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PROPERTIES OF SELECTED HDF PULP WITH RECOVERED FIBERS ADDED

The paper aims to clarify the effect on pulp properties of adding fibers from used fiberboards to standard fibers. Fibers from industrial HDF, from used fiberboards and their mixtures were tested using a laboratory Fiber Analyser. Data were obtained directly for both fiber length and fiber width. The pulp was tested using computer image analysis to calculate the area share of different fiber length and width classes. The results show that the largest changes in pulp fiber dimensions occur when the percentage of recovered fibers, RF, is between 15% and 30%. The results obtained show that a qualitative analysis of fiber can be a useful tool for assessing the potential properties of fiberboards, especially when new materials are used.

Keywords: wood fibers, recovered fibers, HDF, fiber dimensions

Introduction

In Poland, medium-density fiberboards, MDF, are produced from pulpwood, small timber poles and wood waste from forests and other sectors of the wood industry, sawmills and plywood trimmings, rolls after peeling, chips, sawdust, and other sources. The yearly consumption of the raw material for MDF production amounts to approximately 4.6 × 10^6 m^3. With the rapid growth of the Polish wood industry over the last decade, a deficit of raw material is now becoming a reality. In 2010, it was estimated to be approximately 0.6 × 10^6 m^3 and increasing. This deficit can be partly eliminated by the utilization of fibrous material from the agricultural industry and/or from recycled wood. Straw surplus is estimated to be between 8 and 13 million mg/year [Hikiert 2005], and the quantities of recycled wood approx. 5.5 to 6 × 10^6 m^3 /year [Danecki, Paluchiewicz 2009]. Both types of materials can be used in the production of particleboards and fiberboards. However, a part of them, as used in MDF, hardboards and insulation boards, can only be reused in the production of fiberboards.

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The lack of raw wood is not just a local problem. For many years, scientists and producers have been struggling to find efficient ways to utilize other fibrous materials in panel board production. A new process has been developed in Great Britain, called the “Fibersolve” process, whereby the recycled MDF or particle boards are disintegrated in autoclaves using pressurized steam at a high temperature to produce reusable fibers [Kearley, Goroyias 2004]. A different process has been established in Germany where the recycled MDF is fed through an extruder to produce fibers [Roffael et al. 2009, 2010]. In Poland, trials have been carried out to recover fibers from MDF in a one-stage refining process.

The morphology of secondary fibers will depend both on the source of the fiber as well as on the production method.

Methods and materials

In this study an analysis of standard HDF fibers, recycled fibers and mixtures of those fibers, was carried out using a previously developed methodology [Klimczewski et al. 2009]. The recycled fiberboards included uncoated MDF (80%), lacquered HDF (10%) and uncoated Hardboard, HB, (10%). The recycled boards were crumbled in a knife mill. The milling chamber was equipped with a strainer which sorted the wood particles with mean sizes below 38 mm. Chips were formed from crushing the recycled wood and a mixture of particles resulted. The chips were immersed in water to increase the moisture content, MC. The MC was increased from 6–7% to approx. 50%, and the soaked chips were then fed into the refiner, with the grinding gap set to 0.1 mm.

Standard HDF pulp was produced under industrial conditions with a defibration temperature of 120–140°C, and the total time of heating and defibration set between 4–6 minutes.

The prepared mixtures of fibers (in proportions of mass) are shown in the table 1 below:

Table 1. Pulp composition of mixtures of HDF and RF Fibers
Tabela 1. Skład mieszanin włókien standardowych na HDF i włókien poużytkowych

Run *Próba*	Recovered fibers *Włókna poużytkowe* (%)	Industrial HDF fibers *Włókna przemysłowe na HDF* (%)
1	0	100
2	100	0
3	15	85
4	30	70
5	55	45

Methods of pulp measurement

The fiber dimensions were determined using a digital fiber analyzer. The fibers were diluted in water and then the required sample size (2 g dry weight) was transferred to the measuring chamber. Data were obtained directly for both fiber length and fiber width. Additional information on the number of fibers, number of fiber kinks, kink angles, fiber curl, and the proportion of fines was also obtained, but is not reported in this paper. This well established technique opens up new research perspectives.

A MorFi LB01 laboratory instrument was used in this study. The percentage distributions of fibers were divided into 90 classes: 9 classes of fiber width (classes above 75 µm were classified as shives and are therefore omitted from the charts) and 10 classes of fiber length were obtained.

A set of evaluation criteria was used to obtain information about the quality of particular pulp. Such a task was not easy to perform as the number of publications in this area is limited. The proportions of particular fractions of fibers have a very diversified influence on board properties [Nelson 1973; Park et al. 2001; Xing et al. 2004]. It has been known for many years that a very important parameter is the ratio of fiber width to its length [Suchsland, Woodson 1991]. Fibers of fractions characterized by a substantial length (above 1.7 mm), even though less frequent, decide to a considerable degree the basic strength parameters of boards, due to a potential surface of created bonds and a high probability of contact with many other fibers, among other things. Short fibers can strengthen the structure of boards by filling the space between the large fibers. On the other hand, shorter fibers can tend to align themselves along the forming direction and hence to worsen the contact between large fibers. When this occurs there is a lowering of bending strength, while at the same time it can advantageously affect the internal bond [Back 1987]. Therefore, it was suggested that the indices which account to a high degree for this potential should be introduced. These indices were assumed to be the estimated average fiber surface area for each of the 90 classes, calculated as the product of the mean width and mean length of fibers in each separate class.

$$A_i = \frac{L_{i\bar{x}} * W_{i\bar{x}}}{10000000} \tag{1}$$

Where: A_i – area index of fiber class *i*
$L_{i\bar{x}}$ – average length of fiber class *i*
$W_{i\bar{x}}$ – average width of fiber class *i*

The computational areas of fibers for particular fractions are presented in fig. 1 for a 100% HDF pulp.

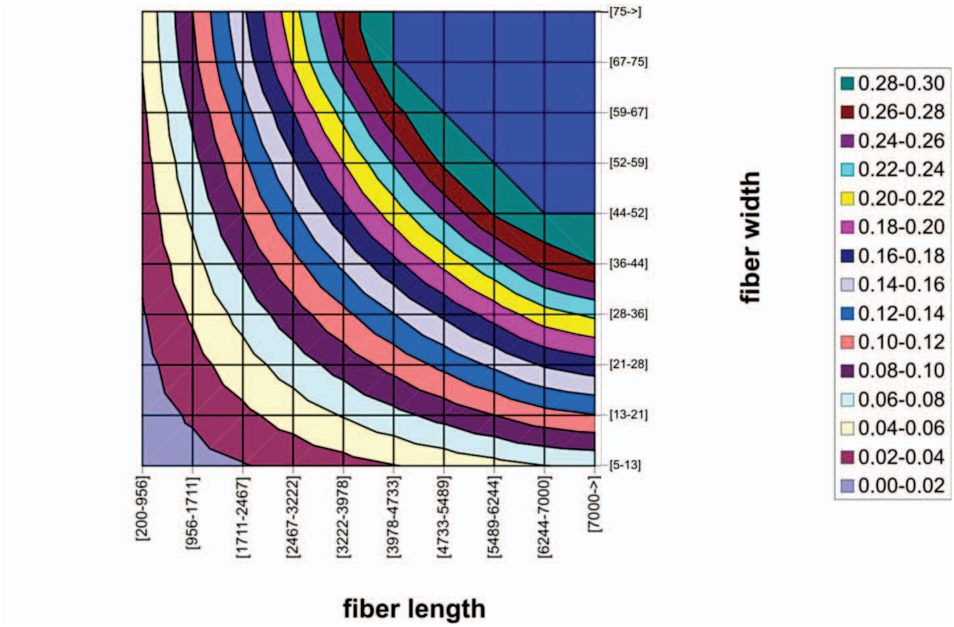

Fig. 1. Fiber length – width data for typical fibers, showing the proportions of relative fiber areas in each fraction
Rys. 1. Długość i szerokość typowych włókien, pokazujące udziały powierzchni każdej frakcji

The fiber areas in each class were computed by multiplying fiber length and width, using the recorded numbers of fibers in each class. The results are presented as percentage shares of computational areas of fibers in each class in the computational area of the whole pulp.

$$P[\%] = \frac{n_i * A_i}{\sum_{c=1}^{90} (n_c * A_c)} * 100\% \qquad (2)$$

Where: n_i – number of fibers of class i
A_i – area index of class i
n_c – number of fibers of class c
A_c – area index of class c

Presenting pulp characteristics in this way allows a more precise assessment of the pulp quality in comparison with the numeric proportions of the fibers, and facilitates the observation of significant differences among the various process parameters.

Results and discussion

Fiber Analysis 1 – 100% HDF

The first analysis carried out was for a standard HDF pulp. The results are shown in fig. 2, which is a plot of fiber length versus fiber width. The trends are similar to those previously obtained for the same type of pulp [Klimczewski et al. 2009].

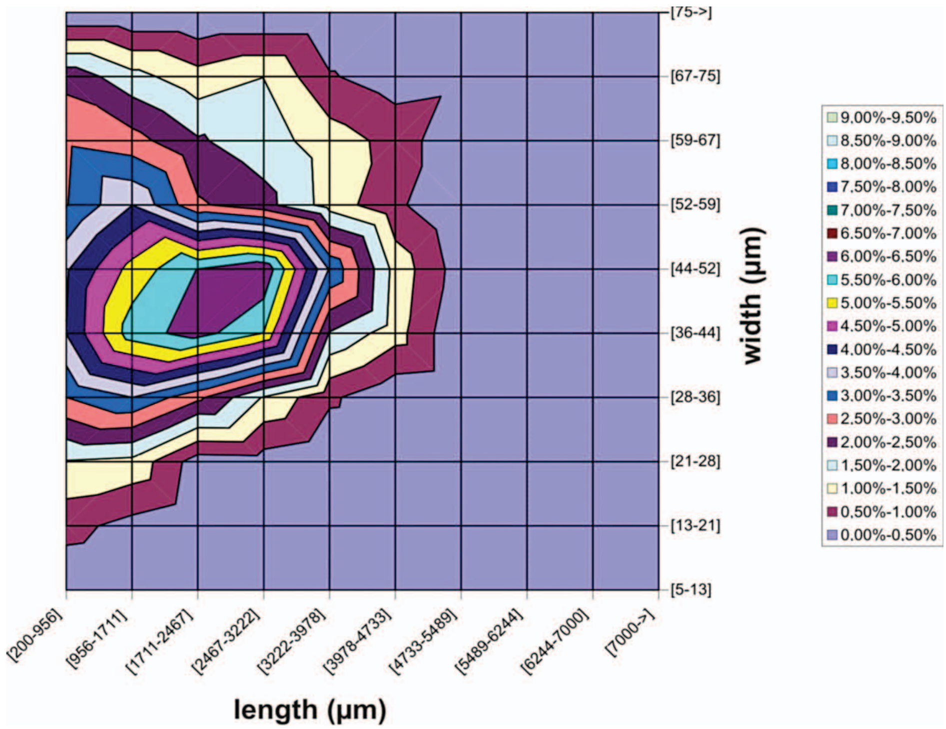

Fig. 2. Fiber length-width data for typical HDF pulp fibers, showing the proportions of relative fiber areas in each fraction
Rys. 2. Długość i szerokość standardowych włókien na płyty HDF, pokazujące udziały powierzchni każdej frakcji

It can be noticed that the data obtained (fig. 2) reflect to a high degree the anatomical structure of wood used for production. Almost all parts of the pulp consist of fiber classes of length 200–4733 µm and width 28–67 µm. In stark contrast, the dimensions of the basic elements constituting the fibers in pinewood (*Pinus silvestris* L.) are as follows: tracheids are 1800–3500 µm long and 20–40 µm (tracheids of spring wood) or 13–25 µm wide (tracheids of summer wood) [Kokociński 2002]. The greatest areas were recorded for fiber classes of width 36–52 µm and length 1711–3222 µm. There was also a significant proportion (51%) of short fibers (200–956 µm) in the whole range of measured widths. It is important to note that the amount of very short fibers was responsible for only 21% of the area. This affirms the phenomenon of fiber cutting in the pulp production process.

Fiber Analysis 2 – 100% recycled fibers, RF

Fig. 3 is a plot of fiber length versus fiber width for 100% recycled fibers. The data in fig. 3 are typical for recovered fiber (RF) pulp obtained from used fiberboards (mainly MDF). The greatest area share was recorded for the fiber fraction of length 200–956 µm and width 36–52 µm. The short fibers (200–956 µm) in the whole range of measured widths amounted to 71% of total fibers which were responsible for 43% of the area share (table 2). It seems that the properties of the pulp from the used boards should substantially reflect the properties of standard pulps. However, in the pulp made from used boards, in comparison with the industrial MDF pulp [Klimczewski et al. 2009], there was a significantly lower proportion of the fraction of the fibers of a length above 2467 µm. The main reason for this was the process of obtaining the pulp, in which the fibers were significantly shortened.

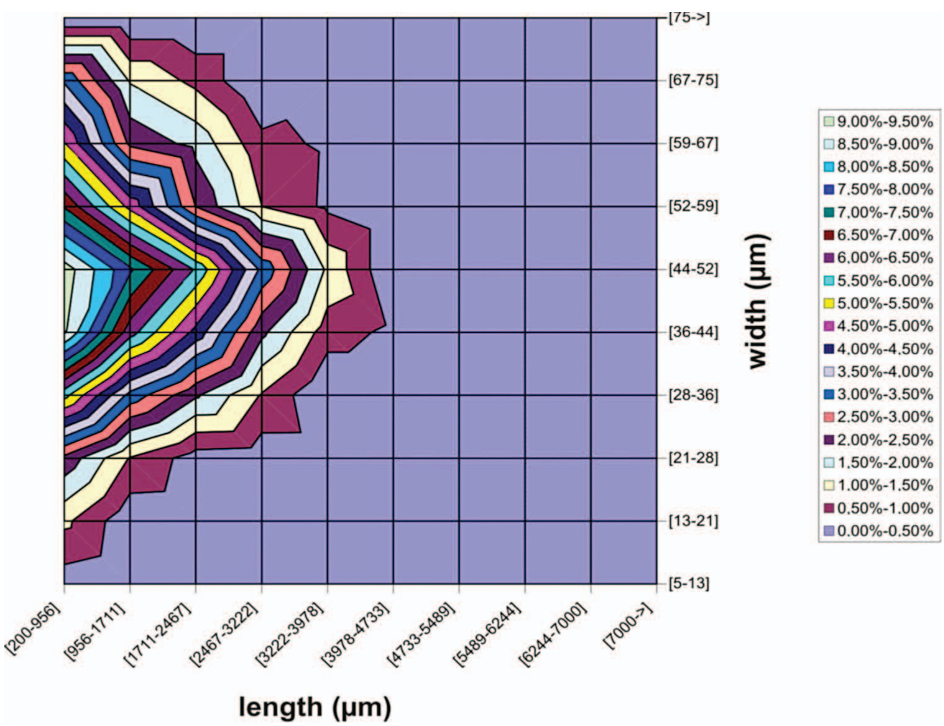

Fig. 3. Fiber length-fiber width data for typical RF pulp fibers, showing the proportions of relative fiber areas in each fraction

Rys.3 Długość i szerokość włókien użytkowych, pokazujące udziały powierzchni każdej frakcji

Fibre Analysis 3 – 85% HDF/ 15% Recovered fibers RF

Fiber length-width data for this mixture of fibers are presented in fig. 4. The main difference between the industrial HDF 100% pulp (fig. 2) and the pulp mix with 15% of RF (fig. 4) is a 4% decrease in the share of fiber classes with a width 36–52 µm and length above 1711 µm.

The shares for the fiber classes with lengths 200–1711 µm and widths 28–59 µm were increased by the same amount. There were no other significant differences.

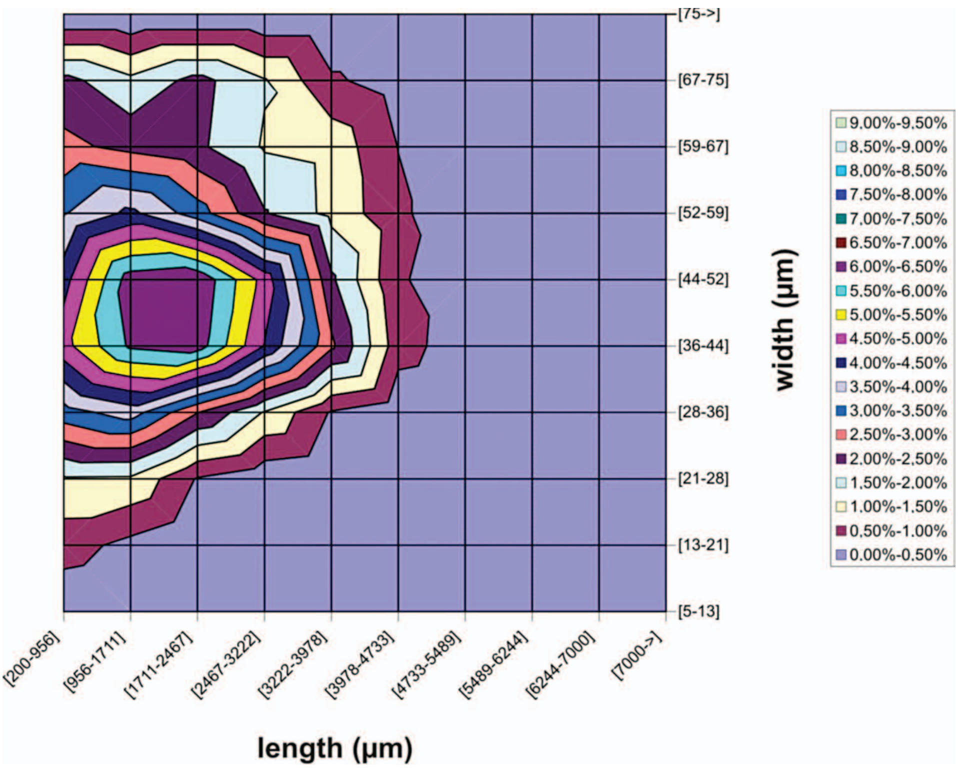

Fig. 4. Fiber length-width data for a mixture of 85% HDF fibers and 15% RF fibers showing the proportions of fiber areas in each fraction
Rys. 4. Długość i szerokość włókien w mieszaninie składającej się z 85% włókien standardowych i 15% włókien poużytkowych, pokazujące udziały powierzchni każdej frakcji

Fiber Analysis 4 – 70% HDF/ 30% recovered fibers, RF

Fiber length-width data for a mixture of 70% HDF fibers and 30% RF fibers are presented in fig. 5. It can be seen that the addition of 30% RF fibers caused a significant difference in the pulp properties. The greatest area share was recorded for the fiber fraction of length 200–2467 µm and width 36–52 µm. Short fibers (200–956 μm) over the whole range of measured widths amounted to 62% of the total fibers, accounting for 32% of the area share (11% more than for the 15% RF pulp mixture). The largest area share change (8%) was recorded for the fibers of a length 200–956 μm and width 28–59 μm (table 2). The shares of the fiber classes with a width of 36–52 μm and length above 1711 μm decreased by 6% compared to the HDF pulp.

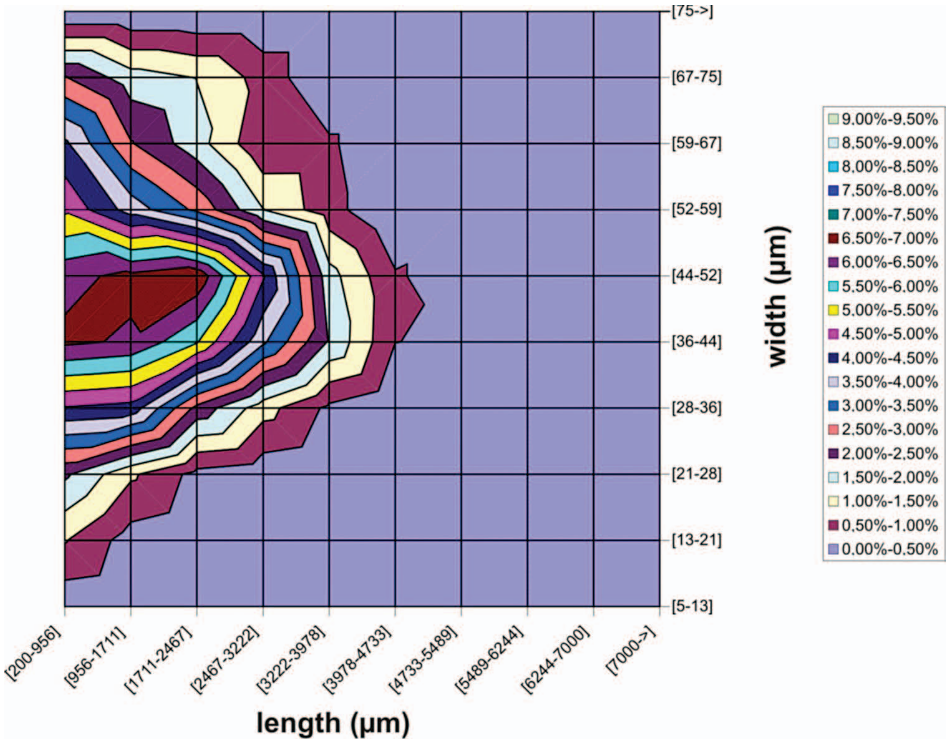

Fig. 5. Fiber length-width data for a mixture of 70% HDF fibers and 30% RF fibers showing the proportions of fiber areas in each fraction
Rys. 5. Długość i szerokość włókien w mieszaninie składającej się z 70% włókien standardowych i 30% włókien poużytkowych, pokazując udziały powierzchni każdej frakcji

Fiber Analysis 5–55% HDF/ 45% recovered fibers, RF

The length-width fiber data for the 45% addition of RF to the HDF fiber is presented in fig. 6. The changes in the pulp properties continue. Compared to the pulp with 30% RF content, a further increase (by 2%) in the area share of the length classes 200–956 μm within the whole range of measured widths can be observed, amounting to 64% in the fiber numbers and 34% in the area shares (table 2). In addition, a decrease (by 2%) in the fiber classes of width 36–52 μm and length above 1711 μm was noticed.

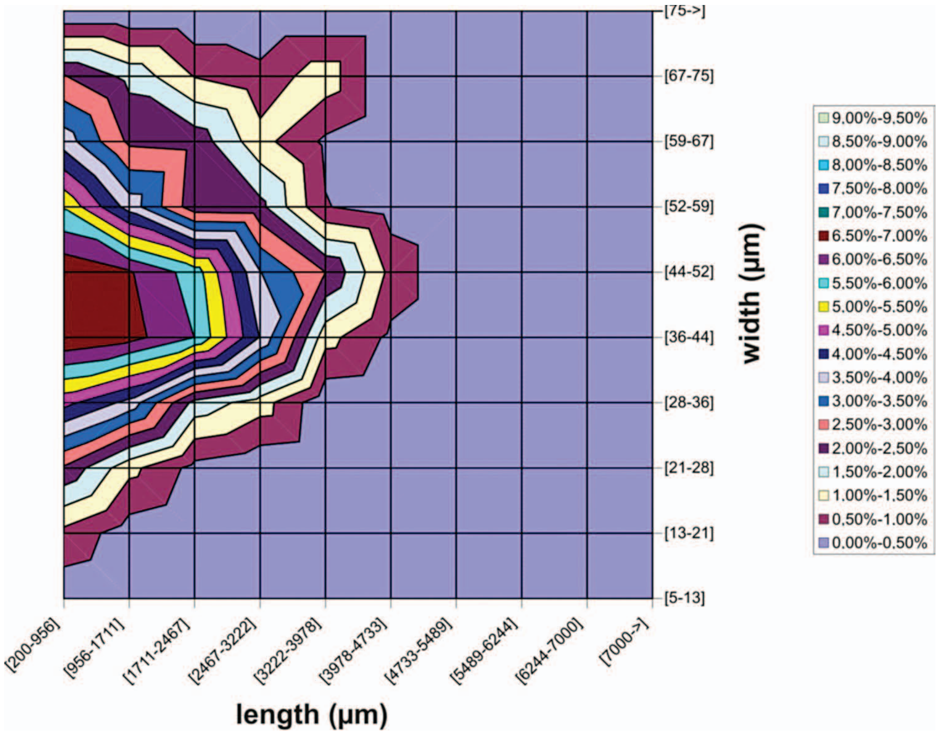

Fig. 6. Fiber length-width data for a mixture of 55% HDF fibers and 45% RF fibers showing the proportion of fiber areas in each fraction
Rys. 6. Długość i szerokość włókien w mieszaninie składającej się z 55% włókien standardowych i 45% włókien użytkowych, pokazujące udziały powierzchni każdej frakcji

Selected numerical results are presented in table 2.

Table 2. Fiber area and fiber number data for selected pulp fractions for various mixtures of HDF and RF fibers
Tabela 2. Powierzchnia włókien i dane liczbowe dotyczące włókien standardowych i użytkowych oraz ich mieszanin na płyty HDF

Fiber area share *Udziały powierzchni włókien*								
1	2	*3*	4	*5*	6	7	8	9
Length classes *Klasy długości włókien* (µm)	200–1711	all *wszystkie*	200–956	all *wszystkie*	200–956	200–956	2467–3222	above *powyżej* 1711
Width classes *Klasy szerokość włókien* (µm)	28–59	above 52 *powyżej*	all *wszystkie*	below 28 *poniżej*	28–59	36–52	36–52	36–52

Table 2. Continued
Tabela 2. Ciąg dalszy

1	2	3	4	5	6	7	8	9
100%HDF	32%	32%	21%	5%	14%	8%	12%	32%
100% RF	53%	33%	43%	6%	31%	18%	6%	18%
15% RF	36%	34%	23%	5%	16%	9%	9%	28%
30% RF	43%	30%	32%	5%	22%	13%	8%	26%
55% RF	45%	32%	34%	5%	24%	14%	7%	24%
Fiber number share *Udziały ilości włókien*								
Length classes *Klasy długości włókien* (µm)	200–1711	all *wszystkie*	200–956	all *wszystkie*	200–956	200–956	2467–3222	above *powyżej* 1711
Width classes *Klasy szerokość włókien* (µm)	28–59	above 52 *powyżej*	all *wszystkie*	below 28 *poniżej*	28–59	36–52	36–52	36–52
100%HDF	50%	24%	51%	15%	32%	18%	5%	16%
100% RF	64%	24%	71%	15%	49%	29%	2%	7%
15% RF	54%	24%	52%	15%	35%	19%	4%	14%
30% RF	58%	23%	62%	15%	41%	23%	3%	11%
55% RF	60%	23%	64%	15%	43%	25%	3%	10%

Summary

The results of the experiments show that the largest changes in the pulp properties occurred with the addition of between 15% and 30% of RF fibers to the HDF fibers. This can also be confirmed by the mechanical test of the panels produced from the pulps used [Project 2011]. The strength properties were negatively affected by a decrease in the fiber classes with a longer length (above 1711 µm), and an increase in swelling was caused by a significant increase in the small fiber classes (with length 200–956 µm).

The analysis conducted is another example showing that pulp quality assessment can be a useful tool for judging the potential properties of panels produced from pulp. It is particularly important in situations where new materials are introduced into the production process.

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WYBRANE WŁAŚCIWOŚCI MAS WŁÓKNISTYCH PRZEZNACZONYCH NA PŁYTY HDF Z DODATKIEM WŁÓKIEN POUŻYTKOWYCH

Streszczenie

W niniejszym artykule przedstawiono właściwości mas włóknistych, niezbędne do określenia przydatności tych mas do produkcji płyt HDF. Do badań wykorzystano standardowe włókna z drewna sosnowego pozyskane w warunkach przemysłowych oraz włókna otrzymane w warunkach laboratoryjnych ze zużytych płyt pilśniowych (włókna poużytkowe). Włókna poużytkowe pozyskano z płyt: „surowych" MDF (80%), lakierowanych HDF (10%) i „surowych" płyt pilśniowych twardych (10%). Włókna standardowe, włókna poużytkowe i mieszaniny tych włókien przygotowane w różnych proporcjach poddano analizie w aparacie MorFi. Masa każdej analizowanej próbki wynosiła 2 g z.s. włókien, co umożliwiło wykonanie ok. 4 tys. pomiarów (długości i szerokości włókien) w każdej z nich. Udziały procentowe powierzchni włókien określono dla 90 klas (9 klas szerokości i 10 klas długości).

W wyniku przeprowadzonych badań, na podstawie analizy porównawczej z danymi otrzymanymi dla mas przemysłowych stwierdzono, że włókna poużytkowe mogą być dodawane do standardowych włókien w ilości 15–30%, bez ujemnego wpływu na właściwości mas przeznaczonych do produkcji HDF.

Jednocześnie wykazano, że ocena jakościowa włókien może być użytecznym narzędziem do oceny potencjalnych właściwości płyt drewnopochodnych o budowie włóknistej, szczególnie w sytuacjach, gdy do wytwarzania płyt stosowane są nowe surowce.

Słowa kluczowe: włókna drzewne, włókna poużytkowe, HDF, wymiary włókien