Effect of heat treatment of poplar solid wood on physical and mechanical properties

COST Action FP 0904
Thermo-Hydro-Mechanical
Wood Behaviour and Processing

Nancy Université, France
Laboratoire d'Etudes et de Recherche sur le Matériau Bois

Program & Book of Abstracts

Workshop

"Current and Future Trends of Thermo-Hydro-Mechanical Modification of Wood Opportunities for new markets?"

March 26-28 2012
Nancy, France

Preface

Book of abstracts includes the scientific program and the extended abstracts of papers presented at the second COST Action FP0904 conference on "**Current and Future Trends of Thermo-Hydro-Mechanical Modification of Wood, Opportunities for New Markets?" at Université de Lorraine in Nancy, France** on 26–28 March 2012.

The main objective of COST Action FP0904 is to achieve a better understanding on mechanical and chemical transformations of wood during Themo-Hydrous (TH)/ Thermo- Hydro-Mechanical (THM) processing through collaborations between different researchers from the wood and material sciences. This Action provides cooperation and encourages research between research groups from academia and industry to help to overcome the challenges being faced in scaling-up research findings, improving full industrial production, process improvement, in understanding the relations between the processing parameters, materials properties and the development of new products. The COST Action FP0904 consists of three Working Groups (WGs):

WG1: Chemical degradation of wood under Thermo- Hydrous treatment
WG2: Modelling of Thermo-Hydro-Mechanical behaviour of wood during processing
WG3: Innovation and new products by Thermo-Hydro-Mechanical processing

The objectives of this conference is to present and discuss the state of art in THM and TH processing, to identify the problems being faced in transferring the laboratory research finding to industrial production, to get a better understanding of the processing needs, the process improvement, the development of new ideas, new products and opportunities for new markets. The conference will bring together experts and young scientists from European academia as well as from other countries, and industry. The keynote speakers, lecturers, poster presentations and WGs meetings contribute to spread the latest research works, the exchange and development of new ideas and to build up collaborations between laboratories and research activities.

Nancy and Lorraine has a long history in the field of forestry and wood sciences in France and is therefore an excellent place to organize this meeting. This conference is organized by LERMAB staff from Université de Lorraine in association with INRA, CRITT Bois, Pôles Fibres and ARBOLOR.

On behave of the COST Action FP0904 Management Committee I would like to thank everybody that kindly contributed to this Action FP0904 conference: all the authors and specially the keynote speakers, Ramdane Younsi, Antonio Pizzi, Rémi Tessier du Cros and Timo Tetri.
I gratefully acknowledge the help of the Scientific Advisory Committee in reviewing the abstracts and preparing the scientific program.
I thank the Vice-chair of the Action, Dennis Jones for his availability and help.
I express my sincere gratitude to the Philippe Gérardin, Mathieu Pétrissans, Anélie Pétrissans, Christine Gérardin, Stéphane Dumarçay, Anna Poletto, Emmanuel Fredon and Eric Masson for their works in preparing the book of abstracts and organizing the conference.

Parviz Navi
Chair of COST Action FP0904

Current and Future Trends of Thermo-Hydro-Mechanical Modification of Wood Opportunities for new markets?

March 26-28, 2012, Nancy, France

Faculté des Sciences et Technologies - Université de Lorraine
Boulevard des Aiguillettes, BP 70239
54506 Vandoeuvre les Nancy

Congress Organization

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Congress scientific program

Thermo-Hydrous (TH) and Thermo-Hydro-Mechanical (THM) treatments are increasing in popularity primarily at research level, as well as at commercial level across Europe and worldwide. The range of applications associated with these processing tools is considerable, including heat treatment, welding of wood, wood moulding, densification, large bending, profiling, wood artificial ageing surface densification and composite wood panels construction.

Establishing a knowledge base for these techniques will help in the basic understanding of the THM treated wood, through detailed assessment of the complex interactions of wood components at the micro- and macromolecular level. This understanding will help evaluate performance in use, understanding load capabilities, the limitations of products and the overall service life of processed wood. Indeed, these factors will help build up a quality control system for wood and wood products based around TH, THM-open and THM-closed systems.

Considering the preceding points, we expected presentations in the following four sessions:

- Session1: TH treatment of wood
- Session 2: THM treatment of wood in closed system
- Session 3: THM treatment of wood in open system
- Session 4: Market applications of TH and THM treated wood

Congress Venue

Nancy is a city of about 350000 inhabitants and has a large tradition in Higher Education and Research. The 3 Universities of Nancy and another one in Metz have recently merged into the large Université de Lorraine (50000 students). The French School of Forestry was established in Nancy in 1825. There is also a tradition of research and training in Wood Sciences (ENSTIB established in 80's), in Agronomy and in Engineering Sciences.
The congress will take place at the Faculty of Sciences and Technologies, boulevard des Aiguillettes - 54506 Vandoeuvre lès Nancy.

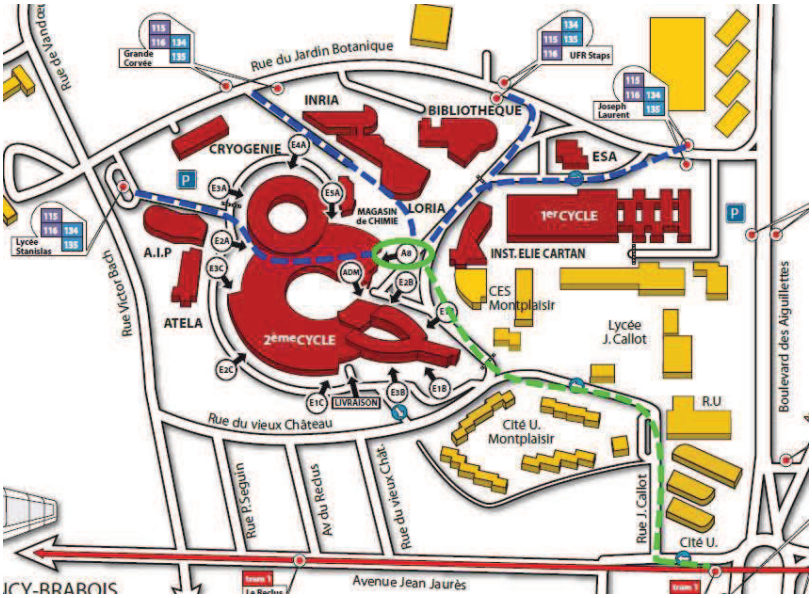
Main Building

Registration, information and scientific program will take place in the building A, amphitheatre A8

How to get to the congress venue?

By train : Various trains allow connection from Paris and Strasbourg Airports to the Nancy railway station (1h30 from Paris ; 1h from Strasbourg) which is located in the centre of the city. In this case, the

best solution is to take an hotel in the centre of Nancy. Then take the Tramway line N°1, direction CHU for 15 min, get out at "Vélodrome" and walk 5 minutes towards the "Faculté des Sciences et Technologies" (along the green way on the scheme) or by city bus, lines 115, 116, 134, 135 and follow on arrival the blue ways on the scheme



A full map of public transport is available on the link:
http://www.sciences.uhp-nancy.fr/Pdf/plan/plan_CGFTE.pdf

By road: if you decide to come by car, you can choose an hotel at the proximity of the Faculty of Sciences and Technologies where the congress will take place. The access plan by car is available at the following link.
http://www.sciences.uhp-nancy.fr/Pdf/plan/plan_lorraine.pdf

Banquet: Monday, March 26, 2012

The banquet will take place at the "Salle d'honneur des Universités", place Carnot (bus 134-135 see Public transport network p. 160, 161)

Tourist informations

All the needed precisions will be found in the following website: http://www.ot-nancy.fr

Scientific Program

Monday March 26, 2012

08h00-08h30 — **Registration at the desk (meeting place)**

08h30-08h50 — **Opening Session**

08h50-09h30 — **Keynote, Working Group 1**

Ramdane Younsi p.20
An overview of numerical modeling of high temperature thermal treatment of wood
R. Younsi, D. Kocaefe & Y. Kocaefe

09h30-10h30 — **Oral presentations - TH treatment of wood (Working Group 1)**

Utilization of thermodesorption coupled to GC-MS to study stability of different wood species to thermodegradation, **K. Candelier**, M. Chaouch, S. Dumarçay, A. Petrissans, M. Petrissans, P. Gérardin p.22

Accelerated aging of wood by thermo-hydrous treatment, **J. Froidevaux**, J. Gril, P. Navi p.24

Naturally and artificially aged woodh a comparison of spectrochemical data with multivariable analysis, **C. Ganne-Chédeville**, A.S. Jääskeläinen, J. Froidevaux, M. Hughes, P. Navi p.28

10h30-11h00 — **Coffee Break**

11h00-12h20 — **Oral presentations-TH treatment of wood, cont'd (Working Group 1)**

Durability of thermally treated woodh influencing factors and variability, **H. Militz**, S. Bollmus, A., A. Gellerich p.32

Identification of diffusion properties of thermally modified wood, **W. Olek**, J. Weres p.36

Heat treatment of wood for energy purposeh effect of the treatment intensity on mechanical resilience measured by a new impact device, F. Pierre, G. Almeida, **P. Perré** p.40

Alteration of the pore structure and the capillarity of wood due to thermal modification, **M. Zauer**, A. Pfriem, A. Wagenführ p.42

12h20-13h50 — **Lunch**

13h50-14h30	**Keynote, Working Group 2**	
	Antonio Pizzi Wood joints adhesion and performance in mechanical friction welding of wood without adhesives	p.46

14h30-15h30	**COST FP0904 Short Communications and Short Term Scientific Mission**	
	SHORT COMMUNICATIONS	
	Investigation of Mechanical Properties Changes of Poplar Wood during Heat-treatment, A. Enayati, **F. Taheri**	p.48
	Study of dimensional stability and EMC of poplar wood (Populous alba) treated at different heat-temperature and initial moisture content, **A. Enayati**, F. Taheri	p.50
	SHORT TERM SCIENTIFIC MISSION	
	Chemical modifications of *Tilia cordata* wood during thermo-hydro-mechanical treatments investigated by FT-IR and 2D IR correlation spectroscopy, **Carmen-Mihaela Popescu**, Julien Froidevaux, Maria-Cristina Popescu, Parviz Navi	p.52
	Mechano-sorptive creep of heat treated and innate beechwood **A. Straže**, Z. Gorišek, S. Pervan, J. Froidevaux, P. Navi	p.56
	Dynamic wettability of surface densified wood densified in open system, **A. Kutnar**, L. Rautkari, K. Laine, M. Hughes	p.60

15h30-16h00	**Coffee Break**

16h00-17h00	**Short Oral Poster Presentation**	
	Color response of mountain pine beetle (MPB)-attacked wood during thermal modification, J. Cai, L. Cai, T. Ding	p.64
	Prediction of the crack initiation during drying process of green wood h experimental and modelling approaches**,** F. Dubois, R. Moutou Pitti, J.F. Destrebecq	p.68
	Mechanical properties of heat treated French species wood, S. Hannouz, R. Collet, L. Bléron, R. Marchal, P. Gérardin	p.72
	Modification of Moisture Diffusion Coefficient in Wood (Sorbus Torminalis) due to Thermal Treatment, D.V.B. Santos, R. Rémond, G. Almeida, P. Perré	p.76
	UV Ageing and Thermal behaviour of Wood Treated with Ionic Liquids, C. Croitoru; S. Patachia, C. Friedrich, E. Pintilie, C. Vasile	p.78
	Water and organic solvent uptake along axial direction of wood densified in a closed system, M. Petric, F.A.. Kamke, B. Kricej, M. Pavlic, A. Kutnar	p.82
	Furfuryl alcohol impregnation for improved plasticization and fixation	

17h00-17h30	**Poster Presentation**

19h00-19h45	**Official Opening Session** **« Salle d'Honneur des Universités »** ***Place Carnot, Nancy***
20h00-22h00	**Congress Dinner** **« Salle d'Honneur des Universités »** ***Place Carnot, Nancy***

Thuesday March 27, 2012

08h50-09h30	**Keynote, Working Group 3**	
	Rémi Tessier du Cros Application of wood welding on wine and spirit wood barrels, Tessier du Cros, Lefort, De Beauregard, Mirabel	p.106
09h30-10h30	**Oral presentations, THM treatment of wood in closed system (Working Group 2) open system (Working Group 3)**	
	Evaluation of relaxation stresses in green wood slice during drying process, O. Saifouni, **R. Moutou Pitti**, J-F. Destrebecq	p.108
	Characterization of the welding zone of spruce by UMSP, **M. I. Placencia**, G. Koch, A. Pizzi, F. Pichelin	p.112
	Mode I and II fracture characteristics of welded wood bonds, **M. Rhême**, J. Botsis, J. Cugnoni, P. Navi	p.116
10h30-11h00	**Coffee Break and Poster Presentation**	
11h00-12h00	**Oral presentations - THM treatment of wood in closed system (Session 2) open system (Session 3), cont'd**	
	IR heating of green wood while peelingh a numerical model, **A. Dupleix**, S.A. Ould'Ahmedou, L. Bléron, L.E. Denaud, F. Rossi	p.118
	Mesoscopic Modeling of Nonisothermal Moisture Diffusion in Wood **S. Abbasion**, M. Gilani, D. Derome, J. Carmeliet	p.122
	Mechanical and microscopic characteization of densified wood at various growth ring orientation and densification ratios, P. Toussaint, L. Coutaghe, C. Barthram, **M.C. Trouy-Triboulot**, J.F. Bocquet	p.126
12h00-13h50	**Lunch**	
12h30-14h10	**Keynote, Working Group 4**	
	Timo Tetri Developments and Markets of Thermally Modified Wood Products	p.130
14h10-15h30	**Oral presentations, Market applications of TH and THM treated wood (Working Group 4)**	
	ESR-spectroscopy as a potential method for the quality cotnrol of thermally modified wood, **M. Altgen**, C. Welzbacher, M. Humar, H. Militz	p.132
	Effect of thermo-hydro-mechanical densification on the surface characteristics of wood veneers and glue consumption, **P. Bekhta**, J. Sediacik	p.136
	Physical characterization of spruce (*Picea abies Karst.*) modified with vacuum treatment method, **S. Ferrari**, O. Allegretti, I. Cuccui, J. Sandak	p.138
	Softwood strand-boards manufacturing without adhesive using linear friction welding technology. **Bianchi, S.**, Placencia Peña, M.I., Ganne-Chédeville, C., Pichelin, F., Sandberg, D.	p.142

15h30-16h20	**Short Oral Poster Presentation**	
	Wood surface densification - Removing set-recovery by heat-treatment, K. Laine, L. Rautkari, A. Kutnar, M. Hughes	p.144
	Changes of selected properties of thermally and/or with technical plant oils modified black alder wood (Alnus glutinosa (L.) Gaertn.), A. Fojutowski, A. Noskowiak, G. Pajchrowski	p.146
	Is it possible to detect thermal treatment of wood in low temperatures ? J. Sandak, A. Sandak, O. Allegretti, S. Ferrari, I. Cuccui, M. Fellin, G. Fragnelli, S. Cerullo	p.150
	Effect of phenol-formaldehyde resin content and density on performance characteristics of MDF, J. Mihailova, V. Savov, K. Petrov	p.154
	Steaming of black locust and beech timber for colour modification, L. Tolvaj, R. Nemeth	p.156
	The influence of individual veneer orientation on the shape stability of planar lamination, L. Blomqvist, J. Johansson, D. Sandberg, G. Kifetew	p.160
	Interrelationship of Forestry Stand Parameters and Product Quality of Domestic Softwood and Hardwood Species after Heat Treatment, H. Pleschberger, O. Vay, R. Stingl, F. Putzhuber, H. Hasenauer, C. Hansmann	p.164
	Viscoelastic Thermal Compressed (VTC) wood - commercialization potential. N.R. Macias, C. Knowles, F.A. Kamke, A. Kutnar	p.166
16h20-17h00	**Coffee Break and Poster Presentation**	
17h00-18h20	**Oral presentations, Market applications of TH and THM treated wood (Working Group 4) , cont'd**	
	Scale effectds and influence of vapour generation during friction welding of spruce boards, **B. Hahn**, B. Stamm, Y. Weinand	p.170
	Investigation on fibre reinforced moulded wood pipes for the conduction of brine at high temperature and pressure R. Putzger, R. Eckardt, S. Eichhorn, K. Nendel, **P. Haller**	p.174
	How to Avoid Thermal Run-Away during the Heat Treatment of a Stack of Boards, Contribution of a Comprehensive Dual Scale Computational Model, **P Perre**, R Rémond	p.178
	Wood surface densification vs. bulk densification - Improving or decreasing material properties, **L. Rautkari**, K. Laine, A. Kutnar, M. Hughes	p.180

Wenesday March 28, 2012

08h30-10h00	**Working Groups**
	Working Group 1, Amphithéâtre 8 Working Group 2, Meeting room ST 33 Working Group 3, Meeting room ST34
10h00-10h20	**Coffee Break**
10h20-11h00	**Working Groups**
	General discussion with all the working groups
11h00-12h30	**Management Committee Meeting**

Abstracts

Effect of heat treatment of poplar solid wood on physical and mechanical properties

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Key words: poplar wood, heat treatment, dry mass lost, strength, stiffness

Wood heat treatment results in wood modifications that in some case can be considered as an improvement (lightening of the material, increasing of decay resistance, lowering of MC, shrinkage and swelling reduction) and in some others as a lack in the material (strength decreases and stiffness as well behind given threshold). Because for some wood derivates lightweight is a very important factor the effect of given mass losses on physical and mechanical properties of poplar wood (*Populus alba* L.) was investigated. Not much work was performed on poplar wood after bibliography (see Nazerian et al. 2010). A preliminary test at different treatment temperatures (6 samples per temperature verified to have homogeneous densities at test start by a Kruskal-Wallis test) was performed. The mass of the samples was measured at given time intervals in order to verify the mass lost during time and the test was stopped when an oven dry mass of 23% was lost. The oven dry mass lost in time is reported in Figure 1.

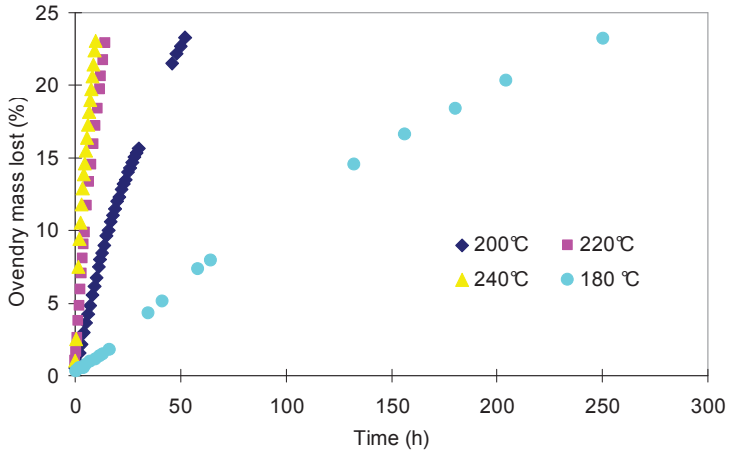

Figure 1. % of oven dry mass lost during time at different temperatures

In order to verify the effect of different temperatures on physical and mechanical properties of poplar wood a temperature of 180°C and a temperature of 220°C were chosen for the tests. As can be observed between 180 and 220°C the process speeds up very much and this could lead to different effects. Specimens of poplar wood 8x8x130 mm were prepared in the same piece of wood and as close as possible each other in order to limit wood heterogeneity. The samples were in number of 12 for each test and verified to have an homogeneous density (386 kg m^{-3}) before the test start by a Kruskal-Wallis statistic test and were treated with a conventional oven and by means of heating plates both at atmospheric pressure. The treatment was performed on samples that were previously oven dried and on samples kept at 20°C and 65% RH just until the treatment begans. The samples were treated until oven dry mass lost of 7, 8 and 10% were reached. The mechanical tests were performed by a three points bending test according to ISO 3130 (except specimen dimensions) for MOR,

and with the same device for MOE. The device span was 100 mm. The treatment type as well as treatment time are reported in Table 1. The physical (density, shrinkage coefficient) and mechanical (MOE, MOR) properties variations after thermal treatment are reported in Table 2. The arise of statistically significantly differences were highlighted by means of non parametric statistic tests and in particular by a Mann Whitney test for paired values and by a Wilcoxon signed-rank test for independent data.

Table 1: Treatment parameters and time

Treatment name	Treatment Type	Treat. T [°C]	MC at treat. start (%)	Treat. time [h:m]
-7 dry 220	Oven	220	0	7:00
-10 dry 220	Oven	220	0	7:30
-7 wet 220	Oven	220	9.8	7:00
-10 wet 220	Oven	220	10.3	8:00
-8 dry 180	Oven	180	0	33:00
-8 dry 180 HP	Hot plates	180	0	40:00

As can be observed, in Table 2 the treatments executed by conventional oven and by hot plates at 180°C result in similar time schedules (33 and 40 hours) in order to have a similar dry mass lost (7.9 and 8.0 %). The time difference could be because of the different points the temperature is measured (thermocouple in the air for the oven and at the contact point between wood and plates for the heating plates) for the two treatments leading to small temperature differences inside the material.

Table 2: Physical and mechanical parameters average variations after treatment.

Treatment name	Dry mass lost [%]	Density lost [%]	Wet mass lost [%]	Rad. shrink. reduction [%]	Tan. shrink. reduction [%]	MOE lost [%]	MOR lost [%]
-7 dry 220	7.4	7.2 (*s*)	9.7	43.6 (s)	56.6 (*s*)	16.3 (*s*)	20.8 (*s*)
-10 dry 220	10.0	7.0 (*s*)	12.2	53.6 (*s*)	49.6 (*s*)	14.5 (*s*)	27.2 (*s*)
-7 wet 220	7.0	7.1 (*s*)	9.1	49.0 (*s*)	36.4 (*0*)	4.2 (*s*)	22.5 (*s*)
-10 wet 220	9.6	8.0 (*s*)	11.5	38.8 (*s*)	34.9 (*0*)	7.6 (*0*)	26.3 (*s*)
-8 dry 180	7.9	5.6 (*s*)	11.8	26.5 (*0*)	29.3 (*0*)	2.2 (*0*)	32.3 (*s*)
-8 dry 180 HP	8.0	8.3 (*s*)	12.0	37.5 (*0*)	31.0 (*0*)	13.6 (*s*)	28.8 (*s*)

s: indicates statistically significant differences, *0*: non statistically significant differences between before and after treatment. Dry mass lost, density lost, wet mass lost, radial shrinkage reduction, tangential shrinkage reduction and MOE are referred to paired data, MOR is referred to control samples.

In table 2 can be observed how to a given dry mass lost corresponds a lower density lost because of the permanent dimensional reduction of the specimen after treatment. At the same time can be observed how the wet mass lost (after having equilibrated treated samples at 20°C and 65% RH) is higher then the dry one because of the lower final MC. The lower MC results in relevant reductions of radial and tangential shrinkage that seem to be higher the higher is the treatment temperature but quietly independent from the mass lost. As regards mechanical behaviour it can be observed a moderate decrease of MOE and a relevant decrease of MOR after treatment. As can be observed for 220°C the treatment starting on wet samples (equilibrated at 20°C and 65%RH) results in lower decrements of MOE if compared to samples where the treatment starts on oven-dry samples. The oven 180°C treatment of oven dry samples result in a very small MOE reduction if compared to hot plates. Hot plates treatment of oven dry samples present a MOE reduction in line with the oven dry samples treated at 220°C. As regards MOR it is clear how, the higher is the mass lost in the case of 220°C treatment, the higher is the MOR decrement. MOR does not seem to be influenced by

the treatment of dry or wet samples for 220°C treatment. The treatment performed at 180°C present the worse results as regards MOR reduction.

Acknowledgments: The authors gratefully acknowledge the financial support of the Toscana Regional Administration with the project TEMA.

References

Nazerian, M., Ghalehno, M.D. & Kashkooli, A.B., 2010. Effect of heat treatment of poplar plies on physical and mechanical properties of laminated veneer lumbers. In *Fifth International Poplar Symposium (IPS V) - Poplars and willows: from research models to multipurpose trees for a biobased society - Orvieto, Italy, 20-25 September 2010*. Orvieto: CRA.