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THERMAL DEGRADATION OF *EUCALYPTUS GRANDIS*, *PINUS SPP*. AND *GOUPIA GLABA* TIMBER

Edna Moura Pinto
Ph.D., LaMEM/SET/EESC – São Carlos School of Engineering, USP – University of São Paulo, Av. Trabalhador São-carlense 400, CEP 13666-590.   Tel. (++55) 16 3373 8227. São Carlos/SP, Brasil. (emoura@sc.usp.br)

Carlito Calil Junior
Ph.D. Tenured Professor. LaMEM/SET/EESC – São Carlos School of Engineering, USP – University of São Paulo, Av. Trabalhador São-carlense 400, CEP 13666-590. Tel. (++55) 16 3373 9320. São Carlos, SP, Brasil (calil@sc.usp.br)

Abstract

Thermal action on timber causes it to degrade through combustion of its chemical components, which leads to the release of vapors, combustible gases and char. This diminishes its load capacity due to the reduction of its cross section by charring and to changes in its mechanical properties of strength and stiffness as a function of its exposure to high temperatures. The charring rate of timber has been studied in several countries. It is known the results have been obtained in different ways for different species. The purpose of this paper is to study a charring behavior of three different species of wood, planted in Brazil (*Eucalyptus grandis, Pinus Spp.* and *Goupia glaba*). The results obtained from structural members are discusses by numerical and experimental means, Two methods proposed in standards currently used to determination of charring rate will be compared with the results obtained in this experimental and theoretical study. The numerically simulated temperatures obtained for the 10 mm depth were slightly lower than those obtained experimentally. Even so, the result obtained can be considered satisfactory considering the difficulties faced in obtaining thermal parameters for charred and partially charred wood. The results of the numerical model were in good agreement with the experimental results for the 20 and 30 mm depths, indicating that the model can be applied to estimate, to a good approximation, the char depth in structural wood members under conditions of fire.

Keywords: timber, fire safety, charring rate, experimental analysis, numerical analysis.

Introduction

Thermal action on timber causes it to degrade through combustion of its chemical components, which leads to the release of vapors, combustible gases and char. In timber, the reduction of load capacity is due mainly to the gradual decrease in the cross section, Figure 1, which is converted into char, and to the reduction of its mechanical properties of strength and stiffness. In the study of timber as a structural material, the formation of char is thus a crucial parameter in view of the loss of strength of the structural member resulting from the reduction of the cross-section. Studies by Truax (1959) allowed, for estimation of the reference temperature at the base of the charred layer, offering an invaluable aid to determining the rate of conversion of wood into char, i.e., the charring rate. Truax suggested that the charring temperature ranges from 615 to 550 °F (324 to 288 °C). For the purpose of implification, this temperature is assumed to be 290 °C based on proximity to previous researches of White (1988) and EN 1995-1-2 (CEN 2004). The charring rate is therefore an important design factor for evaluating the stability of structural wood elements and their load capacity when subjected to fire. Although the wood inside the beam is not exposed to sufficiently high temperatures it is nevertheless affected by the temperature, which reduces its mechanical properties by degrading its chemical compounds.

Figure 1-Definition of residual cross-section and effective cross-section.

The charring rate of timber has been studied in several countries. It is known the results have been obtained in different ways for different species. The purpose of this paper is to study a charring behavior of three different species of wood, planted in Brazil (*Eucalyptus grandis, Pinus Spp.* and *Goupia glaba*) whose physical and mechanical properties render it appropriate for structural applications.

Methods

This study was conducted with three samples (0.05mx0.20mx2.30m), for each species (*Eucalyptus grandis, Pinus Spp.* and *Goupia glaba*) they were exposed to heat according to the heating curve recommended by the ISO 834 (1999) standard (one face exposition).

Thermocouples were placed at three depths (10mm, 20mm and 30mm),and for some samples the thermocouples were placed at 40mm, Figure 2.

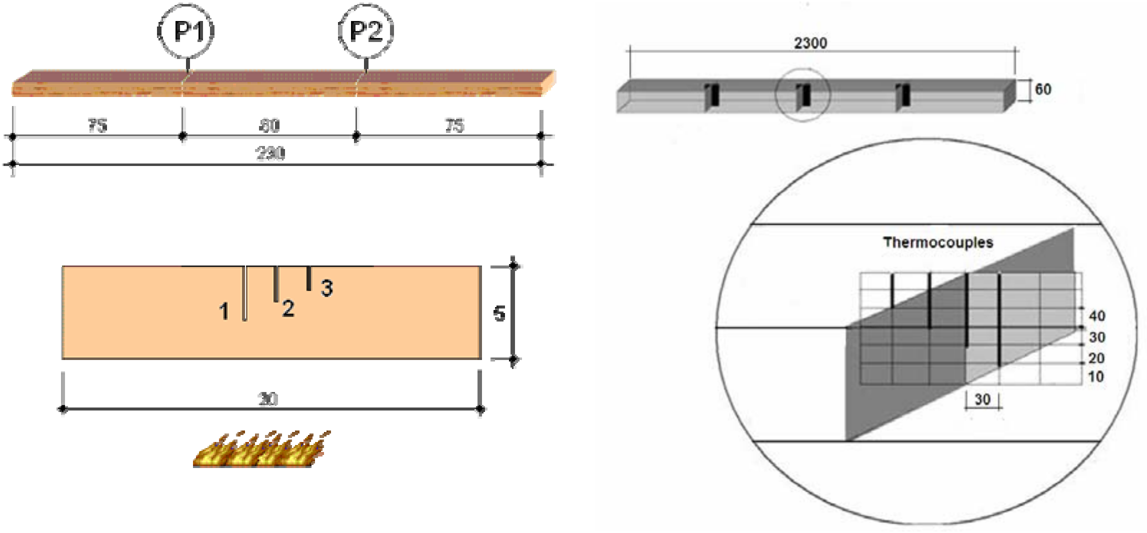

Figure 2 – Thermocouples implantation.

The timbers were placed on the horizontal gas furnace, Figure 3.timber, whose physical and mechanical properties render it appropriate for structural applications.

Figure 3 – Horizontal gas furnace.

Numerical Modeling

The numerical models were built based on the Finite Element Method (FEM), using ANSYS version 8.0 software. The density was determined by thermogravimetric analysis, as described by PINTO (2005).

Specific Heat

The wood's specific heat is given by the curve obtained by essays. Between 0 and 200°C, this curve adopts the equation presented in POON (2003), Eq.1, where c is given in kJ/(kg.K) and θ is the temperature in ºC.

$$c = 1{,}125 + 0{,}00452\ \theta, \qquad (1)$$

The values proposed for temperatures exceeding 350°C are the same as those of the curve presented by Knudson cited by JONES (2001). A linear interpolation is adopted for specific heat values ranging from 200 to 350°C. This approximation is similar to the one adopted by LAPLANCHE et al. (2004) for their numerical models.

Thermal Conductivity

The thermal conductivity adopted was calibrated to obtain a correlation between the experimental results and the numerical model. The initial conductivity of 0.20 W/(m.K), extracted from the graph published by Urakami and Fukayama cited by HARADA et al. (1998), correlates the values of thermal conductivity at room temperature with the density of the wood.

Relative Emissivity and Convection Coefficient

In this study, we used an approach similar to the one presented in Thomas cited by JONES (2001), which resulted in an emissivity of 0.6. The convective heat transfer coefficient adopted was 13.5, as suggested by POON (2003).

Finite elements of the model

Two types of finite elements were used in the numerical simulation: a 2-D element (PLANE77) to model the beam's discretized cross section and a surface element (SURF151) to apply the convective and radiation boundary conditions to the model. The wood's cross-section was divided into 1.0 x 1.0 cm elements, Figure 4. Two layers of SURF151 elements were applied at the surface, one for the radiation effects and the other for the convection effects at the surface.

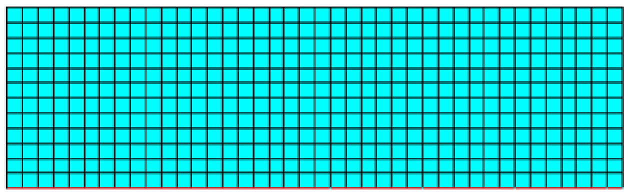

Figure 4 - Discretized cross section

Results and discussion

This research study represents the initial effort in Brazil to the comprehension of tropical timber behaviour on fire. As it is known the results found in literature have been obtained from different ways, in especial for the charring rates. In this study the results were obtain from a real size structural timber beam and it is expected that the experiments results could be express with more accurate a real fire behaviour. The average duration of the tests was 55 min at a maximum furnace temperature of 955°C. The experiment was stopped after the thermocouple at 30mm depth reaches the temperature of 290°C.

Temperature Gradient

The results demonstrate that the temperature near the beam's surface tended to reach a state of equilibrium with that of the external environment, i. e. the temperature of beam surface tends to be near of the temperature of the furnace, figure 5. Inside the section, the insulating properties of the char and the low thermal conductivity contributed to keep the degradation process slow and at an almost constant temperature increase.

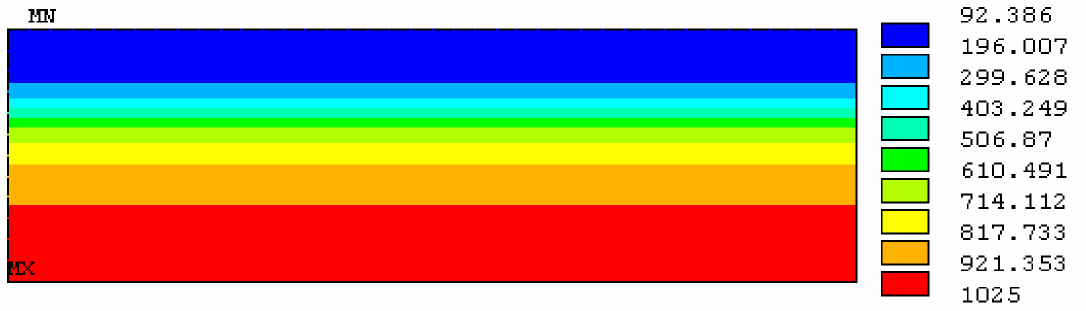

Figure 5 – Model fields of temperature for Pinus sample, t = 60 minutes.

Numerical Modeling

The curves indicate the evolution of temperature as a function of time at the thermocouples installation depths of 10, 20, 30 mm and 40mm. as indicated in Figure 6, 7 and 8.

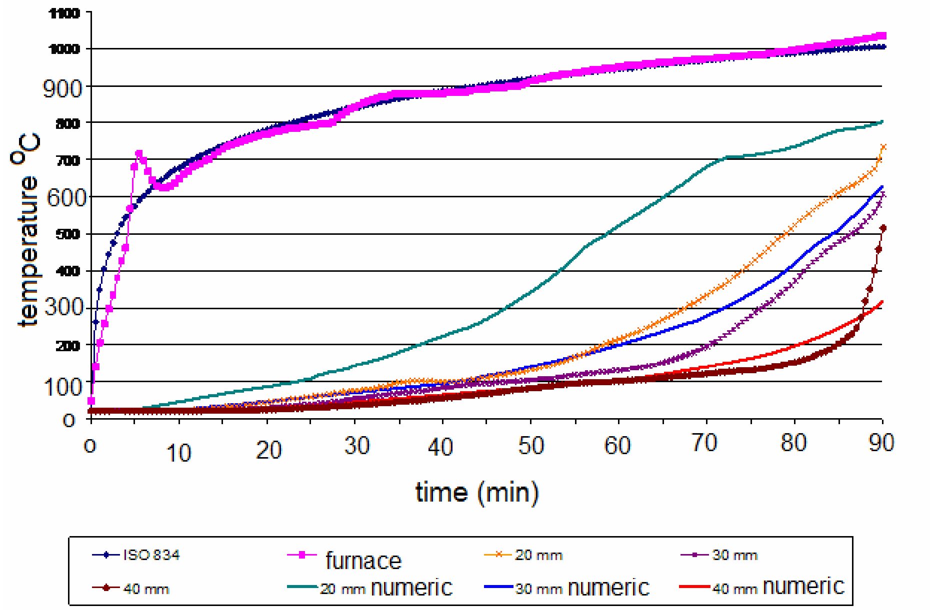

Figure 6 – Evolution of temperature as a function of time for different depths (E. grandis).

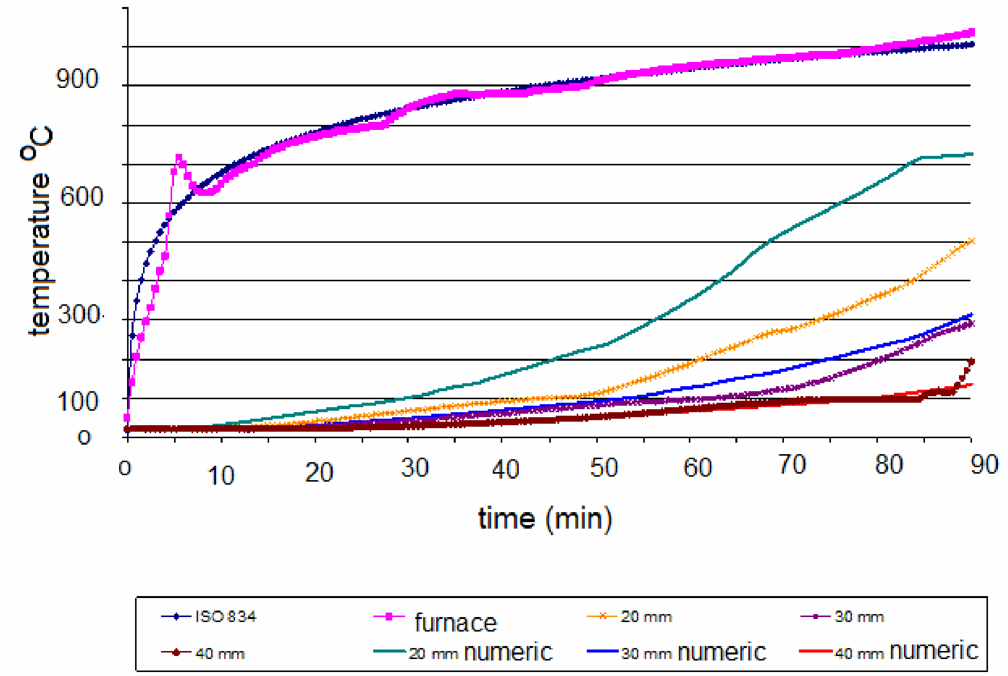

Figure 7 – Evolution of temperature as a function of time for different depths (Cupiuba).

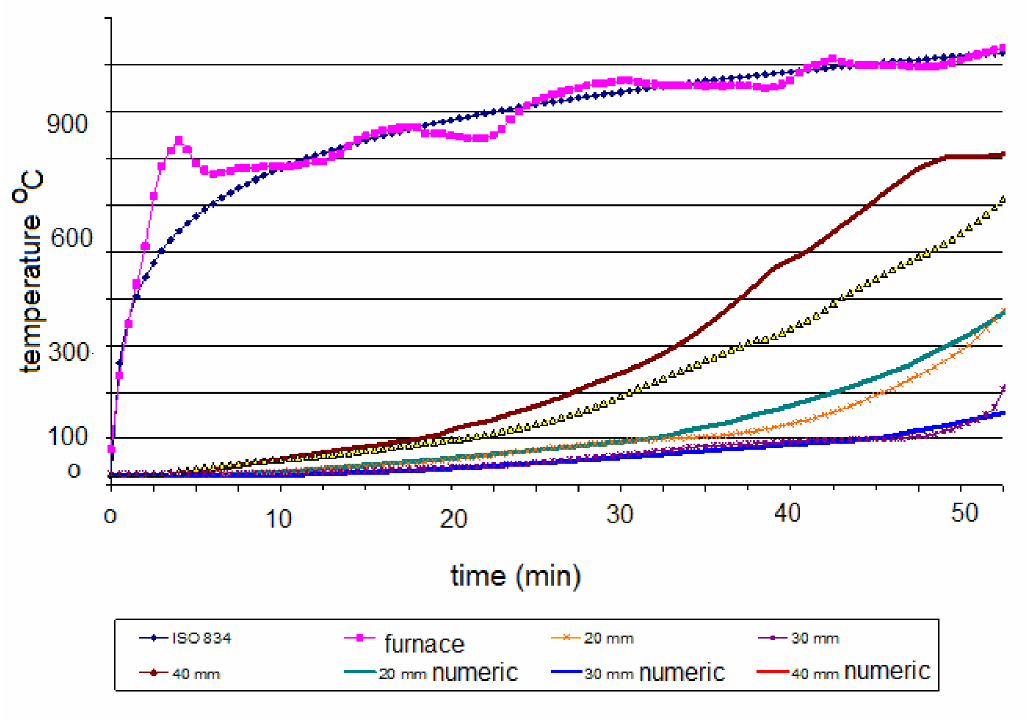

Figure 8 – Evolution of temperature as a function of time for different depths (Pinus).

Charring Rate

The charring rates obtained for the grandis and cupiuba were slightly lower than those obtained experimentally by Schaffer (1967) and White (1988) for hardwoods. The results for Pinus are similar to literatures, Table 1. Results obtained can be considered satisfactory.

Table 1– Charring rates for different species.

DEPTH (mm)	**PINUS**		**GRANDIS**		**CUPIUBA**	
	Charring Rate	**SD**	**Charring Rate**	**SD**	**Charring Rate**	**SD**
10	--	--	--	--	--	--
20	0,5	6,36	0,3	14,5	0,28	0,7
30	0,58	2,3	0,4	1,41	0,34	3,53
40	0,75	2,12	0,45	1,06	--	--

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