MICROWAVE APPLICATION. GRANULAR MATERIALS DRYING OPTIMIZATION IN THE PROCESS OF HOT AIR DRYING

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ABSTRACT:
This evaporation drives a drop in the water level in the upper layers resulting in an increase of the capillary pressure at the surface and refueling the superficial zone under the effect of capillary pressure. After the superficial zone has dried off, the diffusion of the humidity slows at the internal evaporation zone towards the air stream, and the drying speed drops: the values of the temperature and humidity, of opposed directions, tend to counteract. The result is a crust that obstructs the strengthening of the capillaries.

I. CONVENTIONAL DRYING

In the case of conventional drying, the wet material is subdued to a hot air stream. The heat supplied by the oven determines a growth of the temperature at the surface of the material. The growing of the temperature at the surface of the material causes a growth of vapor pressure in that zone. A stream of vapors appear conducted from the surface toward the air flow through molecular diffusion under the influence of the resulted vapor value, due to the difference between the surface pressure and the environmental partial pressure. This evaporation drives a drop in the water level in the upper layers resulting in an increase of the capillary pressure at the surface and refueling the superficial zone under the effect of capillary pressure. After the superficial zone has dried off, the diffusion of the humidity slows at the internal evaporation zone towards the air stream, and the drying speed drops: the values of the temperature and humidity, of opposed directions, tend to counteract. The result is a crust that obstructs the strengthening of the capillaries.

The figure 1 schematically presents heat and humidity distribution for the case of a wet material with a circularly section subdued to a hot air current.

We point out the inconveniences of this drying method that implies only an external heat load:
- it is slow, because the movement of humidity is in opposition with the phenomenon of heat diffusion.
- it can lead to the damaging of the handled material. In fact, if the environmental temperature is very high, the evaporation at the surface of the material may lead to failure cracks or the formation of a crust.
II. MICROWAVE DRYING

In the case of all dielectrics with losses, an electromagnetic wave can induce two processes of a microscopic scale: a free residual loads oscillation (electrons, ions...) and a rotation of the polar molecules at the wave frequency.

The first is characterized by conduction losses and the second is characterized by dielectric losses.

If we apply an electric field to a polar molecule, the couple responsible for the two poles tends to arrange the molecules in the field.

When the electric field spins with a certain pulsation, the dipole will follow the spin. If the pulsation speeds up, the molecule will follow more easily if it is free (so that the water made from 2 hydrogen atoms and one of Oxygen will have OH links forming a 105 degrees angle).

In the case of drying, the vibrations that “peel” the molecules from their position, are always followed by an increase of the internal temperature of the medium that accelerates humidity migration towards the surface.

The picture 2 has shown that the use of microwaves in the process of drying allows the reversing of the temperature value at the core of the material and the acceleration of thermo-migration phenomenon.

In fact, the retention of humidity tends to become, on the course of the drying process, bigger at the core of the product; the this zone and the temperature may be higher at...
the core than at the surface (the electromagnetic power spreads mainly to the zones with great dielectric losses). The waves accelerate the internal evaporation and eliminates the liquid transfer led towards the core of the product, because of the temperature value obtained in a conventional process.

The waves facilitate the migration of humidity from the interior towards the exterior and the source of conventional heat eliminates the liquid flux reaching the surface of the product. This way, the two forms of energy, the classical and the “microwave” one combine in an ideal manner; so the bettering of the global outcome and the shortening of the drying time of the classic procedure is made possible, by adding the microwave radiation sources.

Paresi has done studies concerning the amelioration of the drying technique performances for the porous materials by electromagnetic energy appliance by means of numerical simulation. He has shown that it is possible to find a sum of electromagnetic waves applications with minimum time and energy consumption of the dryer.

This ideal form is obtained by solving the differential coupled and nonlinear equation system: weight transport, heat, waves.

Equation 1 established by Mr. Bories sets out the weight transfer due to the temperature and humidity

\[ \frac{\partial m}{\partial t} = \text{div} (a \text{ grad } m + b \text{ grad } T) \]

where:
- \( m = m(p,t) \) is the humidity measured (supposed to be exact) in the point \( p \) placed inside the material to be dried ant in the \( t \) moment;
- \( T = T(p,t) \) is the temperature measured in the point \( p \) and at the \( t \) moment;
- \( a \) and \( b \) are specific measures of the material, experimentally determined and with respect to the product temperature and humidity.

\[ \frac{\partial T}{\partial t} = \text{div}(c \text{ grad } T) + d \frac{\partial m}{\partial t} + Pd_{m0} \]

The 2 equation points out energy preservation; it characterizes the heat transfer due to the temperature and phase change inside the material.

Where:
- \( Pd_{m0} \) is the microwave dissipated power inside the material.
- \( c \) & \( d \) and \( a \) & \( b \) are analogical measures.

The model take into consideration uses porous materials in the form of a parallellepiped rectangle and allows the simulation through in parallel blades with constant dielectric parameters, thus with constant temperature and humidity, supposing that the drying is symmetric for the hot air and for the electromagnetic radiation. (figure 3.)
Figure 3. Composite drying: Hot air + microwaves.

REFERENCES

