Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLII
Broj 4, 2017.
Strane: 1 – 8

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLII
No. 4, 2017.
pp: 1 – 8

UDK: 631.365.22

Originalni naučni rad
Original scientific paper

FLUIDIZATION QUALITY DETERMINATION METHOD IN DRYERS WITH PSEUDOFLUIDIZED GRAIN LAYER

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Abstract: The investigation results of pseudofluidization grain uniformity in grain dryers. The new method of fluidization quality estimation that allows providing more uniform heating of grain material and enhancing drying process is suggested. The method consists in determining light beam intensity, penetrating through grain layer. The recommendations on choice of optimal structural parameters of drying chamber of grain dryers which should be followed at its designing are given.

Key words*: drying, dryer, method, grain, pseudofluidization, gas distribution grid*

INTRODUCTION

At the present time in agricultural production convective drying of grain material by organic matter combustion products being used as a fuel with higher combustion temperature is widely applied [1-8]. A significant fault of these dryers is high energy consumption (5. ..7 MJ/kg of vaporized moisture) [1].

It dictates the necessity for developing new, less energy consuming, environmentally appropriate technology of grain drying.

The usage of food products drying method in pseudofluidized layer allows speeding up the process significantly. It is very important for increase of technical and economic indicators of drying installations.

The grain layer description in dryers functioning according to the pseudofluidization principle can be at best estimated only visually which is not quite objective. It is

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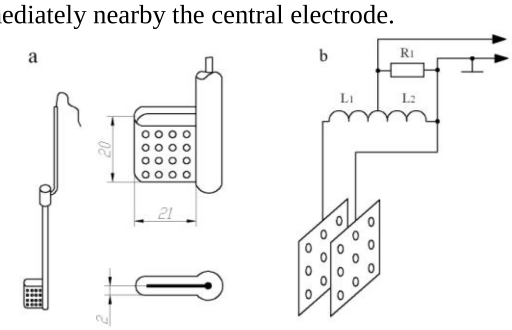
generally recognized and no doubts for this reason many attempts to find more precise determination of pseudofluidization quality were done.

The widest application at gas pseudofluidization the fluidization quality measurements by means of capacity probes is recognized [6-7]. These probes are electric capacitors of different configuration being plunged into boiling layer.

The example of capacity sensor for fine layers with electric field concentrated inside it is presented in figure 1. Sensor plates with coarse perforation are plunged into boiling layer vertically in order to violate solid phase mass circulation in the capacitor measured volume least of all.

As distinct from translucence methods the placement of capacity sensor inside boiling layer as well as any other object causes definite destruction of layer local structure just therein the measurements are being done. For example, extra large bubble can not at all penetrate into test volume between capacitor plates.

Much lesser structural destructions must be caused by open bar sensors. Fig. 2 presents the construction of the similar sensor. Even with ultimate cylindrical symmetry the electrical field inside capacitor is non-uniform and it decreases with a distance from the central electrode. That is why strong change of material density at the test volume periphery will distort the field and influence on total electric capacity just as lower density located immediately nearby the central electrode.



a – construction; b – electric scheme

Figure 1. Laminar capacity sensor (dimensions, mm)

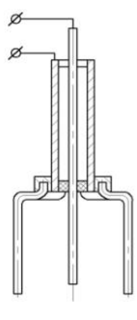


Figure 2. Bar capacity sensor

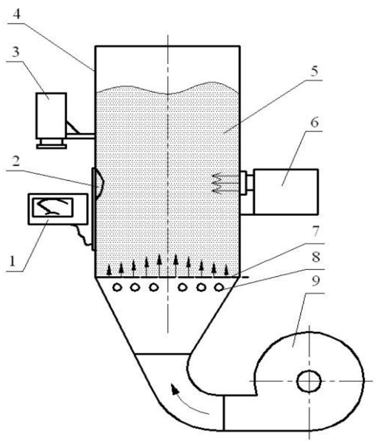
The reliability of quantitative results obtained at usage of quite open "point" sensors is much less, when only one small-sized electrode is plunged into the layer and the second one (for example, the chamber wall) is sufficiently removed. These probes can be used to register just highly sharp discontinuity, for example, the appearance and passing of bubbles. Placing such sensors one above the other while processing oscillograph recordings of both probes it is possible to estimate bubble rise velocity and their diameters.

Thus, in known methods foreign objects should be plunged into pseudofluidized layer. It influenced on pseudofluidization nature [1].

MATERIAL AND METHODS

We suggested the method of determination of pseudofluidization uniformity consisting in determining light beam intensity, penetrating through grain layer. Experimental tests were done on the developed and manufactured installation presented in Fig. 3.

Under the influence of the heated with electric heating elements 8 air flow created by ventilator 9 on grain layer 5 which is located on gas distribution grid 7 the intergrain contacts become weak, bed void fraction increases, and its structure is destructed under certain conditions. Dense grain layer in working chamber 4 merges into condition that reminds boiling liquid h.e. pseudofluidization condition. At that the uniformity degree of pseudofluidized grain layer produces the main effect on drying quality.

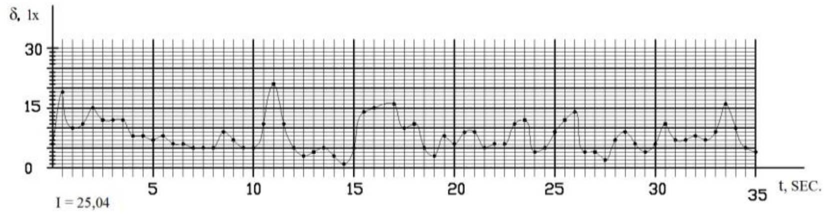


1 - luxmeter; 2 – selenium sensor; 3 – video camera; 4 - drying chamber; 5 – grain layer; 6 – light source; 7 – gas distribution device; 8 – electric heating elements; 9 – ventilator

Figure 3. Scheme of experimental installation and devices arrangement to determine the pseudofluidization uniformity degree

Light emission produced by directed light source 6 was detected by selenium sensor 2, and registered by luxmeter 1 and was recorded by video camera 3.

Oscillograph recordings of luxmeter readings have the form presented in Fig. 4, and allow obtaining detailed amplitude and frequency data. Different lines and hatchings in Fig. 5 present the processing of these recordings to obtain the necessary information.



abscissa – test duration t, sec; ordinate – light flow δ, lux;
I – uniformity index (I = 25,04)

Figure 4. Determining of fluidization uniformity index

Thus, distinguishing definite sufficiently large time interval T, we summarized area under curve $\delta(t)$ and determined mean average deviation $\bar{\delta}$ *of light emission*:

$$\bar{\delta} = \frac{1}{T}\int_0^T \delta(t)dt \qquad (1)$$

Further we drew the corresponding horizontal that separated areas with $\delta > \bar{\delta}$ (spaces with sign «+») from areas $\delta < \bar{\delta}$ (spaces with sign «–»).

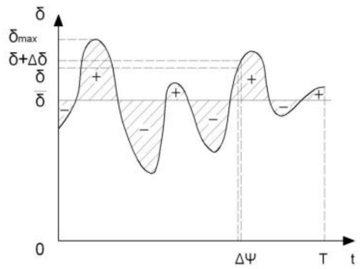


Figure 5. Processing of luxmeter readings

Integrating separately the areas of truncated positive and negative spaces we determine average absolute deviation:

$$\left|\Delta\bar{\delta}\right| = \frac{1}{T}\int_0^T \left|\delta(t) - \bar{\delta}\right| dt = \frac{2}{t}\int_0^T \Delta\delta + dt = \frac{2}{T}\int_0^T \Delta\delta\_ dt \qquad (2)$$

Drawing at the same figure number of horizontals corresponding to neighboring values δ and $\delta + \Delta\delta$, it is possible to add up continuances $\Delta\psi$, during which the light intensity was enclosed in this interval, and to determine this event relative probability $\Delta\omega(\delta) = \sum \Delta\psi / T$.

Uniformity index *I* was interpreted as relation of average deviation $\bar{\delta}$, to oscillation frequency ν: $I = \bar{\delta}/\nu$, where ν oscillation frequency.

According to the experiment uniformity indexes were connected with pseudofluidization in the following way: high degree of uniformity corresponds to index 7, satisfactory – index from 7 to 15, low, with increasing piston flow – from 15 to 32.

RESULTS AND DISCUSSION

Experimental investigations were done in order to ground the drying chamber structural parameters providing the specified limits of variation of uniformity index *I* of wheat seeds pseudofluidized layer, which was determined according to intensity variation of light beam penetrating through grain layer. In this regard it was necessary to study the effect of the variation of diameter d and pitch h of holes of gas distribution grid of drying chamber on uniformity index *I* of grain seeds pseudofluidized layer.

Hole diameter was chosen according to the following values: d = 2; 2,2; 2,4; 2,6; 2,8; 3 mm. At that hole pitch was equal to h = 1; 1,5; 2 mm.

Experimental results of the study of the mentioned above factors effects on uniformity index of pseudofluidized material in the drying chamber are presented in the form of characteristic curves in Fig. 6 and 7. The obtained uniformity index dependences of the fluidized material from holes diameter of gas distribution grid (Fig. 6) at different pitch of the given holes have linear character.

Sharp decrease of uniformity index *I* with grid hole diameter increase takes place to the specified value, and then its continuous increase occurs. Minimum value of index *I* corresponds to the grid diameter values arranged in the interval from 2,4 to 2,6 mm.

On the ground of the obtained results it is necessary in further investigations and also in practical usage to apply grids with c holes diameter from 2 to 3 mm. Further increase of grid hole diameter is unreasonable because of spillage of the part of grain material through them.

Characteristic curves (Fig. 7) of uniformity index *I* from grid hole pitch h indicates that with increase h uniformity index decreases and reaches the minimum value at h = 1,5 mm. The sequential increase of holes pitches results in gradual increase of uniformity index at any specified values of grid diameter.

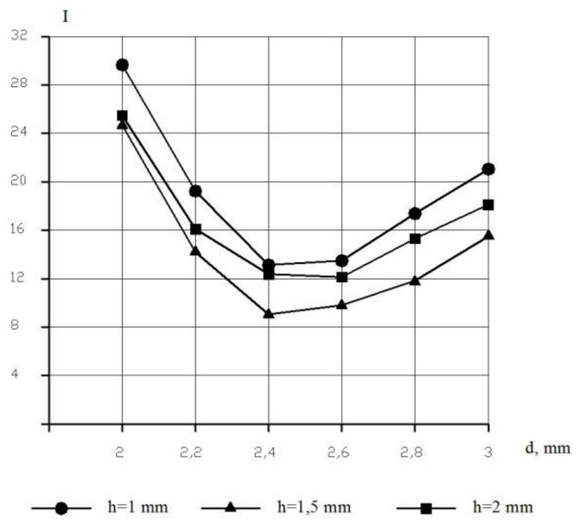


Figure 6. Dependence of uniformity index I from hole diameter d of gas distribution grid at different values of holes pitch h

We consider the further hole pitches increase in gas distribution grid is impossible because of reduction of grid open space and as a result of considerable increase of its hydraulic resistance. The type of the dependence obtained in the course of investigations with sufficient high accuracy corresponds to theoretical one.

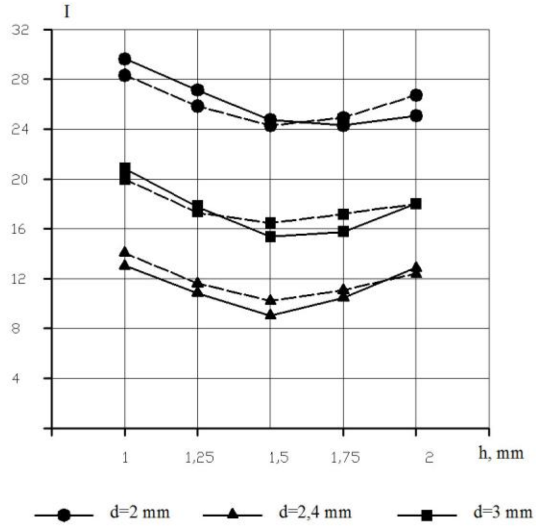


Figure 7. Dependence of uniformity index I from hole pitch h gas distribution grid at different values of hole diameter d

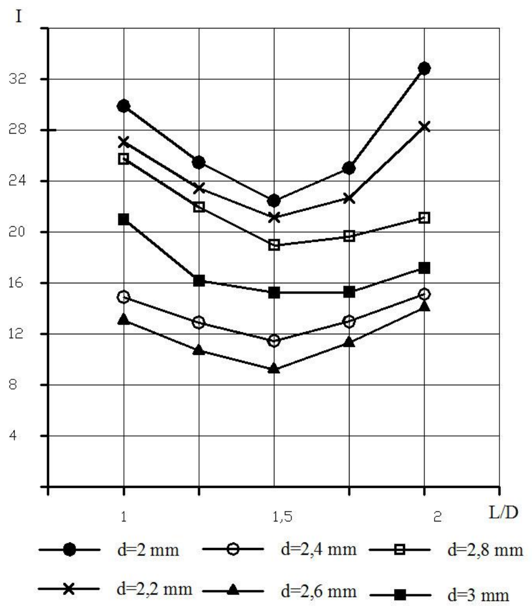


Figure 8. Dependence of uniformity index I from relation value L/D

Pseudofluidization characteristic also depends on relation of height L to diameter D of grain layer. Minimum relation L/D was admitted equal to 1, further decrease this value is unreasonable due to economic reasons, because dryer capacity decreases significantly. Maximum value of relation of height to grain layer diameter, which does not violate fluidization stability was determined by test and was admitted L/D = 2. Characteristic curve analysis of uniformity index *I* from relation value L/D (Fig. 8) at different gas distribution grid hole diameters *d* indicates that the process of grain material fluidization to the value of relation L/D = 2 is stable.

Further increase of value L/D results in transition from fluidized state to piston flow and grain material emission from drying chamber, h.e. at L/D > 2 grain dryer is impossible.

The most qualitative fluidization at minimum uniformity index was observed at L/D =1,5.

Thus, while designing experimental dryer it is necessary to limit the relation range L/D from 1 to 2.

CONCLUSIONS

The optimal parameters of gas distribution device of dryers are determined: diameter and hole pitch of the grid, relation of grain layer height to drying chamber diameter.

At the sake of the specified parameters the best distribution of air flow in pseudofluidized grain layer is performed, its uniformity is increased, the active surfaces values of heat exchange between separate grain and dryer agent are increased, and drying enhancement and more uniform heat penetration of grain are carried out.

The obtained investigation results can be used at designing dryers that operate according to grain layer pseudofluidization principle.

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METOD ODREĐIVANJA KVALITETA FLUIDIZACIJE U SUŠARAMA SA PSEUDOFLUIDIZOVANIM SLOJEM ZRNA

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Sažetak: U radu su prikazani rezultati ispitivanja ujednačenosti pseudofluidizacije u sušarama za zrno. Predložen je novi metod ocene kvaliteta fluidizacije koji omogućuje dobijanje ujednačenijeg grejanja zrnastog materijala i unapređenje procesa sušenja. Metod se sastoji iz određivanja intenziteta zraka koji prodire kroz sloj zrna. Date su preporuke za izbor optimalnih strukturnih parametara komore u sušari za zrno kojih se treba pridržavati pri njenom konstruisanju.

Ključne reči: *sušenje, sušara, metod, zrno, pseudofluidizacija, rešetka za distribuciju gasa*

Prijavljen: *Submitted*:	09.03.2017.
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	25.10.2017.