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Subject: review of PhD Thesis

Review of dissertation thesis written by:

Jakub Dömény

with the topic:

„Microwave Modification of Wood"

This review was compiled upon the request of doc. Ing. Radomír Klvač, dean of the Faculty of Forestry and Wood Technology Mendel University in Brno.

Assessment of the dissertation thesis

The chosen topic, interaction of wood with microwaves, is an actual challenge in the wood technology and wood science. The technique allows rapid heating of the whole cross section. The wood industry benefits from this technology almost for 60 years. However the technology itself is already in practical use, different new applications (e.g. impregnation with new agents) call for research work to reveal the consequences / possibilities of interaction of wood and Microwave radiation.

The very intensive reaction of wood with the electromagnetic field results in high temperatures, internal stresses, loosening of the material's structural integrity due to micro cracks / delamination.

The doctoral thesis contains 116 numbered pages. The introduction part gives a clear picture about the scientific and technical background of the topic, the aims of the thesis are divided into two parts: Part a – technological and technical optimization part, and Part b – material properties part (microscopic, physical properties and mechanical properties).

The Literature Review part refers 214 different literature sources. This high number reflects on one hand the enthusiasm of the candidate to evaluate and involve as much references as possible, on the other hand can lead to redundancy, e.g.:

Page 14.

"*The temperature of wood during MW heating depends on several factors, i.e. power of MW radiation, time of treatment, dimensions of material, MC, frequency and permeability of wood (Norimoto and Gril 1989; Leiker et al. 2004; Studhalter 2005; Brodie 2007b; Studhalter et al.* 2009)." For statements which are directly deductible from physical equations 5 references might not reasonable.

The electromagnetic phenomenon will be discussed deeply, and the theories are projected to the studied material wood, e.g. the macromolecular components (cellulose, lignin hemicelluloses and extractives) are analyzed according to their ability to polarization, which is the key requirement for energy absorption.

The anisotropy (as intrinsic property of wood) is considered as influencing factor too.

Page 13. The candidate cites:

"*Dielectric losses are normally higher along the grain than across the grain (Samson 1984).*"

Please explain the physical background for this phenomenon!

Page 13. The candidate writes:

"*Some published studies report that MW radiation may cause the delamination of wood structure."*

Please explain more in detail the word delamination! Does it mean that the S-layers will be disconnected from each other? Or the middle lamellas are more affected, or cracks occur radially in the cell wall? In the last case delamination won't be the right terminology.

Page 14. The candidate writes:

"The results indicated that parenchymatic cells are the first to get destroyed."

Please justify / explain why the parenchyma cells are the most affected ones? Especially because the candidate's own research shows, that the ray parenchyma cells are strengthening the structure against deformations.

Page 16. Misspelling

MW application n for wood industry

Please give an explanation for the observed phenomenon, cited below!

Page 17. The candidate writes:

"*The measured data showed an opposite MC gradient inside the material in comparison with conventional wood drying and a higher temperature near the surface of the material*."

Page 23.

The molecular formula for acetic anhydride is:$C_6H_{10}O_5$. Is the specific abbreviation AcO_2 exactly the same molecule?

Page 28. Misspelling

In table 1. 5 litters / minute

The choosing of wood species is adequately explained as the candidate analyzed soft- and hardwoods as well. European beech containing red heartwood, hybrid poplar and Norway spruce were investigated. With this set the candidate had low and high density materials, thus allowed the analysis of the densities' influence on the treatments, and material properties' changes.

The methods for treatment and tests are given in detail, thus the investigations are reproducible (of course with the limitations due to wood material's variations).

The scientific findings of the candidate were published in 4 papers in journal (BIORES) with high impact, 1 paper was published in a reviewed journal (ProLigno), and 1 paper is prepared as a manuscript ready for submission. However the papers underwent deep evaluation by the reviewers, I take the liberty to comment even on those papers.

In Paper I, in the "Materials" section basic characteristics of the material are not sufficiently described, like: density, original place of the material in the trunk (juvenile or heartwood). The false heartwood was analyzed but the accurate description of this specific tissue is not discussed adequately, as degree of heartwood forming, or extractive content or proportion of blocked (thyloses) vessels in the tissue.

A positive evolution can be observed in the further papers as the tested material is characterized precisely (density, sapwood or heartwood origin).

General comment to the MW treatments: the intensity of the treatment was given by technical features of the device, like: power, frequency, conveyor speed. However these factors are crucial for industry a more physics oriented value, like absorber energy for one cm^3 wood for one second could have add to the reproducibility.

The role of moisture on the wood, especially for the MW treatment is described in detail. One question arises: Is there any difference in technological parameters or the result of the treatment if instead of freshly cut wood, so called rewetted wood is used (at the same MC level)?

The conclusions are formulated adequately, and generally based on precise measurements and sophisticated stipulations. In Paper III, page 60, conclusion 3, the candidate refers (Torgovnikov and Vinden 2009), which is not necessary, as the conclusions are own finding and do not have to discussed / compared in the conclusion part.

The behavior of wood during treatments is basically explained by using the anatomical knowledge correctly. Especially the explanation of the rays' rules in compression / spring back phenomenon is remarkable.

In Paper V, Page 80, conclusions 4, the candidate writes:

„*MW heating was found to be sufficient way for wood plasticization of the beech wood. However, when other wood species are applied the MW plasticization process should be optimized properly*."

Question to this:
Which parameters of the wood are the influencing factors, which have to be optimized, beside the wood species itself?

In Paper VI, the very high 99% relative humidity is given for a specific climate. Acc. to the reviewer's experience, "normal" laboratory chambers cannot maintain such high values (how about the Sanyo?). The problem is the high risk of condensation due to temperature disturbances.

In the same paper can be read:

"*Beech wood had approximately two times higher substance retention compared to poplar, due to its structural and chemical composition*."

What are the structural and chemical differences between poplar and beech, to explain the phenomenon?

Major findings

The candidate could prove, that:

- MW radiation can highly influence the permeability of the wood in all anatomical directions of wood.
- The material properties and characteristics, i.e. mechanical properties (bending strength), moisture content and surface temperature of the pre-dried wood are highly influenced by process parameters.
- MW heating is an efficient way in terms of rapid plasticization as a pre-treatment for the wood densification process.
- Heating by MW can accelerate the chemical reactions in the acetylation process.

These findings are new and contribute to the wood science considerably.

Importance of dissertation for practice

Due to application of microwave heating the temperature raise can be achieved in the material's targeted location, as the energy absorbance – among other factors - is depending on dielectric properties of the material. The last is in strong correlation with the presence of dipole molecules (like water), thus the location of heat generation can be influenced by elevated water content (e.g. for gluing). Finally the technology needs less energy and the technological steps' duration (in gluing or drying) cost less time, which results in enhanced effectiveness for the industry and contributes therefore to their economic situation very positively.

The application of MW in wood working industry infers optimization of wood species, thicknesses, moisture contents, thus the overheating (burning) and structural damage of wood can be avoided. The candidate's research contributes to this optimization task considerably.

The densification and acetylation processes are emerging technologies to enhance wood's intrinsic properties. Stabilization of wood against moisture influences, and elevating the surface hardness definitely contribute to the local wood products' success, thus the import of durable ad dimensionally stable tropical species can be minimized.

Overall appraisal

Methods, experimental setups, measurements, and the data presented in the dissertation of the candidate withstand the scrutiny appropriate for scientific research, as all the presented experiments are protocolled precisely and are reproducible.

The candidate presented his scientific findings clearly and scientifically.

According to the scientific papers published during the research work of the candidate the examiner is convinced that the candidate's contribution to the dissertation has been sufficient.

The dissertation represents an original work, the findings are verified and the results contribute to the development of the field of wood science considerably. The dissertation compiles with the international quality requirements of a doctoral dissertation (known by the examiner).

Presumptions and recommendations for PhD declaration:

The reviewer recommends this thesis for defense; in case of positive result I recommend awarding Jakub Dömény the PhD degree.

Sopron, 2016. 04.25.

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Prof. Dr. Róbert Németh

head of institute