Features of designing feeding hoppers of loose materials of low productivity in agriculture

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Abstract. Hopper installations are the main constituent of machines units of agricultural production. They are used in operations connected with storing, transporting and processing of loose grain materials. In spite of the simplicity of construction they have a serious drawback relating to a certain loose material property. The loose material while being outflowed from the capacity forms arched (bridge) structures that prevent a normal gravitational outflow resulting in it acquiring an unstable character. In this work, some methodology is given to calculate a vibrational dome breaking device with a lateral outlet opening that provides a steady supply of grain of different moisture. The facility developed enabled to achieve a steady grain outflow of various moisture from bins with lateral output openings under conditions that had never been possible before. The device developed enabled to achieve a steady grain outflow of various moisture from bins with lateral output openings under conditions that had never been possible before. In general, the results obtained show that the application of dome breaking device can be used in hopper installations to ensure steady grain outflow of various moisture and low productivity.

1 Introduction

The goal of this work is to propose some calculation methodology of parameters and modes of dome breaking device operation that provides a steady supply of grain of different moisture from bins with lateral output openings. As a rule, to prevent from forming of both dynamic (sliding) and statistical (steady) arches, the dome breaking devices are used in axis symmetrical bins [1-3]. In this work, we have investigated the ratio of dome breaking device vibration frequencies and that is of the destruction of domes for the particular loose material.

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2 Statement of the Problem

The general calculation methodology of parameters and modes of the dome breaking device operation for a grain bin with a lateral output opening is as following:

2.1 Determining of the expediency of the dome breaking device installation

Let's define the possible number of domes *N* in the area of the most possible formation and destruction of domes by formula (1) for a bin with a lateral output opening [4]:

$$N = \frac{b \cdot \left(\frac{15 \cdot d}{cos\alpha} - h\right)}{d^2} \tag{1}$$

where *b* is the width of the bin, *d* is the conventional diameter of a particle, *a* is the angle of the bottom inclination of the bin to the horizon, *h* is the height of an output opening, 15*d* is a dome forming distance where the formation of dynamic domes depending on the loose material properties is possible.

If *N*>0 it means that in the bin at any time in a steady outflow mode, there is some maximum number of domes that equals *N*. On the reverse, *N<0* unstable domes within given geometrical dimensions of the bin and loose material do not exist.

2.2 Determining of the place to install the dome breaking device

For this purpose, it is essential basing on the size of a dome breaking section to calculate an active zone in which the domes will be destructed on the front wall of bin *L*:

$$L_s = \frac{15 \cdot d}{cos\alpha} - h \tag{2}$$

As the observations for outflow [4] and modellings of outflow process (Timolyanov, 2016) for the outflow of a hydraulic kind show the destruction of domes along the front wall of bin *L* is sufficient (Fig.1).

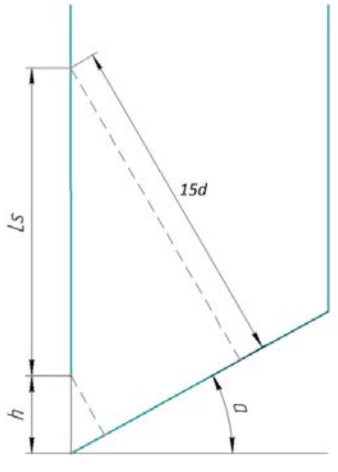

Fig. 1. A hopper bin with a lateral output.

For normal and mixed kind of outflow the destruction of the domes along a front bin wall is necessary as well as the ones consisting of stagnant zones being formed on the bottom.

2.3 Determining of dome breaking impact force on grain material

One equivalent dome produces some average meaning of force F on the wall of a bin during a forming or destructing process. Thus, we will calculate the force F with which it should act on the loose material consisting of a multitude of domes by formula:

$$F_{tot} = k \cdot (F) \cdot N \tag{3}$$

where k is a stretch empirical ratio of storage (for hydraulic mode of the outflow k equals to 1.2, for mixed and normal one k equals to 1.5).

The choice of the ratio of storage k is explained by forming of stagnant zones on the bin bottom under the mixed and normal outflow.

2.4 Determining of the choice of dome breaking device vibration frequencies

The main task of the dome breaking device is to destruct domes with a frequency more in rate than the frequency of their forming by 20-40% for the stabilized mode of outflow. According to the observations for outflow it is revealed [4] that an average frequency of amplitudes of a dome breaking device should be chosen resulting from the dome destructing frequency and will satisfy the condition:

$$\lambda < \nu \leq \mu \tag{4}$$

where λ - bin forming frequency; ν - bin breaking device operation frequency; μ - bin breaking frequency.

It is recommended that the frequency of dome breaking device operation should approximate or be equal to the frequency of dome breaking. If the dome breaking device operation frequency approximates the frequencies of dome forming, one can observe the so-called resonance of “oscillations” of domes supported by dome breaking device operation. That, in its turn, can cause the dome forming intensification that leads to the outflow stoppage. And, as dome forming is accompanied by strong “attacks” it may cause destructive conditions of bin construction [5]. One can define the frequency of dome destructing by using the methodology suggested in author’s work [6].

2.5 Determining of dome breaking device oscillations amplitude

The amplitude of oscillations of the vibrational dome destructor (Fig. 2) will be calculated as the difference between the sizes of dome forming distances for n and $n + 1$ numbers of domes taken into consideration as well an increment of a form of a grain particle:

$$A \cdot H'_{(n)} = \left(AB_{(n+1)} - AB_{(n)}\right) \cdot sin\alpha + \Delta f \tag{5}$$

where AB is a dome forming section for the dome destructed will be determined as:

$$\langle AB_{(n)} = d \cdot \left\{\frac{1}{2} cosn\pi + \frac{3}{2} + \left[n - \left(\frac{1}{2} cos\alpha n\pi + \frac{3}{2}\right)\right] sin\beta\right\}. \rangle \tag{6}$$

$AB_{(n+1)}$- the size of doming section for a dome consisting of one ball more than that of a destroyed one:

$$\langle AB_{(n+1)} = d \cdot \left\{\frac{1}{2}cos(n+1)\pi + \frac{3}{2} + \left[(n+1) - \left(\frac{1}{2}cos\alpha(n+1)\pi + \frac{3}{2}\right)\right] sin\beta\right\}.\rangle \quad (7)$$

Δf - additional form increment:

$$\Delta f = \frac{1}{2} d(1 - \sin(\alpha) \quad (8)$$

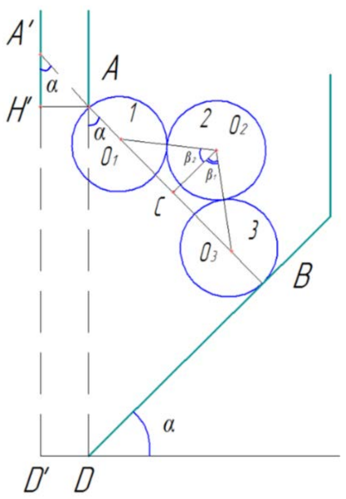

Fig. 2. The dome formed out of 3 circular grains.

2.6 Determining of the loose material consumption

Loose material consumption of a bin, working with steady feeding (i.e. steady outflow mode) will be determined as the mass of destruction loose material domes in outlet cross-section per time unit.

$$q = q_0 \cdot \left(1 - e^{\frac{-\nu h}{\mu d}}\right) \quad (9)$$

where q_0 - nominal bin consumption, $kgph$; ν - frequency of dome breaking device operation, Hz; h - doming size of an outlet, m; μ - dome breaking frequency, i.e. the frequency of loose material doses output from a bin; d - nominal caryopsis grain diameter;

In case of stabilized outflow process conditions, nominal bin consumption q_0 will be determined:

$$q_0 = h \cdot l \cdot \mu \cdot \rho \cdot d \quad (10)$$

Watching the outflow process points to the fact that the frequency of loose material output from a bin, working at stabilized outflow process condition mode in case of doming, corresponds to dome breaking frequency μ [3].

Based on proposed methodology for model bin (height 1 m,– width 0.4 m, thickness – $0.25\ m$, bin bottom inclination angle – 45 degrees) an active dome breaking device (a useful model patent № 166543) has been built [7]. Dome breaking device (Fig. 3) is a plate, fixed in resilient members 2.

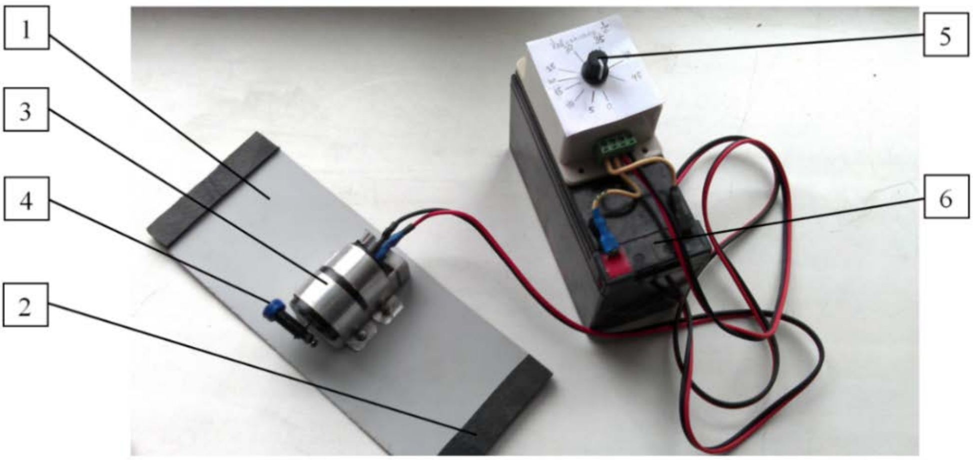

Fig. 3. Designed dome breaking device.

On the plate there is a vibrator, which is a direct current motor 3, with an axial misbalance installed on its axis 4. The motor control is provided by means of thyristor voltage regulator 5, electrical feeding of a circuit is provided by accumulator 6. Voltage regulator was marked on the basis of bin wall shake frequency in resilient members, and had the ability to change the shake frequency from 0 to 45 Hz (Fig. 4).

3 Results and Discussion

Under dome breaking device vibration frequency 30Hz (grain moisture), corresponding with dome breaking frequency for the particular loose material, and a model bin (bin bottom inclination angle 45 degrees, outlet height 25 mm) the maximum consumption of conditioning moisture (0,54 kg/c). Under frequency 15 Hz the consumption contained 0,4kg/c, under10Hz it was 0,3kg/c, and under the frequency 5Hz the outflow had an unstable mode. It has been discovered that when dome breaking device vibration ran to the dome destructing frequency, graded (maximum) bin consumption which was possible for the given outlet size was observed. When vibration frequency of a dome breaking device ran to doming frequency the loose material outflow was unsteady.

With the increase of grain moisture its consumption meaning reduced under the same meanings of dome breaking device frequency. This is related to the appearance of a thin liquid film that led to the appearance of additional intermolecular connections between the grains.

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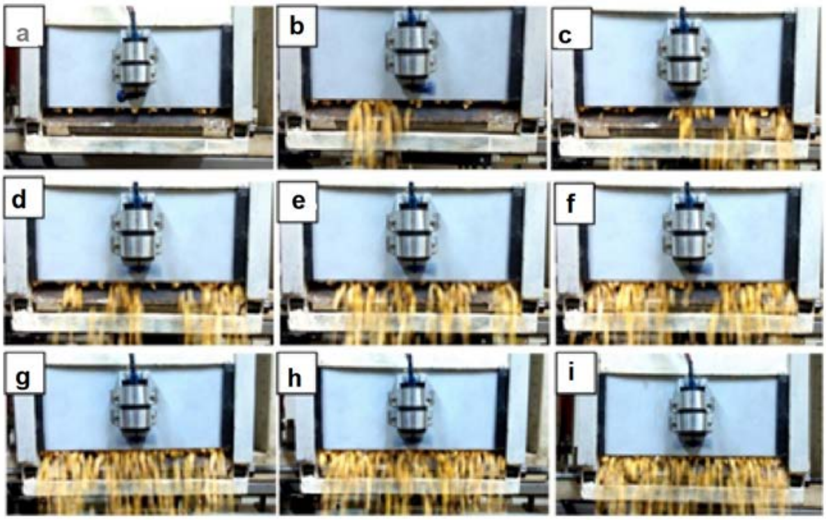

Fig. 4. Corn outflow (moisture 18%) from the bin, under the bin outlet height 25 mm, bin bottom inclination angle 45 degrees, under device shake frequency: *a)* 0 Hz; *b)* 5 Hz; *c)* 10 Hz; *d)* 15 Hz; *e)* 20 Hz; *f)* 25 Hz; *g)* 30 Hz; *h)* 35 Hz; *i)* 45 Hz.

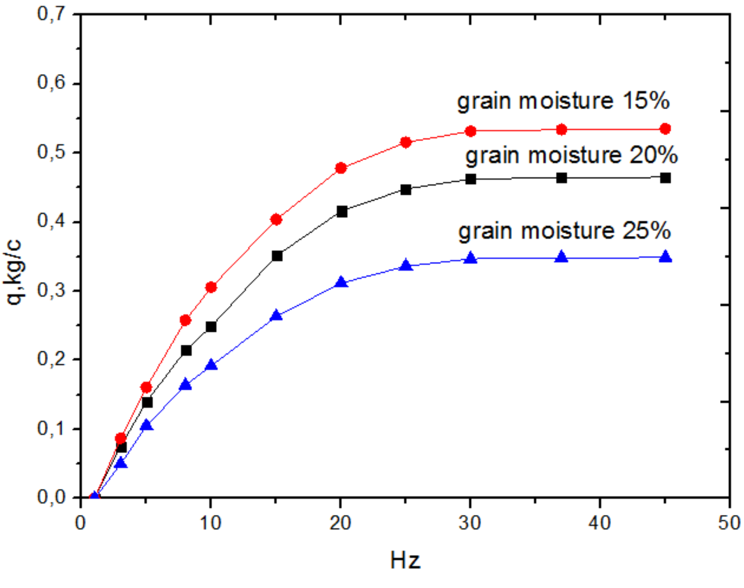

Fig. 5. The graph of vibration frequency dependency of dome breaking device from calculated bin size.

4 Summary

After having analyzed the collected data and graphic charts, we came to the conclusion that the offered dependency determining parameters and modes of dome breaking device operation for a bin with a lateral outlet, made it possible to create a dome breaking device and achieve steady outflow of different moisture (18-30%) grain from a bin under conditions, when the outflow hadn’t occurred yet. It was discovered, that the optimum dome breaking device vibration frequency for grated consumption support of a bin is a loose material dome destruction frequency. On average, under model bin h = 50 mm output opening height the time of wheat outflow was reduced by 17-23%.

References

1. N.M. Bespamyatnova, Y.A. Bespamyatnov, V.V. Reutin, U.A. Semenikhina, *Vibro-planting crops and fertilizer*, 234 (2015)
2. N.M. Bespamyatnova, S.G. Dobrovolskaya, V.F. Hlystunov, *Control modes of the adaptive frequency bridge breakers device for unloading of grain materials from hoppers*, 101 (2015)
3. K.A. Timolyanov, V.S. Kunakov, IRJ, *Determinations of the form of vaults in the grain silo with side outlet withdraw with stroboscopic effect,* **1**, 41-44 (2016)
4. N. I. Klenin, *Investigation of the milling and separation of grain,* 424 (1977)
5. G.A. Kuzin, *Intensification of threshing and separation process in threshing machines of combine harvesters,* 505 (1989)
6. C. Kanadfoiski, *Grundlagen erntetechnishen Baugruppen*, **2**, 312 (1973)
7. N.I. Chursin, *Research of technological process in rotary threshers of harvesting machines*, 295 (1970)