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CRITERIA OF KILN SELECTION FOR DRYING GREEN TIMBER OF FAST GROWING SPECIES

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ABSTRACT

Green timber of Polish fast growing hardwood species is characterized by the high initial moisture content exceeding even 200%. Therefore, during the kiln drying of the timber high capacities of kiln heaters are required. The paper presents a set of problems, which may occur during the drying. A practical example of kiln drying of green poplar timber is discussed. The criteria for the proper kiln selection are given.

Key words: fast growing hardwood species, poplar wood, kiln drying, kiln malfunctions

INTRODUCTION

The operation of convective kilns for drying timber is often related to the problem of the distinct decrease of drying quality when timber assortment is changed to a new one. The quality decrease is usually observed when the new assortment is the green sapwood of the hardwood species of high initial moisture content and low density. The additional feature causing problems with the drying quality is the common requirement for obtaining natural light color of timber after drying.

The objective of the paper is to present reasons of incorrect operation of kilns during drying green timber as well as to analyze the selected factors characterizing drying processes of timber of fast growing species.

FACTORS INFLUENCING DRYING PROCESSES

The operation of convective kiln drying depends not only on properties of timber (i.e. species, thickness, initial and final moisture contents, assortment etc.), but also on drying parameters, i.e. **temperature** and **relative humidity**, being the result of the selected drying schedule. The balance of evaporated moisture, the amount of drying air and the intensity of mass transfer between timber surface and drying air lets to obtain another parameter characterizing the process, i.e. **air velocity**.

ANALYSIS OF POTENTIAL REASONS OF KILNS' MALFUNCTIONING

Thermal power of heaters

The too low power of heaters, especially in winter, extends the heating phase (including thawing) and does not allow keeping air temperature on the required level during drying. It also causes lower intensity of evaporation and additional problems with removing humid air because of frequent closing vents, when air temperature drops below the set value. Therefore, the longer drying times are observed.

If the green timber is dried and a kiln is properly selected then the power of heaters should not significantly influence a drying process. It results from the fact that the power of heaters is a function of the temperature difference between the heater surface and drying air. The temperature difference is usually set in the designing process of heaters on the level of Δt = 20 K for the highest temperatures of drying air, which are observed for moisture contents lower than the Fiber Saturation Point (FSP). In the first phase of drying (i.e. for moisture content much higher than the FSP) the drying air temperature is usually 20 K lower than in the last phase. Therefore, the double temperature difference (i.e. 40 K) between the heaters' surface and drying air causes the doubled power of heaters

However, problems of the heater power may appear when parameters of heating medium are changed, e.g. when the heating system is changed from the steam system to the low-pressure water system (the drop of temperature) then the significant decrease of the power is observed. The problem with the output of heaters may also appear when a kiln was set to dry already pre-dried timber or hard drying hardwood species (e.g. oak or beech) and then turned to dry green timber of fast growing species.

Capacity of fans of recirculated air

Fans of recirculated air should ensure air velocity in gaps between timber layers inside the charge at the technically and economically justified level of 2-2.5 m/s [2]. However, for timber drying with additional requirement of keeping the natural light color, the recommended air velocity is equal to 3-4 m/s [1]. The required capacity of fans results from the geometry of a kiln charge as well as from thickness of stickers. However, the recommended air velocity may be insufficient for the charges of high depth and kilns without fan reversion. The recommended values of air velocity should be considered together with the changes of air parameters during flow through the timber charge. The air velocity decrease caused by closing gaps between layers of boards because of uncontrolled leaning of timber packages, leaving a free space below a false ceiling or between a package front and kiln side walls always results in the increase of air humidity inside a charge and the decrease of air temperature. When green timber has to be dried and a high amount of moisture should be evaporated, the too low amounts of drying air create good conditions for mould development in the first phase of drying.

Kiln charge loading

Except the kiln geometry the run of the process depends also on filling the loading space with timber packages. Leaving free spaces between the upper surface of the kiln charge and the false ceiling or between package fronts and side walls of kilns causes losses of recirculated air. Therefore, air flows through the free spaces and does not take part in drying. The negative results of uncontrolled air flow are well seen for moisture contents above the FSP. The decrease of air amount in a load obviously affects:

- decrease of evaporated moisture (decrease of drying rate),
- increase of air humidity and decrease of air temperature (differentiation of the drying rate).

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The less evident negative results are:

- disturbances in operation of computer control systems caused by a malfunction of sensors of air temperature and humidity (sensors readings do not correspond to the real values of parameters of air leaving the charge),
- decrease of the ram effect in zones of overpressure and negative pressure of fans causing decrease of the capacity of vents.

Location and dimension of vents

The performance of vents operation depends on several factors:

- air ram effect or negative pressure in the zone of vents (see the Section 3.3.),
- vent diameter,
- difference in humidity of removed and replaced air,
- vents location, e.g. in the zone of air leaving timber (higher humidity and higher efficiency) or after mixing recirculating air with replacing air (lower humidity and lower efficiency).

Parameters of drying and ambient air

When high amounts of moisture have to be evaporated from timber and next removed from the kiln, the parameters of drying air are of great importance for the proper operation of the kiln. It results from the close relation between the drying air temperature and the mass of moisture contained in the air at the constant equilibrium moisture content. In the initial phase of evaporation, when free water is removed, for the majority of the species the drying schedules assume the equilibrium moisture content equal to 14-16%. However, the absolute humidity of air related to the equilibrium moisture content changes with temperature. The decrease of the difference (ΔX) between values of the absolute humidity of drying air and ambient air causes the increase of the amount of air exchanged through the vents. The difference is especially small for low temperatures of drying air (low-temperature schedules) and high temperatures of ambient air (i.e. in summer). The small differences are the main reason of too low efficiency of vents and therefore disturbances of kiln operation. The difference ΔX directly influences the unitary demand of air required for evaporating 1 kg of moisture.

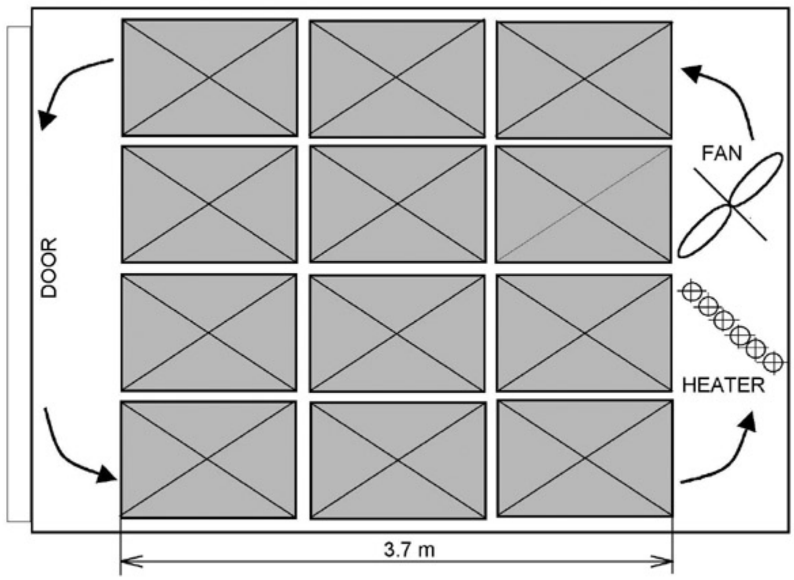
Influence of temperature on the evaporation rate

In the initial phase of drying when the evaporation front is located near the surface of timber, the rate of taking in moisture by air practically depends on the three factors, i.e. air velocity, air humidity and temperature. The temperature decrease inside the charge influences the change of air humidity and drying rate (i.e. flux of evaporated moisture from timber surface). It results from earlier investigations [3] that at the equilibrium moisture content of 16% the decrease of temperature from 60 to 30°C causes the decrease of the flux from 0.18 to 0.09 $kg/(m^2 \cdot h)$ for the green timber. Therefore, the temperature decrease of air flowing through the charge may cause significant differences in moisture contents of dried timber as well as mould development.

VERIFICATION OF REASONS OF KILN MALFUNCTIONS

The presented above potential reasons of extending drying time and lowering drying quality were verified by performing a test process for green timber of the fast growing species. The test was made in a kiln without the false ceiling (see Figure 1). In such type of kilns, the kiln malfunctioning during green timber drying is the most common.

Fig. 1. Kiln charge formed by timber packages



Technical characteristics of the kiln

The kiln dimensions were 9 m (width), 5 m (depth) and 4.1 m (height). The volume of the kiln charge was 135 m^3. The power rating of heaters was equal to 280 kW. The rating of fans was 10 kW and the volumetric rate of flow was 90000 m^3/h. The way flow of air through the charge was equal to the double depth of the charge (i.e. 2 · 3.7 m = 7.4 m).

Characteristic of kiln charge and timber

The drying test was made for 55 mm thick poplar timber with length of 3, 4, 5 and 6 m. The oven-dry density of timber was 350 kg/m^3. The mean initial moisture content was ca. 170%. The charge was made of timber packages and its net volume was 62.4 m^3. The thickness of stickers was 30 mm, while the thickness of the bolsters separating packages was 80 mm. Although, the kiln loading was carefully made, it was not possible to omit all of the free spaces between the upper surface of the kiln charge and the false ceiling as well as fronts of packages and side walls of the kiln.

Drying air parameters and their control

The moisture content drying schedule was selected by the computer control system of the kiln appropriately to the timber species, thickness and the assortment. The initial temperature of drying was 44°C and after 120 h raised to 51°C. In the initial phase of drying, when free water was evaporated, the equilibrium moisture content was assumed to be constant and equal to 14%. The sensors of air temperature and relative humidity of the kiln computer control system were located in the plenum space on the side wall of the kiln.

Air velocity

The mean velocity of air flow in the kiln charge was 1.92 m/s. The velocity in the width of the charge was varying from 1.74 to 2.06 m/s. The detailed balance calculations showed that the 68% of air was flowing through the charge. The remaining 32% of air was flowing through spaces formed by bolsters between packages, the space between the upper surface of the kiln charge and the false ceiling as well as the space between fronts of packages and side walls of the kiln. The air did not take part in timber drying and caused the deficit of drying air. Additionally, the air disturbed values measured by sensors of the kiln computer control system.

Power rating of heaters

During the initial phase of 110 hours of drying (including heating) the heaters were working with their maximum power capacity. Next, the graduate decrease of the capacity was observed and after 150 hours of drying the heaters capacity was constant and equal to 55% of the maximum.

Parameters of drying air

The set values of temperature and equilibrium moisture content as well as the real values of the both parameters (i.e. measured in spaces between layers of boards in packages) are presented in Figures 2 and 3. The observed range of changes of temperature and equilibrium moisture content results from reversing air circulation. The maximum values of temperature concerned the air flowing into the charge, while the minimum were related to the air flowing out. The changes in the values of equilibrium moisture content had the opposite character. The observed amplitudes of the measured values of parameters of air flowing in and flowing out were high and exceeding the maximum of 10 K for temperature and 12% for equilibrium moisture content. Moreover, the high difference between the set value and the measured value of equilibrium moisture content was observed in the initial phase of drying. The increase of temperature of drying air to 51°C caused the decrease of the difference between the set and the measured values of equilibrium moisture content. The obtained results clearly indicate that the air flowing through the charge could not take in the whole amount of moisture. The increase of air temperature caused the increase of the ability of taking in moisture and therefore caused the decrease of the difference of the observed equilibrium moisture content values. The too low amount of air and too low air temperature significantly reduced the ability of taking in moisture.

Fig. 2. Drying air temperature and equilibrium moisture content measured in a package above fans

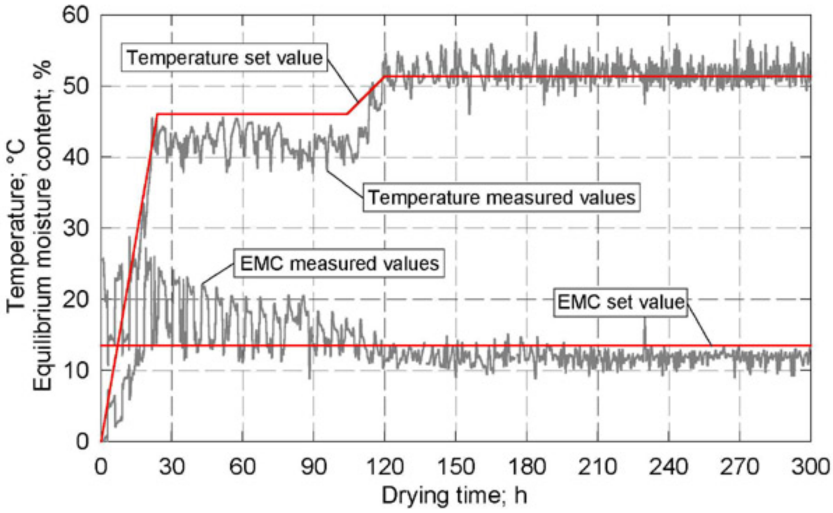
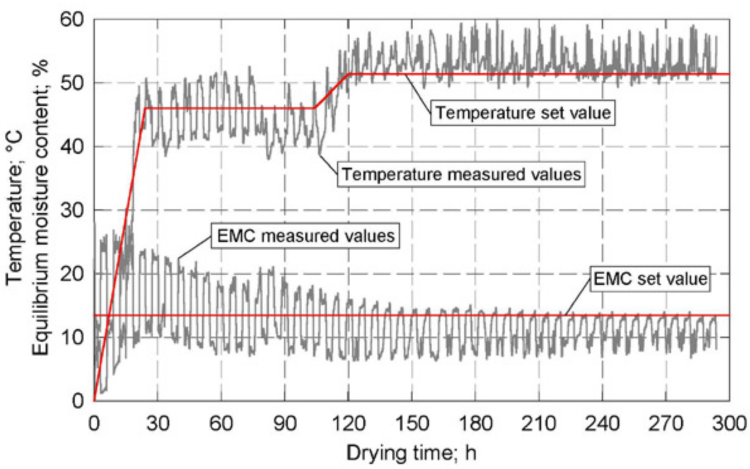


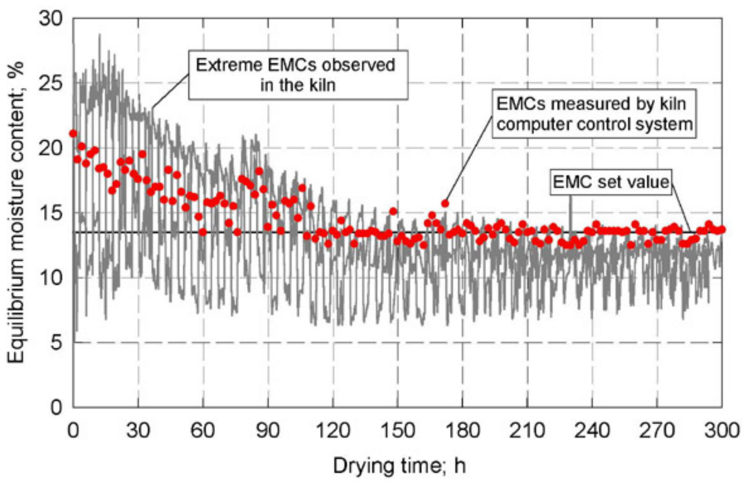
Fig. 3. Drying air temperature and equilibrium moisture content measured in a package under heaters



Measurements of air parameters by the kiln computer control system

The values of equilibrium moisture content measured by the kiln computer control system are presented in Figure 4. The plot also presents the extreme observed values of equilibrium moisture content inside the charge. The obtained results show that the values of equilibrium moisture content, measured by the sensors of the kiln computer control system located on the side wall of the kiln, differ significantly from the values measured inside the charge. It is partially the result of mixing air flowing out of the charge (air of high humidity) with the short circuiting air (air of much lower humidity).

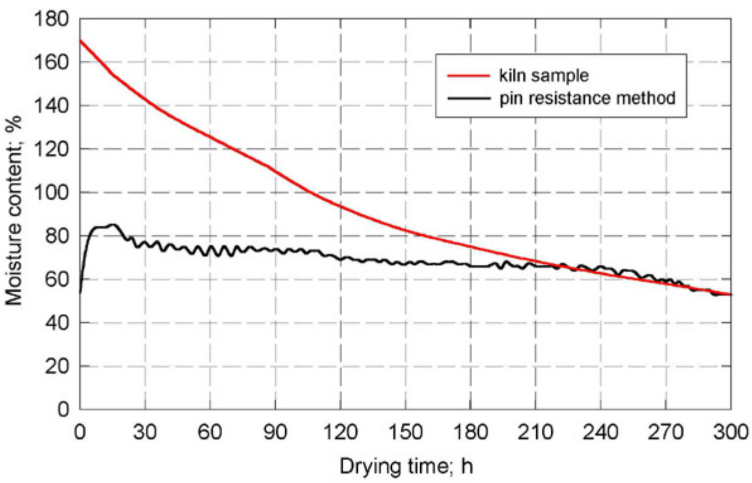
Fig. 4. Equilibrium moisture content - measured by the kiln computer control system and the extreme values observed in the kiln



Timber moisture content

Figure 5 presents changes of timber moisture content measured by the kiln computer control system (the pin resistance method of the on-line measurements) and obtained from kiln samples. The range of application of the pin resistance method is much below the values of timber moisture contents observed in the first stage of poplar drying. Therefore, the kiln computer control system was unable to inform the operator on the real run of drying as well as the predicted duration of the process. The false values of timber moisture content indicated by the computer control system are sometimes the cause of complaints ("the kiln does not dry timber"). In the analyzed drying process the mean drying rate was ca. 13%/day for moisture contents above 70% (i.e. the mean flux of evaporated moisture was ca. 2800 kg/day) and ca. 6%/day for lower moisture contents.

Fig. 5. Timber moisture content measured by the kiln computer control system and obtained from kiln samples



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Drying time

The observed drying time of the process (without heating, equalizing, conditioning and cooling) was 550 hours. The drying time was approximately 50% too long for the applied drying schedule. The detailed analysis of the system showed that the long drying time was not caused by the capacity of vents (the maximum flow rate of air to be exhaust of the kiln was 1340 m^3/h, i.e. 2.4% of the total rate of drying air). The main reason of the long duration of drying, especially in the initial phase of drying (high moisture content of timber and low temperature of drying), was the limited ability of air to take in moisture because of humidity increase and temperature decrease during air flow in the part of the charge.

CONCLUSIONS

The kilns without the false ceiling have the doubled length of air travel in the charge in comparison to the kilns with the false ceiling and the same depth of the charge. Therefore, the kilns without the false ceiling can not be recommended for drying green timber of fast growing species especially when low temperature schedules are applied.

The recommendations for a convective kiln for drying green timber of fast growing species are as follows:

- high amounts of drying air are required (it may be achieved by higher air velocities $v >> 2$ m/s or thicker stickers s >> 25 mm),
- the depth of the loading space has to be low in order to shorten the length of air travel in the charge especially at low temperatures of drying air,
- the short circuiting of air should be minimized,
- the power rating of heaters and capacity of vents should ensure the flux of evaporated moisture from timber of minimum 0.1 $kg/(m^2 \cdot h)$.

When drying green timber of fast growing species, the low temperature schedules should not be applied, especially in summer, when temperature and relative humidity of ambient air are high.

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