MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT **MINISTRY OF EDUCATION AND TRAINING**

VIETNAM NATIONAL UNIVERSITY OF FORESTRY

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IMPROVING THE QUALITY OF ACACIA HYBRID *(Acacia mangium x Acacia auriculiformis)* WOOD BY THERMO-MECHANICAL TREATMENT METHOD USED FOR FLOORING PRODUCTION

MAJORITY: FORESTRY PROCESSING TECHNOLOGY

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SUMMARY OF ENGINEERING DOCTORAL THESIS

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ABSTRACT

<u>Official thesis title:</u> "Improving the quality of Acacia hybrid *(Acacia mangium x Acacia auriculiformis)* wood by thermo-mechanical treatment method used for flooring production"

I. INTRODUCTION

Acacia hybrid wood has been oriented by the Ministry of Agriculture and Rural Development as a key tree in the program of replacing small timber plantations into large timber plantations under Decision 774 / QĐ-BNN-TCLN dated April 18, 2014. Acacia hybrid has many advantages such as straight grain, relatively beautiful color, but Acacia wood also has many disadvantages such as light wood, low mechanical strength, high water absorption, and uneven wood quality. Therefore, the current wood products from Acacia wood do not attract many users, especially used as flooring.

In order to attract customers using flooring from fast growing wood, we intend to improve the quality of raw wood materials such as increase the hardness, increase the dimensional stability, ... Currently, there are more interests on the modification technology of wood by thermo-mechanical (T-M) method. This is a technology that uses high temperature and pressure to increase the density of the wood, thereby improving some physical properties, improving wood mechanical strength and reducing curvature. buckled for wood. This technology is an environmentally friendly technology because no toxic chemicals are used in the production process, the machine is rather easy to use because it is similar to the equipment currently used in wood processing plants today.

II. OBJECTIVES, RESEARCH CONTENTS AND METHODOLOGY

2.1. Research objectives

2.1.1 Theoretical objectives

- Based on the study of the relationship between compression ratio, time, temperature of wood compression by thermo-mechanical method to find the change in structure, mechanical and physical properties of Acacia hybrid wood to elucidate the modification mechanism by thermo-mechanical method for plantation timber in general and Acacia hybrid wood in particular.

- Contributing to supplementing the theoretical basis of the wood modification technology by thermal-mechanical method, as a basis for determining thermal-mechanical technology parameters for Acacia hybrid wood.

2.1.2. Practical objectives

- Determining the effect of thermo-mechanical modified wood to change the microscopic structure of Acacia hybrid wood.

- Determining the effect of compression ratio, temperature and compressing time on wood properties (in technology modified by thermo-mechanical method) to Acacia wood properties.

- Finding reasonable technology parameters for modifying Acacia hybrid wood by thermo-mechanical compression method to produce flooring.

- Proposing a technological process for producing flooring from Acacia hybrid modified by thermal-mechanical method.

2.2. Research content

- Review the theory of TM modification of wood.

- Determination of glass transition temperature of wood (Tg).

- Studying the effect of compression parameters on physical properties, mechanical properties and resistance to fungal discoloration of Acacia hybrid wood.

- Research to identify the optimal regime of modifying Acacia hybrid wood by thermo-mechanical compression method.

- Studying the density distribution according to thickness and changes in wood structure when compressing wood by thermal-mechanical method.

- Test results and optimize the compression mode parameters from which to propose the technological process of manufacturing flooring.

2.3. Main research method - Experimental method

The main method of the thesis is the empirical method, using the experimental design method to meet RMS surface and analyzing and evaluating the results by **Design Expert 11.0** software.

Design method based on the following function: N = 2 ^ x + 2x + 6cp (1.1).

In which: N- experimental numbers, x- variables, cp- center point. The distance from the center to the star point α = 2k / 4, where k is the input variable (k = 3), so α = 1 , 6819. Experimental levels are arranged at 5 levels (-α, -1, 0, 1, + α). The number of experiments was calculated according to formula (1.1) and processed by Design Expert 11.0 software to obtain the experimental mode in Table 1.1.

Table 1.1. Experimental parameters with 3 influencing factors

Seri	**Code**	**CR (%)**	**Temp (ºC)**	**Time (m)**
CĐ1	K1	40	160	120
CĐ2	K2	40	160	120
CĐ3	K3	30	140	180
CĐ4	K4	30	180	60
CĐ5	K5	40	160	120
CĐ6	K6	40	126	120
CĐ7	K7	50	140	180
CĐ8	K8	40	194	120
CĐ9	K9	50	180	180
CĐ10	K10	40	160	120
CĐ11	K11	40	160	19
CĐ12	K12	57	160	120
CĐ13	K13	23	160	120
CĐ14	K14	30	180	180
CĐ15	K15	40	160	120
CĐ16	K16	50	180	60
CĐ17	K17	50	140	60
CĐ18	K18	30	140	60
CĐ19	K19	40	160	120
CĐ20	K20	40	160	221

The experiments in the model, the experimental results (Y) and the predicted model results (Y ') are shown through the correlation between the indicators function Y and the influence parameters xi:

Y = bo + b1 x1 + b2 x2 + b3x3 + b12 x1 x2 + b13 x1 x3 + b23 x2 x3 + b11 x12 + b22 x22 + b33 x32 (1.2).

In which: Y - norm functions (elasticity return, anti-expansion coefficient, specific gravity, mechanical properties ...); xi- the coded value of the variables; bo - free coefficient; bi - linear coefficients; bii: - quadratic coefficients.

Testing standards:

(1) Resilience: The method is applied by Heger, 2004; (2) Specific gravity:

TCVN 8048-2: 2009; (3) Water absorption: ASTM D4446-08; (4) Static bending strength: TCVN 8048-3: 2009; (5) Longitudinal compressive strength: TCVN 8048-5: 2009; (6) Surface hardness (static hardness): TCVN 8048-12: 2009; (7) Abrasion: JAS-007; (8) Mold resistance: TCVN 11356: 2016; (9) Density distribution by thickness: By DENSE-LAB mark 3, E.W.S.GmbH; (10) Structural analysis: S-4800 and ImageJ software.

III. RESULTS AND DISCUSSIONS

3.1. Wood plasticization temperature

The temperature of the glass transition state of the wood is in the range of 62-72 ^{o}C; Consistent with the method of direct heating on heat presses.

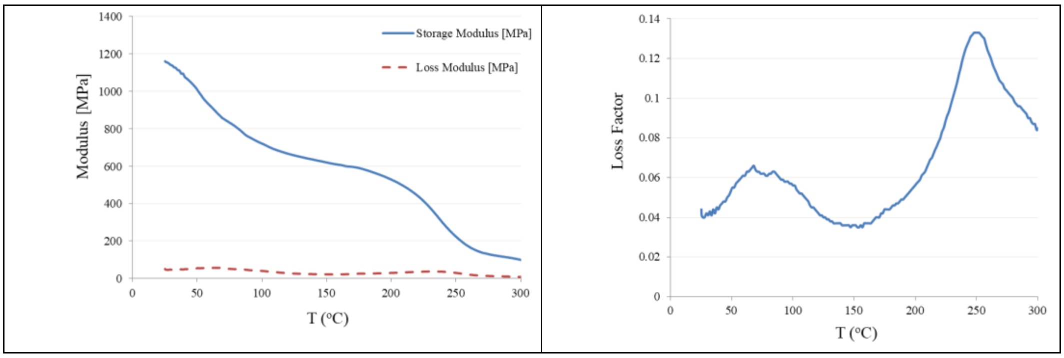

Figure 3.1. Plasticization temperature of Acacia hybrid wood

3.2. Influence of compression parameters to change the microscopic structure of Acacia hybrid wood

Compressed wood with hollow areas decreased significantly from 19.16% to 13.61%, Wood vessels are wood cells with largest changes. Wood after compression does not have broken.

Before modification **After modification**

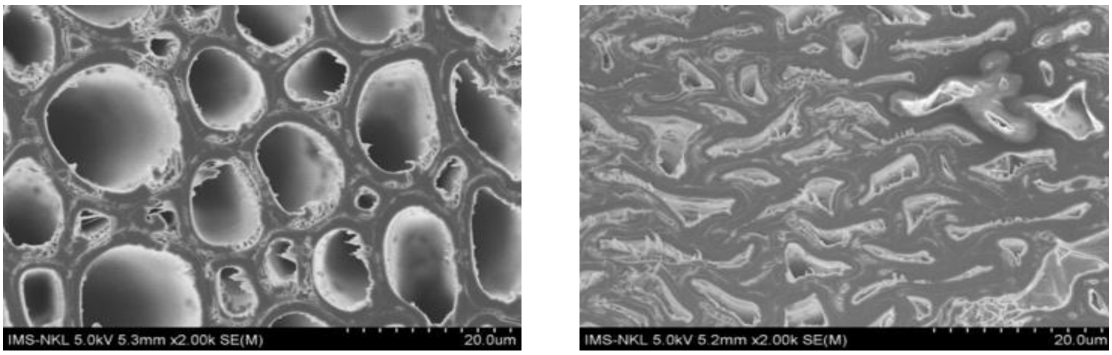

Figure 3.2 Comparison of Acacia hybrid wood structure before and after compression

3.3. Influence of parameters on the physical properties of Acacia hybrid wood modified by thermo-mechanical method

The elasticity of compressed wood reaches from 2.86% to 5.89%, the higher the compression ratio, the greater the elasticity of compressed wood. As the temperature and compression time increase, the elasticity of the wood decreases.

The density of wood is from 0.76 g/cm^3 to 1.09 g/cm^3; The higher the compression ratio, the higher the density of compressed wood. As the temperature and compression time increases, the density increases, but the density of compressed wood will decrease slightly when the temperature exceeds the threshold of 180 ^oC and the time exceeds 180 minutes.

Acacia hybrid compressed wood after heat treatment has good water-absorbing (WRE) resistance, the value reaches 15.12% to 31.21%. This is an important indicator to evaluate the stability of the flooring board in environments with high humidity.

3.4. Influence of compression parameters on the mechanical properties of Acacia hybrid wood treated by thermo-mechanical method

Flexural strength and tensile compressive strength increase with increasing compression ratio; but when the temperature and time increase over 160 ^oC and 120 minutes, the flexural and compressive strength tend to decrease.

Static stiffness increases as other parameters increase; but when the temperature and time increased over 160 ^oC and 120 minutes, the static hardness decreased, but the static hardness of all modes increased sharply compared to the control sample.

The lowest abrasion is 0.13% and the highest is 0.49%. All other modes after compression have shown that the abrasion of the compressed wood is better than the uncompressed wood sample. Abrasion decreases with temperature, pressing time increases and compression ratio decreases.

3.6. Influence of compression parameters to mold resistance of Acacia hybrid wood treated by thermo-mechanical method

Wood after compression has a better mold resistance than the control sample, the highest result is 38 times.

3.7. The effects of compression parameters on density, density distribution

Compression ratio has a clear influence on KLRtb, KLRmax and KLRmin; Unclear influence on the value of PD and Pb.

3.8. Optimum technology parameters for heat treatment of Acacia

hybrid wood

Compression rate: 34%; Pressing temperature and pressing time: 180 ^{o}C and 180 minutes; Pressing temperature and pressing time: 155 ^{o}C and 100 minutes

3.9. Regarding the production process

The thesis has introduced the technological process of producing flooring from Acacia hybrid wood by thermal-mechanical method including 6 stages. The process has been recognized as Technical Progress according to Decision No. 96 QĐ-TCLN-KH & HTQT of MARD signed on March 17, 2020

LIST OF PUBLICIZED ARTICLES, SCIENTIFIC WORKS RELATED TO THE THESIS

Year of publication	Name of the scientific article	Journal name	Author/Co-author
2018	Effects of pressing temperature and pressing time on mechanical, physical properties of Acacia hybrid wood (*Acacia mangium x acacia auriculiformis*)	Journal of Forestry Science and Technology	**Co-author**
2019	Effect of compression ratios on some properties of densified Acacia hybrid, Eucalyptus urophylla and Pinus merkusii wood by thermod- mechanical treatment method	Journal of Forestry Science and Technology	**Co-author**
2019	The influence of process parameters on the springback and through thickness density profile of Acacia hybrid wood (*Acacia mangium x Acacia auriculiformis)*	Journal of Forestry Science and Technology	**Co-author**
2019	Isolation of some strains wood decaying fungi and determination of against the rotting fungi ability of Acacia hybrid wood denatured	Journal of Forestry Science and Technology	**Co-author**