

WDC 2012

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*Challenges and Opportunities Related
to Tropical Lumber Drying*

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Ivaldo Pontes Jankowsky, coord.



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Foreword

This is the twelfth edition of the Wood Drying Conference, and by the first time a meeting of the IUFRO Wood Drying Working Party is held in South America. No doubts that all persons involved in the organization are proud to collaborate to have this meeting in Brazil.

Wood drying still is very important in any modern wood manufacturing industry, as due its time and energy importance as well to add value and quality to wood based products; and this approach becomes more important when the concern is the tropical wood.

Brazilian tropical forest represents around 30% of natural forest in the world and is calling international attention regarding its use and preservation. There is a commitment of Brazilian authorities to avoid the deforestation and to incentive the Sustainable Forest Management, which implies in the introduction of different and less known wood species in order to manufacture added value products.

Using Dr. Manfred Vanek words, “conferences are an essential part to solve the big puzzle of wood drying, as they give us the chance to discuss exciting issues and exchange new ideas”. The WDC 2012 theme, Challenges and Opportunities Related to Tropical Lumber Drying, reflects the concern about the sustainable use of tropical forest and also drives the scientific discussion and research to tropical lumber.

This publication contains the abstracts of 28 oral presentations and 31 posters, selected from 86 submissions; and it is part of our contribution to achieve the Conference objectives.

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ORAL PRESENTATIONS

Influence of extractives on water vapour sorption on specimens of *Chilean* wood species

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Abstract: The equilibrium moisture content was determined for 28 wood species from Chile at 20°C and 35, 50, 65, 80 and 93% relative humidity. Using the averages of experimentally determined values, selected parameters of the Hailwood Horrobin model, such as fibre saturation point, mono- and polymolecular sorptions as well as inaccessibility of the sorbent to sorbate and the specific surface of the sorbent, were computed. The influence of extractives on the equilibrium moisture content was investigated.

Keywords: wood extractives, water vapour, sorption properties

Volume losses as a tool for assessing the quality of kiln dried eucalyptus' wood

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Abstract: Drying defects which modify the structure and dimensions of wood are extremely harmful, causing limitations of use. Among these defects are surface and end checks, collapse and warping. The aim of this work was to analyze wood drying quality of *Eucalyptus grandis*, *Eucalyptus saligna* and *Eucalyptus dunnii* for loss of volume. The wood of the three species was kiln dried together, with the same drying schedule and conditions in a conventional-temperature pilot kiln. This way it was assumed that there was a similar analysis of all three species.

Three kinds of volume losses were evaluated: total - from saturated (initial) to machined (final) condition; shrinkage - from saturated (initial) to 10% moisture content; machining - from 10% moisture content to machined condition (final). Shrinkage loss means: the natural reduction in wood volume resulting from drying bound water under the fiber saturation point; machining loss represents the volume reduction after planing and trimming the dried boards; total loss represents the yield in wood from raw material (saturated boards) to final product (planed and ready to use boards).

Eucalyptus grandis was dimensionally the most stable wood and presented the smallest volume loss due to shrinkage. Although both have different shrinkage behavior, *Eucalyptus grandis* and *Eucalyptus saligna* presented the same drying quality for machining and total volume losses. These species can be considered similar for kiln drying. *Eucalyptus dunnii* presented the worst quality in drying, and cannot be kiln dried in the same batch as *Eucalyptus grandis* and *Eucalyptus saligna*. Its drying schedule was not appropriate and must be improved, since this species presented high amounts of boards with drying defects.

Keywords: Kiln drying quality, volume loss, eucalyptus wood.

Determination of the free shrinkage of wood at the cellular level using an environmental scanning electron microscope

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Abstract: Shrinkage at the cellular level has been evaluated using an environmental scanning electron microscope (ESEM). Shrinkage is calculated from pairs of images taken at the same experimental conditions (magnification, work distance, high voltage) without remove the sample from the microscope, one image collected at saturated conditions (8 Torr, 1 °C) and the other in air-dry state (4 Torr, 16 °C). A software program called MeshPore has been used to determine shrinkage based on a closed chain of reference points chosen from the anatomical markers at the external part of the zone of interest.

Measurements of transverse shrinkage were performed on earlywood and latewood zones from Norway spruce (*Picea abies*). The interested zones were isolated from the rest of the annual ring with the aid of a microtome blade, insuring the measurement of the free shrinkage. The use of ESEM brings the main advantage to study the cellular morphology changes and cell wall thinness caused by the shrinkage.

Keywords: Wood cellular shrinkage, environmental scanning electron microscope (ESEM), image analysis, MeshPore, softwood, Norway spruce.

Drying properties and predictions of pre-drying curves of *Eucalyptus nitens*

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Abstract: Some drying properties were determined and the drying curves were predicted during pre-drying of *Eucalyptus nitens*. In particular the variability of transversal shrinkage and collapse were evaluated. Fourth trees, each of them from different families, were collected from plantations of *E. nitens* growing in the 8th Region of Chile. Wood samples for shrinkage and collapse were obtained from the first log, in three successive positions from pith to bark. Samples of 25x70x450 mm were prepared and then properly stacked for pre-drying at 30°C. Collapse was determined as the difference of shrinkage before and after reconditioning at 20% moisture content. The drying curves were calculated using an overall mass transfer coefficient. It was found that the transversal shrinkage and collapse tended to increase with the position in the radial direction, although there were some exceptions in which they increased in transition zone. The pre-drying curves were satisfactory predicted using an overall mass transfer coefficient.

Keywords: Wood pre-drying, collapse, overall mass transfer

Reduction in tropical hardwood hygroscopicity submitted to additional heat treatment

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Abstract: The hygroscopic characteristics of wood directly influence the environmental moisture adsorption and desorption to which it is exposed. These are inherent characteristics of wood that appear during its lifetime, causing unwanted defects.

In order to reduce the hygroscopic exchange with the surrounding environment; in this study we tried additional heat treatments with air dried and conventional kilns dried timbers.

The selected woods were two species commercially known as Jatoba and Muiracatiara, from which radial and tangential boards were collected; both air dried and kiln-dried; selected from a flooring manufacturer's stock. These boards were cut to samples for heat treatments, which consisted of wood exposures to 60°C, 75°C and 90°C during periods of 24, 48, 72 and 96 hours.

After heat treatments the samples were conditioned at a low relative humidity environment (Condition 1) and after reaching the equilibrium moisture content, they were conditioned at a high relative humidity environment (Condition 2). The samples' moisture contents were measured after heat treatment and conditioning.

The results showed that the Jatoba lumber equilibrium moisture content was lower than that of Muiracatiara; a similar behavior was found for tangential samples when these were compared to the radial ones and for kiln-dried in relation to air dried lumber. However, these differences are not important for the lumber industrialization processes. As far as heat treatments go, 90°C provides the lowest of equilibrium moisture content and the lowest rates of hygroscopic potential.

Among heat treatments the most effective was the exposure to 90°C, regardless of exposure time. This treatment reduced wood hygroscopicity and this effect was more pronounced in the kiln-dried than in air dried wood.

Keywords: Hardwood, hygroscopicity, moisture content, heat treatment.

Evaluation of Kiln-Drying schedules for Wild Cherry wood (*Cerasus avium* (L.) Monench)

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Abstract: Wild cherry wood (*Cerasus avium* (L.) Monench) lumber with a nominal thickness of 5 cm from Duzce region in Turkey was dried through conventional kiln drying using two different programs which are unprotective drying schedules, and protective drying schedules. The aim was to obtain the most desirable kiln schedule for keeping the wood quality at an appropriate level up to final moisture content of $12 \pm 2\%$ was reached. Intensity of warping (twist, bow, cup, crook) occurrence, superficial, internal and end checks, residual stresses, drying rate, and moisture gradient in the dried woods were measured, and the results were analyzed. The results showed that there was a more homogeneous moisture profile, fewer occurrences of superficial checks, and absence of internal checks in the protective drying schedules due to low warping values compared to the unprotective drying schedules. Therefore, it seems that protective drying schedules might be recommended as optimum program for wild cherry lumber drying at commercial scale from Duzce region.

Keywords: Wild cherry wood; drying schedule; drying quality

The use of RFID technology in drying and other thermal processes of wood.

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Abstract: High temperatures ($>50^{\circ}\text{C}$) are applied in a lot of processes in wood industry and monitoring of temperatures is a critical point, in order to follow the process properly. The most common method in practice to transfer the information is the use of cables, which connect sensors to data loggers. The accuracy of the method depends of course on the quality of the equipment, on the quality of the cables and on distance between sensor and signal receiver. For traceability reasons it is also essential many times to record temperatures achieved inside a chamber or –much better – inside wood core and recall them long time after the process has finished. Nowadays this can be achieved using RFID technology, without any need of cables, whenever and wherever you wish. In present paper a series of experiments are presented, where this technology was applied and the accuracy of the sensors was examined. Traceability is possible, as well, verifying temperature and time data.

Keywords: Wood drying, Data recording, RFID, semi-passive, battery assisted, temperature sensor, condition monitoring.

Variation of the stress wave velocity during the drying of woods

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Abstract: The stress wave technology is used to predict the mechanical properties of woods. In this study, the variation of the stress wave velocity (SWV) during the drying of woods was investigated with the purpose of evaluating the viability of use the technique to estimate the wood moisture content (MC).

A stress wave timer was used to measure SWC in the longitudinal direction of the samples of Cathay poplar (*Populus cathayana*) and Larch (*Larix gmelinii*) (typically 500x20x20 mm) in drying according to typical kiln schedules. The results indicated that the SWC decreased in general with increasing MC, and the relationship curves of different samples for each species were obvious difference. Instead of raw stress wave velocities, the velocities were transformed to relative velocities (RV): V/V_0 , where V is velocity at any MC and V_0 is the velocity at oven-dry state. Below the special moisture content point which each species had its own, the curves of different samples for each species tended to be a master curve of the species in the new linear relationship of V/V_0 and MC. It suggests that this method presents potential measuring the MC of wood during the drying process.

Keywords: stress wave velocity; moisture content; wood drying

Evolution of Wood Drying Processes Technology and of Equipments

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Abstract: Before wood can be turned into consumer goods and products; drying is the most important phase of the industrialization process, as it is then that the greatest value is aggregated to the final product. When the drying process is correctly carried out in kilns, a considerable reduction in time, greater control over the defects and hence products with better quality standards is obtained. When adding quality to wood-based products, this necessarily includes not only the process of the wood drying in all its aspects but also its interaction with its variables: wood drying equipment; control of the drying process; human resources involved and random variables. Since the Brazilian forestry industry is very competitive worldwide, it is useful to assess how the timber industry uses current technology and to examine the cost of equipments on the market. We analysed how technology has evolved in the drying process and make considerations about the importance of knowing the species of wood to be dried, as well as about the equipment involved for obtaining quality products. Visits were made to a conventional kiln manufacturing industry and to three factories in Tietê and Itu, Sao Paulo state. The factories seek to add value to the final product and perceive the role of operators in the drying process. The most used conventional kilns had a higher cost than other types of kilns, even though the former ones are the most common and most frequently used by lumber drying firms. One of the reasons for choosing these types of kilns is their volume capacity to meet the market demand and their operational independence from climatic factors.

Keywords: drying applied, equipment, processing.

The Water States and Migration in Yellow Poplar Drying Monitored with Time-domain NMR

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Abstract: Green wood generally contains water in three forms: water vapor, free water and bound water. Usually bound and free water in wood during drying are studied separately since it is difficult to identify these two water forms simultaneously with traditional methods. Time-domain nuclear magnetic resonance (TD-NMR) technique can easily distinguish water states according to spin-spin relaxation time (T_2) and give more quantitative information on water in wood than any other method. In this study, water states in yellow poplar drying are investigated with TD-NMR. Also, water migration is also analyzed.

The results of this study show yellow poplar has at least 5 water states according to T_2 values at moisture content above 100%. The longest T_2 is about 400 ms for free water and the shortest T_2 is about 1 ms for bound water. The amount of 5 water states in yellow poplar sample decreases at the same time with drying while bound water has slow decreasing rate.

Through TD-NMR technique, water states in wood drying is distinguished easily, but also, different water state migration can be analyzed quantitatively. This technique will benefit wood drying modelling and simulation.

Keywords: Water states, migration, NMR, relaxation time.

Liquid water sorption in dried Norway spruce and Scots Pine timber measured with CT scanning and viewed as a percolation process

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Abstract: Liquid flow in wood is complicated to study, since wood is a nonhomogeneous, hygroscopic porous, anisotropic material. However, study of wood-water relations is important, since many properties of wood are influenced by the presence of water. For example, during outdoor use, exposure to free water from dew, rain and condensation influences the durability of wood against fungi. The distribution of chemicals during impregnation and the ability to dry are other aspects dependent on the flow of liquid in wood. Therefore, understanding the behaviour of the capillary network is of importance in both drying and wetting. In this study, simulations of liquid water absorption in wood as a fibre network (percolation) have been compared with experimental water absorption in the longitudinal direction in Norway spruce and Scots pine. With computer tomography (CT scanning), water distribution during liquid flow can be shown visually and can be measured using image processing. Liquid water absorption in end grain of spruce has been measured with CT scanning after 0.5, 6, 24, 48 and 72 hours of liquid water absorption and during drying at room temperature during 6, 24 and 48 hours. Moisture content profiles have been measured in heartwood and sapwood. Generally, the MC profiles are lower for heartwood than for sapwood in both spruce and pine. The MC profile differed between the species. In some of the pine specimens, a plateau developed that was not found in spruce. The simulations according to the percolation method show general agreement with the measured results.

Keywords: Wood-water relations, capillary network, Norway spruce, *Picea abies*, Scots pine, liquid flow, CT scanning, percolation.

Modeling of heat transfer in *Pinus* sp.

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Abstract: The analysis or experimental aids of mathematical tools are necessary for a rational use in wood drying technology. The mathematical models used to study drying generally express transient conduction problems and simplified boundary conditions. In some cases these can be solved by analytical solutions and in other cases by numerical methods.

The use of mathematical modeling and numerical simulation of the heating process of wooden boards and the Kollmann and Côté Junior (1968) equations to calculate the coefficients of thermal and physical properties make it necessary to use numerical methods.

This paper proposes an algorithm developed and tested, based on a numerical procedure for the simulation of heating wooden boards. The results obtained indicate that it is possible to extend this investigation to obtain a reduction of time and thus of drying costs. A system of differential equations for the numerical solution for the problem was used. The equation was integrated by the Runge-Kutta method. The algorithm was implemented in the computer program MATLAB.

The model was validated by comparing the results obtained in simulation with analytical ones. Heating was simulated for different thicknesses, moisture contents and basic densities, and it was found that it is possible to reproduce real data with low errors. The models used are very promising for applications in other segments, and are considered a good tool to support decision making.

The results show that heating time increases with increasing thickness of the boards, moisture content and basic density of wood. Studies on convective coefficients should be made because many variables are involved in a single coefficient. The set of equations for calculating the coefficients of thermal and physical properties presented by Kollmann and Côté Junior (1968) can be used in future studies.

Keywords: Simulation, heat transfer, thickness of piece, wood density.

Investigation of beech drying with oscillating conditions using flying wood test and loaded beams: need for a new mechano-sorptive model

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Abstract: In this work, the effects of moisture content variations produced by oscillating drying conditions have been studied by the way of non-symmetrical drying (flying wood) and loaded drying (3-point bending test). Our experimental data seem to prove that the activation of the mechano-sorptive creep by oscillations of the moisture content at the board surface is very limited. The analysis of the results thanks to the code seems to prove that the unclear conclusion about oscillating conditions could be explained by the noise in the reference drying conditions. In opposition with the experimental observations, the implementation of classical mechano-sorptive models in TransPore is by far too optimistic, which means that these models are not adapted when the material is submitted to numerous oscillations.

Keywords: Drying stress, beech, oscillating conditions, mechano-sorptive model, flying wood,

The effect of green kerfing on warp reduction and bending properties of fast-grown pine lumber

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Abstract: The available log supply in Uruguay comprises trees that grow so fast in intensively managed plantations that they reach sawn timber size in 25 to 30 years or less. Trees harvested at this age contain high proportions of juvenile wood, which may lead to excessive drying defects (e.g. warp). Previous work showed that saw kerfs perpendicular to the grain on the wide surfaces of green red pine lumber improved drying and reduced warp without decreasing strength. The kerfed board simulated an I-joist in which the resulting end grain enhanced the subsequent drying.

The aim of this study was to evaluate the effect of green kerfing on the drying performance and subsequent bending properties of fast grown loblolly and slash pine studs. One hundred boards (100 x 50 x 3200 mm), kerfed and controls including flatsawn, quartersawn and semi-radial sawn were kiln dried for 13 days until a moisture content of 11%.

Warp was measured on kerfed and control boards: cup, bow, crook and twist. No statistical difference was found between treatments due to a high variability of the data. Radial and tangential shrinkage was determined in both kerfed and control boards, also without statistical difference between kerfed and controls.

Edgewise bending tests were performed for kerfed and controls. Results indicate that kerfing did not reduce the bending properties for none of the three sawing patterns.

Keywords: Wood drying, kerfing, warp, bending properties.

Formulation of the energy consumption in conventional kilns: results obtained with a global approach and implementation in a multiscale computational model

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Abstract: A formulation able to compute the energy consumption during wood drying in a conventional kiln was derived in a previously published work (Perré et al. 2011). Used in a global approach (drying duration and conditions, stack and kiln characteristics), this formulation allows consumption values to be obtained, which are in good agreement with the experimental data reported in the literature.

This formulation was also embedded in a multiscale computational model able to consider the drying of a whole stack of boards, together with the kiln chamber. This comprehensive model will not be presented here, but some results are proposed to prove the potential of this complex tool.

Keywords: Board, stack, thermal loss, air renewal, differential heat of sorption, latent heat.

Evaluation of beech wood defects due to different drying schemes

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Abstract: Drying above the fiber saturation point is pure water transport without shrinkage. Shrinkage starts from moisture content below the fiber saturation point. This is motivated by the fact with development of strain and stress, occurs only that point. The paper presents the results obtained in an experimental study concerning the influence of drying temperature on beech wood (*Fagus sylvatica* L.).

Sound wood samples (dimensions: 1000mm x 250mm x 28mm) without red heart were cut from white (unsteamed) beech timber parts. The wood was taken from the Jezerc Area, 1600 meters above sea level and the cut wood samples were air dried from green condition to below fiber saturation point. They were then kiln dried to the final moisture content of 12% at different temperatures: 50°C, 65°C, 75°C, 80°C, 100°C, 110°C and the same relative air humidity: 55%.

The main defects found on the kiln dried beech were discolorations due to chemical reactions and cracking. Nevertheless, the level of defects was within the expected limits of 3 – 4% of the total volume of the beech wood lumbers.

Keywords: defects, discoloration, beech lumbers, drying

An easy method to indicate conventional kiln schedules

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Abstract: In spite of the facility to find kiln drying schedule indications for the most common lumber species, it still is problematic to indicate adequate kiln schedules to dry lumber of the lesser known species. Aside from the traditional trial and error method, the available methodologies could fail when they did not represent the real conditions of an industrial drying process or due the need of excessive time and work.

Amongst the methods that consider the effect of the lumber physical characteristics on its possible behavior during the kiln drying; the technique which quantifies the rate of moisture loss and intensity of drying defects, when the lumber is submitted to a drastic drying condition, presents a coherent suggestion of conventional drying schedules. However, this technique requires long tests (24 to 36 hours of duration), and the necessity of periodic measurements generates an operational difficulty.

The present research objective was the improvement of the above methodology, evaluating samples with different dimensions; aiming at reducing the testing time and keeping the reliability on the indication of an adequate kiln schedule. Therefore, samples of nine well known lumber species regarding their behavior during conventional drying, with volumes of 400.0, 168.8, 50.0 and 25.0cm³, were dried at a constant temperature of 100.0°C. Before the test the specific gravity and initial moisture content were determined, and during the drastic drying the rate of moisture loss and the intensity of surface and end checks were quantified. After the samples reached a moisture content equal or below 5.0%, the intensity of collapse and internal checks were measured.

Using a multiple regression analysis, it was possible to determine the correlations between the measured variables in the 100.0°C test and the parameters in the literature which suggested kiln schedule [initial temperature (Ti), final temperature (Tf) and drying potential (PS)]. The analysis of variance and the analysis of estimated dispersion values confirmed that the methodology of drying at 100.0°C, using test samples with a volume of 50.0cm³ (1.0cm of thickness, 5.0cm of width and 10.0 cm of length), is valid to suggest kiln schedules for conventional kiln drying; based on the observed values of moisture loss rate and end checks intensity.

Keywords: Kiln schedule, tropical lumber, kiln drying.

Development of suitable drying schedule for 50mm asanfina (*Aningeria altissima*) species, using stress technique in a smoke dryer in Ghana

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Abstract: Drying of wood is the first and most important step in the manufacture of “value added” wood products. However, the conventional kiln-drying is time consuming; energy consuming and also produces several kiln defects, hence not suitable for small scale wood manufacturers to dry their lumber. It is therefore against this background that this research was conducted to develop a suitable drying schedule for 50mm Asanfina species using a smoke dryer (Appropriate technology) to either prevent or reduce the above mentioned problems.

Stress technique method (A residual strain release method) was used to obtain the stress distribution along the test sample boards with the following dimensions: board length between 1.2 to 3.0 m, board width of 150mm, board thickness 50mm. Information on stress distribution, moisture content, moisture gradient and shrinkage were obtained periodically during the entire drying process and measured as function of time. Five test runs were carried out in this study.

Varying drying temperatures were used to dry the wood samples for test 1, 2, 3, 4 and 5 in three drying phases (initial, intermediate and final). Evaporable moisture, strain levels and critical moisture contents derived from the control test helped greatly in the further development of the subsequent test schedules.

The study revealed that the suitable drying schedule for 50mm ASANFINA (*Aningeria altissima*) using the smoke dryer was 20 days (27% delayed) whereas the time for the currently recommended conventional schedule is 16 days, but incurred energy and other overhead cost. Subsequent test runs in this study revealed that stress development and moisture content of the tested schedules had similar drying patterns under varying temperatures.

The study also revealed that tensile strains were higher in magnitude than compressive strain for the species. The study further revealed Asanfina wood dried to 8% is protected from both insects and fungi and movement in service is not altered, also defects such as Surface checks, End splits, Case hardening, Honeycombing, Cell collapse and Distortions were highly insignificant at 0.01 and 0.05 probability levels in this study at both the student t and f-tests. Moisture contents and stress development were both highly significant at 0.01 and 0.05 probability levels in this study at both the student t and f-tests.

Schedules 1, 3, 4 and 5 showed significant difference in drying defects, which could have been attributed to experimental errors. Of the five schedules used in study, results indicated that schedule two (2) gave the suitable prescription (temperatures and drying gradient) as a new drying schedule for the above-mentioned species, which has stood time in the protection from insects and fungi and this is the first time a smoke dryer has been used successfully in Ghana to dry Asanfina. In conclusion all experimental results supported the objectives in this study.

Keywords: Asanfina (*Aningeria altissima*), development, suitable drying schedule, 50mm, stress techniques and smoke dryer.

Mechanism research on the ultrasonic cavitation during wood ultrasound-vacuum combined drying

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Abstract: Ultrasound is an efficient non-thermal drying method and it could improve the drying rate without significantly heating the material. In this paper, *Fagus sylvatica* was taken as experimental specimen to study the effect of ultrasound cavitation on wood vacuum drying. Temperature sensors were used to measure the temperature fields inner wood during drying process; Electron microscope scanning method was used to study the internal microstructure of wood after drying process. The results show that, ultrasound cavitation could improve the temperature inner wood during the drying process, and the temperature increased as time went by and became constant at last; Ultrasound cavitation involved water pathways (such as catheter and pit) disruption, as a result, compared with the untreated specimens, the bordered pits of wood treated by ultrasound were broken. The optimum drying model for ultrasound vacuum wood drying was established. This study provided theoretical guidance for the ultrasound practical drying production.

Keywords: ultrasonic cavitation, internal temperature field, microstructure, optimum drying model.

The effect of ultrasonic pre-treatment on the drying rates and microstructure of *Eucalyptus*

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Abstract: This study was to use ultrasonic as a pre-treatment method prior drying of eucalyptus which dimension was 20mm×20mm×20mm. Ultrasonic pre-treatment with the ultrasonic temperature of 20°, 40°, 60° and 80° for 20, 40, 60 and 90min had been compared with untreated samples. After that dried at the low temperature of 40° and relative humidity of 70%(EMC was 12%). Then based on the comparative analysis of drying rates, water effective diffusion coefficient and Cryo-SEM, the effects of ultrasonic pre-treatment temperatures and time on the drying rates and microstructure had been obtained. The results shows that ultrasonic pre-treatment can improve the drying rates of the *Eucalyptus* by 3%-110% and the drying rates also improved by 26.31%-53.45% with the increasing of treated temperatures. Moreover, the drying rates of the *Eucalyptus* can improve by 22.73%-45.35% with the increasing of the pre-treatment time which is less than 60min, but reduce by 1.44%-15.84% if the pre-treatment time exceeds 60min. Besides, the ultrasonic pre-treatment can increase the drying rates by improving the water effective diffusion coefficient of the test specimen and change the microstructure which clean the thylose and open up the pits

Keywords: ultrasonic pre-treatment, drying rates, microstructure, eucalyptus.

Wire rope stress-laminated timber bridge

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Abstract: Currently Brazil needs to develop sustainable alternatives for construction and rehabilitation of bridges up to twelve meters span, in order to solve the problem of shortage of town, state and even federal roads. Since 1995 the Wood and Wood Structures Laboratory (LaMEM - Portuguese acronym) is researching the system across stress-laminated timber bridges. Results using reforestation wood and other national materials show the feasibility of using this system in the construction of new bridges in areas with low population density to increase access to these areas and to improve traffic safety. This work studies theoretical and experimental wire rope of stress-laminated timber bridges. The main aim of this research is to analyze the performance of the bridge and study the influence of temperature and humidity on the mechanism of loss of pre-stressing of laminated boards with wood.

The research uses a Eucalyptus citriodora laminated wood board 3.5 m long, 8 m wide and 0.25 thick. This bridge has a data acquisition system of load cells connected to each one of the thirteen wire ropes, which are laid transversely across the bridge and pre-stressed by the anchorage system.

The results to date show that with increasing temperature and decreasing moisture a greater loss of pre-stressing occurs, and with decreasing temperature and increasing humidity the pre-stressing increases.

Keywords: Loss of pre-stressing, Stress-laminated timber bridges, Wire rope stress-laminated.

Hot water solubility of pre-steamed *Eucalyptus grandis* wood

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Abstract: The wood of *Eucalyptus* presents several serious problems during the drying process. To minimize this, the treatment known as pre-steaming is used; that is an application of steam to the sawn wood prior to drying. The pre-steamed wood presents better performance and profitability for the lumber industry.

Furthermore, the application of temperature and high humidity to the wood may change some of its properties by acid hydrolysis which degrades some components, such as the hemicelluloses.

The objective of this study was to compare the solubility in hot water of control and pre-steamed *Eucalyptus grandis* wood. The pre-steamed wood was treated with steam at 90°C for three hours and one hour for initial heating. For this, five boards of control wood and five boards of pre-steamed wood were analyzed. The solubility in hot water levels was determined according to TAPPI standard T 1 wd-75 (TAPPI, 1999).

The result showed that the level of solubility in hot water was not statistically modified. The control and pre-steamed *E. grandis* wood showed similar performances.

Keywords: *Eucalyptus grandis*, pre-steaming, solubility in hot water content, drying process.

The model of forming process of collapse of wood cell

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Abstract: Through analyzing effects of water surface tension, capillary, temperature and moisture content in wood strength and collapse conditions, we derived that the value of cell surface tension and minimum radii of capillary is the main force for pushing down the wood cell.

In this study, the wood cell collapse forming process is analyzed. The results show that capillary tension and drying stress are main forces to collapse wood cell. Also the model of wood cell collapse forming process is developed.

Keywords: Collapse, Mechanism, Model.

Microwave and steam Injection drying on laser incised sugi lumber: temperature and moisture distribution

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Abstract: It is remaining essential to explore drying methods that can dry lumber as fast as possible with acceptable degrades, especially for impermeable species. The aim of this study was to investigate the application of microwave, steam injection drying, and combination of both methods on CO₂ laser incised sugi lumber, especially on temperature and moisture distribution.

The squares (120 mm x 120 mm) of sugi (*Cryptomeria japonica* D. Don) lumber were used and half of them were incised by CO₂ laser with incising density of 2500 holes/m². The samples were dried by five drying methods, which were steam injection drying, microwave drying and three type combinations of microwave heating and steam injection drying. Steam injection drying was conducted by injecting superheated steam (120°C) through the plate with temperature of 140°C to the chamber kept on 0.05 MPa above atmospheric pressure. Microwave drying were conducted by using microwave operating frequency at 2.45 GHz and specific main power at 3 kW. Temperature profile, drying rate, and final moisture content distribution of sugi were observed to evaluate the process.

The results indicate that microwave heating can increase the temperature of incised sample to 100°C in within 10 minutes, while incised and no-incised sample dried by steam injection required 40 and 211 minutes, respectively. Temperature pattern of specimen that irradiated by microwave were contrast to the temperature pattern of steam injection drying. Incised samples dried by combination of microwave heating one hour and steam injection drying showed the highest drying rate (MC from 92% to 17% in 14 hours). However, the smoothest final moisture distribution was found in incised sample dried by microwave though completed in 62 hours. Incising and microwave heating seems to be positively contributed on increasing drying rate and the uniformity of final moisture content distribution.

Keywords: laser incising, sugi, steam injection, and microwave

Heating characteristics of softwoods in a high frequency field

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Abstract: The research aimed to establish whether dielectric heating of wood at high frequency could be accomplished at maximum speed and minimum temperature fluctuations and degrade. The intention was to develop optimized heating schedules for the effective pasteurization (phytosanitation) of green timbers.

Results are presented for three softwood species, namely, western hemlock (*Tsuga heterophylla*), lodgepole pine (*Pinus contorta*) and western red cedar (*Thuja plicata* Donn.) and for testing configurations of one specimen with two cross sections: 40x90 mm (pine and cedar) and 114x114 mm (hemlock).

Data analysis revealed that the electric field distribution within wood was a strong function of its dielectric properties. Specifically, homogenously distributed moisture content within wood generated constant electric field values while the opposite resulted in sudden drops and rises of the electric field strength with heating uniformly dispersed due to a fast conductive redistribution from hot to colder areas. Convective losses into ambient air may reduce the average heating rate of a timber shell by about half.

Keywords: heating rate, dielectric, radio frequency, timbers, phytosanitation.

Influence of Fan Speed on Airflow distribution in a Scandinavian Drying Kiln

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Abstract: From the beginning of the 90's the development of drying kilns in Scandinavia has been focusing on increased drying capacity and also making the kilns more flexible in terms of handling differences in dimensions and initial moisture content. In order to facilitate the demand of higher airflows there has been an increase in circulation fan capacity. In a sawmill with modern kilns the fan capacity in a single batch kiln can be over 90 kW, making the drying kiln fans the single biggest consumer of electric power.

Today, more and more sawmills are reviewing their consumption of electric power due to increasing prices. One way of reducing the consumption is to reduce the fan speed when the moisture content is so low that the drying rate is mainly limited by the diffusion properties of the wood and not the airflow. Since modern kilns are designed for high capacity fans there is a lack of knowledge of how a reduced fan speed affects the airflow distribution. This poses a risk of getting reduced quality of the final product due to increased moisture content variation in a batch.

In this study the airflow has been measured inside an industrial drying kiln. For this study two experiments were done with 20 airflow gauges placed inside a kiln. During both experiments the kiln was fully loaded with pre-dried Scotts pine (*Pinus sylvestris*) boards with a thickness of 50 mm. The reason for using pre-dried boards was simply that the gauge was not able to withstand the climate produced during a real process. In order to cover as much of the kiln as possible the gauges were distributed differently for the two experiments.

The results show that about 30 % of the total airflow passes through the bolster spaces which are only about 20 % of the total flow area. This means that a notable volume of air might not be participating in drying of the boards.

The results show also that the relative airflow distribution between the middle and the side of board stacks becomes more heterogeneous at a low fan speed. This trend is also seen for the relative distribution of airflow between bolster and sticker spaces.

Keywords: Wood drying, airflow, drying kiln, energy reduction.

Analysis of the heat demand in batch kilns

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Abstract: During the production of lumber more than half of the entering timber to the sawmill becomes biomass. About 12 %wt of the entering timber is combusted to supply heat for the sawmill. Major part of the heat is supply the kilns. Due to the high evacuation losses the energy efficiency in a traditional drying kiln is only 13 %. This makes the lumber drying to a low and ineffective process in an energy point of view.

Forced drying technologies are a compromise between high lumber quality, low lead time and decreased energy use. Often is the quality and lead time prioritised. This paper advises an appropriate method to simulate the energy efficiency when drying lumber in a batch kiln. To ensure real life drying conditions, with sufficient quality and lead time the initial conditions were made from simulated drying schemes, from simulation program called Torksim. By combine thermodynamics and psychrometric relationship, the energy streams and losses during the drying scheme were established. The program can be used to compare several drying conditions and clarify the magnitude of losses. Different types of technologies affecting the kiln energy efficiency and to compare drying conditions to each other. For instance heat exchanger, heat pumps, condense walls, absorption system etc.

The used drying conditions are suitable for north European lumber and climate, but the initial conditions can be changed for analyses of other types of drying conditions. The program is a usable tool to analyses different types of technologies effect on the kiln energy efficiency and to compare drying conditions and different drying scheme to each other.

Keywords: Wood drying, Bioenergy, Drying technology, Energy efficiency, Sawmill

Comparing weight and capacitance for sorting lumber before drying

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Abstract: Previously the authors proposed the concept of probability charts. In simple words, the probability charts were two dimensional graphics showing the probability of obtaining a certain lumber MC as function of measurable parameters of the green lumber, such as capacitance and weight. In this study, the method was applied to assess the effect sorting lumber before industrial kiln drying. The method was first validated with four additional drying runs: one run containing unsorted lumber and the others containing low, medium and high sorts based on the electric capacitance method. Then, the method was used to assess two typical industrial sorting strategies, namely, sorting by electric capacitance and sorting by lumber weight. It was found that both methods have the potential to increase lumber production and reduce the percentage of over-dried lumber in approximately the same magnitude. For a typical 100 h schedule, sorting in three groups reduced drying time in approximately 10% and the percentage of over-dried lumber to practically zero.

Keywords: Wood, drying, sorting, capacitance, weight

POSTER PRESENTATIONS

Effect of forest management cycle on moisture content, volumetric shrinkage and density: its implications for *Erismia uncinatum* Warm.

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Abstract: This study aimed to determine the possible relationship between physical properties (moisture content, density and shrinkage) and tree origin for Cedrinho lumber (Warm *Erismia uncinatum* Warm). Two trees, one of native forest (Tree I), and other of secondary forest regeneration, 30 years old (Tree II), were sampled in five equidistant positions from pith to bark and for base to top, to determine its physical properties.

Tree I showed higher level of moisture content along all the trunk length when compared to Tree II, 88.2% and 83.4%, respectively. The higher moisture content in Tree I was in the DBH position, decreasing in direction to the base and to the top (less moisture content). Tree II showed a similar moisture distribution, with the higher moisture content in the base position and decreasing to top position.

Mean values of basic density were 0.59 g/cm³ for Tree I and 0.50 g/cm³ for Tree II. The radial variation of basic density followed a typical profile in Tree I, with higher values in the core (heartwood) and decreasing in the sapwood region; while Tree II did not presented a similar variation profile. However, statistical analysis did not prove a significant difference in the radial variation. Considering the length direction, the basic density is higher in the base and decreases to top position; and the differences were significantly different according statistical analysis.

As expected, in both trees shrinkage showed a direct relationship to basic density, with the more dense lumber presenting the higher shrinkage values. The drying rate for Tree I was 0.0274 g/cm² in the capillary range (initial moisture content to 30%), and 0.0086 g/cm² in the hygroscopic range (30% at 5% moisture content); values which could be considered as a low drying rates.

Physical properties of Tree II are characteristic for a still growing tree, and this fact should be considered regarding forest management and a more appropriate use of this species.

Keywords: Physical properties, cedrinho lumber, basic density, forest management.

Partial shrinkage and cracks index in *Eucalyptus grandis* core and mature woods

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Abstract: Drying defects which modify the structure and dimensions of wood are extremely harmful, causing limitations of use. It is known that anatomy structure has direct influence on drying defects, in which weaker tissues lead to higher incidence of defects.

As the wood drying process advances it leads to the removal of bound water and, consequently, the shrinkage of cell walls starts; with possible incidence of defects related to this phenomenon such as end and surface checks.

The aim of this work was to evaluate the difference of partial shrinkage and cracks index in *Eucalyptus grandis* core (with pith) and mature wood (without pith) during natural air drying. Cracks index was measured according to Brazilian Standard NBR 9487 (1986) and partial shrinkage was obtained by stereometric method.

There was not statistically significant difference between the shrinkage of core and mature woods. Lumber from core wood presented worse quality in natural air drying than mature wood. The influence of the piece position in log exerted higher influence on drying quality than the shrinkage.

Keywords: Natural air drying, drying defects, *Eucalyptus grandis*.

Reduction in tropical hardwood dimensional change After an additional heat treatment

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Abstract: Due to the hygroscopic character of wood, a dimensional change can occur in lumber products as flooring and furniture, and prejudice its use. To reduce this effect, this study evaluated the dimensional stability improvement of two hardwood species applying additional heat treatment in conventional kiln and air dried lumber.

The selected woods were species commercially known as Jatoba and Muiracatiara. Quarter and flat sawed boards of each species, both air and kiln dried, were selected from a flooring manufacturer stock. These boards were cut to samples for heat treatment application, which consist in wood exposure to temperatures of 60°C, 75°C and 90°C during periods of 24, 48, 72 and 96 hours.

After heat treatment the samples were conditioned at low relative humidity environment and, after reach equilibrium moisture content, conditioned at high relative humidity environment. The samples rates of shrinkage and swelling were measured after heat treatment and conditioning.

The obtained results allowed to verify that shrinkage of Jatoba lumber was smaller than Muiracatiara one, both in radial and tangential direction. Regarding the air dried wood the shrinkage, as well the swelling, was bigger than kiln dried wood. For the swelling, the Jatoba lumber tangential samples showed higher values than Muiracatiara samples, but the opposite was observed in the radial ones. Lumber exposed to the temperature of 90°C presented the lowest rate of shrinkage and swelling.

It is concluded that heat treatment, mainly at 90° C, reduced the wood dimensional change caused by variation in its moisture content.

Keywords: Tropical hardwood, dimensional change, shrinkage, swelling, heat treatment.

The research of electrode effect on wood drying above fiber saturation point

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Abstract: The electrical resistance method is widely used for monitoring wood drying when the moisture content (MC) of the wood is below fiber saturation point (FSP). But above FSP (MC 30% to 150%) the measurement is complicated as the measuring accuracy is insufficient and repeatability of the results scarce due to unsatisfactory calibration of the method in the mentioned range.

The aim of the study was to investigate the interaction of wood and the measuring electrodes. The experiment of drying of wood was carried out at MC of the wood above FSP, at low temperatures (20°C and 30°C) and at mild drying regimes (98% RH and 96 % RH). The aim was to get the smallest possible MC gradients in the investigated test specimen. Two meters of electrical resistance and three resistance type measuring instruments of wood moisture were used simultaneously in the tests.

Specimens of five different species (*Pinus sylvestris*, *Picea abies*, *Alnus glutinosa*, *Betula pendula*, *Populus tremula*) in the size of 100 x 60 x 60 mm (length x width x thickness) were dried and their MC was measured in uniform conditions (32°C, 96% RH). In total 500 specimens were used in the experiment and the effect of the repeated application of the electrodes on the repeatability of the measurement results was statistically analysed.

In case of pine sapwood and heartwood in the range above FSP also the effect of the processes of corrosion, polarization and depolarization of the measuring electrodes on the measurement results of electrical resistance were investigated.

As a result of the study time limits for periods of intensive growth and stabilization of the corrosion of electrodes were determined. It was also discovered that the polarization and depolarization processes of the electrodes and the wood depend largely on the moisture content above FSP. Residual polarization was also measured and it was determined that in the investigated range above FSP it was relatively stable.

The results of this research can be used to develop the calibration procedure of resistance type wood moisture meters for moisture content above FSP.

Keywords: wood drying, above FSP, corrosion, polarization.

Microcrack occurring during drying in heartwoods with high and low moisture contents

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Abstract: Microcracks occur on the surface of wood at the first stage of drying. It is very important to investigate their morphologic changes because they influence wood quality. In the past study, we visualized microcracks occurring in sapwood of softwood and hardwood with time and it was elucidated that microcracks depended on wood structure. However, it was also assumed that moisture content impacted on microcrack occurring. In this study, microcrack behaviors between black and red heartwoods of Sugi (*Cryptomeria japonica*) that have extremely different green moisture contents and almost the same wood structures were compared.

Small wood samples were cut from heartwood of two green woods. One was black heartwood with 201.5% moisture content. The other was red heartwood with 51.3%. These samples were dried in a controlled environment chamber. Drying temperature was 50°C and relative humidity was below 5%. While the sample was dried, propagation of microcrack was observed with time using a confocal laser scanning microscope. At the same time, electric resistivity of the surface was measured to assess moisture content.

Microcracks appeared on the transverse surface of samples. Most of them occurred at ray parenchyma or between tracheid and ray parenchyma in latewood zone. They advanced toward both pith and bark directions. After they showed maximum shape, they closed, but persisted until the last stage of drying.

There were little differences of these characteristics between black and red heartwoods. However, time until the initial microcrack occurred was quite different between black and red heartwoods.

Keywords: microcrack, heartwood, *Cryptomeria japonica*, confocal laser scanning microscopy

Some aspects of beech wood discolouration during and after drying

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Abstract: Many factors influence the colour of beech wood and some of them are related to drying conditions. Air dried beech wood normally has a uniform pale colour (unless a red false heartwood occurs), used to be called “white” among experts in Europe. Concerning kiln dried beech wood the situation is not the same, as it varies too much from pale reddish to dark brown-red colour.

Present paper adds some more information how to mitigate beech wood discolourations after kiln drying, focusing mainly on experiences and observations made using different handling just after drying of Greek origin beech wood. In order to further examine the discolourations just after drying, during dried lumber storage and further conversion phases, a series of experiments carried out using beech wood, measuring specimens exposed to indirect natural light.

Colourimetric analysis revealed a movement towards darker colours but simultaneously colour differences became less important. Exposition to slight air circulation, in quite dark conditions, revealed also a mitigation in colour differences but not to the same degree.

Keywords: Wood drying, discolouration, beech wood.

Occurrence of cracks in fence posts of *Eucalyptus* sp during the air drying

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Abstract: The eucalypt wood has as inconvenience the incidence of cracks from felling the tree until the end of drying. Round wood used as fence posts must have a low index of cracks to inhibit or prevent colonization by wood decay agents. The objective of this study was to evaluate the index of cracks in fence posts of various species of eucalypt.

Were used fence posts of *Eucalyptus* sp from eight provenance trial stands with 4 year olds, planted in the city of Ribas do Rio Pardo, Mato Grosso do Sul, Brazil. Those posts had 1.50m of length and diameter ranging from 11.2 to 14.8 cm.

After feeling the posts were transported to the city of Botucatu, São Paulo, then debarked and stacked to air drying protected from rainfall. The drying time of the posts was long enough to reach the equilibrium moisture content.

The severity of cracks was evaluated by measuring the length of the cracks along the piece, expressed as the index of crack; which compares the sum of the lengths of the cracks with the total length of the post.

The results showed that the provenances of *E. citriodora* and of the hybrid *E. urophylla* x *E. camaldulensis* (Proc. vm01) are less prone to crack and, for the diameter class evaluated, those species are most suitable for use as fence posts.

Keywords: *Eucalyptus* sp, index of cracking, round wood, air drying

Drying and machining properties of poplar hybrid clones from three growing sites

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Abstract: Drying quality of seven hybrid poplar clones from three growing sites was evaluated on 35-mm thick boards following three types of drying schedules, high temperature (HT, 95-115°C), elevated temperature (ET, 82-90°C), and conventional temperature (CT, 50-82°C).

Machining tests were also performed on the kiln-dried specimens at 8% MC according to ASTM D 1666-87. Drying quality assessment was based on drying rate, final moisture content variation, shrinkage, warping, surface and end check frequency, and color change.

Overall, drying performance was affected in decreasing order by kiln-drying treatments, log position, and clones. The high initial moisture content of poplar boards combined with their low density and apparent variable permeability made them prone to collapse, especially during HT drying. Drying time varied with a ratio of 2, 1.5 and 1 for CT, ET, and HT, respectively. ET and CT drying schedules were more suitable to minimize color change and checking.

Poplar clones performed well for planing and sanding. Machining performance was affected in decreasing order by machining processes, clones, kiln-drying treatments, and growing sites. The best planing was obtained at a 20° rake angle and at 24 knife marks per 25.4 mm.

Conventional drying positively affected planing performance compared with the other two drying processes. Sanding using 180-grit sandpaper performed best. Three clones were selected as more suitable for machining and one for drying.

Keywords: Wood drying, drying behavior, hybrid poplars, machining.

Hailwood and Horrobin sorption isotherms for tropical woods: *Brosimum rubescens*, *Enterolobium schomburgkii* and *Carapa guianensis*.

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Abstract: The equilibrium moisture content is one of the main parameters in the development of the drying process and the final use of wood. Given the lack of information regarding the equilibrium moisture content of tropical woods, extrapolations based on data obtained for temperate woods are used, with considerable deviations in some cases.

Adsorption isotherms for andiroba (*Carapa guianensis*), satine (*Brosimum rubescens*) and batibatra (*Enterolobium schomburgkii*) woods were determined experimentally, in environments with temperature and humidity controlled by means of saturated saline solutions. The Hailwood-Horrobin one hydrate model was fitted with experimental data.

A general tendency toward a reduction in the equilibrium moisture content with an increase in temperature and an increase in the equilibrium moisture content with an increase in relative humidity was observed.

The hygroscopicity of the *Carapa guianensis* wood is greater than that of the *Enterolobium schomburgkii* wood, which in turn is greater than that of the *Brosimum rubescens*. The possible causes of this variation are the chemical composition and the accessibility of the adsorption sites. The isotherms fitted to the Hailwood and Horrobin model obtained coefficients of determination above 97%, with average relative errors of 4.8%.

The adsorption energy increased in the order *Brosimum rubescens*, *Enterolobium schomburgkii* and *Carapa guianensis*, partially explaining the same tendency observed for the equilibrium moisture contents.

Keywords: Sorption isotherm, adsorption energy, Hailwood and Horrobin isotherm.

Nondestructive evaluation of drying stress level on wood surface using near infrared spectroscopy

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Abstract: We propose a non-destructive technique for rapidly measuring the stress level of wood surface using near infrared (NIR) spectroscopy combined with multivariate analysis.

Five boxed-heart square timbers of Sugi (*Cryptomeria japonica* D. Don) were dried at a temperature of 45°C. A Partial least squares (PLS) regression model for predicting surface released strain (ϵ) was developed using NIR spectra obtained from the 4 timbers during drying. The predictive ability of the model was evaluated with the remaining timber not included in the model development.

The PLS regression model gave a strong correlation between laboratory measured ϵ and NIR predicted ϵ . The R^2 was 0.81 and the standard error of prediction was 0.0013 within the ϵ range between -0.0046 and 0.0045. The ϵ change during drying that was predicted by the model showed a similar trend as the laboratory measured one. The predicted elapsed times to reach the maximum tensile ϵ and stress reversal roughly coincided with the laboratory measured times.

These results suggest that NIR spectroscopy has potential to predict the drying stress level on timber surface and to detect the critical periods in drying, such as the points at maximum tensile stress and stress reversal.

Keywords: wood, drying stress, surface released strain, nondestructive evaluation, near infrared spectroscopy

Dual-Energy X-Ray absorptiometry as a potential tool for non-destructive evaluation of two-dimensional moisture content distribution and average moisture content in solid wood

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Abstract: The objective of this study was to improve the new method to evaluate moisture content in solid wood using dual-energy X-ray absorptiometry principle suggested in our previous study. A newly developed flatbed digital X-ray sensor instead of analog X-ray films was used to obtain X-ray images of wood samples and ion-exchange water using two different X-ray beams generated with 15 kVp and 40 kVp tube voltages.

A linear relationship was shown between wet-basis moisture content and average PMMA-equivalent-thickness ratio of 15 kVp to 40 kVp. A linear regression equation was derived from the relationship, and the standard error of estimate using the equation was determined to be 14 %. Eliminating the estimates of ion-exchange water, the standard error of estimate was 12 %, which is almost the same error as the standard error of estimate 10 % in the previous study.

This result shows that a prediction of moisture content of a large sample has almost the same accuracy as a prediction of moisture content of a small sample. The necessary duration of X-ray exposure was drastically reduced from 3050 seconds to 49 seconds per one wood sample using the digital sensor. When the method was applied to predicting 1 cm square mesh moisture content distribution of a 24 %-moisture-content sample, however, the standard error of estimate was 23 %.

Observing the X-ray radiographs showed that the errors were caused in part by the artifacts probably due to the presence of the sample on the sensor. Even though further investigation is necessary for reducing the standard error of estimate, the DXA method in the present study has a great potential to predict solid wood moisture content non-destructively.

Keywords: dual-energy X-ray absorptiometry, non-destructive evaluation, moisture content, moisture content distribution, *Cryptomeria japonica*

Estimates of equilibrium moisture content of wood to the city of Paragominas (PA)

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Abstract: Whereas the seasonal variation in moisture content is a factor of major importance both in natural drying as well in artificial drying of lumber, the objective of this paper is to present estimates of the wood equilibrium moisture content for the city of Paragominas, Pará, Brazil.

This kind of information is very important for local lumber processing industries, to guide its drying process to reach moisture content values that enable the flawless performance in the mentioned locality.

The estimates were made applying the equations proposed by Simpson, which are based on the sorption theory of Hailwood and Horrobin. The climatological data for the periods 1973 - 1988 and 2000 - 2011, were provided by Eastern Amazon Embrapa and the National Institute of Meteorology, respectively.

It was noticed, for the city of Paragominas, monthly values of the equilibrium moisture content from 13.7 to 19.2%, with an average of 16.6%. The air dried lumber hardly will reach moisture content below this value, being imperative the artificial drying in the case of products directed for marketing in drier sites.

Keywords: Simpson equation, equilibrium moisture content, lumber drying.

Moisture movements during drying of green glued glulam beams from Norway spruce sideboards

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Abstract: Form defects such as cup, crook, twist and bow, often causes low volumetric and economical yield in dried sideboards of Norway spruce. The high stiffness and density of sideboards, however, make them attractive to use as structural timber. The green gluing process i.e. gluing of unseasoned timber (with the subsequent drying) can make gluing of side boards efficient and can overcome the difficulties in utilization of side boards for structural applications.

In present work, a study where computed tomography was used to monitor the drying process of a green glued glulam beam is presented. The beam had a dimension in cross-section of approximately 105×235 mm² and consisted of eleven sideboards, planed and flat wise glued together with a 1-component polyurethane adhesive. After curing, and prior to drying, the beam was split into two halves, of approximate size of 50×235 mm².

The drying took place in a small drying kiln and computed tomography scanning was done every second hour throughout the drying process to get the density distribution in the beam. When the drying was finished the temperature in the kiln was increased to 103 °C and kept for 24 hours, as to get a dry density reference. By use of an algorithm for subtracting the dry density, the moisture evaporation throughout the drying process could be estimated. Despite the harsh drying conditions, with a wet bulb depression of 10 °C already from the start of the drying process, no formation of cracks or other quality problems could be seen in the process. Neither could any moisture gradient from the outer to the inner boards be detected.

Keywords: Computed tomography, process monitoring, moisture gradient.

CT scans of appearance grade radiata pine boards during accelerated temperature (90°C) drying

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Abstract: An X-ray CT scanner is used to scan twelve 100x25mm boards during drying at 90°C dry bulb, 60°C wet bulb. Twenty scans at 10mm intervals along the length of each board are taken at 6 points in time during drying and after steaming.

An elastic image registration technique is described allowing the moisture content to be computed from the moisture and oven dry density maps. While the original intent of examining surface check formation could not be achieved due to insufficient spatial resolution at edges, the resulting images are useful, showing that moisture content distributions in drying are variable both within and between boards and that simplistic assumptions based on homogeneous moisture movement rarely apply to actual boards.

This dataset could be used provide the necessary moisture distribution data to drive a finite element stress analysis.

Keywords: Wood drying, drying behavior, moisture distribution.

Mathematical model of drying *Hevea brasiliensis* wood

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Abstract: This work proposes the fitting of drying curves obtained experimentally for *Hevea brasiliensis* wood through a mathematical model. This fitting was based on the Simpson model and the chi-square statistical method. Simpson's model states that drying rate wood is proportional to average moisture content.

In order to establish the construction the drying curve, it was used 108 specimens of *Hevea brasiliensis* wood with dimensions 10 mm x 20 mm x 100 mm that were drying in a laboratory kiln. The drying control was performed through gradual temperature increase in order to minimize the errors arising due the drastic loss of moisture by wood. The drying was made by the gravimetric method where the mass was weight every six hours until the timber reached the theoretical anhydrous state.

The drying curve for rubber wood obtained with the simulation made here can be used for estimating the dry time of this species for different kiln temperature settings.

Keywords: Wood drying, mathematical model, rubber wood.

Moisture gradients in thickness and length of teakwood boards

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Abstract: It is known that wood presents moisture gradients during drying, as in thickness as well in length, and these gradients may cause drying defects and poor quality lumber. Due the physics of moisture movement, lumber dries faster at end and surfaces, leading to higher moisture content in the inner part of boards.

The aim of this work was to study the moisture content variations (gradients) along length and thickness of air dried teakwood boards.

Six representative boards of teakwood, with nominal dimensions 40 x 180 x 2.300 mm, were taken from an air drying pack. Initially each board was shared (but not cut) in 30 equal parts, and the moisture gradient across thickness was measured in each part, with a resistance moisture meter. Those measurements were done at deepness of 10 and 20mm, representing 1/4 and 1/2 of board thickness, respectively.

Then the boards were trimmed with a circular saw cutting samples of 50 x 50 x 50mm, which represented the area penetrated by the electrodes. The samples moisture content was measured by the oven dry method, and the result allowed to determine the moisture gradient along the length.

Outer faces of teakwood boards, represented by a more mature tissue, had higher moisture content than inner faces, represented by a more juvenile wood. Moisture gradient in thickness agreed with literature, with higher moisture content at 1/2 than at 1/4 of thickness. Moisture gradient in length of teakwood boards was very heterogeneous, and crescent moisture from one extreme to another was the most frequent pattern.

Keywords: Natural wood drying, moisture gradient, teakwood.

Development of defects and scores for the elaboration of drying schedules and tropical species grouping

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Abstract: The kiln drying behavior of lumber can be estimated through a drastic drying at 100°C, which is conducted using small samples with 10 x 50 x 100mm dimensions. This methodology is based on a statistical approach which correlates the samples drying rate and related defects to kiln schedules.

Seventeen lumber species from Amazon region were sampled and tested, getting an indication of individual kiln schedule (initial temperature, final temperature and drying potential) as well the propensity to show defects during a conventional kiln drying.

Considering that species with similar results in the drying test can be submitted to the same kiln schedule, it was possible to group those species according its drying behavior.

As a result, it is suggested a division of the 17 species in four groups: the first with *Dinizia excelsa* Ducke., *Parkia* spp., *Couratari oblongifolia* Ducke & R. Knuth., and *Vantanea parviflora* Lam.; the second group formed by *Hymenolobium petraeum* Ducke., *Goupia glabra* Aubl., *Schizolobium amazonicum* Huber ex Ducke., and *Caryocar villosum* (Aubl.) Pers.); the third one with *Iryanthera grandis* Ducke., and *Tachigalia myrmecophilla* (Ducke) Ducke.; and the last group including *Cariniana micrantha* Ducke., *Cedrelinga catenaeformis* Duck., and *Couratari stellata* A. C. Smith.

Although those grouped species could be dried following the same kiln schedule, it is important to control the drying process based on the species more difficult to dry (lesser drying rate and higher propensity to develop drying defects).

Keywords: Wood quality, kiln schedule, drying defects, species grouping.

Drying of the Amazon tropical timber

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Abstract: The objective of this study was to evaluate the behavior of woods Ipe (*Tabebuia* spp), Jatoba (*Hymenaea* sp) and Muiracatiara (*Astronium lecointei* Ducke) submitted to air drying.

Lumber of those species was packed for seasoning, getting three packs (one for each species) with approximate dimensions of 1.0 x 1.0 x 2.80 meters (height, width and length respectively).

During the packing the lumber was qualitative and quantitative evaluated concerning the proportion of knots, checks and warping. Initial moisture content of the boards was determined by random sampling and using the oven dry method, according procedures described in Brazilian standard NBR 7190/97. The moisture loss during air drying was measured with the traditional drying control samples, distributed along the laterals of the packs.

Among the species studied there was observed a higher proportion of knots in Muiracatiara, the largest proportion in checks in Ipe and no visual defects in Jatoba. didn't show visual defects.

As expected, it was also observed that the fast moisture loss occurred in boards positioned on the top and on the extremities of the piles.

However, it is known that the loss of moisture from the wood is related to many factors especially its anatomical structure. Among the species evaluated in the process of air drying, Ipe has presented the slowest drying rate, followed by Muiracatiara and Jatoba.

Keywords: wood moisture content, air drying, tropical lumber, Amazonia species.

Use of logs steaming to reduce end-cracks in the sawing and drying of *Hevea brasiliensis* Wood

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Abstract: The *Hevea brasiliensis* wood (rubberwood) presents some difficulties during processing, in part due to incidence of defects associated with the growth stresses, such as cracking and warping.

As one technique used to reduce these defects is called logs steaming, the aim of this study was to evaluate the effect of log steaming in the development of cracks index after sawing and drying of rubberwood. For thus, logs were collected from a 53 years old *Hevea brasiliensis* plantation, located at Fazenda Água Milagrosa, in Tabapuã city, São Paulo, Brazil.

Half of the logs were steamed during 36 hours at a temperature of 90°C and 100% relative humidity, and the other half was kept untreated. All logs were sawed by the system tangential and the obtained lumber was kiln dried. Cracks were evaluated after the logs sawing and after lumber drying.

The results showed that: (1) The log steaming promoted significant decreases in cracks index (37,0% after sawing and 42,4% after drying) in the boards from logs that have reached the temperature of 55 and 60°C in center; (2) the drying caused an increase in index cracks up to 51,8% for boards from logs that do not have reached the temperature of 55 and 60°C in center.

Keywords: log steaming, *Hevea brasiliensis*, end-cracks.

Analysis of costs and energy consumption during drying of hardwoods in Kosovo

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Abstract: In the manufacturing of most hardwood products, drying is a vital procedure. Only after much of the moisture has been removed from wood is the material ready to be made into useful products. Wood drying is the most time and energy consuming process in the hardwood lumber industries. A number of methods are available for drying hardwood lumber, ranging from air and kiln drying to special seasoning processes. The paper presents results of analyses of energy consumption and costs during drying of the two main hardwoods produced in Kosovo: Turkey Oak (*Quercus cerris*) and European Beech (*Fagus sylvatica* L.).

Two drying techniques were analyzed: controlled air drying and normal temperature kiln drying. The wood samples (dimensions: 1000mm x 250mm x 28mm) were air dried from green condition to below fiber saturation point continued by kiln drying to the final moisture content of 12%. During the drying processes wood quality was evaluated regarding drying rate, time of drying, moisture content gradient, casehardening and occurrence of drying defects.

Results showed that the energy consumption during drying process had a significant effect on the final costs of the hardwood products in Kosovo.

Keywords: air drying, kiln drying, costs, energy consumption, drying quality.

Comparing methods to indicate conventional kiln schedules for tropical species

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Abstract: To indicate adequate kiln schedules to dry lumber of the lesser known species still is complicated. Besides the traditional trial and error method, the available methodologies could fail because it did not represent the real conditions of an industrial drying process or due the need of excessive time and work.

The most common and of easy access methods are based on the lumber specific gravity or on its maximum moisture content; but those methods do not consider physical characteristics as the permeability as well the tendency to present drying defects as surface and end checking. Amongst the methods that consider the effect of the lumber physical characteristics on its possible behavior during the kiln drying, the technique which quantifies the rate of moisture loss and intensity of drying defects, when the lumber is submitted to a drastic drying condition, results in a more coherent suggestion of conventional drying schedules.

This paper compare the kiln schedules obtained according two methods based on specific gravity and according the method of fast drying of small samples (1.0cm of thickness, 5.0cm of width and 10.0 cm of length) at constant temperature of 100.0°C.

For 12 tropical lumber species, the method of fast drying resulted in more conservative schedules, also allowing to group different species in a same kiln schedule and pointing which is the more difficult to dry species. This information is important to industrial drying operation, because it is possible to control the drying process based on the more problematic species and to reduce the level of losses due drying defects.

Keywords: Kiln schedule, tropical lumber, kiln drying.

Study of wood drying with two-stage compression high temperature heat-pump

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Abstract: A drying equipment of two-stage compression high temperature heat pump was developed. This heat pump drying equipment is capable of switching between one-stage compression and two-stage compressing.

Components and working principle of two-stage compression high temperature heat pump equipment were introduced in this paper.

Drying experiment was conducted with *Pinus massoniana*. The results showed that this equipment had great energy saving performance and the average energy recycling rate could be achieved beyond 28%.

Meanwhile, by means of two-stage compression and utilization of new refrigerant (R245fa), condensing temperature and heating temperature reach 120° and 110°, respectively.

Keywords: High temperature, wood drying, two-stage compression, energy saving, *Pinus massoniana*.

Effect of drying temperature on preservative impregnation in Japanese Cedar

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Abstract: There has been much research into the relationship between drying methods and preservative impregnation. Different drying methods have been reported to have an influence on the penetration of Japanese cedar. However, the details are unclear. In this study, sapwood of Japanese cedar dried under different temperatures were impregnated with preservative. The absorption and penetration of the preservative were then investigated.

A green Japanese cedar (*Cryptomeria japonica*) log was used in this study. Two types of log were cut from this log: 20 cm logs to make small drying samples and 50 cm logs to dry directly. The 20 cm logs were cut into eight equal pieces passing through the pith. Samples containing only sapwood (S) or both sapwood and heartwood (SH) were prepared from these. Half of both the S and SH samples were coated with epoxy resin except for the bark sides. The rest were not coated.

After being dried at six different temperatures, namely, 20, 37, 60, 80, 100, and 120°C, stick specimens were cut from the sapwood of the dried samples. These specimens were coated with epoxy resin, except for one side of the transverse ends, and were then impregnated with copper azole (CUAZ) solution using a vacuum treatment method. Absorption was measured from the weight of the specimens before and after impregnation. The penetration area was determined after visualization of the preservative on transverse surfaces with chrome azurol S. The 50 cm logs were dried at 20 and 100°C. Absorption and penetration area were investigated in the same way as that for the small drying samples.

In coated samples, a great difference in absorption and penetration was observed, depending on the drying temperature. However, there was no difference between the absorption and penetration observed in S and SH. On the other hand, absorption and penetration in logs dried at 20°C were significantly better than those in logs dried at 100°C. From these results, it was concluded that drying temperature is one of the factors affecting CUAZ impregnation in Japanese cedar.

Keywords: Impregnation, drying temperature, *Cryptomeria japonica*.

Behavior of temperature in *Hevea brasiliensis* wood during the logs steaming

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Abstract: Log steaming is a technique applied previously to drying in order to reduce the levels of growth stress, to increase the permeability and drying rate, to improve the dimensional stability, and to reduce the initial moisture content and moisture gradient. *Hevea brasiliensis* (rubberwood) is a species with high level of growth stress, which causes defects at sawing process and during drying. The application of the log steaming is thus attractive to minimize defects in the wood processing. So, the objective of this study was to investigate the behavior of the temperature during the log steaming of *Hevea brasiliensis*.

Eight logs of *Hevea brasiliensis*, with 53 years old and average diameter of 33.9cm, were used in the experiment. Disks were obtained to determine the moisture content and specific gravity of wood. In the logs were inserted thermocouples type "T" in order to register internal temperature, which was recorded by a Datalogger. The log steaming process was carried out on logs in a dryer for 36 hours under steam at 90°C and 100% relative humidity.

The results showed that the average specific gravity was 0,54 g/cm³ and the average initial moisture content was 87,97%. Maximum temperature reached in the center of logs was 74,2°C. These results are important to determine the exact time to the log steaming process.

Keywords: Log steaming, *Hevea brasiliensis*, temperature

Effect of thermal modification on physical properties of juvenile and mature woods from *Eucalyptus grandis*

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Abstract: The dimensional variation of wood can difficult the use of certain species where dimensional stability is an important factor. At present, the option for the use of more stable limber species may have impediments due to economic factors and limited availability. One of the main disadvantages of *Eucalyptus* wood is its pronounced heterogeneity and shrinkage. An attractive way to improve the dimensional stability and thus add value to the wood is the use of thermal treatments on the material.

Thus, this study was aimed at evaluating the effect of thermal modification on the physical properties of juvenile and mature wood from *Eucalyptus grandis*.

This study utilized wood from 30 years old *E. grandis* trees collected from a Forestry Institute of São Paulo plantation located in Manduri, São Paulo, Brazil. Four dried boards were planed to 24mm thickness and cut into smaller pieces measuring 0.60m in length. One of these samples was kept in its original condition, and the other piece was reserved for the thermal modification at 180°C over a period of 2.5 h according to the application of patent developed by Severo and Calonego (2009).

Then samples measuring 30x20x50mm were cut and placed in a oven at 103±2°C until they reached 0% moisture content, following procedures described in Brazilian standard NBR-7190/97. Subsequently, the samples were placed in a climatic chamber at 21 °C and 65% relative humidity (RH) and later were submerged in water until the cell walls were completely saturated. After each hygroscopic phase, the samples were weighed, and their dimensions were measured by using a 0.01g accuracy balance and a 0.01mm accuracy micrometer.

The results showed that the thermal modification caused: (1) decrease of 6.8% in the density at 0% equilibrium moisture content of mature wood; (2) significant decreases of 35.6%, 38.9%, 25.5% and 56.7% in the maximum volumetric, tangential, radial and axial swellings of mature wood; (3) significant decrease of 14.7%, 13.4%, 14.2% and 39.4% in the respective properties of juvenile wood; (3) significant decreases of 13.7% and 21.3% in the equilibrium moisture content of juvenile and mature wood, respectively.

The influence of thermal modification in juvenile wood was lower than in mature wood and caused a greater uniformity in the physical variations between these types of wood.

Keywords: thermally-modified wood, *Eucalyptus grandis*, juvenile and mature wood.

Effects of PF impregnation on drying of poplar lumber

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Abstract: Several techniques has been studied to improve physical and mechanical properties of plantation poplar lumber, to increase the added value, and to extend application field of low density planted lumber.

The influence of drying on planted Poplar lumber (*Populus tomentosa*) strengthened with low molecular weight phenol-formaldehyde (PF) resin was studied in this paper.

Results showed that the PF impregnated lumber's drying rate and diffusion coefficient was evidently lower than that of control samples. When MC is beyond FSP, the drying rate for tangential and radial board is just 21.1% and 26.2% compared to control samples, and diffusion coefficient was 25.2% and 32.1% of that for control samples.

When MC is below FSP, the drying rate for tangential and radial board is just 22.9% and 34.3% compared to control samples, and diffusion coefficient was 22.2% and 34.6% in the same comparison. The PF impregnation influenced the difference between tangential and radial board's drying, its difference was disappeared.

Keywords: PF, Impregnation treatment, poplar lumber, drying

Evaluation of crack incidence in two diameter class fence posts of *Eucalyptus* sp.

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Abstract: This study approach was the possibility that different classes of diameters of the same species may present significant differences in size and intensity of cracks when dried in the same way, due possible effects of physical properties and growth stresses. So, the experiment correlates the fence post diameter to the level of cracks occurred during air drying.

Fence post of *Eucalyptus urophylla*, *Eucalyptus camaldulensis* and a hybrid of *Eucalyptus grandis* x *urophylla* were collected from uniform plantation. The posts, with 1.5m long meters and diameter classes ranging from 10.0 to 14.5 and 15.5 to 25.0cm were cut and debarked in the same, and then exposed to air drying under shelter (to avoid rainfall) until reach the local equilibrium moisture content.

The severity of cracks was evaluated by measuring the length of the cracks along the piece, expressed as the index of crack; which compares the sum of the lengths of the cracks with the total length of the post.

The results showed that index of cracks were always lower in the smaller diameter classes for all species of *Eucalyptus*. For *E. urophylla* wood, the index of crack at the base of large fence posts was 80.0% higher than of the smaller diameter, and at the top, the difference was about 38.3%. For the hybrid of *E. grandis* x *urophylla* this difference was, respectively, 9.5% and 160.0%; and for *Eucalyptus camaldulensis*, 56.0% and 228.5%.

Keyword: *Eucalyptus* spp, round wood, air drying, end cracking.

Spreading and penetration of a water droplet on native and heat-treated wood

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Abstract: A custom device was conceived to place a water droplet (diameter c.a. 0.5mm) at the surface of wood and follow its evolution. The device comprises a minute needle, micrometric displacement stages, a backward light, a telecentric magnifying lens and a fast camera.

Before each test, the wood surface was carefully prepared using a sledge microtome. Due to the difficulty to cut heat-treated wood, the surface was always prepared before heat treatment (220°C, 1 hour). Earlywood and latewood samples of fir, before and after heat-treatment, were tested with the droplet placed on a transverse section (imbibition along the longitudinal direction). Image processing allows the evolution of droplet height, droplet diameter and apparent contact angle to be obtained.

Based on the Washburn's law, a theoretical model was developed to predict the evolution of the droplet height, using the evolution of the droplet diameter as input parameter. Simulated and experimental curves were matched by tuning one single parameter, the true contact angle.

This theoretical model allowed the competition between spreading and penetration depicted by the experimental data to be analyzed in detail:

- the porosity promotes penetration and weakens spreading,
- the contact angle is reduced by heat-treatment,
- the identified values of the true contact angle are always very close to 90°.

Keywords: Porous medium, capillary imbibition, surface tension, theoretical model, contact angle.

Comparing electrical moisture meters for lumber

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Abstract: Electrical moisture meters are very useful in the various lumber manufacturing processes, but it is desirable to get accurate readings of the lumber moisture content. Considering the great diversity of models available, this paper aimed to compare two models from the same supplier as to the readings accuracy.

Moisture content of five tropical species (Boleiro, Cambará, Mescla Arueira, Orelha de Macaco e Taxi) was measured using moisture meters supplied by Lignomat, models MiniMaster HT and Ligno VersaTec. Ten samples of each species (10.0 cm wide, 20.0 cm long and 2.0cm thick) were exposed to air dry with periodical mass and moisture content measurements, till the samples reach equilibrium moisture content. Then the samples were oven dried at 103°C (± 2) to obtain dry weight and to estimate the moisture along the air drying period.

The results were analyzed through linear regression to select the best calibration for each one of the two meters. The HT model has 20 settings for lumber species while the VersaTec model has 98 settings alternatives. Due this difference between models the HT meter could be adjusted to read moisture content for Boleiro, Cambara and Orelha de Macaco with adequate accuracy, while it was possible to get good moisture readings for all five species using the VersaTec meter.

This result was already expected, considering that VersaTec have more up dated technology and a great number of settings possibilities for different lumber species. The main conclusion is that VersaTec moisture meter have the best species settings and allowed more accurate measurements of lumber moisture content for all species tested.

Keywords: Electrical moisture meters, lumber moisture content, lumber drying.

Intelligent sensor architecture based on cyberphysical systems for behavior detecting in wood during processes

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Abstract: The use of more than one sensor to monitor a process is a common practice nowadays. Different kinds of sensors need to be integrated in a system in order to obtain some characteristic of the process.

The focus of this work is to develop new methods in design and construction of intelligent sensors based on cyberphysical systems (CPS) concept to the particularities of the wood drying processes (microclimate). This paper presents the development of a system prototype for remote data acquisition of environmental variables called BRASSEN (acronym to Blue Rain Analyses System Sensor).

The system performs all the functions of a Datalogger and has the task of analyzing climate behaviors in environmental and wood drying process by an intelligent agent, which contains expert systems of the standards related to environmental variables of temperature and relative humidity, and its relation with lumber kiln.

Keywords: Wood drying, drying behavior, quick test, drying control.

Importance of kiln drying to quality standard of solid wood flooring produced in Brazil.

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Abstract: In the wood based industry, kiln drying is an essential step in any manufacturing process of added value product like flooring, furniture or solid doors.

For the solid wood flooring, the National Hardwood Flooring Association (ANPM) established a Quality Control Program to keep a high quality standard for the product, to meet customer requirements and to avoid technical barrier in the international market. Among characteristics as aesthetical aspects, dimensional tolerance and manufacturing defects, the moisture content is the most important aspect due its effect on dimensional changes and possible warping after installation.

This paper presents the evolution of the flooring moisture content as a quality parameter. According the quality standard proposed by ANPM and published by the Brazilian Association for Technical Standard (NBR 15799/10) it is accepted a tolerance of $\pm 1.5\%$ in the nominal moisture content declared by manufacturer; and 95.0% of the inspected pieces should meet the tolerance range.

Results obtained in eight sequential audit inspections, in six different flooring mills, showed an improvement in this quality parameter, increasing the percentage of pieces meeting the standard requirement; but it was also proved that there is no homogeneity in moisture content variation along the time. This pattern indicates an inadequate control of kiln drying process and highlights the importance of kiln drying to achieve a high quality standard.

Keywords: Hardwood flooring, moisture content, quality program, kiln drying.

Correlations between wood physical properties of 10 eucalyptus clones by multivariate analysis

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Abstract: The physical properties of wood are crucial in many areas of this material industrialization, exerting influence on other properties of wood, as mechanical and chemistry proprieties, inflicting in the final product, as well in the material industrialization. This study aimed the comparative analysis and to determine the correlation between the physical properties of wood along the radial and longitudinal directions of ten clones of high productivity Eucalyptus and Corymbia, for better understanding of the existing relationship between water-wood. To this end, six discs were collected at different heights along the stem - 0, DAP, 25, 50, 75 and 100% - of each individual, were for a clone/hybrid, was felled three individuals, totaling 30 trees, located at Capelinha and Itamarandiba cities, Minas Gerais State, Brazil. The discs were deployed in the small samples for basic density, linear and volumetric shrinkage, coefficient of anisotropy and initial moisture content determination. The analysis results were weighted in order of obtaining an average value for the position. Subsequently, the results inherent to the position were also weighed for obtaining the value on the tree, for further correlation. In the evaluation of the experiment, was used the variance analysis in a completely randomized statistical design and the principal component analysis (PCA) on comparative evaluation of the physical properties of wood. As result, there was a high heterogeneity between studied species, which were divided into four distinct groups mainly by density and total shrinkage. The linear and volumetric shrinkage, as also the coefficient of anisotropy shown to be independent of density and they were significantly correlated between themselves, while density was negatively correlated with the initial moisture content.

Keywords: wood physics, eucalyptus, multivariate analysis

