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INDUSTRIAL DEVICES FOR THE THERMAL TREATMENT OF TIMBER. CALCULATION METHOD

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Abstract: *The work comprises the calculation method for wooden mass humidity, calculation of the required time for wood desiccation and the calculation method which has to be considered in the wood desiccation out process in order to achieve the required results. During the drying process it is important to take into account the behaviour of the wood, depending on the species, provenance, type of processing, etc., which leads to the necessity of applying differentiated drying regimes.*

Key words: *thermal treatment, timber, calculation, method.*

1. Introduction

Wood desiccation process is one of the most important stages in the entire processing cycle. Therefore for artificial desiccation, complex installations are being used, monitoring and adjusting an important number of parameters computer and specialized software managed.

2. Calculation Method

In the drying process the following parameters are considered:
1) Limit layer is a thin air layer, tightly bound to wood to be dried surface and does not participate to the movement of drying agent. When water saturated, this layer does not absorb humidity from the wood and hinders the drying process. One of the drying objectives is to slim down this layer to the maximum using turbulent air stream or other means.
2) The humidity gradient means the difference between the humidity of different portions of wood one being moister and the other one dryer, expressed as percentage:

$$\frac{\partial u}{\partial x} = \frac{2(u_i - u_e)}{s} \tag{1}$$

where:

u_i – internal wood mass humidity [%]

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u_e – surface humidity in equilibrium status [%]
s – wood mass thickness [cm]

3) Drying gradient

$$u = \frac{u_m}{u_e} \tag{2}$$

where u_m is the average humidity.
This parameter is important in managing the desiccation process. It must be:

u_m = 2.0 for resin wood
u_m =1.5 for deciduous wood

4) Drying speed

$$v = \frac{m_a}{A.z} \tag{3}$$

where:

m_a – water quantity to remove on the surface A [m^2] of the drying pieces
z – duration of desiccation process [hours]

5) Water diffusion in wood mass. Considering that most of the water is being removed through diffusion, the phenomenon can be expressed as:

$$m_a = \int_0^x K \frac{du}{dx} \cdot \Delta z \tag{4}$$

where:

m_a is the water quantity removed from the wood mass
K - diffusion coefficient
du/dx - humidity gradient
x- desiccation duration

Writing the result $K\frac{du}{dx} = a\ (const)$ we obtain:

$$m_a = a \cdot \Delta z \tag{5}$$

where:
Δz – a limited time period from z, when the values K and $\frac{du}{dx}$ are unchanged.

The diffusion coefficient K is the water quantity (kg) which passes within one hour through a 1 m^2 surface of a 1 m thickness wooden mass, where there is a humidity of 1% at the limit layer. [1]

6) Wood desiccation

At the moment of trees chopping, the wood contains large water quantities, in the range of 110 and 200 % (based on the weight of the desiccated wood). In its natural state the wood cannot be used for construction or industry. The most common method for desiccation is warm or moist air treatment. Two processes are being used: desiccation by vaporizing and the one through evaporation. For the vaporizing method at temperatures below 100 C, when the water in the wood is brought to the evaporation point using heat.

The element which is supporting the moist transfer is the pressure difference of the steam created inside of the wooden mass and the one in the desiccation environment, [2].

The main problems of thermal wood desiccation are:

- Heat transfer to the wood mass by convection, contact, radiation... etc.
- Steam evaporation from the wooden mass using fresh air
- Maintaining the pressure difference

At the desiccation systems using convection, the desiccation environment (air, steam, gas, oil) is transmitting the required heat, from a heat exchanger to the material to be desiccated; further heating for the inner mass is being made by heat conduction at the wood surface. At the desiccation systems using contract , the wooden piece comes in contact with the heated surface, wherefrom it acquires the heat; water removal is being made through the steam produced or by washing the piece with a stream of fresh air, circulated air or by absorption.

Dielectrical heating (capacitive) is being produced into a so-called "dielectric", which is under the influence of a high frequency field, with values ranging between 1 and 30 MHz. Due to friction between the positive and negative molecules, at a variation of the field there is a significant increase of the wooden structure temperature, [3].

7) Air humidity

The absolute humidity u_a is the water contained in 1m^3 of moist air (g/m^3).It reaches its maximum value when the air is saturated, when p_v=p_s,

where:

p_v being the partial pressure of water vapours,

p_s being the saturation pressure at the given temperature.

Introducing more water vapours it results in producing the fog (suspended water drops). Absolute maximum humidity u_{max} represents the weight of water vapours (G), in table 1, expressed in grams, in 1 m^3 of saturated air at a certain temperature (t) and barometric pressure.

Table 1

t=	-20°	0°	10°	20°	30°	50°	80°	100°
G= [g/m^3]	0.9	4.8	9.7	17.3	30.4	82.9	293	585.2

When a saturated air at the temperature t is being heated, t_1>t, becomes unsaturated and can absorb a new quantity of moist; reversed, if the temperature decreases t_2<t, part of the moist condensates. In the desiccation technique, the used air is not water vapours saturated and for a proper description of its status it is used the notion of relative humidity of air.

$$\varphi = \frac{u_a}{u_{\max}} = \frac{pv}{ps} [\%] \quad (6)$$

For dry air, φ=0, because p_v=p_s (the relative humidity of air is expressed usually in %).

8) Temperature of wet thermometer

It describes the air status (desiccating agent) because it represents the temperature of adiabatic saturation, where t_{eh} heat required for evaporation is taken only from the environment.

The psychometric difference:

$$\varepsilon = t - t_u \tag{7}$$

between
t-air temperature and
t_u-wet thermometer recorded temperature
describes the air capacity to absorb moist (desiccation potential). When the air is saturated, $\varphi = 100\%$, $t = t_u$, therefore ε=0.

Establishing the air status by measuring the psychrometric difference is the most used method in the wood desiccating technique. The psychrometer is composed of a usual thermometer with mercury (dry) and a second one having the mercury reservoir covered permanently with a damp cloth, which is placed into the air stream which circulated through the desiccating room in such a way that the water evaporates adiabatically. (As a general rule the wet thermometer is indicating values superior to the one of the real water temperature; for the reduction of errors the air speed is being increased).

Knowing the psychrometric difference $\varepsilon = t - t_u$ the relative humidity of the air can be easily determined using psychrometric formula, tables or nomogram.

9) Wet air diagram

The relations between the parameters which are indicating the air status are presented graphically in the ID, Ix diagram etc. For the necessity f wood desiccating more often are used the Id-Lurie, Id-Krecetov diagrams, which offer the analysis possibility for the processes that intervene into the desiccating process and for the dimensioning if the desiccating systems.[4]

Id-Krecetov diagram is made for an atmospheric pressure of p=745 mm/Hg, and has on the x-abscissa axis the water contents d, and on the y-ordinate axis the heat quantity (enthalpy).In the diagram the angle between the 1-0 line and the y-ordinate axis has been taken as being $171°06'$ in order to reduce the size of the diagram. On the Id diagram there are several families of lines and curves :

- Constant enthalpy lines, I= const (oblique)
- Constant water content lines, d (vertical)
- Isothermic constant lines, t, inclined each one of them under a different angle related to the horizontal line t=100 C
- Relative humidity lines $\varphi = const,$ which are showing at the t=94 C a breakage(upper part of the diagram)
- Partial water vapors pressure, p=const(vertical, in the upper part of diagram)

For the determination of desiccating agent parameters it is necessary to compare two of those parameters, for example t=55° and φ=80%. The isothermic line t=55° intersects the curve φ=80% in the point 3, wherefrom a perpendicular line may be drawn on the scale of water content, showing a value d=92 g/kg, and extending on the pv scale the value pv=96 mmHg is being read. The enthalpy in this point will be 70 kcal/kg. The water evaporation is being produced by the constant enthalpy line I=const.

10) Wood properties and desiccation

During desiccation the wood has different behaviour conditioned by the species, the source whence it derives, the modality of finishing, etc… thus leading to different desiccating regimes. The tissues with thin walls of the wood structure, especially the ones of the pithy rays, do have a weak resistance to high tensions arising during desiccation.

Therefore the species with numerous pithy rays are subject to cracking. The resinous wood, being coarsely ringed, softer and with a specific density reduced are more prone to cracking than the ones with being finer ringed.

For the species with spread pores, the width of rings has not a major influence upon the quality of desiccation. When very dry wood mass is being desiccated, the free water evaporates easily and fast, while the linked water is being more difficult removed, requiring an additional heat quantity.

11) Fibre saturation humidity ($u_{s.f}$)

It varies between the species, between 23% at the as hand 31 % at the larch, for t=20 C. By heating them this humidity is beig reduced. Following Krecetov, if at t=20 C $u_{.s.f}$=30%, at 65°, $u_{.s.f}$=26%, at t=90° , $u_{.s.f}$=20%.

Desiccation faults (tensions, deformation, cracks) are appearing only after the wood humidity has decreased below $u_{.s.f}$, from that moment the wood starting to shrink.

Green wood has different humidity : the poplar 150-200%, fir and alder 100-150%, pine, spruce, larch, beech and oak 80-100%, acacia, ash 40-60% etc... The floated wood kept in the conservation basins may increase significantly its humidity: fir up to 230%, pine up to 175%, beech up to 130%, oak up to 110% etc… The timber pieces do have smaller moisture near the faces, corners, bevels and ends compared to the middle therefore deformation and cracks occur.

The wood being in different stages of desiccation is denominated as: wet wood if it has been kept a long period in water; moist wood, the one freshly chopped (green), semy-dry; air desiccated wood (u=12-20%); artificially desiccated wood (u= 7-12 %).

12) Wood equilibrium humidity

Being a porous material, the wood absorbs water vapours from the environment until it reaches the equilibrium state for the given temperature.

For the same air status, the equilibrium status is almost equal for all wood species. The property of wood o reach a constant humidity, related to the air status is very important in the desiccating technique, because it allows to determine the point up to which a certain lot of material needs to be desiccated.

If the relative humidity and temperature of the air at the usage place is known, the final humidity of the wood after the desiccating process can be established, in order to achieve the best stability in use.

In the table the use humidity's for wood are indicated (u_{ech}).

The curves that indicates the relationship between the air's relative humidity and u_{ech} at constant temperature are denominated as sorption isotherms. They indicate the steam absorption from the air-vapours environment and reverse the cease of humidity (desorption) related to the humidity and temperature and air, following the hygroscopic balance laws. For the bound water, desorption isotherms are placed above the sorption ones (phenomenon called hysteresis), due to presence of air in the wood capillaries.

The specific density of wood is significantly influenced by the humidity.

Thus at u=100%, the spruce weights 770 g/cm3, at maximum humidity of u=192% 1115 g/cm3, whilst at 0% its weight is only 440 g/cm^3.

If ρ_c-the specific conventional density, and u_i and u_f - initial and final humidity the water quantity removed through desiccation is:

$$A_e = \frac{\rho_c (u_i - u_f)}{100} \tag{8}$$

Influence of the specific density upon duration of desiccation can be written as:

$$\frac{z1}{z2} = [\frac{\rho_{0,1}}{\rho_{0,2}}] \tag{9}$$

The dense wood dries slower, do have deformation and cracks, because of a more difficult contraction compared to the light ones. Contraction starts immediately after the wood has lost its bound water and it is maximum on a tangent direction, being 45-70% more reduced radially and almost inexistent along the fibres. The biggest contractions, during desiccation occurs at poplar, sycamore maple, beech, hornbeam and oak and the smallest at birch, oak tree, cashew, linden, and acacia.

Because when transforming longs into timber it is not possible to follow the wood fibre (which is nonlinear), timber have also cut fibres, the pieces being thus prone to curvature during desiccation. Resin, tanning and colouring substances do have an important influence upon the desiccation result, an important part of the wood darkens its colour during desiccation.

3. Conclusion

Green wood contains large amounts of water. In this state, wood cannot be used in construction or industry. The most common way to remove water from the wood is to treat it with hot or humid air. Two main processes are distinguished: vaporization drying and evaporation drying.

During the drying process it is important to take into account the behaviour of the wood which leads to the necessity to apply differentiated drying regimes.

From the variety of parameters which have to be adjusted related to the species of wood, thickness, initial humidity, external temperature and humidity of the air and the type of product to be made from the wood, every system can only be dimensioned and constructed only after proper documenting the particulars of the final products to be made.

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