RESEARCH OF PARTICLE GEOMETRICAL PARAMETERS AND AERODYNAMIC FEATURES OF GRANULAR ORGANIC COMPOST FERTILIZERS

Antanas Pocius, Egle Jotautiene, Juozas Pekarskas, Ramunas Mieldazys, Algirdas Jasinskas
Aleksandras Stulginskis University, Lithuania
antanas.pocius@asu.lt

Abstract. This paper provides the research results of beef cattle granular organic compost fertilizers use and spread by centrifugal spread machinery. For research were used beef cattle granular organic compost fertilizers. For granules making was used matrix with 6 mm and 4 mm holes. There were investigated particle geometrical parameters and aerodynamic features of granular organic compost fertilizers, estimated critical particle speed, coefficient of flutter and others parameters. There were valued influences of geometrical parameters to particle aerodynamic features. Spread equal distributions of granular fertilizers were investigated using fertilizers spreaders "Amazon ZA-M-1201", fertilizers rate – 750 $kg \cdot ha^{-1}$ and 1000 $kg \cdot ha^{-1}$, harvest site – 14 m.

Keywords: granule, organic fertilizers, geometrical characteristics, aerodynamic features.

Introduction

Diverse environmental pollution – a result of human activity. With increasing environmental pollution real danger to any living organism, including human is caused. This leads to the necessity to minimize environmental pollution innovatively solving utilization problems.

Much of the waste in agricultural production consists of livestock waste .For example, on a farm containing 100 dairy cows it is estimated that 14 tons of organic waste is formed per day. Organic waste in agricultural production farmyard manure is classified as avian and swine manure, feed and crop waste, vegetable and fruit processing waste and others [1; 2].

More than half of the total amount of agricultural waste is manure. Three-quarters of the total incoming harvest is processed to manure. 90 % of vegetables, cereals and herbaceous plants used for animal feed, and only 10 % – for human consumption [1; 2].

Manure disposal is an important sphere of livestock activities. Manure as an organic fertilizer value depends on the storage of cattle, manure removal and access to the ground method. Organic fertilizers are fertilizers, containing nutritional elements for plants which have organic compounds form. They are containing nitrogen, phosphorus, potassium, calcium, and other elements necessary for plants, as well as organic material that improve soil properties [2; 3].

Granulation is one of the most effective ways to process and use secondary agricultural products. Granulation is widely used in various industries (chemical, metallurgical, pharmaceutical, food) and agriculture (feed, biofuel, litter production, etc.) areas. Granules pours well and has fairly thick, durable inner structure also lines of equal size, less gathering dust while transporting and using, etc. Granulation is physical – mechanical processes totality when coarse particles are formed with certain dimensions, shape, structure, and physical – mechanical properties.

Innovative activities when recycling organic waste, generated by livestock farms allows to solve all questions related to the use of organic fertilizers and conservation of their priority. The new organic waste processing methods when applying simple technological operations allows to get hold of effective ecological fertilizer. Organic raw material is dried, crushed and granulated while at the same time organic compounds are decontaminated, volume of material and mass is reduced at expense of moisture reduction, besides that nutrient elements concentration increases.

Technology for preparing organic compost from manure and waste feed microbiological has been developed, allowing process animal waste into high-quality granular organic fertilizer. In the course of organic compost and inorganic compounds preparation technology microbiological transformation of the plants to easily digestible form takes place, enriching the soil with biological nitrogen, stimulating plant growth. The prepared organic compost is dried up to 20 % moisture and then granulated.

For effective use of granulated organic fertilizer there many things that are being done: fertilization techniques, technologies, pellet quality and assortment are being improved, optimal rates, proportions, appropriate granule geometric parameters are being selected [4].

Fertilizer efficiency is mainly determined by the even spread of it. For spreading granular mineral fertilizer on the soil surface, spreaders with a working disc elements: one-disk and two-disk are mainly used (Fig. 1). These agricultural machines allow to vary the spread in width, and amounts of fertilizer rash rate.

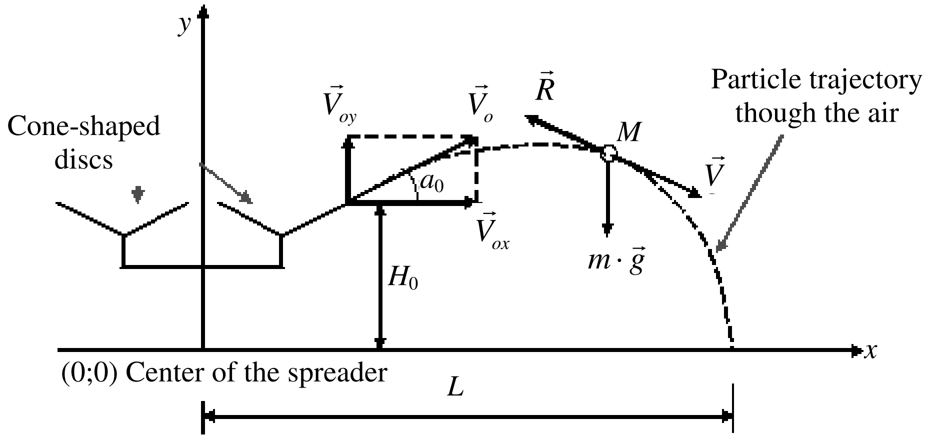

Fig.1. **Particle trajectory though the air:** L – half width of the compartment, m; H_o – initial particle height above the soil surface at the time of particle separation from the disk, m; a_o – angle of particle movement trajectory, deg.; M – material particle; R – external resistance force, N; V_o – external particle speed, m·s^{-1}; V_o – particle speed, m·s^{-1}

In mobile agricultural machinery particles often lose communication and move freely in space. External ballistics laws are applied for those unbound particles movement characteristics [5-7].

For simplifying mathematical description environmental resistance movement pellets can be neglected. Then the complex processes and issues are much easier to deal with. Also it is enough for making engineering decisions and fairly accurately optimizing technological process.

The objects of investigation – beef cattle litter and feed residue compost granulated organic fertilizer.

The aim of examination is to explore new granular organic fertilizer movement in the air flow, estimating pellets aerodynamics properties, and experimentally determine produced granule flutter coefficients and critical speeds of different geometric.

New organic fertilizer pellets are produced, sorting out according to density or spreading with centrifugal scattering apparatus, it is necessary to know the aerodynamical properties: the individual fraction granules critical (vertical) velocity, flutter coefficient and the aerodynamic properties influence on qualitative indicators of fertilizer.

Materials and methods

Most of the times moving or stationary external resistance environment is used (air, water, etc.) in agriculture for transporting, separating bulk materials, and their particles (granules). These environmental resistance laws mainly determined empirically. It has been proven that the environmental resistance is a function of particle velocity: proportional to the velocity (in first-degree), velocity in second degree or velocity of the first and second degree sum [5; 7-9]. Evaluating that particle's midship section and shape during movement remains constant, in the listed proportional dependences, coefficients have constant numerical values.

The relative velocity at which the particles (pellets) gravity force (G) and the air flow's vertical channel external resistance force (R) is equal (Fig. 1), called the critical velocity (V_k). In other words, it is sufficient to determine (was measured) velocity of the air flow in a vertical pipe, at which granules movement velocity in pipe becomes zero.

While doing theoretical calculations, above mentioned proportional coefficients have constants numerical values when particle model shape is spherical. In reality it is not like that, that why theoretical results needs to be combined with empirical in order to determine the actual numerical values of the correction coefficients.

Let's think that each granule is independent of each other during movement in the air flow and is a separate material point (particle) [6; 7] In addition, air density variation is not considered, because particle movement in agriculture takes place in the small height from the ground surface (Fig. 1).

The aerodynamic asses granular properties in air flow. Granule in the air flow is affected by two forces: external resistance force *R* and gravity force *G* (Fig. 2).

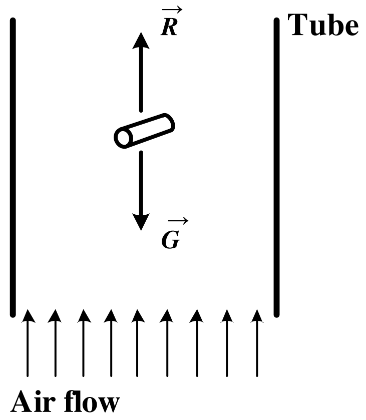

Fig. 2. **The scheme of granules movement in vertical air flow:**
G – gravity force, N; *R* – external resistance force, N

Moving air flow particles external resistance force depends on the mass, size, shape, surface roughness, position of granules and air flow type (laminar or turbulent). If the particles in an air flow moves at a low speed ($v \leq 0.2$ m·s^{-1}) and there is no turbulence then external environment resistance force *R* is triggered by viscosity. In this case this force is expressed as follows [6]:

$$R = k \cdot \rho \cdot A_m \cdot v \text{, N,} \tag{1}$$

where k – air resistance in granule movement factor (coefficient);
p – air density, kg·m^{-3};
A_m – Midship section (granule projection to the plane perpendicular to the direction of air movement vector), m^2;
v – granule movement in the air flow speed, m·s^{-1}.

When the air flow speed is greater than 0.2 m·s^{-1} then the external environment resistance force is calculated as follows:

$$R = k \cdot \rho \cdot A_m \cdot v^2 \text{, N.} \tag{2}$$

Granules of which air flow resistance force is bigger is moving slower from than those with lower resistance force. Acceleration a, which particle gets while moving in the air stream is calculated as follows:

$$a = \frac{R}{m} = \frac{k \cdot \rho \cdot A_m \cdot v^2}{m} \text{, m·s}^{-2}\text{,} \tag{3}$$

where m – grain weight, kg.

Combining equation 3 members, except for the speed v^2, we can express granules flow coefficient:

$$k_s = \frac{k \cdot \rho \cdot A_m}{m} \text{, m}^{-1}\text{.} \tag{4}$$

Than acceleration *a* is equal to:

$$a = k_s \cdot v^2 \text{ , m·s}^{-2}\text{.} \tag{5}$$

Granules flutter can be described by the critical speed. This air flow speed v_k is vertical and directed from the bottom to the top also because of this speed granule is hovering in the air. In this case, the force R (pointing straight up) and pellets gravity force $G = m \cdot g$ (pointing vertically downwards) (Fig. 1) is equal to:

$$R = G = k \cdot \rho \cdot A_m \cdot v_k^2 = m \cdot g \text{ , N,} \tag{6}$$

where g – acceleration due to gravity, m·s^{-2}.

From equation 4 to equation 6 instead of a member ($k \cdot \rho \cdot A_m$) we write member ($k_s \cdot m$) and then we can obtain granules critical velocity expression:

$$v_k = \sqrt{\frac{g}{k_s}} \text{ , m·s}^{-1} \tag{7}$$

From here, knowing the critical speed of the particle it is possible to calculate his flutter coefficient:

$$k_s = \frac{g}{v_k^2} \text{ , m}^{-1} \tag{8}$$

If $G > R$, the particle moves down, if $G < R$, – upwards.

The critical velocity is inversely proportional to the coefficient of flutter which means that particles with higher velocity (v_k) flutter coefficient (k_s) is lower. When changing the air flow speed granules can be sorted into groups, but as accurate as with sieves.

Air flow velocity scale between the lower and upper values is divided into 6 equal classes. First class air flow velocity corresponds to the upper limit of the second class lower speed limit.

The air flow is adjusted so that the air flow speed of the suction duct would increase to the next class values. Each class average velocity of the air is calculated. Each class average air flow in duct value is equal to the class of the granules critical speed. Later on the amount of each class of the critical velocity in the granules percentage of the total sampling weight is calculated.

Aerodynamical organical comspot granular fertilizer properties were investigated using classificator K293. Air flow velocity in the aerodynamical pipe is changing from 6.5 to 18.5 m·s^{-1}. Pellet sampling weight – 1000 g. Test was repeated three times. Air flow velocity in aerodynamical pipe was measured with Aleman 2290-8V5 device.

Granular fertilizer compost granulometrical composition (fractional composition) is determined using Retsch AS 200 sieve. Used sieve set: 7.1 mm; 5.60 mm, 5.00 mm; 4:00 mm; 15.3 mm; 2:00; 1.00 mm; 0.50 mm; 0:25 mm and less than 0:25 mm.

Each test is repeated 3 times. The analysis of variance with three replications design was performed on the data of the fulfilled experiments, using analysis of variance (ANOVA) to determine significance at 95 % probability level.

Results and discussion

Examination of granulated compost fertilizer pellet moisture content, determined that their humidity were from 24.25 to 25.95 %. Although the granules have relatively large (> 20 %) moisture content, which varies over time, but their moisture absorbability is poory influenced by that fact when keeping in hot and humid conditions (30 ºC temperature and 80 % humidity).

Studies using a larger amount of sieves showed that in granulated compost fertilizer (6mm diameter) from 5.6 to 7.10 mm fraction pellets are dominating. Their fraction size depends on the whether fertilizer was sieved before use or not.

Granular fertilizer compost granulometrical composition is changing when granules diameter alters. By examining 4 mm diameter pellet fertilizer granulometrical composition it was found that these fertilizers are dominated by 3.15 to 3.99 mm pellets and a significant amount of 4.0 to 4.99 mm was also found.

Examination of granulated organic fertilizer granulometrical composition determined that in 6 mm diameter fertilizer 5.60 to 7.09 mm granule fraction are mostly observed whereas in 4 mm diameter fertilizer 3.15 to 3.99 and 4.00 to 4.99 mm fraction pellets are dominating (Table 1). It is necessary to sieve fertilizer In order to reduce the amount of small fractions in it.

Table 1

Granulated organic compost fertilizer granulometrical composition, %

Fraction, mm	6 mm diameter granule	4 mm diameter granule
> 7.10	0.38	-
5.60-7.09	80.95	0.36
5.00-5.59	8.31	0.11
4.00-4.99	6.63	23.48
3.15-3.99	2.06	72.96
2.00-3.14	0.98	1.99
1.00-1.99	0.13	0.47
0.50-0.99	0.08	0.05
0.25-0.49	0.13	0.10
< 0.25	0.35	0.48

Achieved results of the test are important for theoretical examination of organic compost fertilizer pellets and centrifugal disc spread machine interaction. They can also be used to support centrifugal disc fertilizer spreader technological parameters.

While studying organic granular fertilizer aerodynamical properties humidity was from 24.25 to 25.95 %. Velocity of air flow in aerodinamical pipe was distributed into 6 intervals, changing it from 6.5 to 18.5 $m \cdot s^{-1}$. From the histogram (Fig. 3) it can be seen that the maximum diameter of 6 mm pellet mass content (over 42 %) is drawn off when the critical air flow velocity in the range of 16.5 to 18.5 $m \cdot s^{-1}$ whereas 4 mm diameter pellet mass content (over 54 %) is drawn off when the critical air flow velocity is in the range of 12.5 and 14.5 $m \cdot s^{-1}$. Organic fertilizer pellets quantitative diffusion Mg integral dependence (percentage) from the critical air flow velocity (V_{kr}) is presented in Fig. 4. Calculated average critical velocity of granules is V_{kvid} = 15.4 $m \cdot s^{-1}$ for 6 mm diameter granules whereas V_{kvid} = 13.5 $m \cdot s^{-1}$ is for 4 mm diameter granules. Granules flutter coefficients are respectively: K_{svid} = 0.42 s for 6 mm granuless and K_{svid} = 0.56 s for 4 mm granules.

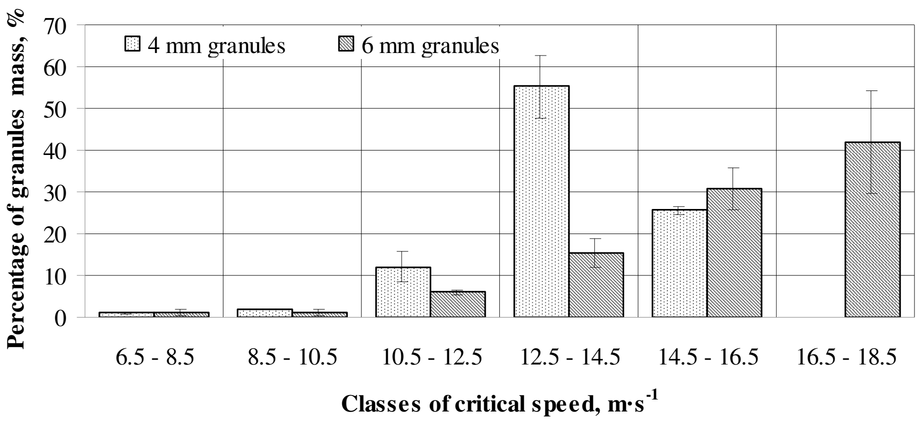

Fig. 3. **Dependence of classes of critical speed to granules mass**

Lighter, smaller fraction pellets is vacuumed by lower velocity of air flow. In order to obtain a more homogeneous group of organic compost pellets, which affects their even spread with centrifugal disc machines, this should be taken into account when sorting granular fertilizers for example with air flow.

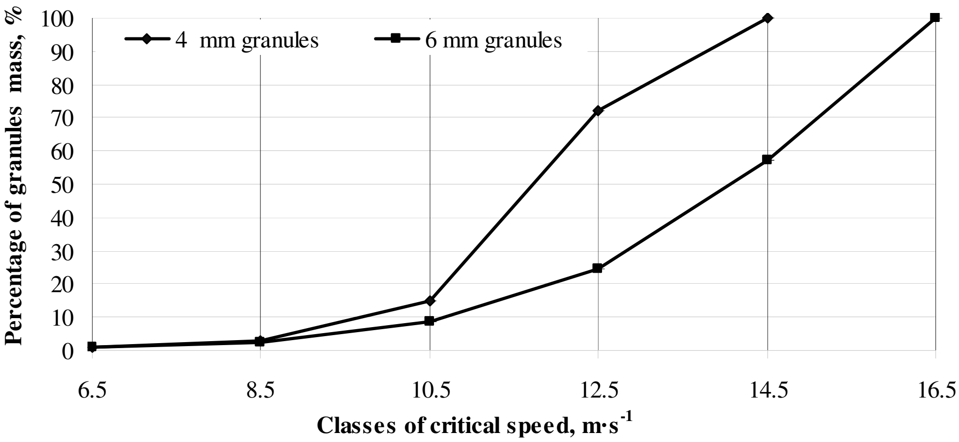

Fig 4. **Dependence of classes of critical speed to granules mass**

Conclusion

1. Granular fertilizer compost granulometrical composition depends on produced granule diameter. In 6 mm diameter fertilizer 5.60 to 7.09 mm granule fraction are mostly observed whereas in 4 mm diameter granular fertilizer 3.15 to 3.99 and 4.00 to 4.99 mm fraction pellets are dominating.
2. Maximum diameter of 6 mm pellet mass content (over 42 %) is drawn off when the critical air flow velocity in the range of 16.5 to 18.5 $m \cdot s^{-1}$ whereas 4 mm diameter pellet mass content (over 54 %) is drawn off when the critical air flow velocity is in the range of 12.5 and 14.5 $m \cdot s^{-1}$.
3. Organic compost fertilizer granular particles flutter coefficient depends on the diameter of produced pellets. When diameter of granule increases (6 mm; $K_{s\ vid} = 0.42\ s^{-1}$), flutter coefficient decreases (4 mm; $K_{s\ vid} = 0.56\ s^{-1}$).
4. Achieved results of the test are important for theoretical examination of organic compost fertilizer pellets and centrifugal disc spread machine interaction. They can also be used to support centrifugal disc fertilizer spreader technological parameters.

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