JOURNAL OF ENGINEERING
annals OF
FACULTY OF ENGINEERING HUNEDOARA
TOME VI (year 2008), FASCICULE 3, (ISSN 1584 – 2673)

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 (Europäishe 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 pup 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%.

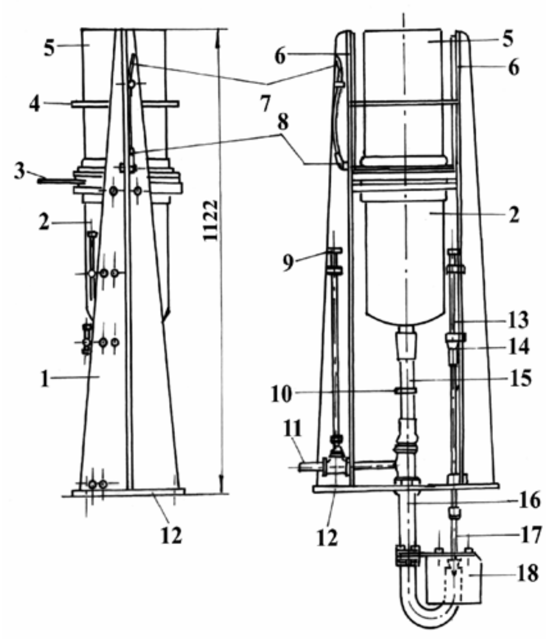

Figure1. Defibrator pulp freeness tester
1 – stand; 2 – bottom cylinder (stationary); 3 – screen; 4 – fulcrum-idle wheel; 5 – top cylinder (movable); 6 – stem of top cylinder; 7 – handle of top cylinder;; 8 – spring bolt; 9 – wheel of water inlet valve;10 – level indicator ; 11 – water inlet valve; 12 – foundation; 13 – plug ring of the valve; 14 – bolt;15 – glass tube; 16 – tube; 17 – drain valve; 18 – plug valve

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

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

The moister content is determinate by the equation:

$$H = \frac{m_H - m_O}{m_O}.100,\ \% \qquad (1)$$

where:

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

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

The determination of moister 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 freeness degree of 23 DS. Freeness degree must be determined whit exactitude of 0.1 DS.

The temperature of pulp mass is determined by non-contactable thermometer (infra-red radiation), whit exactitude of 0.1° C.

4. METHODS AND APPARATUSES FOR DETERMINATION OF FIBERBOARDS PROPERTIES

Fiberboards properties must be determined according to the requirements of European Standards (EN – Europäishe Norm).

The main norms of sampling, cutting and expression of test results for fiberboards 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 fiberboards testing are determined in EN 325:2001 "*Wood-based panels – Determination of dimension of test pieces*". The thickness must be determined whit 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 fiberboards 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 fiberboards according to EN 326-1:2001.

The moister content *H* for every sample must be estimated in percentage of his weight, whit exactitude of 0.1%, using the equation:

$$H = \frac{m_H - m_O}{m_O}.100,\ \% \qquad (2)$$

where:

m_H – weight of test sample before drying, g;

m_O – weight of test sample after drying, g.

The determination of fiberboards 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 fiberboards density according to EN 321-1:2001.

The density, ρ, of every sample (in kg/m^3), should be estimated using the equation:

$$\rho = \frac{m}{b_1.b_2.t}.10^6,\ \text{kg/m}^3 \qquad (3)$$

where:

m –test sample weight, g;

b_1, b_2 –test sample sides length, mm ($b_1 = b_2 = 50$ mm);

t – test sample thickness, mm.

The density must be estimate whit exactitude of 0,01 kg/m^3.

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/mm^2) for every sample should be estimated using the equation:

$$f_m = \frac{3F_{max}l_1}{2bt^2},\ \text{N/mm}^2 \qquad (4)$$

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 whit exactitude of 1 N/mm^2.

The determination of fiberboards swelling in thickness must be accomplished according to the requirements of EN 317:2002 "*Particleboards and fiberboards – Determination of swelling in thickness after immersion in water*".

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

$$G_t = \frac{t_2 - t_1}{t_1}.100, \% \qquad (5)$$

where:

t_1 – test sample thickness before immersion, mm;

t_2 – test sample thickness after immersion, mm.

Fiberboards swelling in thickness must be estimated whit 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 whit saturation steam whit pressure 0,8 N/mm^2 and temperature 164.2°C. The duration of preheating should be determined by using the equation $t = t_1 + t_3 = \frac{F_O.r^2.c.\rho}{\lambda}k_1.k_2 + \frac{q_r.l^2}{8(T_2 - T_1)\lambda}$ whit 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 0.7MPa; 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.

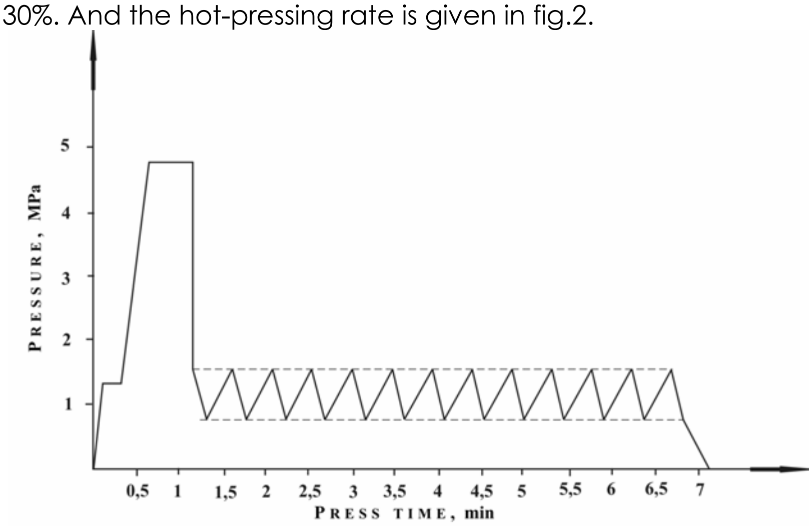

Figure2. Hot-pressure rate used in "Lessoplast" – Trojan

6. EXPERIMENTAL RESULTS

The values of fiberboards properties produced at preheating rates from A_1 to A_6 are presented in tables 1 to 6.

Table.1 Fiberboards properties at preheating rate A_1

Panel number	Freeness, DS	Thickness, mm	Density, kg/m³	Bending strength, N/mm²	Moister content after hot-press, %	Swelling in thickness, %
1	22,8	3,3	910,562	35,86	0,6	27,1
2	23,5	3,2	899,398	34,02	0,4	27,1
3	19,7	3,2	912,931	28,34	0,3	24,5
4	21,4	3,2	900,24	27,10	1,0	25,4
5	22,3	3,5	893,736	35,74	0,8	28,8
6	23,0	3,4	898,261	34,48	0,6	27,1
7	22,9	3,3	906,736	36,72	0,3	26,2
8	19,5	3,2	908,184	30,97	0,4	26,4
Average	21,89	3,25	903,756	32,904	0,55	26,575

Table.2 Fiberboards properties at preheating rate A_2

Panel number	Freeness, DS	Thickness, mm	Density, kg/m³	Bending strength, N/mm²	Moister content after hot-press, %	Swelling in thickness, %
1	17,8	3,2	896,635	32,21	0,7	28,8
2	19,3	3,4	890,367	31,80	0,3	27,1
3	18,6	3,1	884,652	29,73	0,3	25,4
4	16,3	3,2	875,045	23,52	0,4	27,9
5	17,5	3,3	882,35	27,67	0,7	27,1
6	19,7	3,2	869,381	20,98	0,3	26,2
7	16,4	3,2	890,75	33,34	0,5	30,6
8	19,1	3,4	883,458	25,20	0,4	26,3
Average	18,09	3,25	884,08	28,056	0,45	27,425

Table.3 Fiberboards properties at preheating rate A_3

Panel number	Freeness, DS	Thickness, mm	Density, kg/m³	Bending strength, N/mm²	Moister content after hot-press, %	Swelling in thickness, %
1	22,2	3,5	911,083	39,45	0,7	27,1
2	22,0	3,1	896,067	33,62	0,6	28,8
3	18,8	3,3	908,75	35,78	0,3	27,9
4	21,6	3,0	897,433	26,0	0,7	26,2
5	23,0	3,2	902,933	32,07	0,9	27,1
6	21,4	3,4	904,935	28,21	1,3	24,5
7	19,3	3,0	895,783	32,23	1,1	25,4
8	21,8	2,9	908,529	29,91	0,7	28,8
Average	21,263	3,175	903,189	32,159	0,788	26,975

Table.4 Fiberboards properties at preheating rate B_1

Panel number	Freeness, DS	Thickness, mm	Density, kg/m³	Bending strength, N/mm²	Moister content after hot-press, %	Swelling in thickness, %
1	17,6	3,1	885,679	20,85	0,4	27,9
2	17,2	3,4	891,836	30,7	0,7	25,4
3	18,3	3,3	890,164	24,15	0,3	26,2
4	17,8	3,2	886,362	22,02	0,3	27,1
5	18,5	3,2	880,215	28,49	0,7	27,1
6	19,0	3,4	875,386	31,35	0,7	25,4
7	18,2	3,1	871,482	22,76	0,7	27,9
8	17,1	3,2	880,02	27,83	0,5	26,5
Average	17,96	3,24	882,643	26,484	0,54	26,02

Table.5 Fiberboards properties at preheating rate B_2

Panel number	Freeness, DS	Thickness, mm	Density, kg/m³	Bending strength, N/mm²	Moister content after hot-press, %	Swelling in thickness, %
1	16,2	3,1	866,245	22,81	0,7	27,9
2	17,1	3,1	858,830	24,89	0,7	28,8
3	16,4	3,1	861,723	27,26	0,7	29,7
4	15,9	2,9	852,019	20,94	0,6	25,5
5	15,7	3,1	857,290	26,19	0,5	27,9
6	15,6	3,3	848,693	22,03	0,7	26,2
7	17,3	3,2	856,328	28,68	0,4	25,3
8	16,4	3,1	859,305	25,04	0,5	28,0
Average	16,325	3,113	857,5541	24,73	0,6	27,413

Table.6 Fiberboards properties at preheating rate B_3

Panel number	Freeness, DS	Thickness, mm	Density, kg/m³	Bending strength, N/mm²	Moister content after hot-press, %	Swelling in thickness, %
1	20,1	3,0	895,937	24,74	0,7	28,8
2	17,3	3,2	900,1	29,91	0,3	27,1
3	18,7	3,2	902,026	30,42	0,7	27,1
4	19,3	3,3	892,718	28,0	0,3	26,2
5	17,8	3,3	890,771	26,98	1,0	26,2
6	18,5	3,4	889,325	25,67	0,3	25,4
7	17,0	3,5	891,832	27,83	0,6	24,5
8	20,6	3,2	903,402	31,90	0,7	26,8
Average	18,663	3,263	896,1319	28,181	0,575	26,5125

7. CONCLUSIONS

Table7 presents average values of fiberboards properties at different preheating rates.

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

Preheating rate	Freeness, DS	Thickness, mm	Density, kg/m³	Bending strength, N/mm²	Moister content after hot-press, %	Swelling in thickness, %
A_1	21,89	3,25	903,756	32,904	0,55	26,575
A_2	18,09	3,25	884,08	28,056	0,45	27,425
A_3	21,263	3,175	903,189	32,159	0,788	26,975
B_1	17,96	3,24	882,643	26,484	0,54	26,02
B_2	16,325	3,113	857,554	24,73	0,6	27,413
B_3	18,663	3,263	896,132	28,181	0,575	26,513

In figure.3 and 4 are presented the variation of fiberboards density and bending strength at different preheating rates.

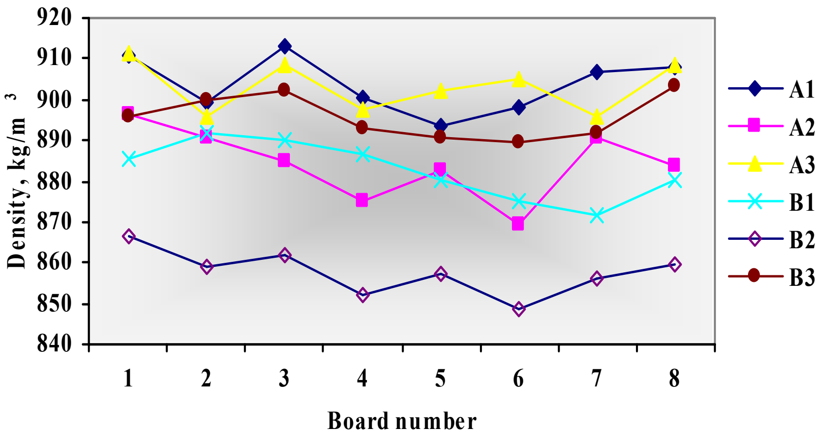

Figure 3. Variation of fiberboards density at different preheating rates

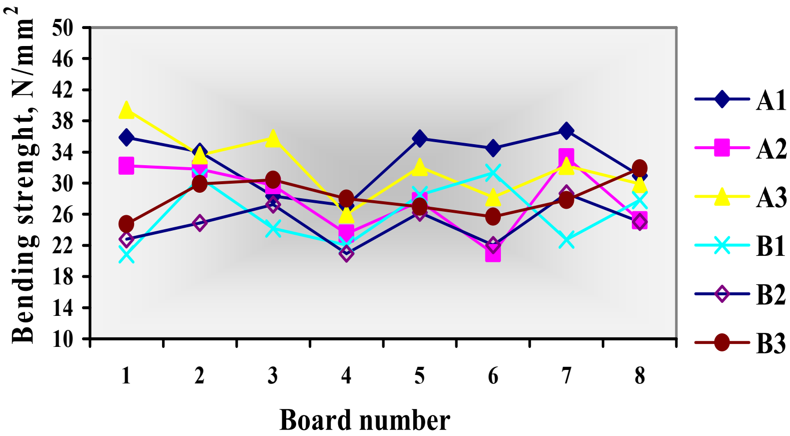

Figure 4. Variation of fiberboards bending strength at different preheating rates

From the presented data can be seen that highest density and bending strength had the fiberboards produced at preheating rate A_1, respectively 903,189 kg/m^3 and 32,904 N/mm^2. And lowest values of those indicates had fiberboards produced at preheating rate B_2, respectively 847,554 kg/m^3 and 24,73 N/mm^2. The relative drop of fiberboards density at the others preheating rates, in comparison whit A_1 is as follow: – 2,18%; A_3 – 0,06%; B_1 – 2,34%; B_2 – 5,11%; B_3 – 0,84%.

The presented data leads to the conclusion that optimal preheating rate, for concrete wood-raw material, is preheating rate A_1, 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.

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