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PROBLEMS OF LOOSE MATERIALS STORAGE

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ABSTRACT: This article describes basic methods of loose materials storage. There are well known problems induced of mechanical properties of mixtures of loose components while storing. This article is focused on equations describing mechanical behavior of such materials and methods of loose materials mechanical properties testing.

Key Words: Loose materials, contact surface, material constants, storage, feeding mixtures

DÖKME MATERYALLERİN DEPOLAMA SORUNLARI

ÖZET: Bu çalışma dökme materyallerin depolanması ile ilgili temel yöntemleri açıklamaktadır. Depolama sırasında dökme materyal karışımlarının mekanik özelliklerinden kaynaklanan bazı problemler oluşmaktadır. Bu çalışmada, dökme materyallerin mekanik davranışlarını açıklayan eşitliklere değinilmiştir ve bu materyallerin mekanik özelliklerini test etme yöntemleri üzerinde durulmuştur.

Anahtar Kelimeler: Dökme materyal, temas yüzeyi, malzeme sabiteleri, depolama, yem karmaları

1. INTRODUCTION

Loose materials belong to the most common agricultural materials. These are being frequently used during the feeding mixtures production as well as pellets and briquettes production. Manipulation and transportation of materials makes almost 70 % of labor time in agriculture. Knowledge of mechanical properties of loose materials and its mechanical behavior is then undoubtedly necessary.

The dimension of the impacting stress is not dependency merely of the material body, however is influenced also by the final loose shape of body forming. Body might be formed at rest or during the motion.

Body of loose material could be formed in few basic phases:

1. Strewing of loose material to the tank,
2. Extracting of loose material layers from the top or bottom of the storage tank,
3. Deflection of storage tank or stored loose material movement etc.

Loose material body is considered as solid, when the deformations caused by external forces or stresses are elastic. Mechanical properties of loose materials are then characterized by following formulas:

$$m \cdot g \cdot \sin\alpha = f \cdot m \cdot g \cdot \cos\alpha \quad \text{[N]} \qquad (1)$$

If the formula (1) is valid, then a particle of loose material, with its weight m, placed on the pile, will be balanced.

$$f = tg\alpha = tg\varphi \quad \text{[-]} \qquad (2)$$

$$\alpha = \varphi \quad [^\circ] \qquad (3)$$

A particle of ideally loose material will hold on surface when the angles α and φ are the same. When the angle of material α is changed, it's increased till the material reaches a limiting angle value α_l, a limiting angle of stability.

2. LOOSE MATERIALS STORING

Loose materials are frequently being stored in storage tanks or silos. These equipments should provide optimal storing conditions for a chosen material, be fully or partially integrated in a production line and to protect the loose material of weathering.

Tanks could be then divided by the stored materials, time of storing, its capacity and other technological functions and features (Maloun, 2001).

Pressure of the material impacting the surface of the tank is a function of the material parameters and geometry of the tank. Tanks are normally divided into two groups, especially for a design and construction purposes.

Pressures in the low and broad tank: A pressure on the bottom is a function of the material height, parallel to the hydrostatic pressure. Pressures on the walls are changing with the increasing or decreasing of material height. Tank is considered as low, when the height is considerably smaller than the width or a diameter of tank. For a value of the pressure impacting the bottom of tank is valid following formula:

$$p = \rho \cdot g \cdot h \qquad [\mathrm{Pa}] \qquad (4)$$

where;
ρ: specific weight of the material [kg.m^{-3}]
g: gravity acceleration [m.s^{-2}]
h: height of the material [m]

Pressures in the tall and narrow tank: Height of such tanks is significantly larger than its diameter or width. Due to, a burden of the material induces a component force, perpendicular to the wall of the tank. Such force induces a friction force, being appointed to the top. In order to a hydrostatic pressure, taking effect on the bottom of the tank is considerably smaller, than is accordant to the material height. For a maximal pressure on the wall of the tank is possible to induce following formula:

$$p_w = \frac{\rho \cdot g \cdot A}{c \cdot f_w} \qquad [\mathrm{Pa}] \qquad (5)$$

where;
A: area- surface of the material cross section [m^2]
c: circumference of the tank (cross section of the material) [m]
f_w: coefficient of the friction between the material and a wall of the tank [-]
Formula (5) is valid in cases, when the height of the tank is at least ten times greater than its hydraulic diameter.

$$p_w = \frac{\rho \cdot g \cdot R}{f_w} \qquad [\mathrm{Pa}] \qquad (6)$$

where; R is a hydraulic radius. For a cylindrical tank is possible to define R as:

$$R = \frac{d}{4} \qquad [\mathrm{m}] \qquad (7)$$

d: diameter of the tank [m]

2.1 OPERATIONAL PROBLEMS OF LOOSE MATERIAL STORING

Most of the problems during the period of loosing material storage are connected with the humidity and pests. These could be prevented by top quality management, represented by the excellent quality of incoming product or further protection and treatment.

Other problems of loose materials storage are caused by mechanical nature of the tank and loose material itself.

Homogeneity of feeding mixtures is one of the most important factors of animals′ feeding. Composition of the feeding mixtures was traditionally well controlled factor, especially in the meaning of maximal production effectiveness reaching. On the other hand, problem of loose materials homogeneity has been mostly reduced to develop and monitor analytical methods of its examination. Problem of the loose material homogeneity could be judged by two basic aspects. From the point of view of nutrients content, ideal homogeneity is often unreachable. Knowledge of the homogeneity of loose materials could serve as an indicator of quality system controlling process. In order to obtain reliable results, there is a necessity of correct sampling, measuring and proceeding and testing of loose mixture samples.

Problems of mechanical nature are frequently described by the cavity forming, seen during the emptying of the tank. Such cavities are dangerous to the crew. Other problem is represented by self – sorting of material's particles. In cases, where declared homogeneity of loose mixture is required, and such self – sorting is a serious problem.

While the emptying of the tank, material movement is characterized by so called primary and a secondary movements. Primary movement is aimed vertically, caused mostly by the weight of the material and its pressure. Primary movement of the particles creates an elliptic cavity of primary movement.

Secondary movement is other movement of particles, changing position of their axles. By the rotations and twisting, particles are minimizing a space, among the particles. There is a phenomenon of material's compression, causing an elliptic cavity of secondary movement.

Emptying of the tanks is another risky operation, causes loss of the quality of the final product.

3. SELF SORTING OF LOOSE MATERIALS

Mixture of loose material is composed of particles of different sizes, weights and other mechanical and physical properties. Emptying, as well as filling of the tanks by loose mixtures often causes self sorting of the filled material. Self sorting of material is a material attribute, describing a material's susceptibility to the sorting by fractions. These fractions are characterized by weight, size etc. Layers of fractions are not sharply defined; however the quality of the mixture is lost. Self sorting of feeding mixtures is also observed during the transport, in order to keep a degree of homogeneity, feeding mixtures are very often granulated and formed into pellets (Anděl, 1992; Přikryl, 1997).

Self sorting during filling of the tank is caused by the different values of aerodynamic drag of each particle sizes. During the free fall, these are most significant factors of aerodynamic drags sizes of particles and their shapes. As well as after the drop of particles, some of them are bounced back. Generally, heavier particles have lower value of the surface resistance, in order to these are formed on the basis of pile. Contrary, the lighter particles are found on the top of the pile.

A surface of the emptying gap is a limiting parameter of material flow and speed. A surface S_e of the emptying hole should be designed by following formula (Jílek, 1980):

$$S_e = (5y)^2 \cdot c \qquad [\mathrm{m}^2] \qquad (8)$$

y: equivalent diameter of the particle [m]
c: coefficient of the safety, could be determined by the further formulas or found in tables (Myslivec, 1953). [-]

Coefficient of fluidity c_f indicates an ability of material to flow, to make a movement. Such ability is mainly influenced by material coefficient of the friction (*f*) (Zenkov, 1952).

$$c_f = 1 \pm 2\cdot f^2 - 2\cdot f\cdot\sqrt{1+f^2} \quad [-] \qquad (9)$$

Force, having an effect on the surface of emptying gap is equal to:

$$F = \rho\cdot g\cdot h\cdot S_e\cdot\left(1-\frac{f\cdot d\cdot h\cdot c_f}{2\cdot S_e}\right) \quad [\mathrm{Pa}] \qquad (10)$$

where;

d: diameter of the emptying gap (If this is not round, an equivalent diameter is induced). [m]

h: height of the material in the tank, in the case of material movement is such value equal to the height of elliptic cavity of secondary movement. [m]

A pressure on the surface of emptying gap is then defined as:

$$p_y = \frac{F}{S_e} \qquad [\mathrm{Pa}] \qquad (11)$$

By the knowledge of material constants and a pressure, a theoretical velocity of the material flow; actually the velocity of emptying v_e could be stated (Maloun, 2001):

$$v_e = \sqrt{\frac{2\cdot p_y}{\rho}} \qquad [\mathrm{m.s^{-1}}] \qquad (12)$$

However, real value of the velocity of material flow is affected by the materials′ properties. Due to, μ_f a correcting coefficient of effluence is induced.

$$\mu_f = f\cdot tg\varphi \qquad [-] \qquad (13)$$

Then a real velocity v_{er} of material flow is:

$$v_{er} = \mu\cdot\sqrt{\frac{2\cdot p_y}{\rho}} \qquad [\mathrm{m.s^{-1}}] \qquad (14)$$

By the knowledge of real velocity of emptying is possible to express an efficiency of the emptying process (Krupička and Ďurkovič, 1981; Dražan and Jeřábek, 1979):

$$Q_m = v_{er}\cdot S_e\cdot\rho \qquad [\mathrm{kg.s^{-1}}] \qquad (15)$$

4. EXPERIMENT

For a laboratory purpose, binary mixtures of feedings were tested. Binary mixtures were sorted by the sieve test and then tested for self sorting during the emptying of the tank. Materials were chosen to simulate real feeding mixtures in order to provide valid and robust results, useable in practice. In this article, a measurement of composition changes during the emptying of tank filled by mixtures of wheaten pollard and rape grit is figured. Samples of same weight were collected during the material flow in same time intervals (10 s). Then the samples were processed by sieving machine AP2; by that, particles of pollard and rape were separated and rates of each component were obtained. Such weight shares were weighed by laboratory scale (Rapido 754-05) and recalculated to apportionment of particles distribution. Then is standard deviation *s* of the particles share equal to following formula:

$$s = \sqrt{\frac{1}{n-1}\cdot\sum_{i=1}^{i=n}(P_1 - P_2)^2} \qquad [-] \qquad (16)$$

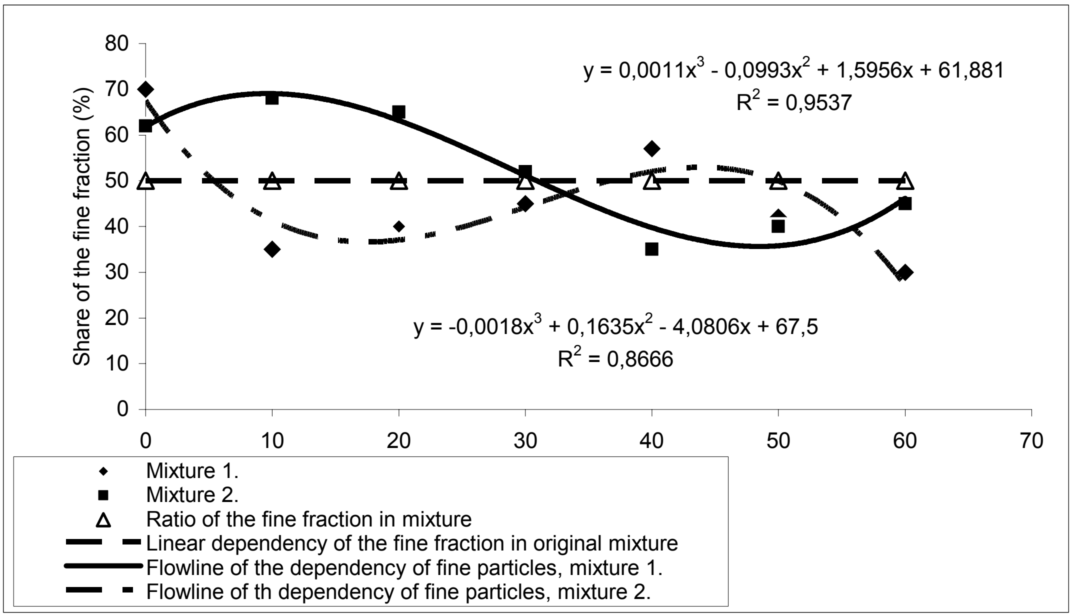

Fig.1 Shares of fine particles of mixture 1 and mixture 2 during the tank discharging.

P_1 is a percentage representation of the fine grained particles and P_2 is a percentage representation o the coarse grained particles (Maloun, 2001).

As testing mixtures, three mixtures with a different fraction composition of fine and coarse particles were chosen.

Mixture 1: rape and wheaten pollards. Fine particles- wheaten pollard with an average size of the core 0.3 mm, Coarse particles- rape pollard, with an average size of the core 2 mm. Ratio of fine and coarse particles was 1:1, total weight of the mixture is 1000 g. A diameter of the emptying gap is 25 mm.

Mixture 2: rape and wheaten pollards. Fine particles - wheaten pollard with an average size of the core 0.3 mm, Coarse particles- rape pollard, with an average size of the core 2 mm. Ratio of fine and coarse particles was 1:1, total weight of the mixture is 1000 g. A diameter of the emptying gap is 20 mm.

Mixture 3: rape and wheaten pollards. Fine particles- wheaten pollard with an average size of the core 0.3 mm, Coarse particles- rape pollard, with an average size of the core 2 mm. Ratio of fine and coarse particles was 0.4:0.6, total weight of the mixture is 1000 g. A diameter of the emptying gap is 15 mm.

5. CONCLUSION

Feeding mixtures are nowadays irreplaceable component of animal feeding and whole animal production. During the production, manipulation, storing and pre- consumption processing could be easily degraded by loss of homogeneity, caused by self sorting. In some cases loss of homogeneity leads to the decreasing of production effectiveness, worse scenario is when the health condition of the animals is affected by non-homogenous mixture (Simons, 1966).

By the experiment was proven a fact, that during the emptying of the tank a separation of fine and coarse particles as well as self – sorting occur. In a case of mixture 1 and mixture 2, has been proven an influence of the diameter of emptying gap to the speed of the emptying as well as an influence to the particle distribution. Finer particles share was significant at the beginning of the process. Then, due to a relatively large diameter was decreasing, till the point of break, almost at the end of emptying, when share of fine particles rose again, after the final separation of coarse particles. Mixture 3 was characterized by lower (40%) share of the fine particles and the emptying gap of the tank was smaller than in the previous measurements. Such conditions have changed conditions of the process, when share of fine particles was constantly decreasing, gradually, without distinctive changes of particles share.

Results of the measurements were analyzed by statistical programs and graphs, while statistical formulas of regressions with high interval of confidence were found out.

The knowledge of homogeneity has a pivotal meaning either for application or for a control of specifically effective materials. By the choice of appropriate homogeneity testing method is generally even possible testing of mixing device. It may also provide time graphics of mixing different components as well as saving of production time. Time saving will enable to manufacturers reduction of operating costs, maximal use of equipments and machinery, in other words higher level of production effectiveness. This trend is clearly visible within last years by the most of producers of feeding mixtures. Knowledge of

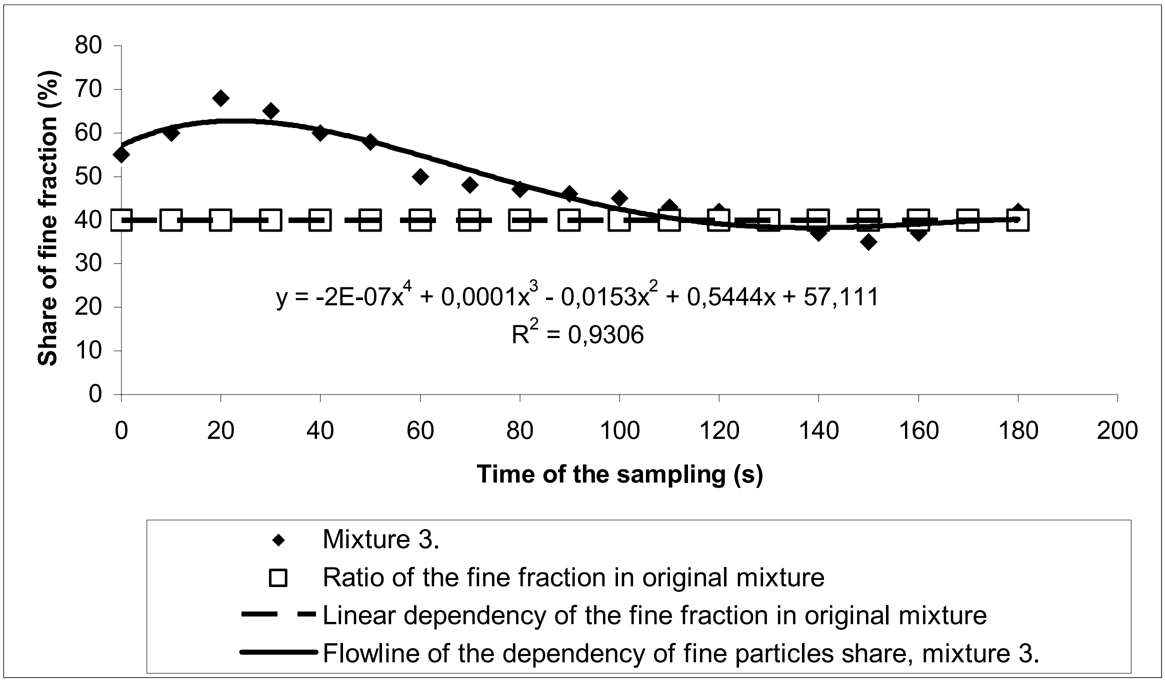

Fig.2 Shares of fine particles of mixture 3 during the tank discharging.

homogeneity also could be understood as a backward structure to agricultural machine producers.

Knowledge of homogeneity is also necessary in the other industrial branches like a pharmaceutical and building industry. Basically, all of the methods of loose material testing and its interpretations are all the same (Karanský, 2006).

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