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EXPERIMENTAL EQUIPMENT FOR BULK GRAIN AERATION IN SMALL FARMS

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Abstract

The paper presents experimental equipment for bulk grain aeration in small farms. The operation of this equipment is based on the kinetically energy produced by pneumatically shock wave. The pneumatically shock waves are produced by short impulses that are discharged into the bulk grain. Due to the impulse sonic velocity the wave energy is able to move large bulk grain quantity, and to realize the bulk material aeration, too. The paper presents the technical possibility to extend this procedure, with adequate equipment for bulk grain aeration in small or larger farms.

Key words: *aeration, bulk grain, equipment, pneumatically shock wave, small farms.*

INTRODUCTION

Actual preventive method for pest and insects control consists in environmental conditions monitoring (temperature, humidity, chemical and biological conditions) inlet silos bulk grains, to combat or interrupt the biologic cycle of pest/ insects. For medium or longer period of grains' storage in silos, usual method recommends more often energicaly manual or mechanical aeration realized by spooner equipment. Due to the intensive impact and friction phenomena between grain particles during mechanical spooner, the sensible life stage of insects (eggs, larva) are almost inactivated or killed. In the same time, during the mechanical spooner the bulk grain a short natural ventilation is realized. The traditional method for bulk grain ventilation stored into large silos in larger farms is based on artificial ventilation, but no mechanical spooner is possible. (Banu, 2001; Rosca, 2010)
Many years ago, in USA and west European countries, to prevent any problem in bulk materials stored in bunker or silos, discharging equipment (technical and commercial well-known as Air Cannon, or Big Blaster), were used. (Big Blaster - Martin Engineering; Airchoc - Standard Industrie). The Big Blaster Air Cannons are pneumatic systems (Figure 1), bulk material moving that quickly release compressed air into a storage vessel to restore flow to material that is clinging, rat-holing, bridging (a) or arching (b). Air Cannon System consists of one or more air cannons mounted on the storage vessel. (Martin Engineering - BIG Blaster M3404 -01/ 08)

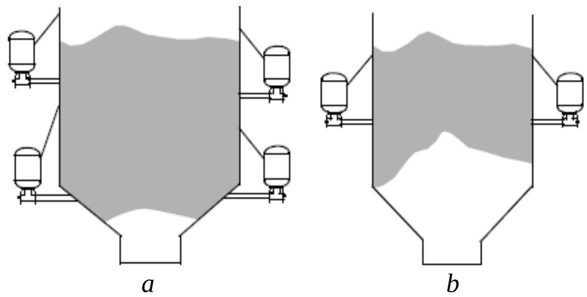

Figure 1. In bunker bulk material problems solved by Air Cannons Systems (*a* - bridging; *b* -arching)

In Romania there are known several technical applications for solid or powder bulk materials (large electro-thermal plants, cement plants, raw materials for metallurgy, dust filtering system for belt conveyors), and for viscous materials in food industries (Figure 2). (ICMET Craiova Catalogue)
There are known research works concerning the effect of impulsive kinetically energy of the shock waves on plastic deformation of thin metallic parts (Roşca, 2001; Roşca et al., 2006), on metallic bunker stability (Năstăsescu, 2005; Roşca, 2004; Roşca et al., 2008), and for nuts

fruits harvesting (Roşca, 2005; Roşca et al., 2005), respectively.

Figure 2. Pneumatic shock wave system on metallic bunker for malt viscous milling in beer plant

MATERIAL AND METHOD

The experimental equipment consists in a fast discharge device mounted a small bunker wall (Figure 3). Considering visual / demonstrative considerations, the bunkers' walls were made in transparent high density polypropylene (end of life use recyclable plastic material).

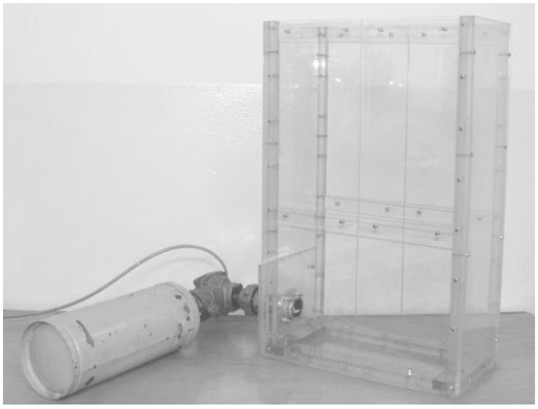

Figure 3. Experimental equipment for bulk grain aeration in small farms

Before recycling, the plastic parts were tested to determine static and impulsive dynamic stability.

In a previous project, experimental equipment (Modular Equipment for Nuts Harvesting by Pneumatic Impulses - MEHPI) was designed to replace the effect of the wind blasts, with orientated air blaster shock waves, which replace the velocity and orientation of strong winds. (Roşca, 2005; Roşca et al., 2005). The main operational component of MEHPI consists in a fast discharge device (FDD).

The same FDD was used for the presented paper.

In principle, FDD is composed 8 dm^3 capacity storage vessel with a special fast discharge pneumatic valve (Figure 4).

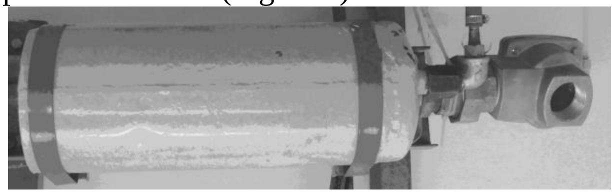

Figure 4. Fast discharge device

The FDD operation is based on the effect of the compressed gas discharge with high velocity from a storage vessel. During this fast process, the gas flow is characterized by high rate pressure variation. Therefore there is no heat exchange with the outside environment, and the flow process can be considered adiabatic. When the compressed gas is discharged from a storing vessel (initial parameter p_o, ρ_o, T_o) through a nozzle in the atmosphere (final parameter p_{at}, ρ_{at}, T_{at}), the gas velocity is determined with relation (Roşca and Roşca, 2008; Roşca et al., 2010):

$$v_{max} = \left\{ \frac{2k}{k-1} \cdot \frac{p_o}{\rho_o} \cdot \left[1 - \left(p_{at} / p_o \right)^{\frac{k-1}{k}} \right] \right\}^{1/2} . \qquad (1)$$

Because the ratio (p_{at} / p_o) < 0,5283 , in the minimum cross section of the convergent nozzle / pipe the critical regime is realized, and the maximum flow that is obtained (passing through this cross section) Q_{max} obtained with relation:

$$Q_{\max} = 0{,}04042 \cdot S_{cc} \cdot p_o / T_0^{1/2} , \qquad (2)$$

where S_{cc} is cross section area of the convergent nozzle / pipe (the convergent nozzle D_p = 44mm). Considering the initial and the final parameters of the gas (p_o = 2 -5 bar; p_{at} =1 bar; T_o = T_{at} = 293°K; k=1,4), the maximum velocity v_{max} of the compressed air and pressured CO_2, respectively, discharged from the storing vessel, was calculated.

The medium velocity of shock wave v_{med} was theoretical determined knowing that the medium flowing velocity in a flow section can be determined with relation $v_{med} = 0{,}2\ v_{max}$.

The experimental method to determine the shock wave velocity proposes high speed camera Fastec Imaging type (Roşca A., et al. 2010).

To determine the effective shock wave velocity for compressed air and pressured CO_2 fast discharging (initial pressure p_o = 2…5 bar), a contrast colored fine powder was introduced into FDD convergent nozzle. A modular panel with 0,1m horizontal and vertical grids was used (Figure 5).

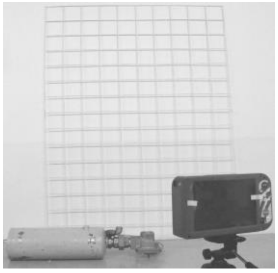

Figure 5. Shock wave velocity using high speed camera

RESULTS AND DICUSSIONS

According relations (1) and (2) presented in theoretical considerations the maximum velocity v_{max} of compressed air and pressured CO_2, respectively, discharged from the storing vessel, and the maximum flow Q_{max} passing through the cross section S_{cc} are presented in Table 1, and Table 2, respectively.

Table 1. Maximum velocity and maximum flow for compressed air fast discharging

p_o [bar]	ρ_o [kg/m^3]	v_{max} [m/s]	Q_{max} [kg/s]
2	2,84	340,2	0,914
3	3,42	365,8	1,010
4	4,53	407,6	1,364
5	5,72	436,7	1,709

Table 2. Maximum velocity and maximum flow for pressured CO_2 fast discharging

p_o [bar]	ρ_o [kg/m^3]	v_{max} [m/s]	Q_{max} [kg/s]
2	3,13	378,4	1,004
3	3,72	402,3	1,098
4	4,87	443,8	1,467
5	6,09	469,7	1,817

According the shock wave theoretical velocity value', the high speed camera image capturing sequence was set for 500 fps. The high speed camera MiDAS 4.0 Express Control Software start was simultaneous triggered with the FDD's electropneumatical fast discharge valve.
The medium velocity [m/s] determined by using theoretical method and the experimental method, respectively, are presented in table 3.

Table 3.Theoretical and experimental medium velocity for compressed air and pressured CO_2 fast discharging

p_o [bar]	Compressed air		Pressured CO_2	
	Theoretic v_{med} [m/s]	Experim v_{med} [m/s]	Theoretic v_{med} [m/s]	Experim v_{med} [m/s]
2	68,1	62	75,7	69,7
3	73,2	67,4	80,5	74,9
4	81,5	75,8	86,8	81,6
5	87,4	82,2	93,9	89,2

The values obtained by using the experimental method are 5…9% smaller then those obtained using theoretical method (viscosity force that occurred due to high velocity shock wave, in the front and at the border of the shock wave, the turbulent flow determines smaller values then the theoretical shock wave velocity).
Operation principle of FDD consists in fast discharge of all the pressured gas (compressed air; pressured CO_2) contained in the storage vessel. The pressured gas weight W_{sv} into 8 dm^3 capacity storage vessel, calculated for four different pressures is presented in Table 4 (for compressed air) and Table 5 (for pressured CO_2).

Table 4. Kinetically energy for compressed air fast discharging

p_o [bar]	ρ_o [kg/m^3]	$W_{sv} \times 10^{-3}$ [kg]	v_{med} [m/s]	$E_{K,dyn}$ [J]
2	2,84	22,72	62,1	43,81
3	3,42	27,36	67,4	62,14
4	4,53	36,48	75,8	104,8
5	5,72	43,36	82,2	146,48

Table 5. Kinetically energy for pressured CO_2 fast discharging

p_o [bar]	ρ_o [kg/m^3]	$W_{sv} \times 10^{-3}$ [kg]	v_{med} [m/s]	$E_{K, dyn}$ [J]
2	3,13	25,04	69,7	60,82
3	3,72	29,76	74,9	83,47
4	4,87	38,96	81,6	129,74
5	6,09	48,72	89,2	192,82

Assuming fast and complete discharge of the all pressured gas weight initial contained into 8 dm^3 capacity storage vessel, the kinetically/dynamic energy $E_{K, dyn}$, determined with relation:

$$E_{K,dyn} = (W_{sv} \times v_{med}) / 2 , \qquad (3)$$

is presented in Table 4, and Table 5, respectively.
The aim of this paper is to realize the bulk grain aeration, and bulk grain moving, too. Thus, the kinetically/dynamic energy $E_{K, dyn}$ must be greater then the potential energy E_{pot} of the bulk grain column weight W_{bg} that exist above the FDD discharge pipe ($E_{pot} = W_{bg} \times g \times H$).
In order to increase the visibility during the experiment efficiency tests, the plastic transparent bunker was filled with successive layers of grain (wheat and corn). The FDD was activated by four consecutive pressures (2, 3, 4, 5 bar).

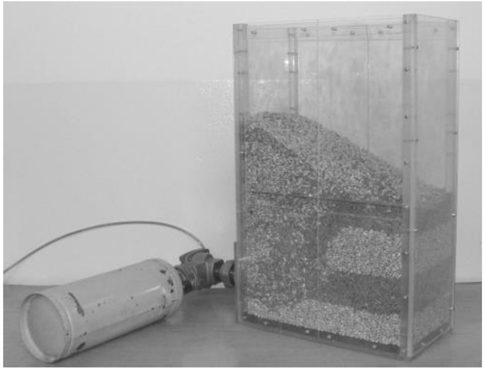

Figure 6. Shock wave dynamic energy realize grains moving / mixing, and aeration

During these experiments it was observed that the shock wave kinetically/ dynamic energy realize each time the grain moving/mixing, and in the same time, the aeration, too (Figure 6).

CONCLUSIONS

Due to the impulse sonic velocity the wave energy is able to move large bulk grain quantity, and to realize the bulk material aeration, too.

This equipment can be modular mounted, when moving / aeration is necessary, on any wooden, concrete or metallic bunker walls in every small farm.

There are proposed more experiments to of observe the possibility of a portable equipment.

With adequate constructive up-grade, the equipment can be preventive or operative mounted on any bunker size for bulk grain moving /aeration in larger farms.

Further experiments are necessary to observe the influence of discharged CO_2 shock wave on grains preservation.

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