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INVESTIGATION OF ROLL DRYING EFFICIENCY

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Summary. The article represents the investigation results of plants drying with the application of oscillating temperature modes and various connection modes for drying agent and atmospheric air. The mathematical model and observed dependences confirming the application efficiency of the suggested drying methods are given.

Key words: mathematical model, plants drying, drying phases

INTRODUCTION

An improvement of quality factors of agricultural material's drying and energy-saving technologies depends on the choice of the drying equipment and setting of rational operation modes. Drying technology of plants in rolls requires an observance of physical and mechanical properties of the material and packing as well as specific data regarding humidity distribution in the volume.

The findings will contribute to the design improvement of drying machines operating on the countercurrent principle and ensure various connection modes for the drying agent that improve the quality and effectiveness of the drying process.

The drying machines efficiency depends on an improvement of the drying modes. The investigation of oscillating temperature processes and packing reversal with the purpose to intensify the moisture output in all the drying phases, heating, constant and incidental drying speed deserve special attention.

INVESTIGATION ANALYSIS

Implementation of roll technology for plants cropping requires an investigation connected with the preprocessing of vegetable material in packing. In the first place, it is characteristic of cropping and drying of rotten straw. Changes in material humidity level during its storing do not depend on the initial humidity only, but also on the packing parameters, location of the humid material and packing tightness. Rotten straw humidity in the roll volume is represented in the regressive dependency [Muchin and Dubkowa 1998]:

$$W = 27{,}7 - 0{,}075\tau_x + 0{,}446W_n + 0{,}133\rho_m + 16{,}28d_p - 19{,}03r_p, \quad (1)$$

where:

W_n – initial humidity of rotten straw , %;

τ_x – storing time, day;

ρ_m – rotten straw tightness in the roll, kg/m^3;

d_p – roll diameter, m;

r_p – location of rotten straw in the roll (distance from the roll center), m.

At roll storing and moisture sorption, the mathematical model is [Muchin and Dubkowa 1998]:

$$W = 16{,}771 - 0{,}037\tau_x + 0{,}203W_n + 0{,}048\rho_m + 3{,}35d_p - 5{,}055r_p \quad (2)$$

As the investigation findings show, the humidity level at drying $W = f\left(W_n, \tau, t\right)$ changes under complicated laws that are defined for practical application in the form of regression equation. The outcome of experiments on rotten straw rolls drying enable to assess energy consumption Q_m and drying time τ_c [Muchin and Dubkowa 2002]:

$$Q_m = -795{,}5 + 2{,}2W_n + 3{,}2\rho_m + 10{,}3m_{вв} \quad (3)$$

$$\tau_c = -1{,}605 + 0{,}045W_n + 0{,}004\rho_m + 0{,}032m_{вв} \quad (4)$$

where:

Q_m –heat consumption, MJ;

τ_c – drying time, hours;

$m_{вв}$ – extracted moisture weight , kg.

MODELLING OF DRYING PROCESS

For theoretical description and model of convective drying of the rotten straw, the thermo-physical properties of the plants [Karawajkow 2002] were defined forming the dependency of rotten straw thermal capacity on the heating temperature and thickness of layer.

However, the theoretical description of convective drying of agricultural materials is quite complicated. It can be done by integral equation of heat and weight transmission. It complicates the application of the methodology at engineering calculations of the drying machine elements as well as drying methods [Lykow 1968, Zelenko 1998, Didukh and Wesołowski 2001].

For real task solutions, the general characteristic of the drying demonstrated in the drying, speed and temperature curves are usually enough. The curve data analysis leads to the kinetic equation of drying [Zelenko 1998]:

$$-\frac{dW}{d\tau} = K\left(W - W_k\right) \tag{5}$$

where:

$\frac{dW}{d\tau}$ – humidity derivative in time;

K – drying coefficient depending on the properties of agricultural material and drying mode, min.$^{-1}$;

W_k – final humidity of the material at drying, %.

Basing on investigations on the drying modeling [Lykow 1968, Okun *et al.* 1984], a mathematical model of oscillating temperature process efficiency investigation at agricultural material drying was developed [Didukh and Kirchuk 2002].

Oscillating temperature process of agricultural material drying obtained by the by-turn heating and cooling provides the condition of intensive movement of moisture from the inner layer to the surface. The drying speed is represented by the dependency:

$$N = \frac{100\alpha_q\left(t_{ca} - t_n\right)}{\rho_0 \cdot R_v} \tag{6}$$

material humidity changes were defined as

$$W = W_k + \left(W_n - W_k\right)e^{-\frac{180\alpha_q\left(t_{ca} - t_n\right)}{W_n \cdot \rho_0 \cdot R_v}} \tag{7}$$

where:

α_q – heat exchange coefficient;

t_{ca} – drying agent temperature;

t_n – surface temperature of the dried material;

ρ_0 – density of dry material;

R_v – relation of the solid volume to its surface.

W_n – initial material humidity at drying, %.

The above-described theoretical principles were checked in computer by the method of dynamic programming enabling to realize the model of oscillating temperature process for flax seeds masses drying.

The comparative analysis of calculation results according to the suggested model showed that the application of oscillating temperature process reduces the combustible material consumption by two times provided the lower layer disposed from the drying chamber, is 0.1÷0.15 m.

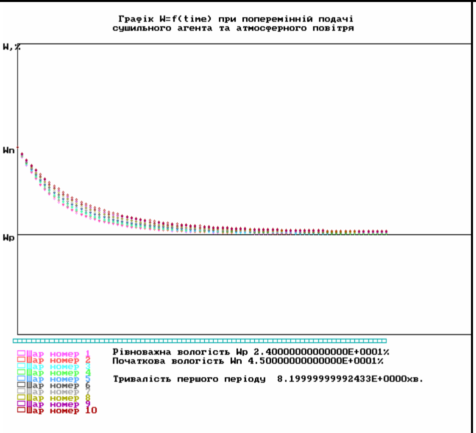

Fig. 1. Dependency $W = f(\tau)$ at the drying agent feeding

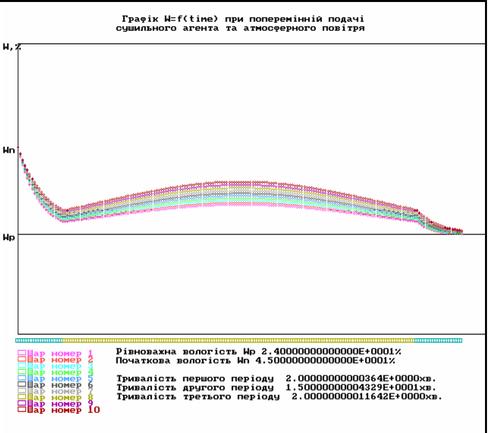

Fig. 2. Dependency $W = f(\tau)$ at alternate feeding of the drying agent and atmospheric air

The peculiarity of plants in roll drying is that the height is 1,0÷1,2 m for rotten straw and 1,5 m for straw materials. Besides, asignificant effect on roll material drying is provided by initial humidity, roll tightness and uniform tightness in the whole volume. As an example, the initial humidity of roll rotten straw above 50% leads to a significant increase of drying time and rotten straw tightness over 180 kg/m^3 does not allow to obtain desirable drying rates with the available drying equipment. Hence the application of oscillating temperature process enables to improve the efficiency of drying process of agricultural material in general.

EXPERIMENTAL INVESTIGATIONS

Under condition of price increase for energy recourses, the searching of new ways for power-consuming drying processes intensifying take on special significance. The drying process investigation of straw in roll was carried out for that purpose.

The investigation was performed on the straw rolls having the parameters: high L = 1.17÷1.21 m; diameter D = 1.18÷1.20 m; weight m = 120÷130 kg; average tightness ρ = 105÷110 kg/m^3. The rolls were formed in the variable volume chamber.

Humidity measuring was taken in the central layers of the roll (relative designations d = 0 sm., d – distance from the roll centre to the tested layer, middle = 30 sm and peripheral d = 60 sм). On the roll height the samples were taken from the side of drying agent (DA) connection L = 0 sm, inside of the roll L = 60 sm, from the side opposite to connection L = 120 sm. The investigation was carried out under the following conditions: air temperature t =11÷17°C, relative air humidity φ = 85÷95%, DA temperature t = 40÷45°C, atmospheric air temperature (AA) t = 15÷18°C, drying agent speed DA (AA) V = 3,6 m/s.

Roll drying was carried out with the application of one way and reversed connection of DA and AA as well as using oscillating temperature modes.

For the setting of rational drying modes the following variants were studied: with one way DA connection (Fig. 1); one way by-turn DA and AA with the cycle period of 2 hours (Fig. 2), 1 hour (Fig. 3) and 0,5 hour (Fig. 4); DA connection from different roll sides (Fig. 5); DA and AA connection with roll reversing (position change against the feeding direction) with the cycle period of 2 hours (Fig. 6) and cycle period of 1 hour (Fig. 7).

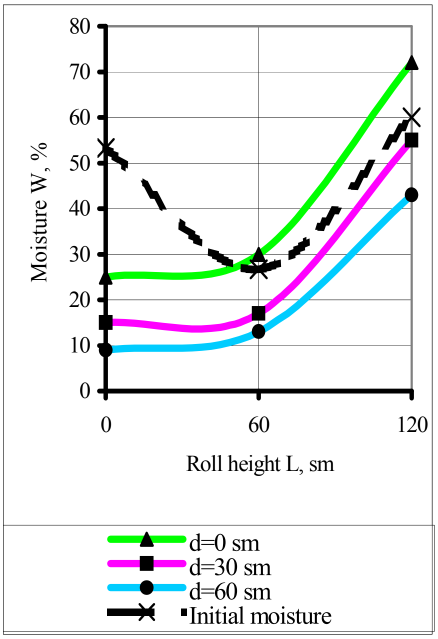

Fig.1. One-way DA connection

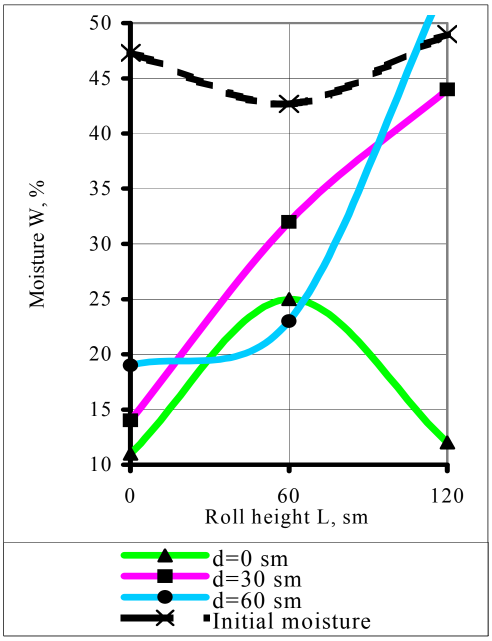

Fig. 2. One way by-turn DA and AA connection (t_c = 2 hours)

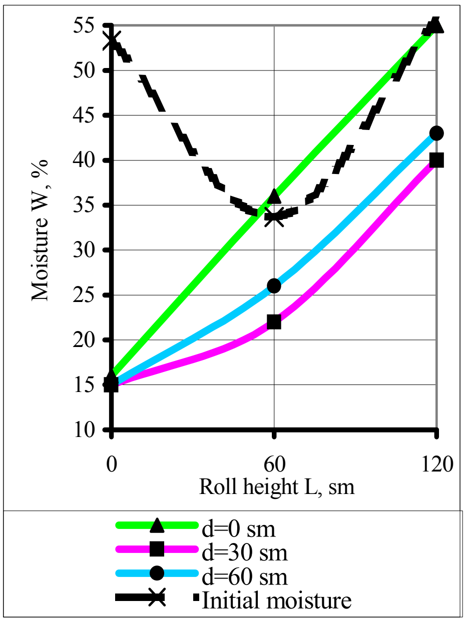

Fig. 3. One way by-turn DA and AA connection (t_c = 1 hour)

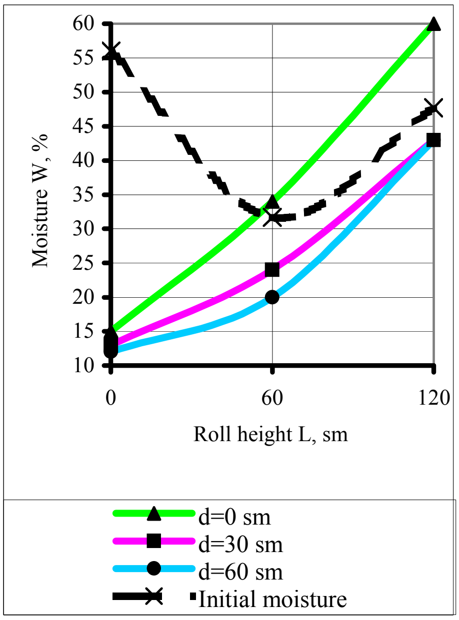

Fig. 4. One way by-turn DA and AA connection (t_c = 0,5 hour)

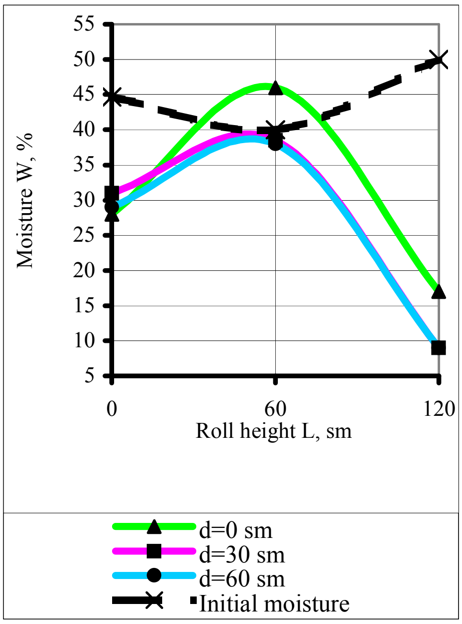

Fig. 5. DA connection with the roll reversing (t_c = 1 hour)

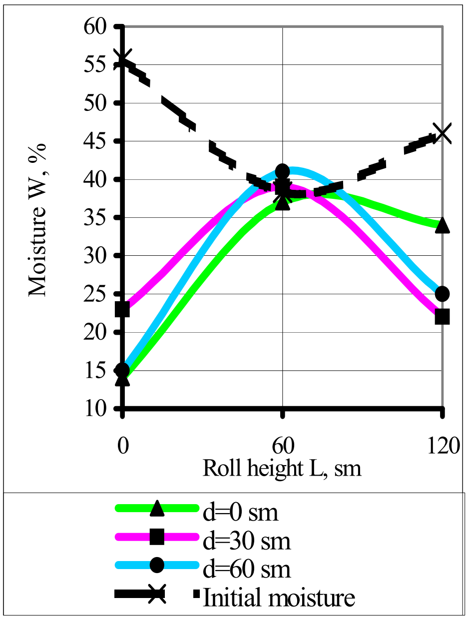

Fig. 6. DA and AA connection with the roll reversing (t_c = 2 hours)

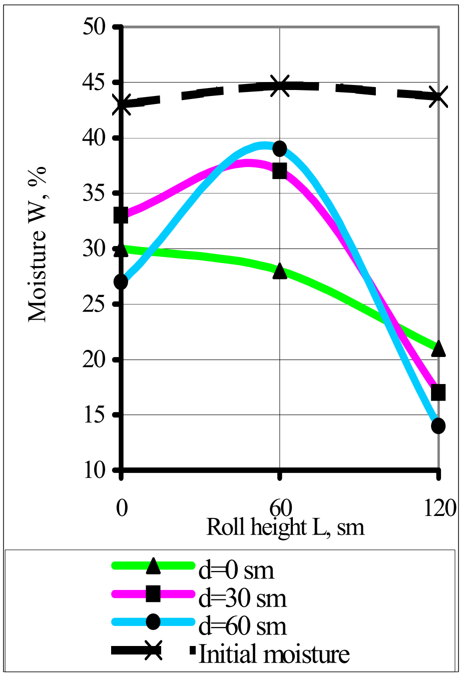

Fig. 7. DA and AA connection with the roll reversing (t_c = 1 hour)

RESULTS

The investigations showed that the material drying in immovable layer with one-way DA connection is less efficient compared to the application of oscillating temperature modes (by-turn DA and AA feeding). Reversing of the packing is appropriate for the humidity distribution improvement.

Application of such drying methods enables to significantly reduce combustion material consumption and improve process quality factors. The design and development of highly mechanized and automated drying equipment is required for the application of the methodology.

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