The Influence of the Constructive and Function Parameters of the Gravimetric Vibration Dosing Systems for Agro-Foods Bulk Solids

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Abstract. In the paper it is presented the working principle of the electromagnetic vibration feeder used for dosing of agro-food bulk solids. The dynamic model of the vibration dosing system consists of a vibrating chute and an electromagnet. The mathematical models of the working and transport process allowed the simulation to present the influence of the functional parameters of the vibrating feeder (amplitude, frequency) and of the material proprieties concerning the transport parameters. It is also presented the construction of the dosing stand with electromagnetic vibrator used for the experimental research of the influence given by the vibration amplitude and the thickness of the material layer from the feeding chute regarding to the dosing precision of different agro-food bulk materials. Finally the paper presents conclusions and the recommendations elaborate to optimize the working regime of the gravimetric vibrating dosing systems used for agro-food bulk solids.

Keywords: bulk solids, dosing system, vibrating feeder, gravimetric dosing, dosing precision, experimental stand.

Introduction
Vibrating feeders are used in gravimetric dosing systems as feeding equipment of the dosing machines and as well as dosing systems, when a high accuracy is not required (Pahl, 1989; Vetter, 1994). The feeders are made of a vibrating chute (channels) or tubes (pipes) that are fixed elastically on stands that receive oscillating movements from rod-crank mechanisms (fig. 1,a) or from vibrating units with eccentric masses (fig.1,b) or from electromagnets (fig.1,c). Magnetic drive systems (Fig. 1,c), which are used as free vibrating or with steering suspension features, make use of the operation at resonance conditions with a safer excitation energy and leading to very compact units. Other drive principles based on motor-driven crank systems (Fig. 1,a), or unbalanced motor vibration systems (Fig. 1,b), arc rarely applied for metering but more usually for conveying applications. Vibration feeders consist of a conveying device which carries the bulk solid layer, the flute or pipe, and the drive unit for the vibration excitation supported by a spring suspension.

The function of vibration feeders is based on the micro-cast effect. The vibration agitation is usually induced by a flute vibrating inclined by 20…45° to the horizontal (Fig. 2). The particles are accelerated starting from definite vibration frequency/amplitude; these acceleration conditions are used to execute a parabolic ejection motion inclined upwards and strike the flute again after an adequate displacement.
Vibration generating mechanism; 2- vibrating mass with transporting chute.

This effect (micro-cast) is repeatedly induced at the exciting frequency with the result that the bulk solid layer which is pre-adjusted by the outlet clearance of the feeder is discharging quasisteadily.

The necessary excitation condition for the micro-cast effect to develop is that the vertical upwards directed acceleration induced by the flute vibrations on the particles is larger than the gravitational acceleration (vertical downwards). Important parameter influences on this displacement process are the vibration frequency and amplitude, the angle between the excitation and the flute axis and the bulk solid properties such as particle size, distribution and shape as well as friction.

For the smaller discharge capacities required of metering applications magnetic vibration drive units are mainly used (Fig. 2) as they are very compact and can be easily controlled [2].

Fig. 2. Magnetic vibration feeder: 1-vibration flute; 2 - vibrator housing and other components; 3- electromagnet; 4- mobile magnetic coreplate; 5, 6-additional masses; 7 - spring; 8 - control device; 9 - suspension springs;10-transported material Sf - vibration amplitude (free side); Ss-vibration amplitude (working side).

Magnetic vibration feeders have proven reliability, low maintenance and wear, short start-up and switch-off periods, and can be easily controlled and conveyed. Vibration feeders represent spring-mass systems with two masses to be considered: the mass of the part feeding the bulk solids \( m_a \) consists of the vibrating flute or pipe 1, the bulk solid mass 10 and the magnetic vibrator 2-4. The second mass \( m_f \) involved is that of the free side consisting of the mobile body 5 and 6. Both masses are connected by springs 7. The electronic control unit 8 is connected with the normal AC voltage supply. Normal 50 Hz excitation will yield a 100 Hz vibration frequency, with thyristor control 25 and 50: efficient control of the vibration amplitude is possible (Vetter, 1994).

THEORETICAL ASPECTS

The natural frequency \( f_e \) of the spring-mass system without attenuation can be determined with the masses \( m_a \) and \( m_f \) and the spring constant \( C \).

\[
f_e = \frac{1}{2\pi} \sqrt{\frac{C}{m_a}}; \quad (3.12)
\]

\[
m_f = \frac{m_a \cdot m_f}{m_a + m_f}. \quad (3.13)
\]

The vibrating system responds to an excitation frequency \( f_a \) with adequate amplitudes which grow the nearer \( f_a \) approaches the natural frequency \( f_e \) \( (f_a/f_e = 1, \text{ resonance}) \). The natural frequency decreases with growing attenuation (Fig. 3), the amplification factor \( V \) is very strongly influenced by attenuation. In order to operate vibration feeders close to resonance the system has to be adequately tuned (masses 6, Fig. 2). The effective attenuation is induced by friction, e.g. internally in the bulk solids, and externally at surfaces.

Fig.3. Amplification factor of vibration amplitudes \( V \) depending on the excitation frequency ratio \( (f_a/f_e) \).

Figure 3 demonstrates slightly subcritical excitation to be the most recommended type of operation as growing attenuation and bulk solid mass
on the flute, which usually coincide, implement a stabilizing effect (DE, EF). At critical and supercritical operating conditions a destabilization must be taken into account (AB, BC).

For metering purposes close to resonance conditions the automatic control of the vibration amplitude is strongly recommended to keep the disturbance potential within narrow limits. The measurement of the set vibration amplitude can be achieved by acceleration sensors (Fig. 4) or by stationary vibration displacement transducers (Fig. 5) (Vetter, 1994). With the combined control system for the vibration amplitude which automatically keeps the operational conditions close to the resonance frequency it is possible to obtain good linear and reproducible vibration feeder characteristics.

**Experimental Research**

For the experimental research of the influence of the functional parameters for the vibrating feeder over the dosing precision, it was developed an experimental stand, a representation of its construction being presented in Figure 2 (Popescu, 2005). The vibrating dosing system uses an electromagnet to produce the vibrations on the conveying vibration chute. Depending on the value of the vibration parameters (amplitude and frequency) the bulk solids will flow accordingly. An important advantage of this dosing method is that material is fed in the weight cell 1 uniformly and with smaller impact on the weight scale. The dosing system is periodically fed with material from hopper 6, and will be refilled at the moment when the minimum level of material in the hopper is reached. According with the characteristics of the dosed materials, it can be used different technical solutions for placing some agitators in such way that the material will flow properly on the vibrating chute 3 as well as possible so that it will be obtained a material flow dependent only on the vibration parameters. The stand is controlled from panel 8 where the parameters for the dosing process are established.

The vibration chute is powered from an electromagnet, which is controlled by the microcontroller and the computer linked at automation panel 8. An inductance sensor is attached to the vibration chute, and is used to obtain the value of the real amplitude. The final adjustments for the fine dosing are made by adjusting the amplitude scale vibration to a lower value so that only a small amount of material to be fed on the weight scale 2. The precision of this dosing system is relatively
good if it can be assured a proper material flow to prevent that mechanical bridging and flushing of material will be avoided.

For the automatic monitoring of the dosing process in the case of a volumetric dosing system with vibrator slot, it was built an automatic dosing system using the system presented in Figure 7. For the data processing of the control unit it was used a microcontroller produced by Atmel ATmega 8535. The microcontroller receives on the SPI (Serial Peripheral Interface) interface the results of the analog-digital conversion (ADC) and the integrated circuit that realizes the conversion (AD7730)
is made by Analog Devices and is responsible with the processing of the information collected from the weight resistive transducer. The microcontroller Atmel Atmega 8535 processes the information from the inductance sensor that measures the vibrations amplitude made by the vibrator slot for displacement of the bulk solid. These data will be used for the computation of the theoretical mass flow done by the dosing vibrator slot. For the dosing process optimization it is used a step motor, remote through a ULN 2003 circuit, which allows the gradual closing of the sliding gate at the hopper evacuation following a characteristics according with the weighing result [3]. The ATmega 8535 microcontroller communicates with the PC through the serial interface type RS-232, and the human user can activate through the software application on the PC the following operations: single conversion, calibration, beginning of automatic dosing batch, reset or saving of the dosing data. ATmega 8535 is an 8 bits microcontroller with a low price built based on the RISC architecture that works with frequencies of up to 16 MHz. Most of the basic instructions are executed in a single clock signal [4]. The ATmega 8535 flexible serial interface allows for easy interface to most microcomputers and microprocessors. The serial interface on the AD7730 has the capability of operating from just three wires and is compatible with SPI interface protocols. The three-wire operation makes the part ideal for isolated systems where minimizing the number of interface lines minimizes the number of opto-isolators required in the system. Register lengths on the AD7730 vary from 8 to 16 to 24 bits. The 8-bit serial ports of most microcontrollers can handle communication with these any of this registers, two or three 8-bit transfers.

The communication of the microcontroller with the PC is realized through the interface RS232 and the human user communicates with the computer using the graphic interface that can activate the following commands: start of the dosing process, establishing of the dosing parameters, finalizing of the dosing process (Fig. 6).

**EXPERIMENTAL RESEARCH**

The stand allowed the study of the vibrations amplitude A and thickness h of material layer over the dosing precision for different agro-food materials. Measurements were made using the same amplitude for the rough feed and only for the fine feed were used different values for the amplitude. After setting up of the dosing parameters, the level of the material layer on the vibrating chute 3 (see Fig. 6) was adjusted using the sliding gate 7 from the exit of the material from the feeding bin 6. For each set of measurements it was used the same quantity of material in the feeding bin in order to ensure the similar conditions for each material tested. The weight cell 1 measured the final dose.

**Fig.9. The influence of the material thickness on the dosing precision for different vibration amplitudes (A4>A3>A2>A1):**

- **a** - dosing mass 100 g
- **b** - dosing mass 150 g

For the analyzing of the influences of the material properties and the parameters for the dosing process on the precision of the dosing process, the following characteristics were targeted: 3 types of materials were used with flow characteristics different from one another: wheat flour, wheat pollard and wheat semolina; 3 levels of the material layer on the vibrating chute: h1, h2, h3; 3 levels of the amplitudes for the fine feeding: A1, A2, A3; 3 weights for the final dose of the material: D1, D2, D3 (Popescu, 2005).

A number of 729 tests were made. The results were plotted against the established dose so that the deviations from the reference value could be observed.
Some of the most relevant examples for wheat flower are presented in the figure 9.

CONCLUSIONS
From the analysis of the theoretical and experimental results it can be inferred the following main conclusions:
- the dosing precision decreased with the growth of the vibrations amplitude;
- for the same vibrations amplitude the larger the dose batch the bigger dosing precision was obtained;
- the dosing precision is bigger when the material thickness is the smaller.

From the observations made over the plotted results it can be seen that the amplitude during the dosing process is very important and a static regime of the vibrations amplitudes does not ensure a proper feeding of the material on the weight scale. For the high precision of the doses it is proposed an automated regime for the amplitudes that will adjust them according with the reached value of the weight scale and monitor of flow in such way that it could be controlled. In order to improve the feeding with material and prevent the occurrence of the “material on air” effect a shutting down of flow gate should be installed at the end of the vibrating chute with a progressive shut down in such way that it will limit the flow in the last part of the feeding process for the free flow materials and will shut down the flushing effect.

REFERENCES