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Fibers of secondary ligno-cellulose materials and their influence on properties of insulating fiberboards

Vlakanca sekundarnih ligno-celuloznih materijala i njihov utjecaj na svojstva izolacijskih ploča vlaknatica

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ABSTRACT • *This paper deals with the influence of addition of abraded fiber, as a partial substitute of softwood fibers, on the properties of insulating fiberboard. The fiber used was characterized by fractional composition of fiber length according to McNett (STN 50 0289) using the apparatus for the measurement of fiber length in aqueous suspension (ADV) and according to Brecht-Holl (STN 50 0289) by the determination of water retained by fiber, speed of dewatering and defibrator seconds. Insulating fiberboards were prepared with different content of abraded fiber. Mechanical properties (bending strength and tension strength perpendicular to the board plane) as well as physical properties (swelling, water uptake, thermal conductivity, thermal diffusivity specific heat and volumetric specific heat) were measured for the boards.*

Keywords: *Insulating fiberboards, secondary ligno-cellulose materials, abraded fiber*

SAŽETAK • *U radu je istraživan utjecaj djelomične zamjene vlakanaca osnovne sirovine (mekih vrsta drva) vlakancima dobivenim brušenjem već izrađenih ploča na svojstva izolacijskih ploča vlaknatica. Upotrebljena vlakanca karakterizirana su frakcijskim sastavom duljine vlakanaca prema McNett-u (STN 50 0289) primjenom uređaja za mjerenje duljine pojedinog vlakanca u ispitivanoj vodenoj disperziji (ADV). Osim navedene, primjenjena je i Brecht-Hollova (STN 50 0289) određivanja količine vode zadržane u vlakancu, brzine odvodnje i mjerenja defibratorskih sekundi. Izrađene su i pripremljene ploče s različitim udjelom vlakanaca dobivenih brušenjem. Ispitana su mehanička svojstva (savojna čvrstoća i vlačna čvrstoća okomito na površinu ploče) te fizikalna svojstva (debljinsko bubrenje, upijanje vode, toplinska vodljivost, prolaznost topline, specifična toplina i prostorna specifična toplina) tako pripremljenih izolacijskih ploča vlaknatica.*

Ključne riječi*: izolacijske ploče vlaknatice, sekundarni ligno-celulozni materijali, brušena vlakanca*

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1 INTRODUCTION
1. UVOD

Substitution of wood used for the production of insulating fiberboard by secondary raw material can be an important factor for the increase of competitiveness of an enterprise. According to the EU legislation, in addition to the main product, technologies of wood processing produce a secondary raw material (so far considered as waste) that either goes back to the production process or is further processed into another product including energy. In our case during the insulating fiberboard production fiber "waste" occurs during the equalization of the surface and thickness of the board. So far this "waste" was burnt.

The aim of this paper is to characterize this abrasive fiber and find the conditions of its return to the production cycle.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

Refined and abrasive fiber was obtained from the fiberboard production line. The fiberboards prepared contained 0, 5, 10, 15, 20 and 50 % of abraded fiber related to the absolute dry mass of the fiber used.

Fractionation of fiber was performed on the device according to Mc Nett (4 sorting units with the sieves arranged in cascades) and according to Brecht-Holl (the mass of different fractions is obtained as the mass of fiber rendered on the rougher sieve minus the mass of fibers rendered on finer sieve) (STN 50 0289). Fiber length was measured using ADV-3.1 Analyzer. The ADV-3.1 Analyzer is a laboratory device for quick and objective specification of the length composition of fibers in pulp and paper stock suspensions. The data obtained can be further used to specify fiber coarseness and the ratio of short fiber and long fiber components. The conductivity sensor operates on the basis of conductivity changes in the measurement channel when the fiber passes through the electrode area.

Insulating fiberboard with the density of 250 kg/m³ were prepared in the laboratory line of the Swedish company Defibrator AB. Fiberboards were conditioned at normal conditions (t=20°C, RH=65 %) and their physical and mechanical properties (density, swelling, water uptake, bending strength and strength perpendicular to the board plane) were determined according to the respective standards - STN EN 323, STN EN 622-4, STN EN 310, STN EN 319, STN EN 317. Thermal properties were measured using the apparatus Isomet produced by the company Applied Precision. The device compares time dependence of temperature during the heating and cooling phase and works on the principle of hot wire.

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

In investigating abraded fiber and refined wood fibers of fiberboards of the density of 250 kg·m^{-3} (Tab.1), significantly higher concentration of particles was observed for the abraded fiber than for the original refined one. The portion of particles determined according to Brecht-Holl was 29.42 % for the abraded fiber, while for the refined fiber it was 7.75 %. Mechanical properties are worse due to almost four times higher amount of particles.

The amount of long fibers is decisive for the final properties of fiberboards. Its increasing amount directly improves strength properties. For the abraded fiber, the portion of long fibers determined according to Brecht-Holl is 34.34 %, while refined fibers show as much as 48.65 %. The portion of mean length fiber for the abraded fiber is by 10 % lower and for fine fiber by 3 % higher than for refined fiber. So, abraded fiber shows a higher portion of particles and a lower portion of long fibers.

During fiber fractionation of abraded fiber according to McNett with the mesh size of 50 to 100, half of the amount of fiber is kept in comparison with refined fiber. The difference goes to the residual fine fraction over 200 mesh, which is 31 % for abraded fiber while for refined fiber it is only 11.36 %.

If we suppose that the fractions of 28 mesh and 50 mesh have a sufficient fiber length, then it is necessary to add the sum of suitable fibers of the length over 1 mm contained in the fractions of 100 mesh and 200 mesh. The amount of such fibers was determined by the ADV method with the fractions of 100 mesh and 200 mesh of the abraded fiber. ADV method is not suitable for thicker fibers, i.e. fractions of 28 and 50 mesh.

The fraction of 100 mesh of abraded fiber contained fibers of the length over 1.0 mm in the portion of 55.64 %. In the total fiber mass of the sample, this fraction accounts for 5.54 %. In this mass, 55.60 % of fibers is of the length over 1 mm, which is 3.08 % of the total fiber mass in fiberboard. The fraction of 200 mesh with fiber length over 1.0 mm created 27 % of the distribution i.e. 0.69 % of the total fiber mass in the fiberboard.

In this mass, 27.94 % of fibers is longer than 1 mm, which is 0.19 % of the total mass of fibers in the board. According to Bauer McNett and ADV analysis of fibers of 100 and 200 mesh fraction, the total mass of abraded fibers of the length over 1mm is as follows: 52.275 % (26 mesh) +10.356 % (50 mesh) + 3.08 % (5.540 x 0.5564 = 3.08) + 0.19 % (0.687 x 0.2794) = 65.90 %

It means that abraded fiber contains in total 65.9 % fibers longer than 1mm.

Determination of the amount of short and long fiber on a 120 mesh screen according to Brecht-Holl showed 77.93 % of abraded fiber. The difference between 77.93 and 65.90 is due to fine fiber that is kept on long fibers according to Brecht-Holl method.

According to Bauer McNett during fiber fractionation, 76.98 % is retained on 28 and 50 mesh screens. Fibers longer than 1mm in fractions kept at 100 and 200 mesh should be added to this percentage. 4.47 % is kept on the former mesh and 0.16 % on the latter. It means that a total of 81.61 % of fiber is longer than 1 mm.

Table 1 Properties of abraded and refined fiber (average values for 3 sets in 3 experiments)
Tablica 1. Svojstva brušenih i rafiniranih vlakanaca (srednje vrijednosti za skupine po tri eksperimenta)

Measured quantity *Mjerena količina*		**Abraded fiber** *Brušena vlakanca*	**Refined fiber for boards 250 kg·m^{-3}** *Rafinirana vlakanca*
Dewatering (s) *Brzina odvodnje (s)* (6 g/1000g H_2O)	500 ml	2.48	5.99
	700 ml	3.15	13.79
	800 ml	3.98	23.27
Particles Brecht-Holl (%) *Iverje Brecht-Holl*		29.42	7.75
Brecht-Holl (%)	40 mesh / *otvor sita 40*	34.34	48.65
	120 mesh / *otvor sita 120*	14.17	24.47
	240 mesh / *otvor sita 240*	5.845	5.41
	Over 240 mesh *otvor sita veći od 240*	16.22	13.70
WRV (% water) *WRV (% voda)*		69.9	97.90
Bauer McNett	28 mesh / *otvor sita 28*	52.27	55.85
	50 mesh / *otvor sita 50*	10.35	21.13
	100 mesh / *otvor sita 100*	5.540	10.51
	200 mesh / *otvor sita 200*	0.687	1.14
	Over 200 mesh *otvor sita veći od 200*	31.142	11.36

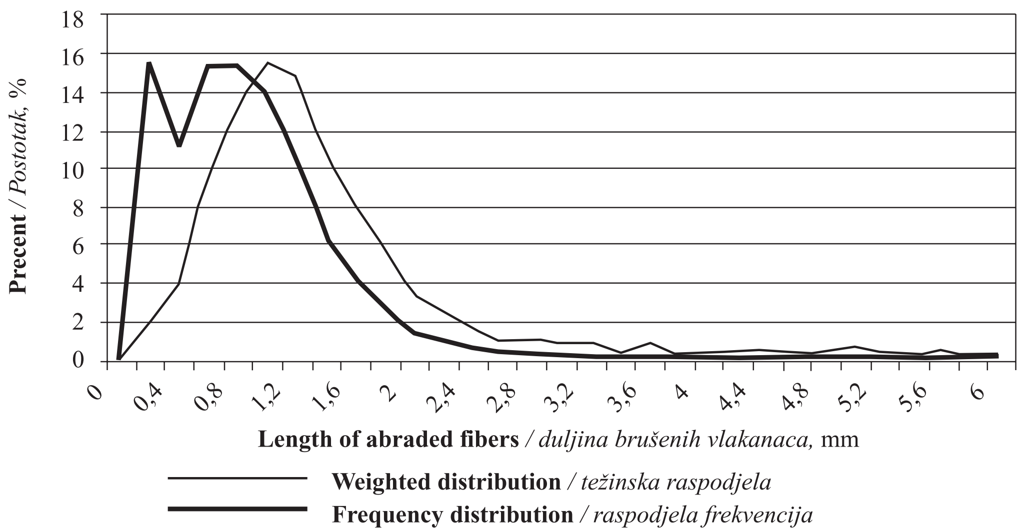

Figure 1 Analysis of length of abraded fiber fraction 3 on a 100 mesh screen determined by ADV method (the length over 1 mm shows 55.64 % of weighted distribution)
Slika 1. Analiza duljine brušenog vlakanca frakcije 3 s otvorom oka sita 100 određenoga ADV metodom (duljina vlakanca veća od 1 mm iznosi 55,64 % težinske raspodjele)

When abraded fiber is used, the fraction of fine fiber obviously increases either in the board or in technological water. Generally the increase of the fraction of fine fiber in insulating fiberboards shows an adverse reaction on the board properties.

Significant difference in the properties of abraded fiber can be observed in the speed of dewatering. Time of flow for 800 ml of abraded fiber is 3.98 seconds; for refined fiber in the same case it is around 27 seconds. In spite of higher fraction of fine fibers, the time of dewatering for abraded fiber is significantly lower. It means that the fiber shows not only decreased ability to retain water but also its ability to create mechanical van der Waals and hydrogen bonds with other fibers are lowered. It results in decreased physical and mechanical properties of the boards.

This reasoning is also confirmed by the amount of water retained by fiber (WRV), where the percentage of retained water is significantly lower than that for refined fiber. Also the value of Defibrator seconds (DS) is significantly lower. With the increase of the fraction of abraded fiber, the time of water flow decreases in the deter-

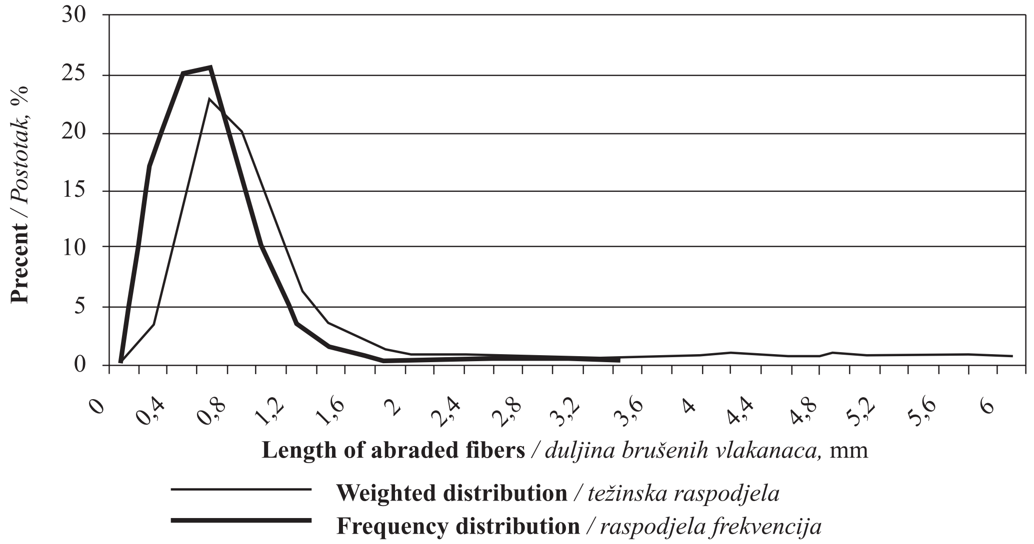

Figure 2 Analysis of length of abraded fiber 4 on a 200 mesh screen determined by ADV method. (The length over 1mm shows 27.94 % of the weighted distribution)
Slika 2. Analiza duljine brušenog vlakanca frakcije 4 s otvorom oka sita 200 određenoga ADV metodom (duljina vlakanca veća od 1 mm iznosi 27,94 % težinske raspodjele)

mination of DS ending only at 28.5 % of 100 % of abraded fiber. The decreasing value of DS is given in Tab. 2.

The analysis of the properties of abraded fiber shows that the addition of abraded fiber would increase the portion of particles and fine fibers in boards. Even longer abraded fibers would decrease the bonding ability of fibers in boards that would result in worse board properties. It is therefore necessary to optimize the amount of added abraded fibers in order to utilize cheap secondary raw material keeping the board properties optimal.

The boards with increasing proportion of abraded boards were prepared for the determination of influence of the added amount of abraded fiber. These boards were used for testing physical and mechanical properties characteristic for insulation board properties. We measured the bending strength and tension strength perpendicular to the board plane. The original value of the bending strength was 2.42 MPa and for 50 % of abraded fibers content it decreased to 0.85 MPa (Tab. 3).

Wood ultimate bending strength and tension strength in the board plane were tested with respect to mechanical properties. The bending strength decreased from the original value for the board without abraded fibers from 2.42 MPa to 0.85 MPa for the board with 50 % content of abraded fibers. (Tab. 3). Tension strength decreased from 64 kPa to 25.3 kPa for the boards with 50 % content of abraded fibers.

Table 2 Defibrator seconds (DS) of wood fiber with different portion of abraded fiber
Tablica 2. Defibratorske sekunde ukupne mase drvnih vlakanaca s različitim udjelom brušenih vlakanaca

Abraded fibers, % *Brušena vlakanca*, %	0	5	10	15	20	25	50	100
DS, s	36.8	31.2	27.8	23.1	20.5	19.0	14.0	10.5

Table 3 Physical and mechanical properties of boards with abraded fibers
Tablica 3. Fizikalna i mehanička svojstva ploča izrađenih uz dodatak brušenih vlakanaca

Specimen number *Broj uzorka*	**% of abraded fibers** *Postotak brušenih vlakanaca*	**Density** *Gustoća* $kg \cdot m^{-3}$	**Bending strength** *Savojna čvrstoća* MPa	**Tension strength** *Vlačna čvrstoća* kPa	**Swelling after 2 hours** *Bubrenje nakon 2 sata* %	**Water uptake** *Upijanje vode* %
1-3	0	281	2.42	64.0	2.19	11.9
5-7	5	280	2.25	60.0	2.33	12.48
9-11	10	274	2.19	59.0	2.31	13.05
13-15	15	274	2.07	58.0	2.42	16.12
17-19	20	273	1.69	46.3	2.79	16.3
21-23	25	261	1.39	44.3	2.78	16.6
25-27	50	243	0.85	25.3	3.47	20.3

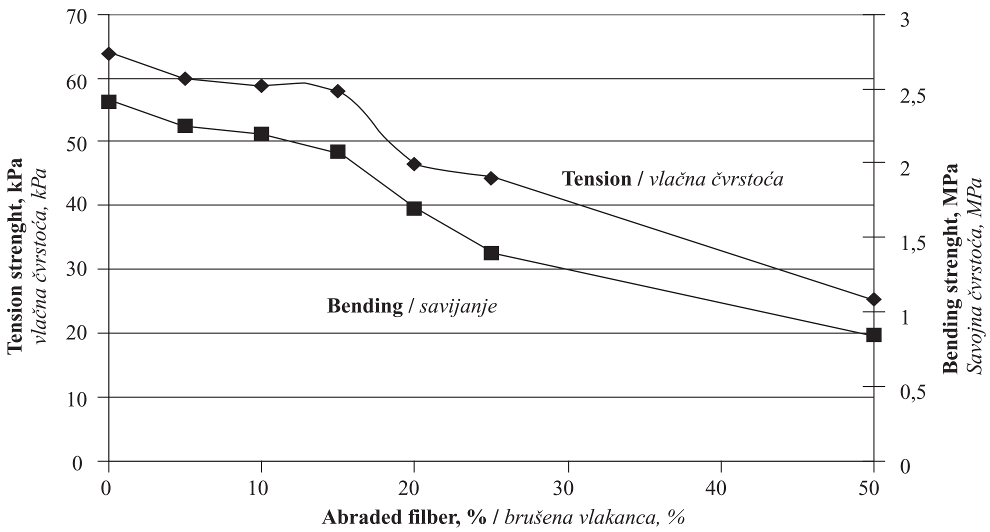

Figure 3 Ultimate bending strength (■) and tension strength (◆) versus abraded fibers content
Slika 3. Konačni iznosi savojne (■) i vlačne čvrstoće (◆) ploča s obzirom na sadržaj brušenih vlakanaca

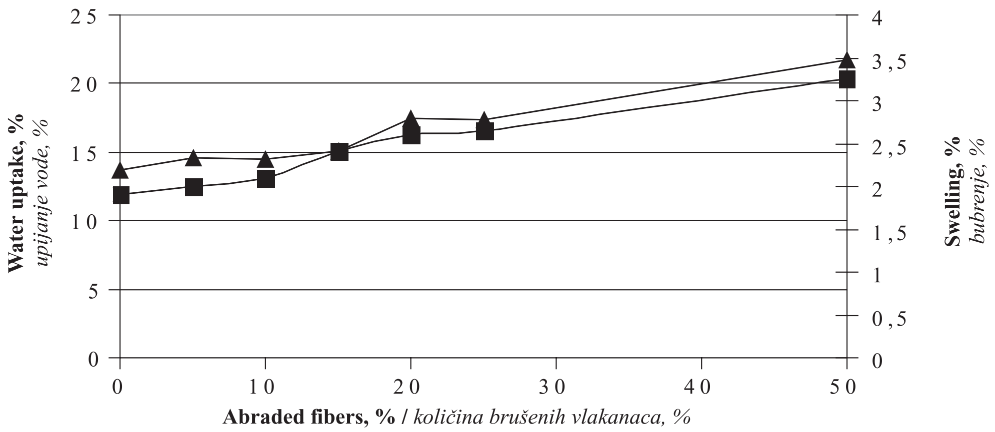

Figure 4 Water uptake (■) and swelling (▲) as a function of abraded fiber content
Slika 4. Upijanje vode (■) i debljinsko bubrenje (▲) kao funkcija količine brušenih vlakanaca

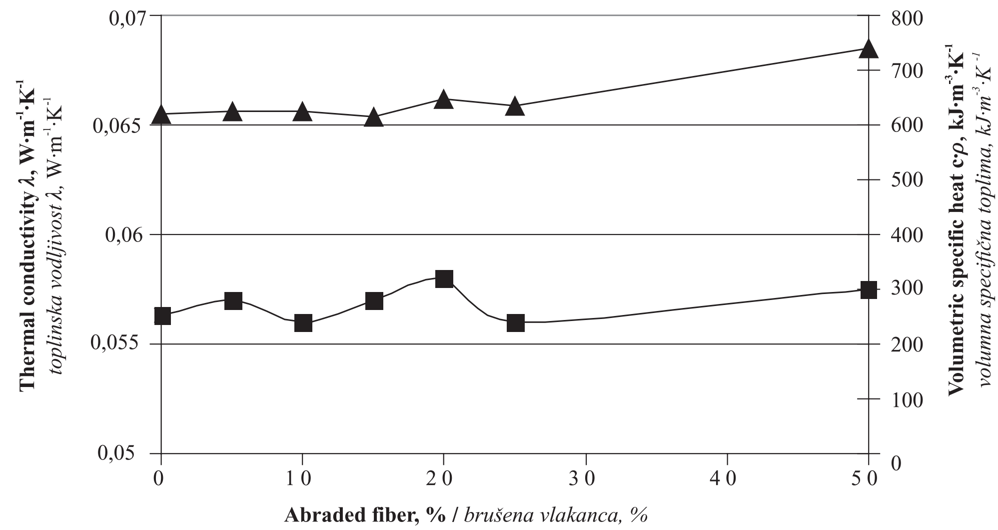

Figure 5 Thermal conductivity λ (■) and volumetric specific heat $c\rho$ (▲) of boards as functions of abraded fiber
Slika 5. Toplinska vodljivost λ (■) i prostorna specifična toplina $c\rho$ (▲) ploča kao funkcije količine brušenih vlakanaca

Figure 3 shows the relationship between the strength values and abraded fibers content. It can be seen that a more significant decrease of mechanical properties of boards occurs when the content of abraded fibers in the board is more than 15 %.

Physical properties (swelling and water uptake – Fig. 4) show the decrease at the same level. Swelling increases from 2.19 % to 3.47 % and water uptake from 11.9 to 20.3 %.

An addition of 5 % of abraded fibers decreases ultimate bending strength by 7 %, and tension strength by 6 %, while swelling and water uptake increase by 6.4 % and 4.9 %, respectively. An addition of 10 % decreases bending strength by 10.5 %, tension strength by 7.8 %, and swelling and water uptake by 5.5 % and 9.7 %.

The analysis of abraded fibers properties indicate that the decrease of physical and mechanical properties of boards is caused mainly by the decrease of bonding properties and also by higher content of fine fibers and particles in abraded fibers.

Thermal properties (thermal conductivity λ, specific heat c and also volumetric specific heat $c \cdot \rho$ of the boards) are constant up to 25 % of abraded fiber. The values for 50 % of abraded fibers are higher. The average value of λ for the boards without addition of abraded fibers is 0.056 $W \cdot m^{-1} \cdot K^{-1}$ and for the board with 50 % of abraded fibers λ is 0.0575 $W \cdot m^{-1} \cdot K^{-1}$.

4 CONCLUSION
4. ZAKLJUČAK

The analysis of properties of abraded fiber shows an adverse influence of the addition of abraded fiber on the properties of insulating boards. It is caused by higher content of particles and fine parts in abraded fiber and also by the fact that abraded fiber is not magged. As a result, even long fiber has a low ability to form bonds with other fibers which leads to low values of defibrator seconds, rapid dewatering of fibers and lower amount of retained water. From technological point of view, some of the properties are positive (dewatering speed, less water retained). They provide faster dewatering of mat and higher dry mass of mat during pressing that gives a possibility to shorten the pressing time and save energy needed for drying.

It can be stated, based on physical and mechanical properties of laboratory prepared boards with the content of abraded fibers from 5 % to 50 %, that the addition of abraded fiber of 5 to 10 % causes the decline of board properties to 10 %. A stronger decline occurs when the content of abraded fibers in the board is more than 15 %.

An addition of abraded fibers of up to 25 % does not influence the values of thermal conductivity, specific heat and volumetric specific heat of the boards.

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