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Statics and kinetics of decreasing the moisture content of technical seeds

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ABSTRACT: In this article, the process of decreasing the moisture content to the demand level will be studied based on the technical seeds reduction humidity statics. The moisture content of the technical seeds will not decline till the equilibrium moisture, that it will be equal to ωp = *10-13 %.*Variation of the average moisture content and average temperature of the technical seed with time,i.e. the kinetics of the moisture content decreasing (drying) process, has been analyzed. This process allowed calculating the amount of steamed humidity from production and heat expenditure according to the kinetic regularities. It has been concluded that the moisture content decreasing process is divided into the periods of glowing, permanent speed and the lowering speed. It has been determined that the first period of moisture content decrease consisting nearly 60% of the process duration runs at approximately constant rate and at constant or slow decrease of the seed temperature. The second period of the contact moisture content reduction method is characterized byreduction inmoisture decrease rate, moisture decrease due to convective drying, and availability of the second critical point that can be exactly determined on the temperature curve. So, it is observed that during the moisture content decrease, the moisture is passed from inner layers to the surface; as a result, moisture contentonthe seed surface and inner layers is reduced. The moisture content of the technical seeds is not reduced to the equilibrium moisture content, which means it will come to 10-13%.

KEY WORDS: technical seed, moisture content, temperature, speed, time, statics, kinetics, critical point, moisture content decrease/reduction, heat expenditure, heat and mass exchange.

I.INTRODUCTION

Increase of the export capability of our country and improvement of the economic indicators are related to export of agricultural products. Nowadays, we are focusing on the order of our President on enhancing the attention to reduction of the amount of exported cotton and production of finished products in future[1-4].

Along with enhanced attention on step by step development of cotton recycling and production of finished products, development of innovation technologies of agricultural product recycling and production of exportable products directly depends on carrying out of research studies.

Decrease of technical seed moisture content is not only a heat-physical process but also a technologic process which has an important form of relation between seed and moisture content.

The principles of moisture content and heat exchange between the technical seed and heated surface form the process theory foundation. At that, during the heating (moisture content decrease) process, structure-mechanic, technologic and biochemical changes in the technical seed are observed. Changes of these features are associated with a change in the relation of the seed moisture content [5-7]

II. ANALYTICAL INDICATORS

Moisture content reduction to the moisture requirement level (10-13%) is studied based on the technical seed moisture content decrease statics. Here, the technic seed moisture content does not decrease to equilibrium moisture contentω_p, i.e. it is equal to ω_p = *10-13 %*.

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Seed is considered as a substance with capillary pores through its structure, and evaporation the moisture content from this kind of solids causes to break the connection between the seed and the product (technic seed) that its moisture content can be decreased. Right during this process, the amount of energy consumption is very important.

During the process of corn treatment by means of heat, internal and external heat and mass exchange process is a complex process to investigate experimentally.

During the technical seed, particularly corns, moisture content reduction process by heat treatment,a reliable way to study the internal action of the weights study of the moisture content and heat areas [8, 9].

The kinetics of the moisture content reduction (drying) process is considered asvariation of the average moisture content$u(\tau)$and average heat $t_{aver}$of the technical seed with time. The kinetic principle of this processallows calculating the amount of steamed moisture content and heat release rate from the product.

Moisture content reduction (drying) is a non-stationary process, i.e. the product moisture content, temperature and moisture content reduction rate change over time. In the moisture content (drying) reduction theory, such changes are described by means of graphs, “moisture content reduction (drying)”, “moisture content reduction rate (drying rate)”and temperature curves [10,11].

To plotsuch graphs, information shall be acquired through moisture content reduction (drying) experiments. At that, parameters like the heater surface temperature shall always be kept constant.

During the technical seed moisture content reduction (drying) process, its moisture content shall be taken based on the calculation of weight change. To this end, during the moisture content reduction process the weight of the technical seed shall be measured at a certain time interval.

The moisture content reduction (drying) rate means the technical seed moisture content change in time unit ($d\omega/d\tau$, *%/hour*).The moisture content reduction (drying) rate shall often be presented through graphic differentiation of drying curves. The moisture content reduction (drying) rate in a given time shall be determined as the bending angle($tg\ \psi$) of the tangent the drying curve is passing ata certain moisture content of the technical seed (fig.1).

III. RESULTS AND ANALYSIS

In the beginning of the process, the technical seed moisture content rarely changes through curve AB, i.e. it rapidly heating (fig. 1). The heating duration is related with the measurements and modes of the materials the moisture content of which is to be decreased. Therefore, as the technical seed is tiny, the heating step is so small that it cannot be seen in drying curve.

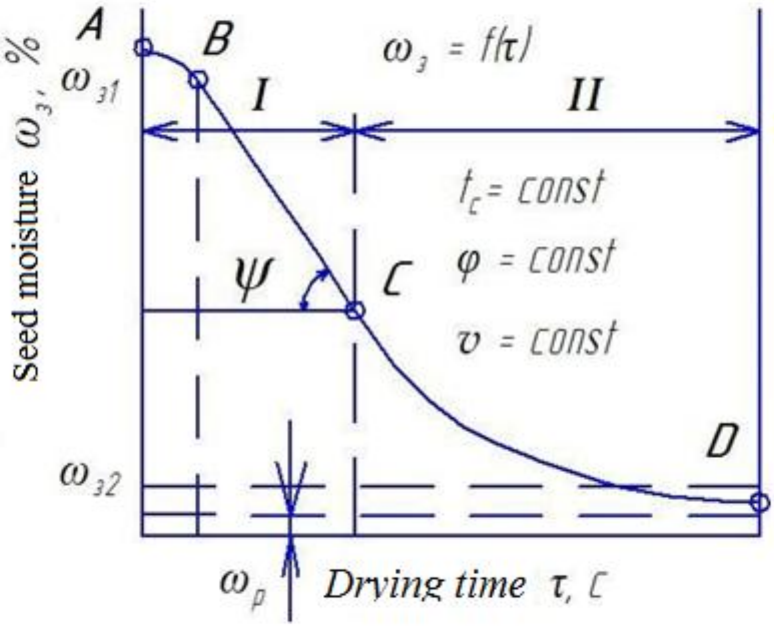

Fig1. Moisture content reduction (drying) curve:

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$\omega_з$–technical seed moisture content, %; (indexes 1 and 2 –seed moisture content at the initial period of the seed and seed moisture reduction end, respectively); t_c –temperature in the seed reduction equipment, °C; φ– relative moisture content of the air in the equipment, %; v –air velocity in the equipment, m/s [12, 13].

As the technical seed temperature is increasing, its moisture removal rate increases and then the moisture content changes along the straight line BC. This is the first period of moisture content reduction process. After a certain time, the evaporation process decreases at certain moisture content value (point C in fig. 1); from this time on and till the end of the process, the moisture content of the technical seed changes along the curve. This is the second period of the moisture content reduction process.

Capillary-colloid materials (technical seed) moisture content reduction rate (fig. 2a) and one-time moisture content removal (fig. 2b) may be determined through the curves.

At a heating step, the moisture content reduction rate increases from 0 to the maximum N^c.

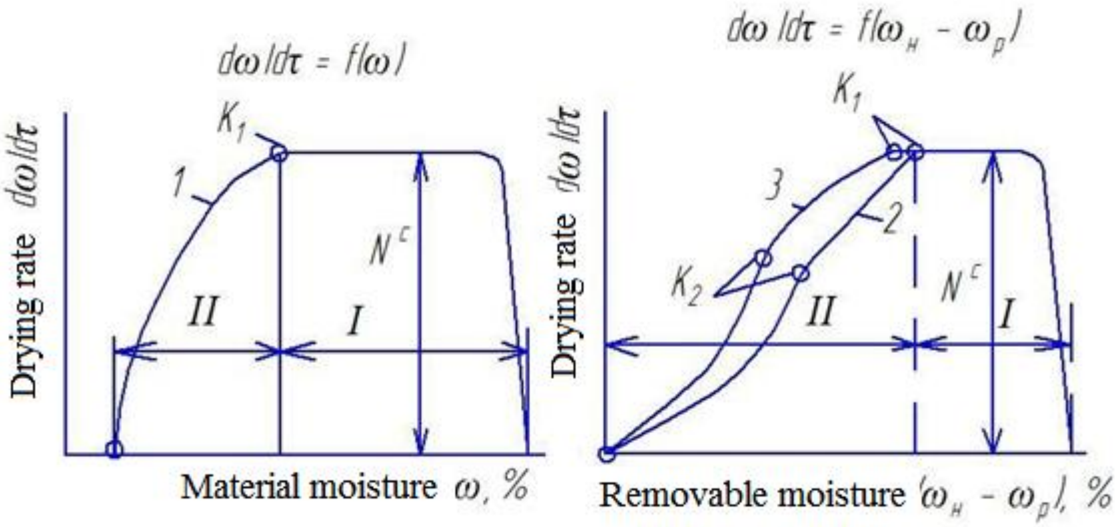

Fig2. Moisture content reduction curves:

1 – colloid materials; 2, 3 – complex systems, colloid capillary-porous materials (corn, bread seed etc.).

During the first period (*I*), moisture content reduction rate is constant; therefore it is called the constant rate of moisture content reduction. Then, starting from the first critic moisture during the second moisture content reduction period, the moisture content reduction rate is decreasing. Hence, the second period (*II*) is called the moisture content reduction period. When it achieves the equilibrium moisture content level, the moisture content reduction rate will be zero.

Depending on process mode, dimensions, structures, moisture relation shapes, different materials have different moisture content reduction rate curves. Technical seed falls under group of materials defined bycurve 2.

Change of the average (integral) temperature of the technical seed shall be defined by the graph shown in figure 3.

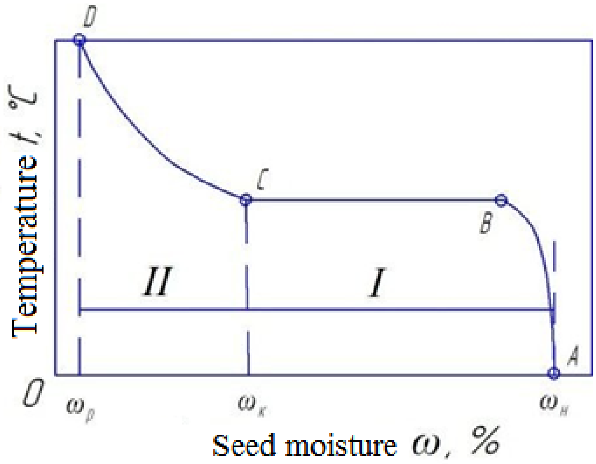

Fig3. Temperature curve

However, while drying the technical seed, the whole process shall run in the moisture content reduction rate condition. The main reason behind this is that direct heat transfer to the seed and its moisture content is low.

In order to analyze the above-stated principles, use of the graph of united curves of moisture content reduction 1, moisture content reduction rate 2 and temperature 3 seems appropriate (fig. 4).

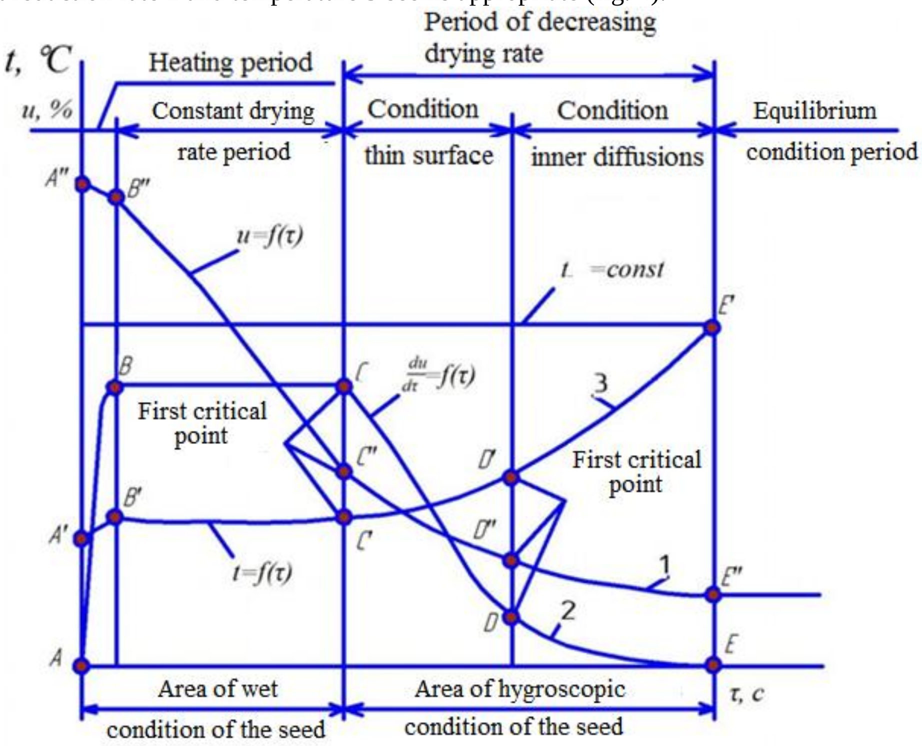

Fig4. Kinetics of the technical seed moisture content reduction process

A method of heat transfer to the technical seed shall be selected so that to meet the following two main requirements: the seed shall have the quality in compliance with relevant standards and the moisture content reduction process shall be efficient in terms of energy consumption.

For this reason, the moisture content reduction process in connection with the surface heated by means of electricity during the period thin-layer movement in the screw conveyer that has technical seed which the fertility is not very high should be studied in certain order.

We will investigate particular periods of the moisture content reduction process during the contact heating surface of the moisture content of one technical seed that moves at very low speed (fig. 4).

During the moisture content reduction starting period (during heating period), the technical seed temperature increases (A'B' section); this, in turn, will be followed by moisture evaporation from its surface and increase (AB section) in moisture content reduction rate (A"B" section). The moisture evaporation from the seed surface shall form the difference of the moisture content between the seed surface and next layers; as a result, the moisture in the inner layers will start moving towards the seed surface that is contacting with the heated surface. But, with contact heating method, availability of temperature gradient inside the seed will complicate the moisture transfer mechanism (will allow directing the moisture inside the seed). This will take place because the temperature in the seed surface is higher than that in its middle part, i.e. the moisture will have to move in the temperature direction under effect of thermal diffusion.

The steam entering inside the seed and contacting with a layer that is not heated yet will condensate at thepoint near tothe contact and transfer its heat to the next layer; as a consequence, this layer heat up more rapidly [14].

So, the next portions of the steam will enter inside the seed additionally and condense too. At the end of the starting period, the seed will heat up until the temperature at which the steam does not condense,overcome the resistance to its movement, gotill the seed surface and leave it. Transition to the period of constant reduction of the moisture content will take place (BC section). At that, the heat transferred to the seed is mostly consumed for the evaporation of moisture, and the seed moisture content will decrease along the straight line B'C'. The seed temperature does not increase considerably along the straight line B'C'.

During this period, two processes, which are interconnected and run at the same time,occur at the interface with the heated surface of the seed:

1. The contact heat exchange between the heating surface and damp technical seed followed by moisture transfer. Such heat exchange shall be most efficient during the constant drying rate period, because the process runs between the technical seed and the heated surface that provides rapid heat conductivity.
2. The process of change of aggregate state of moisture (steam formation) accompanied by phase change heat absorption and heat transfer inside the seed by means of steam.

The rate of the heat and mass exchange taking place in the steam formation zone at the interface between the seed and heating surface depends on the heating surface temperature as well as on seed density, moisture content, force of pressing to surface and texture of the seed.

An important feature of the constant contact drying rate period is the availability of two steam formation zones in the technical seed: one zone is near to the heating surface of the casing, and another is near to the open surface of the seed.

The steam formed near to the heating surface and transferred through the seed shall be removed off the open surface along with the steam formed near to it. Hence, the drying rate shall be determined by flows of the steam formed in the two steam formation zones; as a result, the contact drying rate during the first period will be higher than the convection drying rate [5].

However, stable steam formation zones may exist only when sufficient moisture content is concentrated in the zones themselves and in the inner layers. For this reason, the moisture content difference inside the seed is caused by the moisture transfer from the seed inside in the form of liquid to both its open surface and the steam formation zone near to the heating surface of the drying unit. Such liquid movement is caused by continuous decrease of moisture content in the peripheral layers of the seed.

So, in the period of constant moisture content reduction rate, the moisture inside the seed shall be transferred in the form of steam and liquid;at that, differentiation of their flows is observed in the contact layer. The liquid flow runs from the contact layer to the steam formation zone in this layer, while the steam flow runs from the steam formation zone to the open surface of the seed.

As the period of constant drying rate ends, the seed obtains certain moisture content (first critical point C) and the drying rate falling period starts. At the beginning of this period, particular sections that are not saturated with moisture occur on the technical seed surface, and the steam formation zone near to the heated surface moves inside the seed. At that, the contact surface of the seed gets dry, the seed temperature drops and heat supply from the heated surface to it sharply decreases. The unsaturated seed surface state occurs. In this period, the moisture moves only to the open surface, therefore the drying rate will depend mainly on external diffusion conditions.

After the seed moisture content reaches the second critical point D, internal moisture diffusion occurs. The entire seed surface will get dry, and the evaporation rate is determined only by the inner diffusion of moisture.

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When the drying rate gets zero (E point), equilibrium condition occurs. But, in reality this process does not occur, since thermal treatment will be finished before its occurrence (the technical seed moisture content reaches 10-13%) [8]. When drying the technical seed, the moisture content is spread unevenly and non-symmetrically: within the entire process the moisture content in the contact layer adjoining to the heating surface is minimum; in the central layers, it is maximum; while at the open surface, it is lower than that in the central layers, but higher than that in the contact layer. Such pattern of moisture distribution is the result of the particular mechanism of material transport at contact drying.

IV. CONCLUSION

Continuous decrease of the technical seed temperature when becoming far from the heating surface is the particular feature of the temperature area.

Analysis of the heating and drying kinetics, drying rate and temperature curves allows us to come to the following conclusions:

The moisture content reduction period includes several periods: heating period, constant drying rate period (first period) and the drying rate drop period (second period); at that, the second period is divided into two parts:

1)the first period of moisture content reduction consisting of nearly 60% of the total period duration is characterized by approximately constant drying rate; it is accompanied by constant or slow seed temperature drop:

2) the second period of the contact drying is characterized by decreasing drying rate, availability of second critical point that is sharply seen in the drying curve and temperature curve in contrast to convective drying;

3)with the contact drying method, the temperature curves and the heating kinetics curves have specific shapes differing from known curves corresponding to other types of drying owing to the peculiarities of heat and mass exchange mechanism of contact drying;

This means, during the moisture content reduction period, continuous moisture transfer from the inner layers to the surface is observed; as a result, the moisture content decreases in the seed surface and inner layers.

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