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(54) **INNOVATIVE WAY OF WOOD-DRYING KILN**

(57) Wood-drying way in kiln basis on wood placement preferably on spacers inside the drying kiln, then providing the interior of the steam, heating it up to displace atmospheric air by steam and continue until the superheated steam is obtained, it characterizes according to invention, that after reaching the inside of the dryer temperature in the range of 70-80°C, wood is relaxing without changing of thermal conditions within the drying kiln for 2 to 3 hours. Then the drying phase is carried out at a maximum of 120°C, preferably keeping it in the range of 105-110°C until it reach the desired final moisture content of wood. The wood cools itself spontaneously, and the entire process is carried out in conditions of atmospheric pressure. Preferable is warming up at a rate of 1-1.5°C per hour.

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Description

[0001] The subject of the invention is a way of drying of wood in a kiln, applicable in the industrial processing of wood.

[0002] Drying of wood is a process of extraction of contained water from a material and it is to obtain a specific moisture content level, depending on the subsequent destination. During each drying process of wood free water evaporation does not change its shape and dimensions. Free water, which is located in the cells and intercellular spaces, it does not affect the shape of the cells. In turn, the bound water evaporation, contained in the cells, where space is limited by the mucous cell causes them to shrinkage. Along with reduced water, evaporation zone moves deep into the wood. The proper conduct of the drying process allows for greater migration of water from the material, and thus get more wood dryness. It was noted that at higher temperatures of drying factor increases the intensity of the drying of the wood.

[0003] The basis of the drying process is the phenomenon of equilibrium of hygroscopic moisture of wood, that is, any temperature and relative humidity of air is responsible (under the hygroscopic humidity) specified equivalent moisture content to that of wood. It depends on the species of wood and the parameters of the environment i.e. decreases with an increase in air temperature and lower humidity. The lower the equivalent moisture content, the easier in a given conditions is the drying process.

[0004] There is a known way of wood drying in the superheated steam. The wood is placed in a very tight drying kiln in the saturated air and very quickly the temperature rises to 90-95°C, and then slowly up to 100°C and above. Superheated steam in the dryer absorbs the evaporating wood water with intensity depending on the degree of overheating (temperature dependency). Such drying process is 2-4 times faster than classical drying, and less is the likelihood of cracks.

[0005] From the American patent description US4246704 is known the way and installation of solid wood drying in particular in the form of boards or prefabricated wood, with superheated steam in order to improve its plasticizing. Revealed know-how is continuous, crossover wood heating at temperatures above 100°C and chilled at a temperature below 100°C in a hermetically sealed chamber. Heating phase takes place under high pressure, without access of air, at temperatures in excess of 110° C. The chamber is equipped with a device to release excess steam to reduce the pressure inside of it. The cooling phase is carried out under vacuum conditions.

[0006] Disadvantages of known ways are the high cost of airtight drying kiln, their rapid corrosion, as well as the possibility of occurrence of wood colour changes. Fluctuations in temperature and humidity inside the dryer may not ensure the preservation of open pores, which in turn may result in the cracking of the material.

[0007] Wood-drying way in kiln basis on wood placement preferably on spacers inside the drying kiln, then providing the interior of the steam, heating it up to displace atmospheric air by steam and continue until the superheated steam is obtained, it characterizes according to invention, that after reaching the inside of the dryer temperature in the range of 70-80°C, wood is relaxing without changing of thermal conditions within the drying kiln for 2 to 3 hours. Then the drying phase is carried out at a maximum of 130°C, preferably keeping it in the range of 105-110°C until it reach the desired final moisture content of wood. The wood cools itself spontaneously, and the entire process is carried out in conditions of atmospheric pressure. Preferable is warming up at a rate of 1-1.5°C per hour.

[0008] In the air saturated with moisture (φ = 100%) equivalent humidity reaches the maximum value for a given temperature and humidity and is called the saturation point (depending on the temperature and the wood is from 22 to 30%). The higher the temperature of the air, and more a mixture of dry air and steam, the more moisture it needs to achieve a state of saturation. At 100°C (at atmospheric pressure) the state of saturation can be achieved only if there is no mixture of air, and is only steam (dry saturated steam). Equivalent moisture content of wood is then about 22%. In turn, overheating of the steam to higher temperature value (at constant pressure) causes a further drop in equivalent moisture content of wood.

[0009] Study of high temperature drying of wood using a gas-steam mixture (steam with air) revealed the existence of a significant improvement in the quality of the dried material. For example, during and after the process of heat treatment of wood were observed:

- unchanged or similar mechanical strength,
- reduced power demand for cutting
- greater smoothness of wood after treatment,
- increased durability of the impact of external weather conditions,
- resistance to mold and mildew,
- less prone to cracks, change dimensions and distortions.

[0010] Studies of different species of wood have enabled the development of new technology by using a unique in the domestic scale steam and gas-steam drying system, made and equipped with computer software giving the opportunity to the appropriate conduct of the process. The moisture content of the mixture to ensure an atmosphere of drying is controlled by an electronic control system.

[0011] During the first phase, the period during which drying speed maintains constant, there is a simultaneous exchange of heat and mass in the border layer and heat flux of flowing drying medium provided is used only to convert the state of water from liquid into gas. During this stage the drying speed is fixed and depends only on the external conditions such as temperature, humidity inside

dryer, speed and type of the drying medium. The temperature of the surface of the material dried at this stage is equal to the temperature of the wet bulb. In addition, in the absence of exchange energy inside the drying medium, the temperature is almost constant. The water in the liquid state is constantly delivered to the surface of the material. It is transported from the interior thanks to the presence of capillary force - liquid flows from areas of higher moisture content to smaller content areas. This means the migration of water from the larger pore to the pores with smaller diameters.

[0012] A period of constant rate of drying lasts as long as the surface is supplied in liquid and its duration strongly depends on conditions of drying process and the properties of the medium. When the moisture content decreases the value of the capillary forces typically increases. At the same time as the occurrence of these phenomena falls migration of liquid phase to the material. This is a decrease in the flow of liquid on a pro rata basis to reduce the moisture content. The end of the first stage is referred to as a moment in which fades the flow of liquid through the surface material. The time needed to achieve this state depends on the conditions in which it is carried out and the properties of the material. Important is also the temperature in this stage of drying - the higher it is the easier is the internal transport of fluids.

[0013] At a time when the final state is reached for the first stage, the pressure of the liquid becomes smaller than the saturated steam pressure. External steam stream is reduced and the heat flux delivered to the medium is temporarily higher than required for the evaporation of the fluid. Excess energy is consumed for heating of the surface and the interior of the material. In this way creates an unstable dynamic equilibrium state. Steam pressure at the surface of material and its movement depend on the temperature and moisture content. To ensure energy balance the surface temperature must rise when the moisture content on the surface decreases. This leads to a decrease in the speed of drying and reduce the amount of heat delivered by the medium. Inside the porous material two zones are formed. In the inner fluid migration dominates and in outer zone diffusion related to bound water and steam. In this stage heat flux must be conducted inside the material, so that it was possible to increase the temperature and the evaporation of the liquid.

[0014] Along with the progress of the drying process, the size of the zone in which migrates the liquid decreases and finally completely fades. When the temperature of the material reaches the temperature of the medium and the moisture content will get a value of equilibrium, the process shall be deemed to be terminated.

[0015] In order to reduce drying time without parallel decline in the quality of the dried material, it is possible to ensure such process conditions, at which the temperature of the material is higher than the boiling point of water. These conditions are supporting the occurrence inside the material overpressure. Thanks to that the pressure difference favours the transport of liquid in the heat-exchange surface direction. Due to the large anisotropy of wooden materials during drying elements, in which experiencing hypertension, there is a bi-directional flow of heat and mass. The specific construction of the wood determines also the direction of the that exchange. The heat and the steam migrate mainly across the material, while part of the steam and fluid flows along. Its ends are saturated with water and sometimes it is possible to extract water from these places.

[0016] The invention is closer presented in the example implementation.

[0017] The test kiln consists of batch type chamber to conduct conventional and high-temperature drying process. The acquisition system is comfortable, to control and archiving the thermophysical parameters of the process. Measurement of moisture content and temperature of the wood and the temperature and relative humidity of the working medium is done using a series of sensors to moisture and temperature measure. In the kiln there are the nozzles supplying steam. Steam, by using the fan, is being transported into the drying area in which the dried material is batched. Generating of the steam continues throughout the time of drying from the start of warming up to the end of the process. Stages of heating and drying are provided to maintain proper temperature in the chamber.

[0018] Convective drying of wood at high temperatures is carried out using superheated steam as a drying agent. The recipient factor of moisture from dried wood is steam (without air). Therefore, the temperature of steam must be higher than the saturation temperature (it must be superheated). Steam saturation temperature at atmospheric pressure is equal to about 100°C (exactly 100°C at P = 101.3 kPa). To evaporate moisture from the material, its temperature must equal at least 100°C. Otherwise, steam contacting with the surface of the material is cooled below the saturation point and causing condensation on material, humidity rise instead of dry. In wood preheated to 100°C moisture travels mostly in the form of steam, since evaporation of water follows, as far as material heating to boiling point at the whole volume of the dried material. In addition, it speeds up the drying process. If we omit the minor differences between the various species of wood, it turns out that the moisture equivalent - and therefore the drying speed - at a fixed pressure depends on the temperature of the steam, which simplifies control of the drying process. However, the temperature control must be very precise, because even small changes in temperature of steam, especially in the range of 100-115°C, significantly affect the equivalent moisture content of wood, and therefore also on the speed and quality of drying.

[0019] In view of the fact that the amount of moisture removed from dried material is relatively large and the construction of the chamber could increase pressure in the chamber, leading to a decrease the intensity of the drying process, stream of evaporated moisture dissi-

pates outside the dryer by freely lockable flap.

[0020] Loading drying kiln with material for drying causes that the gas filling out chamber is air. Therefore, in the initial stages of the drying process to the dryer is introduced steam, and the airsteam mixture of it is removed on the outside. Part of the steam comes into contact with the cold surface of the material and undergoes condensation. This facilitates and accelerates the process of heating and protects against drying its surface layer during heating up. However, this influences on extending of the drying time, because condensated moisture must be evaporated later.

[0021] During the heating up of the material it is led to rapid mixing of air in the kiln with a large amount of steam. It will first drive to saturation of air humidity, and subsequently increasing of steam fraction in this mixture (up to a total removing of air) at a temperature of about 100 °C. Increase of moisture content in the gas inside the dryer when the increase in gas temperature occurs means an increase in the wet bulb readings. After some time the thermometer indicates a temperature of saturation point of steam with the set pressure. This means that the kiln is already free from the air. After reaching the temperature inside the dryer at 70°C increasing of temperature is stopped, and only kept at a level not higher than 80°C, and the wood is relaxed for at least 2 hours, up to a maximum of 3. Also during this time the temperature of the dried material (at least in the external surface area) reaches a level of about 100°C and begins the process of proper drying. Regardless of the temperature of the superheated steam temperature of dried material remains constant as long as the surface of the material is free of water. This is so called the first period of drying. The drying rate is determined only by the conditions of heat exchange between steam and dry wood - the higher the temperature of the steam, the more intensive evaporation. High temperature of drying agent causes that drying process is faster than a conventional hot-air drying.

[0022] The temperature of the steam must be kept near 100°C until there is overheating all over the wood. Heat moving into the wood for about 100°C causes the evaporation of the water contained in wood and move of the water resulting steam toward the surface of the wood, where it is absorbed by the drying agent. Raising the temperature of the drying steam causes it to superheat, which speeds up the drying process further and allow drying below the fiber saturation point. High temperature of wood and lack of air in is of favor of high speed of the movement of moisture in wood in the direction of its surface. Therefore, also in the second period of drying speed of the process depends mainly on the resistance of the conduction of heat into the material, not the steam flow resistance in the pores. As a result, the surface of the lumber remains wet longer than when dried in conventional way. For this reason, the flow velocity of the drying agent has a much greater impact on the drying time. Often it pays to use the speed of the steam between the lumber of 4 to 5 m/s. It is recommended to use spacers with a thickness of 25-30% smaller than in traditional dryers. The temperature of the lumber does not rise more than 100°C as long as in its interior is located the water in the liquid state. Only after its evaporation temperature of wood is increasing and at the end of the drying process the value approaching to temperature of drying agent.

[0023] In superheated steam we can dry primarily coniferous wood, provided that the action of high temperature does not cause adverse changes to its properties. When dried hardwood it should take an extra care, especially in terms of humidity above the fiber saturation point. Some species of wood, for example oak, at high temperatures show a tendency to destroy cells (collapse) and internal cracks, thus drying them this way should be carried out very carefully, thus reducing the flow velocity of steam between lumber. It should not carry out stage of warming up too quickly in order to prevent the "pockets of water" causing the rupture of the dried material from the inside. The best effect is obtained when the speed of warming up is about 1-1.5°C per hour. Thus the wood does not tend to change shape, and inside there are no stresses induced by collapse.

[0024] The temperature of the superheated steam during the drying process must be higher than 100°C. At this temperature water from the surface of the wood evaporates quickly and there is a very intense movement of moisture from the Interior of the material, which protects it against excessively rapid drying of the surface layer. Temperature difference of steam in front of and behind the pile is greater, if smaller is the quantity of steam passing through the pile in the unit of time. It may be 8 to 10 K at stake with a width of 780 mm. At the steam temperature in front of piles of equal to 130°C for its temperature gradually raises behind the stack (as far as the progress of the drying process) from 100°C to 120°C.

[0025] Proper drying process starts at the time when the temperature of the surface of the wood intended for drying reaches 100°C. When wood is wet and the water evaporates, the temperature is constant, maximum about 103°C. The inner layers heat up more slowly, but after some time in the whole cross-section of the element - the temperature is approximately the same. Between the steam in the interior of the wood, at temperatures above 100°C, and steam that fills the dryer's chamber, there is a pressure difference. This difference depends on the thickness of the wood, its density and anatomy. Moisture movement in wood takes place, with the increased partial pressure difference, due to the diffusion of steam.

[0026] The drying process can be divided into several stages. In the first free water of the wood is removed. Moisture transport is exclusively by capillary way. Evaporation of free water from the surface of the wood is conditioned by the temperature and the pressure on the border of water and air. In connection with the structure of the wood water evaporates at different speeds from different sections of the dried material. In the second stage

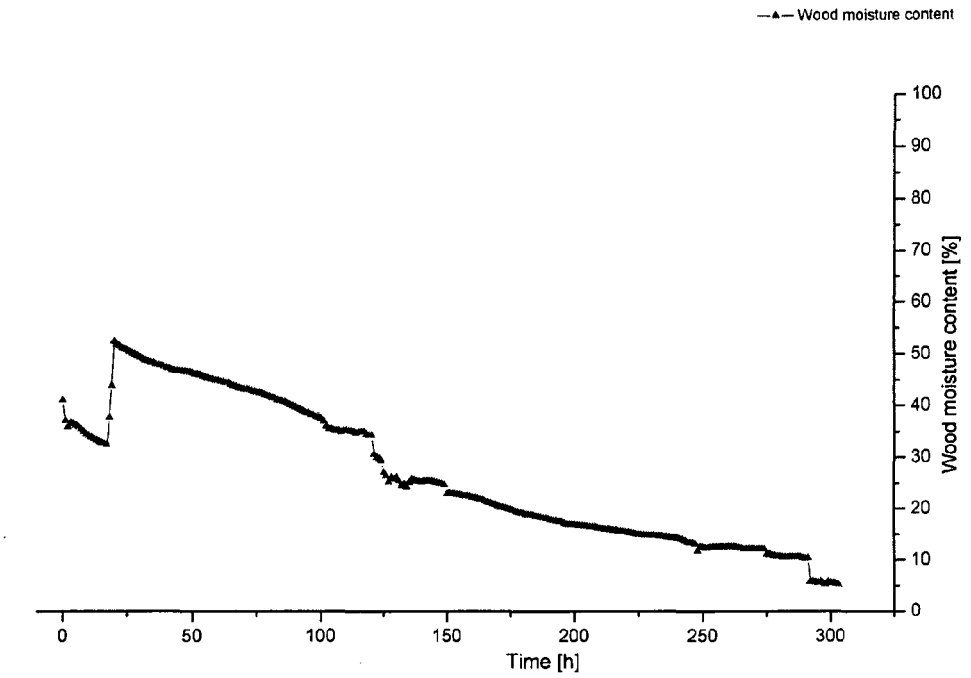
of wood drying water usually occurs already in the form of steam and moves due to diffusion forces. Speed of drying at this stage begins to decrease. In the final stage of the temperature of the wood is coming to the ambient temperature and the diffusion transport of steam only occurs. After completion of the drying process, the moisture content varies usually between 12-15%.

[0027] The chart shows wood's moisture content changes over time.

Claims

1. Wood-drying method in the kiln of wood placed preferably on spacers inside the drying kiln, then providing steam to the interior of kiln, heating it up to displace atmospheric air by steam and continue until the steam is superheated, it momentous that after reaching inside of the kiln temperature in the range of 70-80°C relaxes wood without changing conditions within the dryer for 2 to 3 hours, then the drying phase is carried out at a maximum of 120°C, preferably in the range of 105-110°C, until reaching the desired final moisture content of wood, and afterward wood cools itself spontaneously, and the entire process is carried out in conditions of atmospheric pressure.

2. Method according to the point 1 noteworthy that it is warming up at a rate of 1-1.5°C per hour.



POS. 1. Changes in beech wood sample moisture over time during the drying process using the steam at the temperature 110°C.

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EUROPEAN SEARCH REPORT

Application Number
EP 15 46 0067

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

F26B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	8 March 2016	Haegeman, Marc

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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EPO FORM 1503 03.82 (P04C01)

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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