OPTIMIZATION OF HARDWOOD PULP CHIPS PREHEATING RATE IN WET-PROCESS FIBERBOARD MANUFACTURE

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ABSTRACT: At the present paper are presented the experimental data of hardwood pulp chips preheating rates influence on fiberboards properties. It is overlooked main fiberboards properties, according to the requirements of European standards – EN (Europäische Norm), the determination methods of pulp chips and pulp mass properties, determination methods and apparatuses of fiberboards properties. It is also conducted analyze aiming to establish optimum preheating rate according to the fiberboards properties.

KEY WORDS: research, methods, fiberboards properties, pulp chips, preheating rate, Asplund defibrator

INTRODUCTION

There is a condition of market shortage of fiberboards production in Europe [1], which imposes conducting of an analysis, aiming to optimize the technological rates.

Quality of pulping process is essential for the final quality of fiberboards, for the total energy input, and for the percentage yield of wood raw material [2]. The preheating of pulp chips is very important process in engineered pulp production. That imposes heat treatment of pulp chips, from given wood spices, to be accomplished at optimum rates. During the preheating of pulp chips compound process of heat interchanges accrued and because of that the preheating rates can not be determinate only by theoretical methods. This imposes conducting of experimental analyzes aiming to establish interdependencies between pulp chips preheating rates and fiberboard properties.

1. RESEARCH OBJECTIVE

The research objective is to establish most appropriate pulp chips preheating rate according to the fiberboards properties. To achieve the objective the following tasks must be fulfilled:

a. To determinate which fiberboards properties will be observe, and by their alternations to establish quality of pulp process;

b. To clarify and substantiate the technological parameters of fiberboards manufacturing after pulping process and to stabilize this parameters;

c. To substantiate the main parameters of “Asplund” method pulp chips preheating rate;

d. To draw the experimental plan;

e. To accomplish the experiment;

f. To summarize and analyze the experimental data.

2. FIBERBOARDS PROPERTIES

The first step of compiling the experimental methodology is to determinate which fiberboards properties will be observed. For this propose the standardization requirements
must be examined. The definitions, classification and symbols of wood fiberboards are given in EN 316:2001. The specifications of fiberboards are given in EN 622:2006.

According to those standards the main fiberboard properties are: density, bending strength, moisture content and swelling in thickness after immersion of water.

For the hard boards (density up to 900 kg/m$^3$), values of these properties must vary as follow: bending strength – from 25 to 40 N/mm$^2$; swelling in thickness – from 8 to 35%.

3. METHODS AND APPARATUSES FOR DETERMINATION OF PULP CHIPS AND PULP MASS PROPERTIES

In this research the choice of pulp chips and pulp mass control properties was accomplished according to the practices of technological control in fiberboards manufacturing and especially according to the practices in “Lessoplast” PLC – Trojan by taking into consideration the presence apparatuses in factory laboratories.

The control properties are as follow:

For the pulp chips: fractional composition (chips size) and moisture content.

For the pulp mass: freeness and temperature.

To determine the size of pulp chips will be used vibration screen machine with three screens as follow:

- Coarse screen – diameters of outlets $d = 30$ mm;
- Medium screen – diameters of outlets $d = 10$ mm;
- Fine screen – diameters of outlets $d = 5$ mm.

The screens dimensions are as follow – width/length: 450/450 mm.

The process sequence follows: one kilogram of pulp chips are feed into working machine for 30 second, then machine is stopped and the fractions are assessed in percentages. For example if the weight of pulp chips from coarse fraction is 245 g, then relative part of coarse fraction is 24.5%.

The method for determination of moisture content of pulp chips is as follow:

500 g pulp chips are taken after the sorting machine. The weight of the sample is determinate with exactitude of 0.1 g. Then the chips are dried in drying-oven with temperature 102 ± 3° until constant weight.

The moisture content is determinate by the equation:

$$H = \frac{m_H - m_O}{m_O} \times 100, \%$$

where:

- $m_H$ – weight of pulp chips before drying, g;
- $m_O$ – weight of pulp chips after drying, g.

The moisture content of pulp chips in fiberboard manufacturing must be in limits from 40 to 60%.

The determination of moisture content, in industrial conditions, must be accomplished in period of 2h.

The freeness of pulp mass will be determinate by using Defibrator pulp freeness tester, fig.1. Range of tester is from 9.6 DS (water alone) to 110 DS (Defibrator seconds).

When the concentration of pulp mass in the tester achieves 1.28%, the drain valve is opened and simultaneously the chronometer is started. Straight away when the last amount of water passed level indicator the chronometer is
stopped.

The time for water outflow shows the freeness in DS. For example 23 s correspond to
degree of 23 DS. Freeness degree must be determined with exactitude of 0.1 DS.
The temperature of pulp mass is determined by non-contactable thermometer (infra-
red radiation), with exactitude of 0.1°C.

4. METHODS AND APPARATUS FOR DETERMINATION OF FIBEROARDS
PROPERTIES

Fiberoards properties must be determined according to the requirements of European
Standards (EN – Europäische Norm).
The main norms of sampling, cutting and expression of test results for fiberoards are
given in EN 326-1:2001 “Wood-based panels – Sampling, cutting and inspection – Part 1:
Sampling and cutting of test pieces and expression of test results”.
The dimensions of test samples for fiberoards testing are determined in EN 325:2001
“Wood-based panels – Determination of dimension of test pieces”. The thickness must be
determined with exactitude of 0.01 mm. The measuring of length and width must be
accomplished with exactitude of 0.1 mm.
The determination of moister content of fiberoards must be accomplished according
to the requirements of EN 322:2001 “Wood-based panels – Determination of moister content”. The result of determination can be used to evaluate moister content of fiberoards
according to EN 326-1:2001.
The moister content \( H \) for every sample must be estimated in percentage of his weight,
with exactitude of 0.1%, using the equation:

\[
\frac{m_H - m_O}{m_O} \times 100, \text{ %} \tag{2}
\]

where:
- \( m_H \) – weight of test sample before drying, g;
- \( m_O \) – weight of test sample after drying, g.
The determination of fiberoards density must be accomplished according to the
requirements of EN 323:2001 “Wood-based panels – Determination of density”.
The test result can be used to evaluate fiberoards density according to EN 321-1:2001.
The density, \( \rho \), of every sample (in kg/m³), should be estimated using the equation:

\[
\rho = \frac{m}{b_1b_2t} \times 10^6, \text{ kg/m}^3 \tag{3}
\]

where:
- \( m \) – test sample weight, g;
- \( b_1, b_2 \) – test sample sides length, mm (\( b_1 = b_2 = 50 \text{ mm} \));
- \( t \) – test sample thickness, mm.
The density must be estimate with exactitude of 0.01 kg/m³.
The determination of bending strength must be accomplished according to the
requirements of EN 310:2001 “Wood-based panels – Determination of modulus of elasticity in
bending and bending strength”.
The bending strength \( f_m \) (N/mm²) for every sample should be estimated using the
equation:

\[
f_m = \frac{3F_{\max} l_1}{2bt^2}, \text{ N/mm}^2 \tag{4}
\]

where:
- \( F_{\max} \) – maximum (destruction) load, N;
- \( l_1 \) – distance between fulcrum centers, mm;
- \( b \) – test sample width, mm;
- \( t \) – test sample thickness, mm.
The bending strength must be estimated with exactitude of 1 N/mm².
The determination of fiberoards swelling in thickness must be accomplished according
to the requirements of EN 317:2002 “Particleboards and fiberoards – Determination of
swelling in thickness after immersion in water”.

133
Swelling in thickness $G_t$ for every test sample must be estimated in percentages by the equation:

$$G_t = \frac{t_2 - t_1}{t_1} \times 100\%$$  \hspace{1cm} (5)

where:
- $t_1$ – test sample thickness before immersion, mm;
- $t_2$ – test sample thickness after immersion, mm.

Fiberboards swelling in thickness must be estimated with exactitude of 0.1%.

5. EXPERIMENTAL PLAN

With a view to direct application of experimental results in production practices, the experiment will take place in industrial conditions at the fiberboards mill of “Lessoplast” – Trojan.

It will be used pulp chips of beech ($Fagus$ silvatica L) and cerris ($Quercus$ cerris L) in interrelation 1:2 (33.3% beech and 66.7% cerris).

At the instant technology in fiberboard mill the preheating of pulp chips is accomplished with saturation steam with pressure 0.8 N/mm$^2$ and temperature 164.2°C. The duration of preheating should be determined by using the equation:

$$t = t_1 + t_3 = \frac{F_0 + r^2 c_0 k_1 k_2 + \frac{q_i J^2}{8(t_2 - t_1) \lambda}}{\lambda}$$

with accounting of concrete limitations. Computation of this equation gives for the preheating duration between 1 and 2 min.

For the purpose of research will be defined 6 (six) preheating rates:

- a) Preheating rate $A_1$ – steam pressure 0.8 MPa; steam temperature 169.6°C; preheating duration 2 min;
- b) Preheating rate $A_2$ – steam pressure 0.95 MPa; steam temperature 175.25°C; preheating duration 2 min;
- c) Preheating rate $A_3$ – steam pressure 0.7 MPa; steam temperature 164.2°C; preheating duration 2 min;
- d) Preheating rate $B_1$ – steam pressure 0.8 MPa; steam temperature 169.6°C; preheating duration 1.5 min;
- e) Preheating rate $B_2$ – steam pressure 0.95 MPa; steam temperature 175.25°C; preheating duration 1.5 min;
- f) Preheating rate $B_3$ – steam pressure 0.7 MPa; steam temperature 164.2°C; preheating duration 1.5 min;

From every preheating rate will be produced 8 (eight) fiberboards panels. The technological parameters after preheating will be stabilized at the levels of instant technology in “Lessoplast” – Trojan.

The speed of forming machine will be 21 m/min. Dry content of fiber mat before hot-pressing will be 30%. And the hot-pressing rate is given in fig.2.
6. EXPERIMENTAL RESULTS

The values of fiberboards properties produced at preheating rates from A1 to A6 are presented in tables 1 to 6.

### Table.1 Fiberboards properties at preheating rate A1

<table>
<thead>
<tr>
<th>Panel number</th>
<th>Freeness, DS</th>
<th>Thickness, mm</th>
<th>Density, kg/m³</th>
<th>Bending strength, N/mm²</th>
<th>Moister content after hot-press, %</th>
<th>Swelling in thickness, %</th>
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</thead>
<tbody>
<tr>
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<td>899,398</td>
<td>34.02</td>
<td>0.4</td>
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<td>3.2</td>
<td>912,931</td>
<td>28.34</td>
<td>0.3</td>
<td>24.5</td>
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<td>4</td>
<td>21.4</td>
<td>3.2</td>
<td>900,24</td>
<td>27.10</td>
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<td>25.4</td>
</tr>
<tr>
<td>5</td>
<td>22.3</td>
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<td>893,736</td>
<td>35.74</td>
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<td>28.8</td>
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<td>6</td>
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<td>898,261</td>
<td>34.48</td>
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<td>27.1</td>
</tr>
<tr>
<td>7</td>
<td>22.9</td>
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<td>906,736</td>
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<td>8</td>
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<td>908,184</td>
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<td>903,756</td>
<td>32.904</td>
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### Table.2 Fiberboards properties at preheating rate A2

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<th>Thickness, mm</th>
<th>Density, kg/m³</th>
<th>Bending strength, N/mm²</th>
<th>Moister content after hot-press, %</th>
<th>Swelling in thickness, %</th>
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<tbody>
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<td>3.1</td>
<td>884,652</td>
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<td>3.2</td>
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<td>23.52</td>
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<td>27.9</td>
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<td>3.3</td>
<td>882,35</td>
<td>27.67</td>
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<td>27.1</td>
</tr>
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<td>33.34</td>
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<td>30.6</td>
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<td>3.4</td>
<td>883,458</td>
<td>25.20</td>
<td>0.4</td>
<td>26.3</td>
</tr>
<tr>
<td>Average</td>
<td>18.09</td>
<td>3.25</td>
<td>884,08</td>
<td>28.056</td>
<td>0.45</td>
<td>27.425</td>
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### Table.3 Fiberboards properties at preheating rate A3

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<th>Freeness, DS</th>
<th>Thickness, mm</th>
<th>Density, kg/m³</th>
<th>Bending strength, N/mm²</th>
<th>Moister content after hot-press, %</th>
<th>Swelling in thickness, %</th>
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<td>28.8</td>
</tr>
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<td>Average</td>
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<td>3.175</td>
<td>903,189</td>
<td>32,159</td>
<td>0.788</td>
<td>26,975</td>
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### Table.4 Fiberboards properties at preheating rate A4
### Table 5 Fiberboards properties at preheating rate B2

<table>
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<th>Panel number</th>
<th>Freeness, DS</th>
<th>Thickness, mm</th>
<th>Density, kg/m³</th>
<th>Bending strength, N/mm²</th>
<th>Moister content after hot-press, %</th>
<th>Swelling in thickness, %</th>
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<td>27.413</td>
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### Table 6 Fiberboards properties at preheating rate B3

<table>
<thead>
<tr>
<th>Panel number</th>
<th>Freeness, DS</th>
<th>Thickness, mm</th>
<th>Density, kg/m³</th>
<th>Bending strength, N/mm²</th>
<th>Moister content after hot-press, %</th>
<th>Swelling in thickness, %</th>
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### 7. CONCLUSIONS

Table 7 presents average values of fiberboards properties at different preheating rates.

### Table 7 Average values of fiberboards properties at different preheating rates

<table>
<thead>
<tr>
<th>Preheating rate</th>
<th>Freeness, DS</th>
<th>Thickness, mm</th>
<th>Density, kg/m³</th>
<th>Bending strength, N/mm²</th>
<th>Moister content after hot-press, %</th>
<th>Swelling in thickness, %</th>
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<tbody>
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<td>903.756</td>
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<td>884.08</td>
<td>28.056</td>
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</tbody>
</table>

In figure 3 and 4 are presented the variation of fiberboards density and bending strength at different preheating rates.
From the presented data can be seen that highest density and bending strength had the fiberboards produced at preheating rate A₁, respectively 903.189 kg/m³ and 32.904 N/mm². And lowest values of those indicates had fiberboards produced at preheating rate B₂, respectively 847.554 kg/m³ and 24.73 N/mm². The relative drop of fiberboards density at the others preheating rates, in comparison whit A₁ is as follow: – 2.18%; A₃ – 0.06%; B₁ – 2.34%; B₂ – 5.11%; B₃ – 0.84%.

The presented data leads to the conclusion that optimal preheating rate, for concrete wood-raw material, is preheating rate A₁, whit parameters – steam pressure 0.8 MPa; steam temperature 169.6°C; and preheating duration 2 min.

The drop of fiberboards properties whit decreasing of preheating duration is explained whit insufficient time of pulp chips heating and insufficient time for whole quantity of lignin in middle lamella to exceed his glass point.

While the drop of fiberboard properties whit increasing of steam pressure can be explained whit decreasing of pulp chips passage time through defibrator’s plates, that for the concrete boundary preheating parameters limits can not be compensate by the positive temperature gradient.

This imposes extension of pulping process parameters whit accounting of mechanical processes their dynamic and kinematics.

In fiberboards manufacturing technological parameters of production processes can not be stabilized enough for research purposes. That imposes, in order to determined accurate interdependences between pulp chips preheating rates and fiberboards properties, conducting of laboratory experiments, in conditions maximally simulating the industrial ones, and whit highest degree of stability of others considerable technological factors.

REFERENCES