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

INFLUENCE OF PULP FREENESS ON HARDWOOD FIBERBOARDS PROPERTIES

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ABSTRACT:
At the present paper are presented the methodology, results and results analyze of a study aiming to determined if the factor "pulp freeness" is significant for wet-process hardwood fiberboards properties.
From the experimental data analyze, through probability theory methods, was determined that at equal other conditions the factor "pulp freeness" is significant. And with increase of pulp freeness, in normal conducting of thermo-mechanical pulping process, the fiberboards properties are improving.
KEY WORDS:
fiberboards, pulp freeness, fiberboards properties, factor significance, variance, F-analyze

1. INTRODUCTION

Pulp freeness is conditional indicator characterizing the admission ability of pulp mass for given fluid (water or air) [5,6].

In wet-processes fiberboards manufacturing, pulp freeness, i.e. the dewatering of pulp for determinate time [1], is main technological indicator. Depending on pulp freeness is making conclusions, although indirect, for the quality of pulping process, adjusting the capacity and speed of forming machine. Therefore from main significance is to be determinate if pulp freeness is significant factor for fiberboards properties. Since equal speed of filtration, pulp freeness, had ply of small tear partial and long fibrillated fibers, which in quality attitude are incomparable, it isn't advisable the regression equations between pulp freeness and fiberboards properties to be terminate.

In Bulgaria there is a potential of using small and low-graded hardwood timber for fiberboard manufacturing [3]. Simultaneously with expansion of raw-material base of concrete production, it will fetch to more effective utilization of the available wood-raw material resource, something of big importance with a view to delineated and extended shortage of wood-raw material in Bulgaria [4].

All this imposed the indispensability of research, meant importance examination of factor "pulp freeness" for hardwood wet-processes fiberboards properties, to be conducted.

2. METHODOLOGY

To be determined if pulp freeness is a significant technological factor, having influence on hardwood fiberboards properties and specifically on properties of wet-process fiberboards from beech (*Fagus silvatica* L.) and cerris (*Quercus cerris* L.), most appropriate, because of his advantages, is to be used one factorial variance analyze (F-analyze).

For the task the examined factor will be study in five levels (k = 5). I.e. the fiberboards will be produced through wet-forming (casting) and hot-pressing of pulp mass with freeness as follow: 1) 15 – 17 DS; 2) 18 – 20 DS; 3) 21 – 23 DS; 4) 25 – 27 DS; 5) 30 – 33 DS. For every level will be produced 10 (ten) fiberboards, i.e. number of trials for every level is n = 10.

Accordingly to other studies [4] and manufacture practices, as a resin will be used phenol-formaldehyde in quantity of 2,35% in relation to absolutely dry wood and to improve water resistant will be used wax in quantity of 1,65% in relation to absolutely dry wood.

The hot-pressing will be conducted in two-stage regiment, as follow: I stage duration – 30 s at maximum specific pressure 4,7 MPa (N/mm^2); II stage duration 310 s at specific pressure 1,5 MPa; press closing time – 48 s, press opening time – 48 s; total duration of pressing cycle 436 s; pressing temperature – 200° C.

For the main fiberboard properties, according to European standards requirements, must be used follow symbols and dimensions: density – ρ, kg/m^3; moister content – H %; bending strength f_m N/mm^2; and swelling in thickness after soaking in water for 24h – G_t %; and swelling of water – A, % [14]. The fiberboards properties must be determined according to the standardization requirements [7-13]. For every property should be determined as follow: average – $\bar{x}$, standard deviation S_x, probability factor V_x, average error m_x and significance probability (P value) P_x [4].

In actual fact values of given property x_{ij} aren't equal to the average one at different factor levels $\bar{x}_i$, which from their side aren't equal to general average $\bar{x}$. This can be explaining due two reasons: 1) influence of the factor; 2) influence of accidental interference.

These two influences reflect on deviations sum of squares of control values from general average [4]:

$$Q = \sum_{i=1}^{k} \sum_{j=1}^{n} (x_{ij} - \bar{x})^2 \tag{1}$$

The sum Q is calling total or integral sum. It is divided into two constitutive: $Q = Q_1 + Q_\varepsilon$, where:

$$Q_1 = \sum_{i=1}^{k} \sum_{j=1}^{n} (\bar{x}i - \bar{x})^2 \tag{2}$$

and

$$Q_\varepsilon = \sum_{i=1}^{k} \sum_{j=1}^{n} (x_{ij} - \bar{x}i)^2 \tag{3}$$

The sum Q_1 is coherent to influence of factor, as it is determined from deviations of averages for different factor levels $\bar{x}_i$ from general average $\bar{x}$. It is also called square sum of deviations between test groups.

The sum Q_ε is coherent to influence of accidental interferences, because is constituted from deviations of test values for different factor levels x_{ij} from their average $\bar{x}_i$.

The influence of the factor (pulp freeness) is compared to those of accidental interference, as it should be determined level of significance through variance rating by using F-distribution (Fisher distribution).

The ratio between square sums and degrees of freedom gives the variance rating:

$$S_1^2 = \frac{Q_1}{\nu_1} \tag{4}$$

and

$$S_\varepsilon^2 = \frac{Q_\varepsilon}{\nu_\varepsilon} \tag{5}$$

The rating of S_1^2 is coherent to influence of factor and the rating of S_ε^2 – whit the influence of accidental interferences. That is why verification of significance hypothesis is implemented by the following rules:

1. The S_1^2 and S_ε^2 are determined;

2. The degrees of freedom $\nu_1 = k - 1 = 5 - 1 = 4$ and $\nu_\varepsilon = k.(n - 1) = 5.9 = 45$ are determined and vivificated by $\nu = k.n - 1 = 10.5 - 1 = 49 = 4 + 45 = \nu_1 + \nu_\varepsilon$;

3. The variance ratio is determined:

$$F = \frac{S_1^2}{S_\varepsilon^2} \qquad (6)$$

4. The level of significance is assigned (q = 0,05) and from tables of Fisher distribution is determined $F(q, \nu_1, \nu_\varepsilon)$;

5 The one of follow conclusions is deduced:

- if $F \le F(q, \nu_1, \nu_\varepsilon)$ the factor is insignificant;
- if $F > F(q, \nu_1, \nu_\varepsilon)$ the factor is significant.

In first case the influence of factor, tell on S_1^2 is commensurate or even less with the influence of accidental interference determined by S_ε^2. Because of that it is considered that the influence of factor is insignificant

In second case the critical boundary $F(q, \nu_1, \nu_\varepsilon)$ is exceeded, two influences are not commensurable, that is why conclusion of factor significance is correct.

For the purpose of the study – significance verification of factor "pulp freeness" – it will be conducted verification for the follow fiberboards properties: density, bending strength, swelling in thickness and as raw material will be used oak and cerris wood.

3. EXPERIMENTAL RESULTS

In tabl.1 are given the determined data for oak fiberboards properties depending on pulp freeness.

TABLE 1. Alternation of oak fiberboards properties in relation of pulp freeness

Statistics	Pulp freeness				
	15-17 DS	18-20 DS	21-23 DS	25-27 DS	30-33 DS
Bending strength, N/mm²					
$\bar{x}_i$	15,9	22,2	30,7	36,8	41,1
S_x	1,03	1,45	2,0	2,42	2,48
V_x	6,48	6,26	6,1	2,37	2,8
m_x	0,33	0,46	0,63	0,77	0,78
P_x	2,05	2,07	2,06	2,08	1,91
Swelling of water, %					
$\bar{x}_i$	41,4	36,7	28,4	22,9	18,7
S_x	2,42	2,23	1,6	1,35	1,06
V_x	5,85	6,08	5,63	5,9	5,67
m_x	0,77	0,71	0,51	0,43	0,34
P_x	1,85	1,92	1,78	1,86	1,79
Swelling in thickness, %					
$\bar{x}_i$	34,4	28,6	20,6	18,2	15,0
S_x	2,0	1,7	1,05	1,03	1,33
V_x	5,81	5,94	5,10	5,66	8,87
m_x	0,63	0,54	0,33	0,33	0,42
P_x	1,84	1,88	1,61	1,79	2,80
Density, kg/m³					
$\bar{x}_i$	812	872	920	979	1021
S_x	10,0	12,3	14,6	16,8	16,7
V_x	1,23	1,41	1,59	1,72	1,64
m_x	3,16	3,89	4,62	5,31	5,28
P_x	0,39	0,45	0,50	0,54	0,52

In tabl.2 are given the determined data for cerris fiberboards properties depending on pulp freeness.

TABLE 2. Alternation of cerris fiberboards properties in relation of pulp freeness

Statistics	Pulp freeness				
	15-17 DS	18-20 DS	21-23 DS	25-27 DS	30-33 DS
Bending strenght, N/mm²					
$\overline{x_i}$	17,7	22,3	30,4	38,5	43,1
S_x	1,28	1,34	1,69	2,12	2,44
V_x	7,23	6,0	5,56	5,51	5,66
m_x	0,41	0,42	0,53	0,67	0,77
P_x	2,29	1,90	1,76	1,74	1,79
Swelling of water, %					
$\overline{x_i}$	43,2	38,4	30,7	22,3	19,0
S_x	2,37	2,42	1,93	1,58	1,01
V_x	5,49	6,30	6,29	7,09	5,32
m_x	0,75	0,77	0,61	0,50	0,32
P_x	1,73	1,99	1,99	2,24	1,68
Swelling in thickness, %					
$\overline{x_i}$	36,8	28,2	26,4	19,2	15,3
S_x	2,1	1,64	1,41	1,15	1,08
V_x	5,71	5,82	5,34	6,0	7,06
m_x	0,66	0,52	0,45	0,36	0,34
P_x	1,80	1,84	1,69	1,89	2,23
Density, kg/m³					
$\overline{x_i}$	840	890	943	992	1124
S_x	14,2	18,3	20,7	18,9	22,9
V_x	1,69	2,06	2,20	1,91	2,04
m_x	4,49	5,79	6,55	5,98	7,24
P_x	0,53	0,65	0,70	0,60	0,65

4. ANALYZE OF THE EXPERIMENTAL RESULTS

In fig.1, 2, 3 and 4 are presented the alternation of fiberboards properties in relation of pulp freeness and wood species.

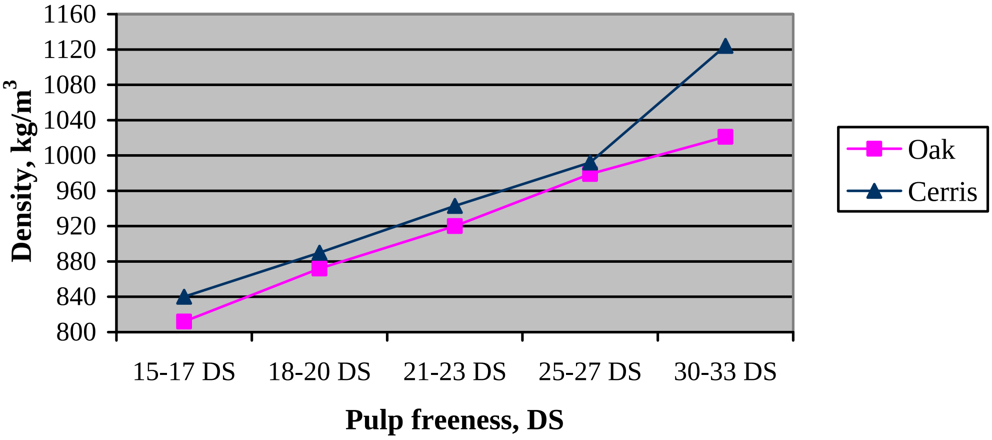

FIGURE1. Alternation of fiberboards density in relation of pulp freeness and wood species

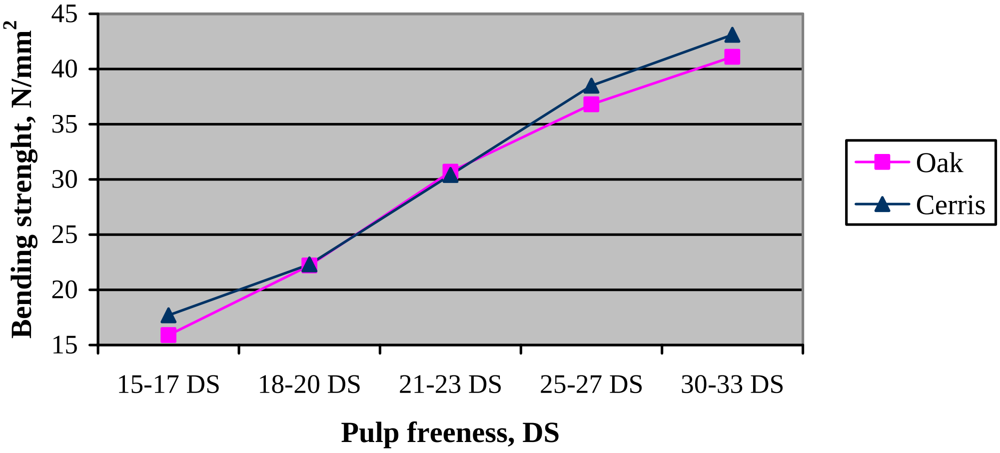

FIGURE2. Alternation of fiberboards bending strengths in relation of pulp freeness and wood species

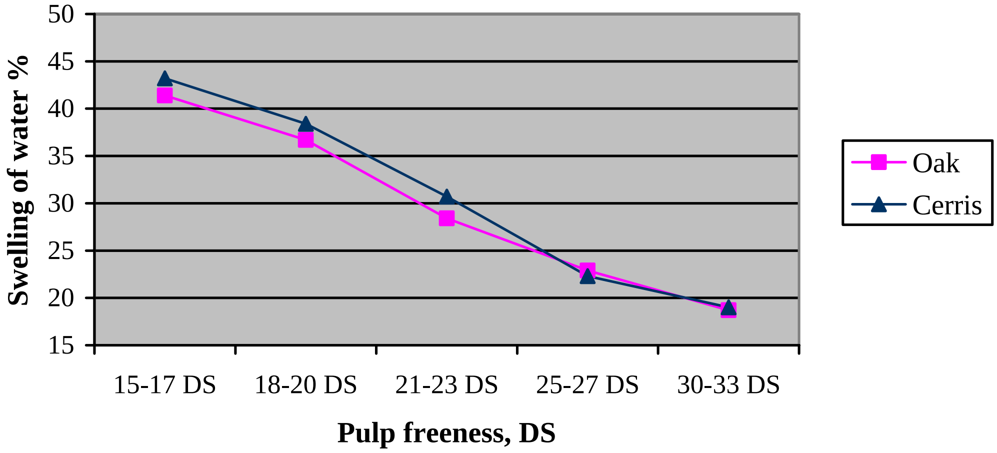

FIGURE3. Alternation of fiberboards swelling of water in relation of pulp freeness and wood species

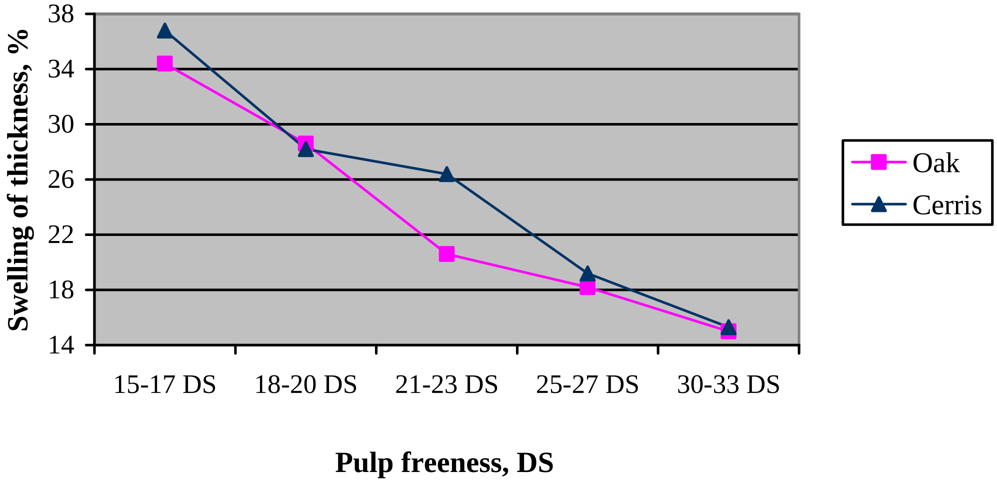

FIGURE4. Alternation of fiberboards swelling of thickness in relation of pulp freeness and wood species

From the experimental results follow the conclusion that with increasing of pulp freeness the fiberboards properties are improving. I.e. the fiberboards density and bending strength are increasing; swelling of water and swelling of thickness are decreasing. This tendency is very clear after pulp freeness exceeds values of 21-23 DS.

The worst properties had fiberboards produced from pulp with freeness of 15-17 DS and the best ones produced from pulp with freeness of 30-33 DS.

The density at pulp freeness 30-33 DS is higher with 27,5% in oak fiberboards and with 33,8% in cerris fiberboards then ones of fiberboards produced from pulp with freeness of 15-17 DS. Respectively for the bending strength percentages are 158,5% and 143,5%. Swelling in thickness of oak fiberboards at pulp freeness 30-33 DS is lower with 129,3 and of cerris fiberboards with 140,5% from those produced of pulp with freeness 15-17 DS.

4.1 Determination of significance in relation to fiberboards density

1) At oak fiberboards

For the density of oak fiberboards – $\bar{x}$ = 920,8 kg/m³.

$$Q_1 = \sum_{i=1}^{k}\sum_{j=1}^{n}(\bar{x}_i - \bar{x})^2 = 27646{,}8, \quad Q_\varepsilon = \sum_{i=1}^{k}\sum_{j=1}^{n}(x_{ij} - \bar{x}_i)^2 = 44605{,}44.$$

$$S_1^2 = \frac{Q_1}{\nu_1} = \frac{27646{,}8}{4} = 6911{,}7, \quad S_\varepsilon^2 = \frac{Q_\varepsilon}{\nu_\varepsilon} = \frac{44605{,}44}{45} = 991{,}23.$$

$$F = \frac{S_1^2}{S_\varepsilon^2} = \frac{6911{,}7}{991{,}23} = 6{,}97, \quad F_{(0,05,\ 4;\ 45)} = 5{,}70 < F = 6{,}97.$$

Therefore in relation of oak fiberboards density the factor “pulp freeness” is significant.

2) At cerris fiberboards

For the density of cerris fiberboards – $\bar{x}$ = 957,8 kg/m³.

$$Q_1 = \sum_{i=1}^{k}\sum_{j=1}^{n}(\bar{x}_i - \bar{x})^2 = 474484{,}8, \quad Q_\varepsilon = \sum_{i=1}^{k}\sum_{j=1}^{n}(x_{ij} - \bar{x}_i)^2 = 81225.$$

$$S_1^2 = \frac{Q_1}{\nu_1} = \frac{47484{,}8}{4} = 11871{,}2, \quad S_\varepsilon^2 = \frac{Q_\varepsilon}{\nu_\varepsilon} = \frac{81225}{45} = 1805.$$

$$F = \frac{S_1^2}{S_\varepsilon^2} = \frac{11871{,}2}{1805} = 6{,}58, \quad F_{(0,05,\ 4;\ 45)} = 5{,}70 < F = 6{,}58.$$

Therefore in relation of cerris fiberboards density the factor “pulp freeness” is significant.

4.2 Determination of significance in relation to fiberboards bending strength

1) At oak fiberboards

For the bending strength of oak fiberboards – $\bar{x}$ = 29,34 N/mm²

$$Q_1 = \sum_{i=1}^{k}\sum_{j=1}^{n}(\bar{x}_i - \bar{x})^2 = 427{,}41, \quad Q_\varepsilon = \sum_{i=1}^{k}\sum_{j=1}^{n}(x_{ij} - \bar{x}_i)^2 = 791{,}86.$$

$$S_1^2 = \frac{Q_1}{\nu_1} = \frac{427{,}41}{4} = 106{,}85, \quad S_\varepsilon^2 = \frac{Q_\varepsilon}{\nu_\varepsilon} = \frac{791{,}96}{45} = 17{,}6.$$

$$F = \frac{S_1^2}{S_\varepsilon^2} = \frac{106{,}85}{17{,}6} = 6{,}072, \quad F_{(0,05,\ 4;\ 45)} = 5{,}70 < F = 6{,}072.$$

Therefore in relation of oak fiberboards bending strength the factor “pulp freeness” is significant.

2) At cerris fiberboards

For the bending strength of cerris fiberboards – $\bar{x}$ = 30,4 N/mm².

$$Q_1=\sum_{i=1}^{k}\sum_{j=1}^{n}(\bar{x}i-\bar{x})^2=453{,}8,\quad Q_\varepsilon=\sum_{i=1}^{k}\sum_{j=1}^{n}(x_{ij}-\bar{x}_i)^2=708{,}1.$$

$$S_1^2=\frac{Q_1}{\nu_1}=\frac{453{,}8}{4}=113{,}45,\quad S_\varepsilon^2=\frac{Q_\varepsilon}{\nu_\varepsilon}=\frac{708{,}1}{45}=15{,}74.$$

$$F=\frac{S_1^2}{S_\varepsilon^2}=\frac{113{,}45}{15{,}74}=7{,}21,\quad F_{(0{,}05,\ 4;\ 45)}=5{,}70<F=7{,}21.$$

Therefore in relation of cerris fiberboards bending strength the factor “pulp freeness” is significant.

4.3 Determination of significance in relation to fiberboards swelling in thickness

1) At oak fiberboards

For the swelling in thickness of oak fiberboards – $\bar{x}$ = 23,36%.

$$Q_1=\sum_{i=1}^{k}\sum_{j=1}^{n}(\bar{x}i-\bar{x})^2=253{,}472,\quad Q_\varepsilon=\sum_{i=1}^{k}\sum_{j=1}^{n}(x_{ij}-\bar{x}_i)^2=454{,}97.$$

$$S_1^2=\frac{Q_1}{\nu_1}=\frac{253{,}4721}{4}=63{,}368,\quad S_\varepsilon^2=\frac{Q_\varepsilon}{\nu_\varepsilon}=\frac{454{,}97}{45}=10{,}11.$$

$$F=\frac{S_1^2}{S_\varepsilon^2}=\frac{63{,}368}{10{,}11}=6{,}27,\quad F_{(0{,}05,\ 4;\ 45)}=5{,}70<F=6{,}27.$$

Therefore in relation of oak fiberboards swelling in thickness the factor “pulp freeness” is significant.

2) At cerris fiberboards

For the swelling in thickness of cerris fiberboards – $\bar{x}$ = 25,18%.

$$Q_1=\sum_{i=1}^{k}\sum_{j=1}^{n}(\bar{x}i-\bar{x})^2=279{,}008,\quad Q_\varepsilon=\sum_{i=1}^{k}\sum_{j=1}^{n}(x_{ij}-\bar{x}_i)^2=490{,}18.$$

$$S_1^2=\frac{Q_1}{\nu_1}=\frac{279{,}008}{4}=69{,}752,\quad S_\varepsilon^2=\frac{Q_\varepsilon}{\nu_\varepsilon}=\frac{490{,}18}{45}=10{,}89.$$

$$F=\frac{S_1^2}{S_\varepsilon^2}=\frac{69{,}752}{10{,}89}=6{,}40,\quad F_{(0{,}05,\ 4;\ 45)}=5{,}70<F=6{,}40.$$

Therefore in relation of cerris fiberboards swelling in thickness the factor “pulp freeness” is significant.

4.4 Conclusions

1) With increase of pulp freeness the fiberboards properties are improving;
2) The improving of fiberboards properties is very clear after pulp freeness exceeds values of 21-23 DS;
3) At equal other conditions the factor “pulp freeness” is significant for wet-process oak fiberboards properties;
4) At equal other conditions the factor “pulp freeness” is significant for wet-process cerris fiberboards properties.

5. CONCLUSION

From the experimental data analyze, through probability theory methods, was determined that at equal other conditions the factor “pulp freeness” is significant for wet-process hardwood fiberboards properties. And with increase of pulp freeness the fiberboards properties are improving.

From that follow the conclusion that in normal conducting of thermo-mechanical pulping process, i.e. when pulp freeness increase not at the expense of cut and tear fibers, but because of growling fibrils share, pulp freeness can be used as significant factor for producing of fiberboards with engineered properties.

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