Aspects Regarding Gradular Systems Phenomenon Flow from Tanks and Silo

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Abstract. In frequent technological processes of food industry the use of classification, gradation, calibration or sifting operation becomes a necessity. All operations need flow phenomenon for granular systems follow by mechanical operation realized through separation in granulometric factions of some polydisperse mixtures of granules and powder, on the basis of particle shape and size. Acquiring a specific type of flow (normal or hydraulic) depends on the ratio of the internal friction angle, the friction angle between particles and the wall of the tank and the inclination angle of the wall of the tank from the evacuation hole. The lower the value of the friction internal coefficient is (the material flows more easily), the more limited the area characteristic to hydraulic flow is.

Keywords: processing raw materials, flow phenomenon, friction coefficient, tank and silo.

INTRODUCTION

Granular material that is subjected to further processing specific to food industry is stored in tanks or silo. During the execution of the technological process the granular material is discharged to the dosing devices with a flow whose value should be correlated with the necessary material that is subject to the technological processes that take place.

From the technical point of view, the general name of tanks is assigned to prismatic or cylindrical containers which store bulk granular materials and which supply continuously and periodically different technical systems.

When the height and the transversal part of the containers have the same size, the storage system is called tank, and when the height is much larger than the dimensions of the transversal section the container is called silo. If the container is low built and is used not for storage, but only for transportation is called bin.

The storage capacity of the tank determines the working useful time of the equipment or of the conveyor belt. The walls of the tank most of the cases are made of a steel plate, being protected against corrosion with anticorrosive lakes and with epoxy resins.

The walls of the tank are affected at the hydrostatic pressure exerted by the granular material from the tank. Due to the friction forces between particles and between particles and the walls of the tank, the pressure on the bottom and the side walls is lower than the hydrostatic pressure created by a liquid column of the same height [3].

The shape of the tanks and bins is taken in on the condition that the filling in and unloading processes are secured, without having accumulation areas of granular material which does not run to the dosing machines.

The tanks and silos used for maintaining granular materials used in food industry have the forms presented in Fig. 1: frustum of a pyramid (Fig.1.a), frustum of a cone (Fig.1.b), parallelepiped shape (Fig.1.c), prismatic (Fig.1.d), semicylindrical (Fig.1.e), or cylindrical (Fig. 1.f).
MATERIALS AND METHODS

The flow of granular material inside tanks can be placed between two limit cases of flowing: hydraulic flow and normal flow. The names of these types of flow proceed from the way the relative movement of granular material layers inside the tanks takes place. The characteristics and differences between these flow methods are presented in Fig. 2.

In case of hydraulic flow (Fig. 2.a), the whole quantity of material located inside the tank is in a state of motion, moving towards the evacuation hole. The hydraulic flow occurs when the friction forces between the material and the wall of the tank are lower than the weight force. The character of this type of flow is abrupt, with flow variations, which is not desirable in case of dosing systems for machines that process raw material.

In case of normal flow, the flow has the form of a funnel. The material discharged from the tank is the one situated on the free surface of the material inside the tank, moving towards the central area of the tank where from it flows gravitational to the evacuation hole through a channel formed around the vertical axis of symmetry, the material near the walls of the tank resting. This type of flow occurs when the friction forces between the material and the wall of the tank and the internal friction forces are greater than the force of weight. For this reason, the material of the peripheral area forms a still layer and in the central of the tank a central tube is built up through which the material will flow to the free surface. The main advantage of this method of flow is the lack of the bottoming, the flow being continuously. The way of flow for the granular products (continuously and discontinuously) and the evacuation speed of the material from the tank through the evacuation hole depend on the value of the hydrostatic pressure developed by the material mass from the tank.
The vertical pressure developed in the material mass can be analyzed by taking into consideration an elementary volume of thickness $dh$ situated at the distance $h$ from the free surface and which stands in equilibrium under the action of the following forces (fig. 3): weight, pressures from the upper surface ($q$) and lower surface of the layer ($q+\Delta q$), the friction forces with the wall of the tank generated by the pressure $p$ revealed by the walls of the tank. The state of equilibrium is generated by the following differential equation:

$$q \cdot A + \rho \cdot g \cdot A \cdot dh = (q + \Delta q) \cdot A + \mu \cdot p \cdot L \cdot dh, \ [4]$$ (1)

where: $q$ – the density of the material from the tank $[\text{kg/m}^3]$, $\mu$ – the coefficient of friction between the granular material and the vertical walls of the tank, $L$ – the side surface length of the cylindrical part of the elementary volume of the material.

By integrating equation (1) and taking into consideration the attenuation coefficient $k$ ($k = 0.2...0.6$) [4], the variation of vertical pressure $q$ depending on the height of the material layer is given by the relation 2:

$$q_{\text{max}} = \frac{\rho \cdot g \cdot R}{\mu \cdot k}, [4]$$ (2)

where $R$ - the hydraulic radius, defined as the ratio between the surface flow area and the perimeter of the draining hole. Graphic representation of equation (2) presents a variation as the one shown in Fig. 4.

![Fig 3. Pressure analyse from granular product](image)

![Fig 4. The variation of the vertical pressure depending on the height of the material layer](image)

![Fig 5. Choosing the most favourable inclination angle of the walls of the tank depending on the internal friction coefficient and the type of the tank conical (a) or prismatic (b)](image)
Acquiring a specific type of flow (normal or hydraulic) depends on the ratio of the internal friction angle, the friction angle between particles and the wall of the tank and the inclination angle of the wall of the tank from the evacuation hole (Fig. 5).

In Fig. 4 are presented the areas that generates the conditions for normal and hydraulic flow. These 2 forms are separated by one curve line (Jenike lines), each curve being characterized by distinct values of the friction internal coefficient.

The lower the value of the friction internal coefficient is (the material flows more easily), the more limited the area characteristic to hydraulic flow is.

By analyzing the diagrams presented in figure 5, important differences between the 2 ways of flowing for tronconical tanks (Fig.5.a) and prismatic tanks (Fig.5.b) can be noticed. The hydraulic way of flowing for a prismatic container in comparison with a tronconical one, can be obtained for higher values of the angle $\theta$.

For high values of the friction angle with the walls of the tank, due to the fact that the pressure created by the material layers is diminished by the friction forces between the material and the walls of the tank, the production conditions of hydraulic flow is reduced, the production of normal flow being thus favored.

RESULTS AND DISCUSSIONS

According to theoretical researches conducted, the flow of granular materials from tanks is the result of interaction between the following forces: weight, friction, cohesion, adhesion and inertia. Because of the internal structure of the granular material, these are not homogenous, they have a spongy structure, the particles being weekly connected and the pressure exerted by the material layer of the tank on the hole leak of a certain size creates a free area (vault) that prevents most of the time the free flow of materials from the tank.

In order to ensure the movement of the granular material to the drain hole, the propensity of the lower part of the walls $\theta$ is determined by the condition of free sliding of the granular material particles under the action of its own weight, this angle having values between 30…45 degrees from the vertical.

As to provide the uniformity of the flow, the task requiring the particle layer situated above the evacuation hole of the material from the tank is considered as being uniformly distributed throughout the surface projection hole. Also, the material layers located at the bottom of the tank are required at compression, demand that is induced by higher layers.

The walls of the tank are applying hydrostatic pressure developed by the tank material. The friction forces between particles and between particles and the tank walls determine their mobility, the effect of their action diminishing the pressure on the bottom and side walls of the tank. Part of the weight of the tank material is balances by these forces.

The flow of granular materials from tanks is the result of interaction between the following forces: weight, friction, cohesion, adhesion and inertia occurring during the discharge of the tank.

CONCLUSIONS

The way of flow of granular materials may be continuous or discontinuous, the material evacuation speed and the way of flow depend on the level of hydrostatic pressure developed by the mass of the tank material.
The tasks that result from forces that require the layer of particles propagate in the material mass from particle to particle, the relative movement of the particles being interrupted by the friction forces that occur in contact points and nearby other particles.

The flow of granular materials inside tanks may be included between two limit flow cases: hydraulic flow and normal flow. In terms of evacuating the tanks, the flow may undertake the following aspects: continuous constant flow, discontinuous flow and flow with material segregation (if the material consists of particles with different sizes and densities).

The hydraulic flow occurs if the friction forces between the material and the tank walls are lower than the weight force, the character of this way of flow being fluctuant.

Normal flow occurs if the forces of friction between the material and the tank walls and the internal friction forces are higher than the weight force. In this case, the material from the peripheral area forms a fixed layer, and in the center of the tank appears a central tube through which the material located on the free surface will flow. The advantage of this way of flow is the lack of bottoming, the flow having a continuous character.

REFERENCES