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THE INFLUENCE OF THE TYPE AND PREPARATION OF LIGNO-CELLULOSE FIBRES ON THE PROPERTIES OF MDF

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ABSTRACT

The influence of the type and preparation of lingo-cellulose fibres on the properties of MDF. The possibilities of utilizing waste-paper were examined in the production of MDF. Two kinds of waste-paper (cardboard waste and mixed waste-paper) in two disintegration sizes each were used. The composition and length of fibres and content of the Klasson lignin were examined. The following properties were obtained in the boards: bending strength, internal bond, modulus of elasticity and thickness swelling. It is apparent that paper fibres can be added to wood fibers in the production of MDF to a maximum of 30%.

KEY WORDS: cardboard waste, mixed-waste paper, MDF, disintegration size of waste paper

INTRODUCTION

The limited supply of wood from the forest has initiated research in other materials for production of wood- panel boards. Investigations of the utilization of fibrous agricultural waste material and of high-molecular polymer are well-known and partially practised in industry. Waste paper is a recycled material which is not on the whole used in the production of paper. The production and consumption of paper increase every year, this is why waste paper resources will also increase. This is the reason why waste paper can be used in other branches of industry. Waste paper contains cellulose fibres in its composition, accordingly it should be used in the first instance production of fiberboards. It is known that waste paper fibres will be of worse quality than fibres from raw wood. However, the tests of the utilization of waste paper are well-founded in this technology.

MATERIAL AND METHODS

The aim of the study

The waste paper was examined as a recycled material in the production of MDF. Two types of waste paper were used: cardboard waste and mixed waste paper.

The scope of the study included:

- the characteristics of the waste paper (determination of lignin content and characteristics of fibres)
- manufacturing of MDF from waste paper and wood fibres
- determination of the structure and properties of these boards

The research methods

The pulps were fractionated in an HS apparatus. The length of fibres in these pulps was measured by a Kajaani FS-200 instrument (Przybysz 2005).

The content of lignin in the wood pulp and in the waste paper pulp was tested by the Klasson method (Melcer et al. 1976).

The microscopic examination of boards was done by a Nikon SMZ 1500 microscope.

The properties of the boards were determined according to the compulsory standards (EN 310, EN 317, EN 319). Boards of an established density of 680 kg/m^3 were produced under laboratory conditions. Waste paper pulp was added to wood pulp in the amounts of 0, 15, 30, 40, 50% in relation to absolute dry wood pulp.

Urea - formaldehyde resin was added as an adhesive in the quantity of 10% in relation to absolute dry fibres.

RESULTS AND DISCUSSION

The content of the Klasson lignin (in % dry pulp) is shown in Tab. 1. The composition and length of wood fibres and waste paper are shown in Tab. 2.

Tab. 1: The content of the Klasson lignin in wood pulp and waste paper pulp

Kind of pulp	Klasson lignin in % dry pulp
Wood chips (*Pinus sylvestris L.*)	28
Wood pulp	37
Cardboard pulp	28
Mixed waste-paper pulp	21

Tab. 2: Characteristics of fibres in wood pulp, cardboard pulp and mixed–waste paper pulp

Kind of pulp	Average length of fibres mm	Content of long fibres in pulp %	Content of medium fibres in pulp %	Content of fine fibres and non-fibre material in pulp %
Wood pulp	2.70	61	12	27
Cardboard pulp	0.55	39	18	43
Mixed waste-paper pulp	0.38	16	24	60

It can be seen from the data in the tables that each kind of pulp differed. The most lignin is contained in the wood pulp (about 36%) and it is far more than in the wood chips (28%). This is a result of partial hydrolysis of hemicelluloses during defibration. The decrease of the content of hemicelluloses caused a several percent increase in the content of lignin in the wood pulp. (Bučko, Klein 1978, Nicewicz 1987).

Less Klasson's lignin was found in the waste-paper pulp than in the wood pulp; in the cardboard pulp 28 %, and in the mixed waste-paper pulp 21% (see Tab. 1). These amounts can seem too high. It is known that craft cellulose fibres contain only several percent of lignin (3-4%) and similar amounts could be expected in waste-paper pulp.

However craft pulps, with small amounts of other pulps, are used in the production of high quality papers. To the production of lower quality paper, e.g. that used for packing (the main component of cardboard waste papers) and newspapers (the main component of the mixed waste papers), there are used significant quantities of semi-chemical pulps and stone wood pulps. The efficiency of the stone wood pulp from wood amounts usually to 95 -97%, and that of semi-chemical pulps – to 70 -80%. It means that significant amounts of the lignin remain in these pulps and hence probably high shares of the lignin in the waste papers.

The mean length of wood fibres amounted to 2.7 mm and was about 7 times as large as the shortest fibres of mixed waste-paper pulp (0.38 mm). The cardboard pulp fibres were about 40% longer than the mixed waste-paper pulp fibres. It was similar with the pattern of fraction composition. In the pulp, there were most proper fibres (about 61%) and least fine fraction (27%). In the cardboard pulp, long fibres were almost 39% while the least advantageous, fine fraction, about 43%. At the same time, in the mixed waste-paper pulp, the proper fraction was 16%, the medium 24% and the fine fraction as much as 60%.

In Tab. 3 are shown the properties of MDF boards manufactured with different proportions of waste paper. It has previously been shown (Nicewicz et al. 2005) that not more than 30% of waste paper should be added. The present study (Tab. 3) shows properties of boards containing up to 50% waste paper.

Tab. 3: Properties of MDF obtained from wood pulp, cardboard pulp and mixed waste-paper pulp

Name of pulp	Variant *	Bending strength N/mm^2	Internal bond N/mm^2	Modulus of elasticity N/mm^2	Thickness swelling %
Wood pulp	100/0	29	0.56	3300	6
Cardboard pulp	85/15	21	0.30	1900	15
	70/30	20	0.27	2200	17
	60/40	16	0,25	2100	17
	50/50	14	0.22	2000	17
Mixed waste-paper pulp	85/15	22	0,33	2000	15
	70/30	20	0.31	1900	17
	60/40	17	0,25	1700	18
	50/50	14	0.24	1400	20

*x/y: x – wood fibre content in a board, y – waste paper fibre content in a board

It is clear from the data in the table that properties of boards deteriorate when the quantity of added waste paper grows. There are two possibilities: either the presence of waste-paper fibres causes a loss in board properties, or they somehow adversely affect the board structure. Therefore, it is worth looking at the distribution of particular fibres, especially on perpendicular cross-sections of boards. The photographs below are microscope pictures of cross-sections of boards obtained with an admixture of waste paper.

In the picture obtained in white light (Fig. 1), the presence of flocculi of waste-paper fibres is already visible, resembling plaits of colour lighter than the particles of pulp. This testifies to the non-homogenous structure of the boards. By means of light of the shortest wavelength (deep violet), the contrast between both kinds of fibres was deepened, due to the low absorption of this light by lignin. Due to this fact, in Fig. 2, there are distinctly visible oblong agglomerates of waste-paper fibres. The observed state has a significant effect on board properties. Hence the flocculi have not been broken during board manufacturing (e.g. in the process of sizing), so it can be stated almost with certainty that the particular fibres which constituted them did not have contact with the glue which was sprayed only on the outer surfaces of the flocculi. As a result, the discussed agglomerates of fibres, although joined with the rest of the board structure, had hardly any internal coherence. Therefore, they constituted significantly weakened zones of the boards. This is what should be recognised as the main reason for the rapid fall in board properties and the growth in their sensitivity to water action with growth in the content of waste-paper fibres. Very similar were the results in the case of boards produced with an admixture of cardboard waste paper (Fig. 3).

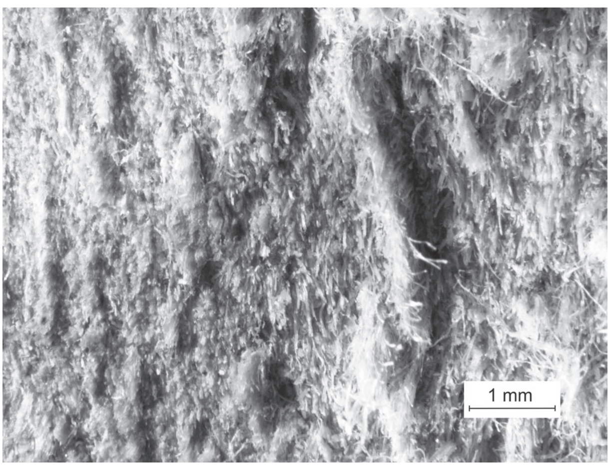

Fig. 1: Cross- section of MDF boards made with 30% mixed waste paper pulp (photo in white light)

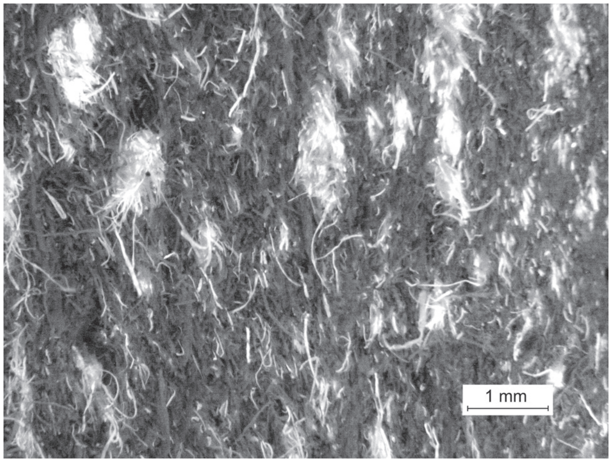

Fig. 2: Cross- section of MDF boards made with 30% mixed waste paper pulp (photo in violet light)

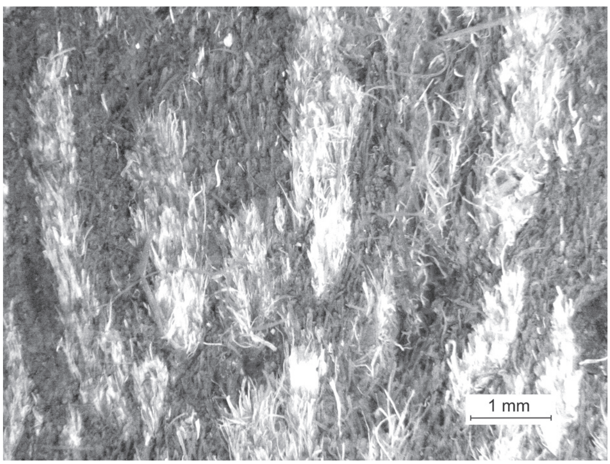

Fig. 3: Cross- section of MDF boards made with 30% cardboard pulp (photo in violet light)

The only conclusion resulting from the above observations is the necessity of breaking the flocculi of waste-paper pulp, possibly into the form of single fibres, because only such treatment will allow us to effectively homogenize the mixture of wood pulp with waste-paper pulp. An attempt at such an operation has been made by means of a high-speed mixer. Full disintegration of agglomerates of waste-paper fibres in the case of both types of waste paper took place after about 3 minutes of mixing, at a mixer speed of 2.5 thousand rpm.

The composition and length of waste paper fibers are shown in Tab. 4.

Tab. 4: Characteristics of fibres in cardboard pulp and mixed–waste paper pulp after disintegration

Kind of pulp	Average length of fibres mm	Content of long fibres in pulp %	Content of medium fibres in pulp %	Content of fine fibres and non-fibre material in pulp %
Cardboard pulp	0.47	32	8	60
Mixed waste-paper pulp	0.42	16	16	68

After disintegration of the flocculi of waste-paper pulp a distinct fall in the content of long fibers (about 7%) and medium fibers (about 10 %) in cardboard of pulps was observed. The high content of fine fibres and non-fibre material caused a decrease of average length fibres of about 15 %. In the mixed waste-paper pulps after disintegration only medium fibers and fine fraction contents changed. In this case an increase the average length of fibres was registered. This resulted from the high content of fine fraction non-fibre material which was calculated from measurements of the length.

Waste-paper fibres prepared in this manner were mixed with wood pulp. From the mixture after sizing MDF boards were produced in the same way as in the previous series. The properties of the obtained boards are shown below in Tab. 5.

Tab. 5: Properties of MDF obtained from wood pulp and waste-paper pulp after disintegration

Name of pulp	Variant *	Bending strength N/mm^2	Internal bond N/mm^2	Modulus of elasticity N/mm^2	Thickness swelling %
Wood pulp	100/0	29	0.56	3300	6
Cardboard pulp	85/15	30	0.53	2700	7
	70/30	31	0.49	2500	8
	60/40	26	0.47	2000	9
	50/50	19	0.45	1980	13
Mixed waste-paper pulp	85/15	27	0.37	2400	7
	70/30	25	0.34	2263	7
	60/40	22	0.32	2100	11
	50/50	20	0.30	1790	14

*x/y: x – wood fibre content in a board, y – waste paper fibre content in a board

It is apparent that the properties of boards have improved significantly in comparison with the first series. Not only has the strength of the boards increased, but, surprisingly, also their water resistance. It is worthy of notice that after breaking the waste-paper flocculi, the previously not very clear difference between cardboard and mixed waste paper became apparent. Boards containing cardboard waste paper in almost all variants had a higher strength (especially tensile strength) than boards with mixed waste paper.

Influence on strength of cardboard - wood pulp boards also have a greated content of lignin. The lignin is a natural binder appearing in wood. Thus the high content of lignin makes the possibility of good bonding of waste paper and wood pulp. It has expression in the increased strength property of cardboard - wood boards compared with mixed waste-paper wood boards. The lignin has influence on the hydrophobicness of boards. The lignin is insoluble in water and it dosen't swell. The degree of its contents therefore has a positive influence on the hydrophobic properties of boards. Investigations demonstrated that the influence of the lignin was better in the case of disintegrated waste paper. Waste paper fibres are uniformly located in the board. Probably there is more direct bond of waste papers and wood fibres (about the largest contents of the lignin).

Microscope observations of the structure of board cross-section are shown in Figs. 4 and 5 as an example of a variant containing 30% of waste-paper fibres.

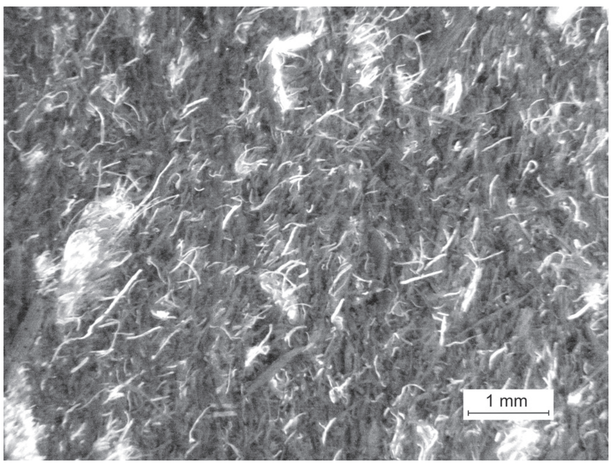

Fig. 4: Cross- section of MDF boards made with 30% mixed waste paper pulp after disintegration (photo in violet light)

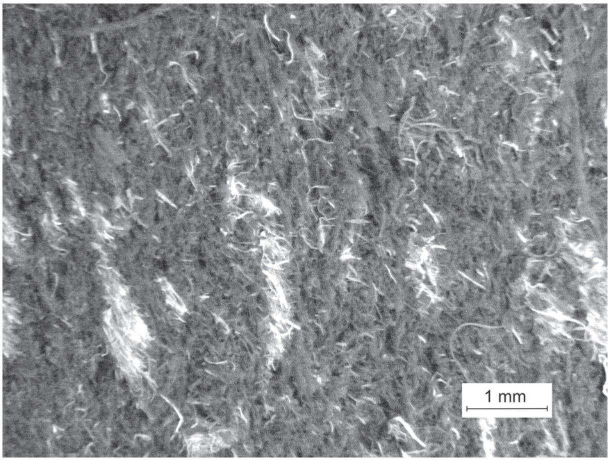

Fig. 5: Cross- section of MDF boards made with 30% cardboard pulp after disintegration (photo in violet light)

It is visible that lighter waste-paper fibres are uniformly dispersed among fibres of wood pulp. Fibres are single, in the field of view there are no flocculae which could weaken the structure of the board. The fibres of cardboard waste paper are longer than those of mixed waste paper (Tab. 4), and they positively affected the strength of boards containing cardboard waste paper. It should be admitted that mechanical disintegration of waste-paper flocculae allowed us to obtain boards of satisfactory properties containing as much as 50% of waste paper.

CONCLUSION

1. Cardboard and mixed waste paper can be used with the same usefulness in the production of MDF.
2. Recycled paper must be separated into single fibres.
3. Disintegration of waste-paper flocculi can be obtained by mechanical mixing.
4. The structure of waste-paper-wood board should be observed in violet light.

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