Universitatea Transilvania din Braşov

HABILITATION THESIS

SUMMARY

Title: SURFACE QUALITY EVALUATION OF WOOD AND WOOD BASED COMPOSITES

Domain: FORESTRY ENGINEERING

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SUMMARY

The evaluation of the wood surface quality, as an expression of the state of the surfaces, characterized by irregularities and deviations from the nominal surface, has been a challenge for research, since the 80s and has remained a topic in continuous debate, due to the fact that wood is a heterogeneous material, containing, in comparison with homogeneous materials, such as metal, a particular series of irregularities (cavities) generated by its anatomy specific to each species. The wood anatomy makes it difficult to measure the surface data, as well as the evaluation of the measured data and the objective numerical expression of the surface quality, whether it is the roughness of the surface generated by processing or treatments applied to wood or other irregularities such as waviness, form errors, surface defects or other types of irregularities. The methods and recommendations offered in the general standards, regarding **the measurement and evaluation of the surface quality**, that is the **metrology of the surfaces**, do not apply well to the wood surfaces, generating unpredictable errors and unrealistic values regarding the surface qualiy. Scientific reports on the wood surface quality are numerous and, in general, researchers have used existing metrology standards and recommendations, without testing their suitability for a heterogeneous material such as wood and without seeking consensus. This makes surface quality reports unreliable and difficult to compare.

The topic of scientific research, presented in this habilitation thesis, "**Surface quality evaluation of wood and wood based composites**"/"**Evaluarea calității suprafețelor din lemn şi a compozitelor pe bază de lemn**", was inspired by the recognized fact that no agreed guidelines exist in wood surface metrology or on how to objectively measure and evaluate the surface quality of a wood or wood based surface and the author is proposing to find answers and solutions to this problem. The first researches in this direction were initiated by the doctorate in the United Kingdom "**The roughness of sanded wood surfaces**"/"**Rugozitatea suprafețelor şlefuite din lemn** " finalized by the PhD degree, awarded by **Brunel University, in 2004**. The doctorate in the United Kingdom was validated in 2005 by the Ministry of Education, Research and Youth. The doctorate researches focused on various aspects of the metrology of wood surfaces, regarding both the measurement and the quality evaluation in the particular case of the sanded wood surfaces. Thus, in the doctoral thesis were analyzed aspects of surface measurement with various measuring instruments, aspects related to the most suitable filters for surface roughness, but also the possibility of separating the anatomy from other wood irregularities, the author developing her own methods of analysis. Starting from these initial researches, the study was deepened by the author, for 15 years (2005-2019) after the completion of the doctorate, testing each aspect, in detail, of the metrology of the surface, adapting them to the latest scientific communications, in order **to define and validate, by dissemination in the scientific circuit, an original method regarding the metrology of wood surfaces and wood-based composites.**
Therefore, the purpose of the research pursued from 2005 to 2019, with a strong focus from 2005-2014, was meant to develop, test in minute details and disseminate a metrology method suitable for wood (material structured in chapter 1) and to use it further for a reliable evaluation of surface quality of wood and wood based products (presented in chapter 2). In similar time framework, during 2006-2016, the author approached also another research direction about an ignored material, the seconday wood resource, its quality and potential for value added applications (chapter 3), while a third research direction, during 2009-2015, was to explore, for the first time, the potential in evaluating the various aspects of the wood surface morphology by using an imaging software-ImageJ (chapter 4).

Chapter 1 has focussed on various components of wood surface metrology informing about problems associated with evaluation of wood surface quality and possible solutions, finally providing a set of best practice recommendations on how to best measure and evaluate the

surface quality/roughness (it is referred along the habilitation thesis as "**the metrology method for wood surfaces**"). It is for the first time that a metrology method for wood surfaces is proposed with the purpose to unify further approaches in this domain and make results between results obtained by different researchers reliable and comparable. This set of best practice recommendations, if automated in dedicated software can serve for optimisation of processing parameters in industry applications. In chapter 1, the metrology method was tested on oak, beech and spruce surfaces sanded with various grit sizes.

The research results from chapter 1 were disseminated, **as first author**, in **28 publications** (among which **10 papers in ISI Web of Science**, 2 book chapters in international publishing houses) and were acknowledged by **138 citations in ISI Web of Science**. Detailed dissemination information is given at the end of chapter 1.

Chapter2. Once a metrology method for measuring and evaluating the quality of wood surfaces was established, it offered the multiple possibilities to apply this knowledge in various domains and materials and it is not limited to these. The wood metrology method was used to evaluate the surface quality of wood, then wood modified by various thermal treatments, wood surface modified by plasma and by laser engraving. Further, the study was extended for wood based panels, as MDF and chipboard, but also wood plastic composites.The analysis was thorough, it was based on the proposed wood metrology method, and, in this way, multiple aspects of the surface quality were observed, which were not discussed in previous literature publications.

It was possible to see ***the effect in measuring the surface quality of the two wood growth areas: earlywood and latewood.*** An important conclusion from this was that measured surfaces should contain both earlywood and latewood, to be relevant for assessing surface quality of wood. The ***studies on planing, milling and sanding thermally modified beech wood*** have shown that heat-treatment at temperatures of 200° C increases the surface roughness in comparison with the untreated wood and this effect is more pronounced with an increase in treatment duration. Another type of wood treatment under investigation and its effects on wood, including those on wood surface quality was **the EDS patented technique (by smoking wood)**, as part of an international contract, where **the author was coordinator**, "**Experimental research regarding the characteristics of beech (*Fagus japonica*) heat treated by EDS technology**"(No. 15826/ (2016-2017) and concluded between Transilvania University in Brasov and EDS Laboratory-Japan. It was observed, among others, a benefic trend of the treatment to homogenize wood properties.The ***studies on the effect of laser engraving***, *the first of this kind in the literature*, on surfaces of beech and maple have shown that the surface roughness increased linearly with the laser power and decreased after a logarithmic correlation with the scanning speed, while correlation curves of surface roughness and wood colour change can help when choosing the laser power-scanning speed combinations capable of giving the targeted colour change with minimum surface roughness. Research on the surface quality of ***plasma modification of wood*** was a good example of an interdisciplinary research where results coroborate for a better understanding of the surface morphology and material behaviour. ***The surface metrology method was further applied on wood based panels and wood plastic composites***. Their surface roughness is significant when panels are used as the substrate for overlays such as thin melamine paper or in the case of WPC, surfaces have to be smooth for a direct painting.

The research results from chapter 2 were disseminated, in **14 publications (9 papers in ISI Web of knowledge)** to which can be added the contribution to one doctoral study on thermally treated wood as member of the PhD advisory board and to a second doctoral study on the laser effect on wood as surface quality consultant. Detailed dissemination information is given at the end of chapter 2. **The author was "main author" or "corresponding" author to the vast majority of those publications**.

Chapter 3 comprised another direction of research, ***about the secondary wood resource*** (***wood branches, wood from thinning operations, juvenile wood versus mature wood***), ***with the purpose to find applications and add value to this ignored resource.*** Inovative type of wood panels with increased aestetics were created, made of crosscut wood branches or from crosscut thin logs, in order to increase the value of this resource. The research on the characteristics and properties of the raw material was complemented with research on the physical and mechanical properties of those panels, as well as with investigations regarding the surface quality of those panels after sanding. This research was part of a **project granted by the CNCSIS (The National Council of Scientific Research in the Higher Education) type A 450/2006: "Eco-conception and eco-technology for furniture and other wood made products obtained from natural secondary resources" (2006-2008), where the author was active member** For pusuing the research on secondary wood research, ***the author has used her experience in wood microscopy as well as in interpretation of wood physical and mechanical properties. Research was complemented with evaluation of surface quality of newly designed panels from secondary wood resource.***

The research results from chapter 3 were disseminated, in **32 publications (6 papers in ISI Web of knowledge), 3 patents** as co-author in ISI Web of Knowledge, to which can be added the **contribution to two doctoral studies** on secondary wood resource, as member of the PhD advisory board. Detailed dissemination information is given at the end of chapter 3. **The author, contributed as "first author" or as "corresponding author" in the majority of them**.

Chapter 4 represents **an original approach to the evaluation of surfaces by using an imaging software -ImageJ**, freely available on the internet, developed at the National Institutes of Health in the United States of America. ***The author has experimented with this software on wood and wood based materials and managed to find useful and original applications.*** One of the applications of ImageJ was to evaluate ***the surface quality of wood based panels after being processed by drilling***. ImageJ was also used as supporting tool, for ***species identification of samples detached from the structure of various objects subject to restoration***. A similar application of ImageJ was employed for ***evaluating the microscopic characteristics of a less known material, the secondary wood resource***, in comparison with wood from stem. ImageJ was used, because it offers an objective quantitative method to separate, measure and statistical data process for some anatomical features of interest. Another application of ImageJ was to ***evaluate the depth of penetration for wood consolidants***, in order to assess the quality of this operation. The last three applications were performed by the author in the framework of **the project CNCSIS PN2 Idei(Ideas) 856/2009-"Development and implementation of an advanced scientific research methodology for sustainable wood (furniture) restoration-conservation and ecodesign"** where the author was active member.

The research results from chapter 4 were disseminated, in **23 publications (2 papers in ISI Web of knowledge),** to which can be added the contribution to one doctoral studies on the microscopy of secondary wood resource, as member of the PhD advisory board. Detailed dissemination information is given at the end of chapter 4. **The author, contributed as "first author" or as "corresponding author" in the majority of them**.

Ongoing and further work:

The author of this habilitation thesis **coordinates, as UTBv partner, two international projects financed by the EU, which are ongoing at this moment of writing.** They will contribute to develop the research and academic activities of the author on furniture creativity and innovative materials and technologies for furniture. These are:

- DITRAMA – "Digital transformation manager: leading companies in Furniture value chain to implement their digital transformation strategy", PN: 601011-EPP-1-2018-1-ES-

EPPKA2-SSA,with 12 partners from 8 European countries, t**otal grant: 994094 euro; UTBv share:46175 euro**. Period of implementation:**01/01/2019-31/12/2021**

- FACET- "Furniture sector Avant-garde Creativity and Entrepreneurship Training", PN: 2018-1-IT01-KA202-006734, **total grant: 324163 euro; UTBv share: 25342 euro**. Period of implementation: **01/11/2018-04/30/2021**

For further scientific work, ***the possibilities are unlimited.*** Surface quality remains a subject of interest ***for any material based on wood, any processing, any wood treatment or modification process***. It is also open to interdisciplinary research, where wood combines with other materials. By knowing the objective values of surface roughness and by understanding the surface morphology, the processes can be optimized and costs will be reduced. Not only surface quality will be envisaged by further studies. The author has proven skills in researching the physical and mechanical properties of wood, in wood microscopy, but also in modifying and treating wood, **knowledge that will be used and developed in research teams and will generate doctoral studies under the guidance of the author of this thesis.**

The results of all research studies of the author, during 2005-2019, were validated by **156 citations in ISI Web of Science-without self-citations (h-index 7).** The most important are **29 papers in ISI Web of Science** (21 as first author and 2 as correspondent), 2 book chapters, as main author, in international publishing houses (ISTE-Willy and Nova Science), 5 books-Ed.Transilvania Univ., 20 papers in journals indexed in international databases (11 as first author), 43 papers in international conferences (7 in international databases) and 3 patents in ISI Web of Science-Dervent.