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I-PAN

INNOVATIVE POPLAR LOW DENSITY STRUCTURAL PANEL

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Document information

Abstract

In the framework of I-PAN, CHIMAR will develop a technology for producing an innovative resin suitable for bonding recycled wood and poplar strands to form light weight OSB panels for structural use.

The R&D objectives for the innovative resin system will be:

- Curing temperature lower than that of the conventional resin systems by up to 10%.
- Compensation of strand moisture contents higher than 3.5%.
- To provide panels with formaldehyde emissions satisfying the most stringent European Standards as per EN 13986.

This report details a preliminary study performed by CHIMAR in view to determine the chemical/physical characteristics and requirements for the resins, which can be used as candidates for developing the innovative binder for LSB within I-PAN.

Keywords

Poplar, wood, OSB, wood-based panels, engineered wood, binder, adhesive

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* Abbreviations of editor/contributor name

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Table 1 - List of abbreviations

OSB	Oriented Strand Board
LSB	Lightweight Strand Board
UF	Urea Formaldehyde
PF	Phenol formaldehyde
MUF	Melamine Urea Formaldehyde
BC	Buffer Capacity

1 INTRODUCTION

I-PAN project aims at providing novel and environmentally friendly solutions in the field of engineered wood boards (or wood-based panels) and particularly in Oriented Strand Boards (OSB) manufacturing process with the target to reach the higher level functional characteristics of Lightweight Strand Boards (LSB). OSB/LSB is a type of wood-based panel consisting of strands of wood pressed together in layers and bonded with a synthetic resin. The wood species used in OSB manufacture include both softwood and hardwood. The resin types typically used include Phenol formaldehyde (PF), Melamine fortified Urea Formaldehyde (MUF) or isocyanate (pMDI). In the I-PAN project a breakthrough lightweight OSB panel will be developed, comprising 50% of its volume of recycled wood and for the remaining 50% of poplar wood by using the upper part of the poplar tree that is commonly underused. To this purpose, a novel OSB manufacturing process will be developed and an innovative binder system will be formulated thus allowing the reduction of energy requirements during the drying and pressing process of OSB manufacture, the minimization of VOC emissions and the reduction of the overall production cost.

In the framework of I-PAN, CHIMAR will develop a technology for producing an innovative resin suitable for bonding recycled wood and poplar strands to form light weight OSB panels for structural use. The innovative resin will be based on formaldehyde and will be of the aminoplastic (urea-formaldehyde, urea-melamine-formaldehyde/melamine-urea-formaldehyde, melamine-formaldehyde), or phenolic (phenol-formaldehyde) type or a combination of these types and it will be combined with a suitable cross-linking agent and possibly with a suitable formaldehyde catcher.

The R&D objectives for the innovative resin system will be:

- Curing temperature lower than that of the conventional resin systems by up to 10%.
- Compensation of strand moisture contents higher than 3.5%.
- To provide panels with formaldehyde emissions satisfying the most stringent European Standards as per EN 13986.

In what follows, a preliminary study is described, performed by CHIMAR in view to determine the chemical/physical characteristics and requirements for the resins, which can be used as candidates for developing the innovative binder for LSB within I-PAN.

2 CONSIDERATIONS AND METHODS

The OSB boards to be developed within I-PAN will be prepared out of poplar strands made from a new fast-growing poplar tree species namely I-214 clone, which is grown in several European countries. Additionally the upper part of the tree log and the tree branches will be mainly used for the preparation of the strands.

In most of the known tree species there is less sapwood than heartwood in the main part of the stem. The proportion of heartwood to sapwood in the main part of the stem vary with the tree species. The only exception lies in young trees and in the youngest portions of the stems and branches of older trees, in which the sapwood naturally dominates since they are young. This means that **poplar sapwood** will be mainly used for the preparation of the strands within I-PAN. Then the following implications can be envisaged:

- The sapwood is of significantly lower density than the heartwood. This means that the strands will have a density that is even lower than the already low density for poplar wood.
- The sapwood has a higher moisture content than the heartwood and therefore requires more energy for drying. More energy for drying means a higher temperature for drying and therefore an increased risk for wood damage due to the uneven migration of moisture.
- The sapwood will considerably shrink upon drying. This increases the risk of wood material fracture during drying. The fracture is not always visible and can only be traced when the board properties are deteriorated without any other apparent reason.
- Swelling is the opposite phenomenon of shrinking and the problem of very high board swelling can be faced when the wood used had considerably shrunk during drying. Therefore the wood drying process has to be very smooth in order to avoid humidity differences/gradients in the wood and excessive shrinking.
- Moreover, the high moisture content makes the wood more susceptible to decay by fungi. Such decay takes place faster in the periods of spring and autumn. A very tight management of the wood log yard is needed to avoid having wood standing for a long time and being exposed to fungal attack thus protecting the wood from decay.

According to CHIMAR experience with wood species similar to the poplar used within I-PAN (i.e. species with low density), such species should be dried very carefully and smoothly to avoid the excessive shrinking and damaging of the wood.

Wood species of low density are normally dried at CHIMAR lab at lower temperatures (around 60 to 70^{o}C) for a prolonged period of time (two-three days) using sufficient air circulation level. This way a smooth migration and evaporation of water/moisture is achieved to keep wood shrinking at a minimum level. The target final moisture content should be around 5-6% in the case of wood veneers for plywood production and around 3-4% in the case of wood chips or strands. In the case of wood chips or strands a moisture content lower than 3% should be avoided as it would cause excessive shrinking. Furthermore, a moisture content higher than 4% should be avoided too as it would cause many processing problems.

It is known that poplar wood has a high Buffer-Capacity (BC) and therefore withstands and negates the pH drop that is chemically induced to allow curing of amino resins. Thus more hardener/catalyst will be needed to cure/polymerize the amino resins used for bonding poplar than for bonding other wood types. The curing time of amino resins will be higher when used for bonding poplar than bonding other wood types and thus the productivity of poplar board manufacturing process will be lower.

The viscosity of the binder resin significantly affects its performance. The operating window is relatively narrow in the case of poplar. It the case of I-PAN the operating window is even smaller since a much higher percentage of sapwood is expected as explained above as well as since the new blender to be developed will be able to handle resins of a typical viscosity value of 100-150 cp. When the resin viscosity is too low, the resin will penetrate into the wood pores and will not be available for bonding. If the viscosity is too high, then the resin cannot be evenly distributed on the wood strands by the atomizers. However, it is preferable to have a high viscosity than a too low viscosity.

3 EXPERIMENTAL STUDY

A preliminary study was performed by CHIMAR in view to determine the chemical/physical characteristics and requirements for the resins, which can be used as candidates for developing the innovative binder for LSB within I-PAN.

Comparison tests were carried out using the I-PAN poplar strands and wood strands of Bulgarian origin. The wood samples analyzed at CHIMAR lab were:

1) Poplar strands delivered by IMAL
2) Tilia strands (already known to cause problems in OSB production) and
3) Spruce strands (strands used commonly in OSB production)

Using the above-mentioned strand samples the following tests were performed:

a) Density determination: the density of the dried strands was determined by measuring the weight and the volume of each sample. The strands were dried for five days at 70^{o}C until their weight became constant.
b) Hollow space/pore volume determination
c) Water absorption determination
d) Comparison of contact angles
e) Comparison of buffer capacity of the examined samples.

The average values of the measurements made are depicted in Table 2. Furthermore, the analysis and the summary of the results are given in Table 3.

A photo showing the contact angle comparison is included in Picture 1.

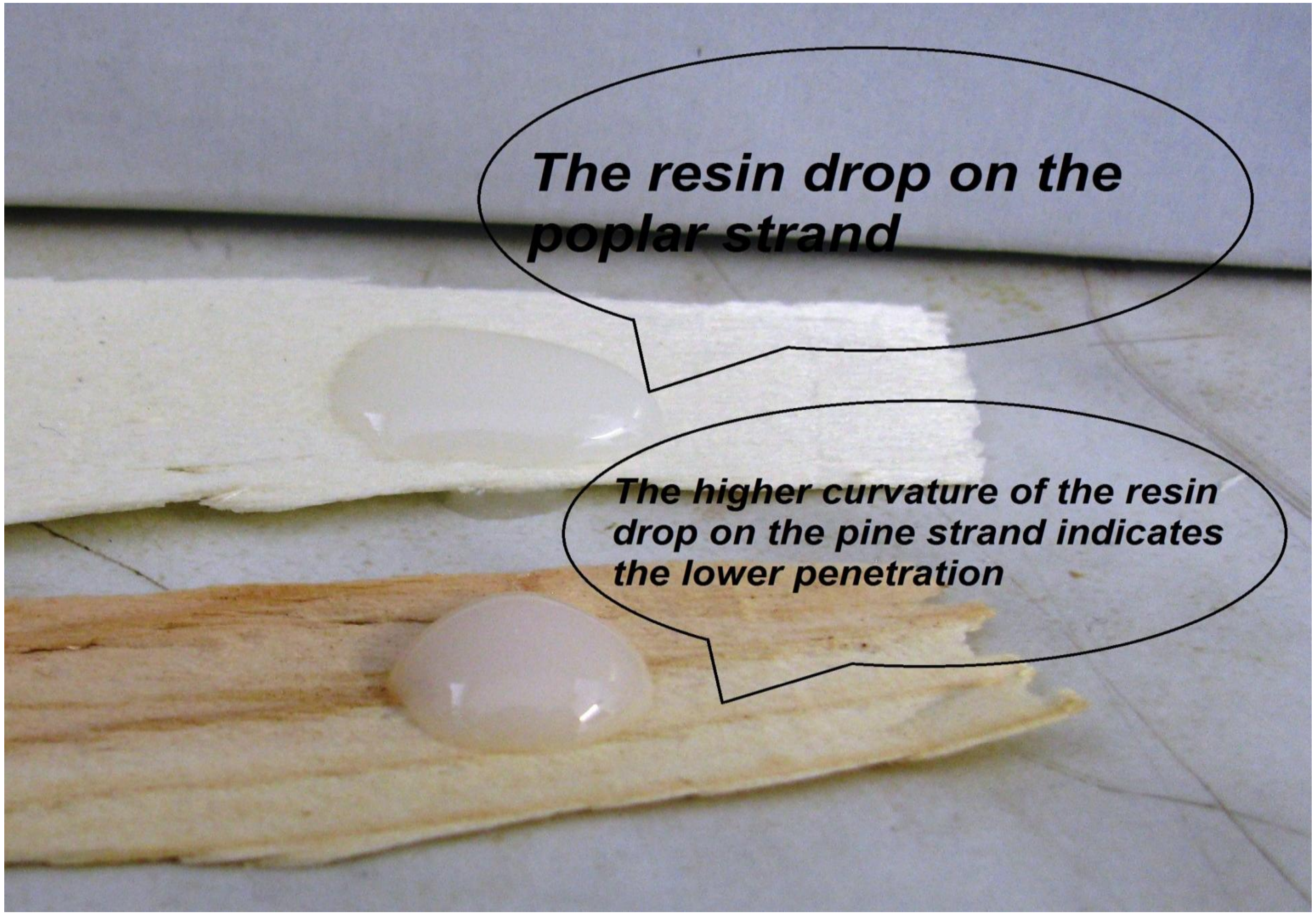
Table 2: Measurements made in strands from different wood species (average values of series of measurements made)

No.	Wood Type	Dimensions, mm			Weight initial	Weight dry	Moisture Content %	Density kg/m^3	1 day	2 days	2 days + 4h	Absorption 1 day	Absorption 2 days	Absorption 2 days + 4h
0	tilia	60	18.5	0.60	0.2890	0.2680	7.84	402.40	0.7028	0.6883	0.718	162.24	156.83	167.91
1	tilia	59	25	0.45	0.3813	0.3612	5.56	544.18	0.7448	0.762	0.7856	106.20	110.96	117.50
2	spruce	80	18	0.70	0.4080	0.3804	7.26	377.38	0.8644	0.9164	0.9607	127.23	140.90	152.55
3	spruce	70	19.5	0.50	0.3868	0.3604	7.33	528.06	0.7484	0.7609	0.7885	107.66	111.13	118.78
4	poplar	53	67	0.50	0.5274	0.5114	3.13	288.03	1.5336	1.4941	1.6104	199.88	192.16	214.90
6	poplar	75	25	0.40	0.2989	0.2862	4.44	381.60	0.6509	0.6341	0.7218	127.43	121.56	152.20
7	poplar	60	28	0.70	0.4401	0.4230	4.04	359.69	1.1782	1.2573	1.2738	178.53	197.23	201.13

Table 3: Summary of the results of the analysis of strands from different wood species

Strand origin/type	Moisture content, %	pH	BC ml 0.1N HCl	Density kg/m^3	Absorption 1 day	Absorption 2 days	Absorption 2 days+4h	Average absorption
IMAL Face	9.00	5.70	6.20	343.11	168.62	170.32	189.41	176.11
IMAL Core	11/3.87 *	6.20	8.00					
Bulgarian tilia	9.2/6.70 *	4.52	5.40	473.29	134.22	133.90	142.70	136.94
Bulgarian spruce	9.1/7.29 *	4.36	4.75	452.72	117.45	126.02	135.67	126.38

*initial/re-dried before absorption test



Picture 1: Comparison between the contact angles of a Urea Formaldehyde resin drop on spruce and poplar strands. The resin viscosity was approx. 300 cp.

4 CONCLUSIONS/RECOMMENDATIONS

The results of the study performed in strands from different wood species revealed the following:

- The poplar strands supplied by the I-PAN partners had a lower density than the strands from other wood types.
- The buffer capacity of the poplar strands is significantly higher than the buffer capacity of the other wood species studied.
- The contact angle of a Urea-Formaldehyde resin on poplar strands indicates a faster wetting than in the case of spruce strands and therefore a deeper penetration of the resin in the wood leading to resin loss.
- The water absorption is much higher in the poplar strands as compared to the strands from other wood species.

Taking all the above findings into consideration the requirements for resin properties can be initially outlined in Tables 4 and 5 below:

Table 4: Required properties of amino type resins

Viscosity at 25°C [cp]	200-250
pH range	7.5-9.5
Solids content [%][1]	64.5-68.5
Specific gravity at 20°C [g/cm^3]	1.280-1.300
Free formaldehyde [%]	≤0.15
Water tolerance at 20°C	1: 0.8 recommended
Gel time [s][2]	60-80
Storage at 20°C	>4 weeks

[1] 2h at 120°C
[2] 3% NH_4Cl hardener w/w on resin solids

Table 5: Required properties of phenolic type resins

Viscosity at 25°C [cp]	250-450
pH range	10.0-13.0
Solids content [%][1]	41-49
Specific gravity at 20°C [g/cm^3]	1.17-1.20
Alkali content [%]	5.0-10.0
Water tolerance at 20°C	>1:10
Gel time [min][2]	10-15
Storage at 5°C	> 6 months
Appearance	clear brown liquid

[1] 2h at 120°C
[2] at 130°C without hardener

The above findings prove that the available resin systems cannot meet the objectives set for the I-PAN resin system and important R&D work should be carried to develop a resin of satisfactory bonding performance for the light weight LSB, which will be produced within the I-PAN project.