross section. The shape of the bin was chosen in order to prevent the formation of arching of the material above the screw feeders especially since the dosing stand has no agitating devices.

The dosing screws used in experiments have a total length of 1080 mm, with the following characteristics:

- constant pitch and diameter screw feeder (Figure 1a): screw flight diameter 125 mm, screw flight step 100 mm, screw flight shaft 40 mm, screw flight thickness 1.5 mm.
- variable pitch screw feeder (Figure 1b): screw flight diameter 125 mm, screw flight shaft 40 mm, with four progressive screw flight steps in the extraction area and a constant 100 mm step in the transport area of the screw, screw flight thickness of 1.5 mm;
- tapered diameter screw flight (Figure 1c): the screw flight diameter starts at 45 mm and reaches 125 mm on the extraction area, screw flight step 100 mm, screw flight shaft 40 mm, screw flight thickness 1.5 mm;
- tapered shaft screw feeder (Figure 1c): screw flight diameter 125 mm, screw flight shaft gradually decreases from 120 mm to 40 mm in the extraction area, screw flight step 100 mm, screw flight thickness of 1.5 mm.

4. Study Results

Because of the complexity of the pressure state inside the material it is difficult to analyse or investigate the conditions in the extraction area of the screw chamber inlet, but from the point of view of the material extraction manner from the feeding hopper by analyzing the free surface of the material there can be observed the way in which the material flows according to each type of dosing screw feeder.

The material free surface area, decreased especially in the region where the screw intake capacity was larger and the possibility of material arching above the screw was minimum.

For example for the dosing screw feeder with constant geometry the extraction pattern is made mainly from the area of the first screw flights of the dosing screw feeder (Figure 3) while above the rest of the screw flights the material stagnate and

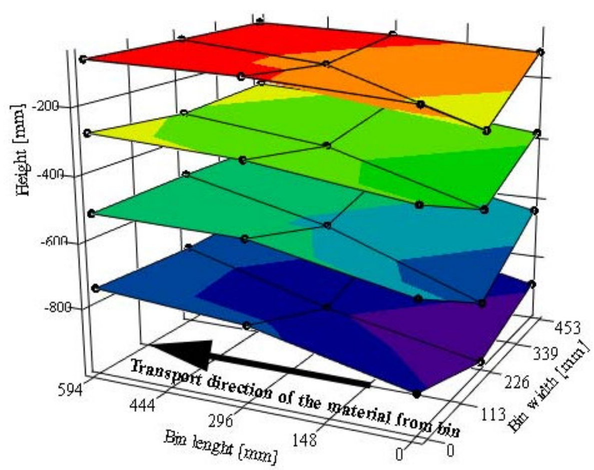

Fig. 3. *Flow profile of a wheat semolina discharged from a feeding bin with a screw feeder with constant geometry*

flow only when the right side of the hopper has a sufficient depth to exceed the natural slope angle of the material.

For the case of a uniform extraction and without mixture of the material from the feeding hopper of the dosing unit, there was studied the profile generated by the dosing screw feeder with variable pitch and constant diameter of the screw flight, resulting the form of the extraction profile presented in Figure 4.

The material extraction profile from the hopper along the dosing screw feeder exposed in the material area is in compliance with the incremental extraction manner of each dosing screw feeder with variable geometry but being strongly influenced by the material characteristics to flow freely or under the form of some rat holes generated mainly above the first pitch.

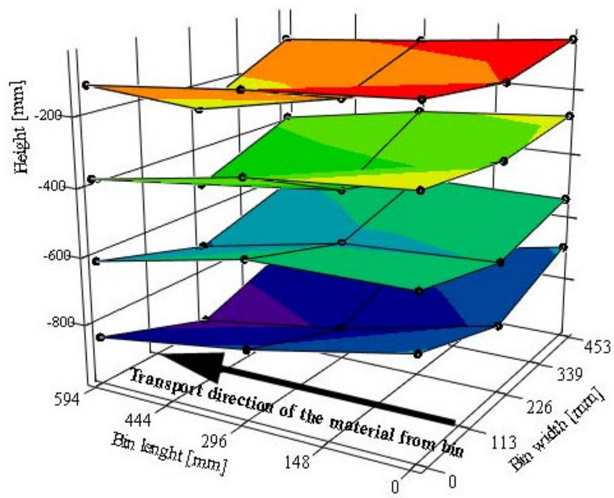

Fig. 4. *Flow profile of a wheat semolina discharged from a feeding bin with a screw feeder with variable pitch and constant screw flight diameter*

5. Conclusions

During the discharge of the bulk material, it can be seen, with the help of these graphic technique, how the screw feeder geometry affects the flow of the bulk materials and the free flow profile can be represented in a shape that is easy to be studied and understood.

As it can be seen from the two graphic representations of the discharge phases, the location of the major flow in the bulk solid mass has shifted from the right side of the bin, in the case of the screw with constant geometry (Figure 3), to the left side and the middle of the bin due to the bigger outtake capacity of the last pitches of the screw with variable increase of the pitch (Figure 4).

This experimental stand can provide important data aspects regarding the residence periods of the bulk material inside the feeding bin and where there are locations of insufficient flow where flow enhancement devices should be used, important in the food industry where it is aimed to achieve uniformity in the quality of the dosed products by reaching uniform times of material feed from the feeding hoppers.

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