Recycling of particle- and fibreboards using the extruder technique

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1. General Introduction

The wood composite industry is mainly a world-wide creation of the last century. The pace of development has been rapid and a continued high speed development is also expected for this century. Technological breakthroughs with new processing machines, quality control devices, better adhesives and use of other lignocellulosics than wood as a raw material will possibly play a great role in the future of this industry.

In Europe, particleboards and medium density fibreboards (MDF) became the backbone of furniture and displaced to a very high extent solid wood from this area. Therefore, it was logical that the development of the furniture industry has been dramatically affected by that of the fibre- and particleboard industry.

Pieces of furniture have a life span of 30 to 40 years in Europe. According to environmental regulations in some European countries deploying of used furniture on the landfill will be forbidden by the beginning of 2005, as the interaction between organic materials and the environment is of a very complex nature. Leached binders may influence the groundwater, biological degradation leads, moreover, to the formation of methane which contributes to the „Green-House-Effect" about 80 times more than carbon dioxide. Figure 1 summarises the reasons against dumping of organic waste materials.

Due to the above mentioned reasons, increasing attention has been given to the issue of recycling in the fibre- and particleboard industry. Many methods have been developed for recycling of particleboards (Roffael 1997). In Germany, the thermo-hydrolytic pulping of mechanically disintegrated chipboards has attracted industrial interest (Boehme and Wittke 2002, Kirchner and Kharazipour 2002).

[1] This research work has been financially supported by the EU (Life-QLK5-CT-1999-01221)

2. Objectives of the work

Our presentation today relates to a new recycling technology for processing of waste composite panels (particleboard, fibreboard) and waste low-grade paper, either alone or in mixtures, to obtain fibres suitable for the production of medium density fibreboard (MDF), a valuable commodity. The patented technology is based on application of the extrusion technique and target also at reactivating the aminoplastic resin used for the bonding of waste panels, so as to enable reduction of the resin level needed to rebond the fibres obtained through recycling. For comparative studies, waste particleboard, fibreboard, and mixtures therefrom, are defibrated in a conventional refiner as commonly used in the MDF industry.

The twin extruder machine contains 7 different compartments (modules). In the first part of the twin extruder the solid material to be extruded is feeded and transported within the extruder through the so called conevying screws. Thereafter, the material to be extruded is subjected to thermohydrolysis under the action of high shear. The high shear is exerted by the so called twin flight reverse pitch self wiping devices. Due to such shear action the material is defibrated and the morphological structure of the lignocellulosics is disrupted. The profile of the extruder can be changed according to the material to be extruded. The defibration process can be done at a temperature as low as 40°C, but it is usually carried out at a temperature of 90°C to 110°C. In extruders working at high pressure the temperature can be much higher. Fig. 2 a) shows the profile of the twin-extruder. Fig 2 b) shows a temperature gradient during the extrusion process. Fig. 2 c) shows the different devices used in the extruder. The devices can be combined in different manners.

In the extrusion process water or pulping chemicals such as dilute sodium hydroxide solution or dilute acids can be added to enhance defibration. Also, the speed of the screws can be changed over a wide range to meet optimal conditions. In our reseach project the conditions were in average as follows:

Maximum temperature during extrusion:	90°C
Water rate flow:	5-10 gk/h
Liquid solid ratio:	1:1:
Defibrated extrudaet:	7-10 kg/h
Dry matter of extrudate:	50-60 %

Using the above mentioned conditions, practically no change in the chemical composition of extruded particle- or fibreboards takes place during the defibration process as long as water is used for the defibration process. However, on using sodium hydroxide as a pulping agent chemical degradation of the resin occurs leading to a decrease in the nitrogen content of extruded fibres compared to that of the original boards. In other words, both the thermo-mechanical (TMP) and the chemo-thermo-mechanical (CTMP) pulping conditions can be applied using the extruder technique. In fig. 3 the chemical composition of the fibre- and particleboards to be extruded are compiled. Fig. 4 presents data on the change of chemical composition of particle- and fibreboards due to extrusion using water and sodium hydroxide as pulping chemicals. In trials no. 1 and 2 using water for the thermohydrolysis the main difference was in the rate of extrusion, in experiment no. 1 the rate was 16,2 kg/h, whereas in experiment no. 2 the rate was 27,2 kg/h. In experiment 3 and 4 particleboards were extruded at a rate of 27,4 kg/h and 14,9 kg/h respectively. In all trials the energy consumption was nearly 400 (w.h/kg). The moisture content of the extruded fibres was nearly 60 %.

In one experiment we compared the properties of the extruded fibres obtained from the extruder technique with those obtained from the refiner technique. According to the results, the degradation of the resin in the refiner is much more pronounced than in the extruder as the values of the nitrogen content clearly show (fig. 5).

The fibres produced from particle- and fibreboards by the extruder technique can be used as a raw material for fibreboards. In fig. 6 the conditions of the production of fibreboards are compiled. As can be seen from the results in fig. 7 the fibreboards obtained without adding any sizing agent show fairly good internal bond strength and also relatively low thickness swelling. As the board is made out of 100 % waste boards the formaldehyde release is still very low. However, the bending strength is compartively low. We have always noticed, that boards, made from 100 % recycled boards do have low bending strength compared to those from wood.

In a further work mixtures of wood, particleboards and fibreboards were disintegrated in a hammermill and extruded together. In another set of experiments every material was hammermilled and extruded separately and thereafter mixed together after extrusion. From both sets of fibres medium density fibreboards were made according to the following conditions.

Conditions used for preparing UF-bonded fibreboards:

Board type:	One layer
Board size:	45 cm x 45 cm x thickness
Board thickness:	20 mm unsanded, 19 mm sanded
Targed density:	800 kg/cm³
Resin:	Urea formaldehyde resin (resin 115 from partner no. 3)
Resin level:	12 % (soled resin based on dryed fibres)
Catalyst:	Ammonium sulphate (2 % based on solid resin)
Size agent:	No sizing agent
Gluing:	Blender technique
Pre temperature:	190°C
Press time:	15 or 25 seconds per millimetre

The results of measuring the physical and mechanical properties are presented in fig. 8. As can be seen from the results mixing pure waste particleboards, fibreboards and pine wood in the ratio of 1:1:1 leads to boards with very low thickness swelling and water absorption. However, the bending strength of the boards was lower than that of boards made out of pure pine wood. Besides, the formaldehyde release of the MDF prepared from different mixtures was also assessed. The results are presented in fig. 9. Accordingly, the formaldehyde release measured using the perforator methode (EN 120) is low and meets the requirement for boards of the E1-class. Moreover, the results show that there is no signifacant differences between the formaldehyde release of the boards prepared from fibres extruded before mixing or after mixing the waste boards. This again can be regarded as a positive aspect as no special care is needed in handling the process as far as the formaldehyde release is concerned. The results of measurements according to EN 717.3 are in full agreement with the results obtained by measuring the perforator value according to EN 120.

Summary

The extrusion technique can be used to recycle particle- and fibreboards separately or in mixture. The fibres obtained can be used as a raw material for medium density fibreboard. The fibreboards obtained under conventional gluing and pressing conditions show satisfactory results as for as the internal bond strength and the thickness swelling are concerned. Also, the formaldehyde release of the fibreboards meets the E1-requirements.

Literature

Roffael, E. 1997: Stoffliche Verwertung von Holzwerkstoffen. Adhäsion 41, 24-27

Boehme, Ch und Wittke, B. 2002: Erfahrungen der Industrie mit dem WKI-Verfahren zum Recycling von Holzwerkstoffen.

Kirchner, R. und Kharazipour, A. 2002: Recycling von Holzwerkstoffen durch das Verfahren der thermo-hydrolytischen Spaltung: Optimierung der kontinuierlichen Prozesstechnologie.

5 Reasons Against Deploying Organic Materials On Landfills

1. Conventionally increasing costs of landfilling due to reduced landfill capacity.

2. Legislative measures prohibiting the dumping of organic matter.

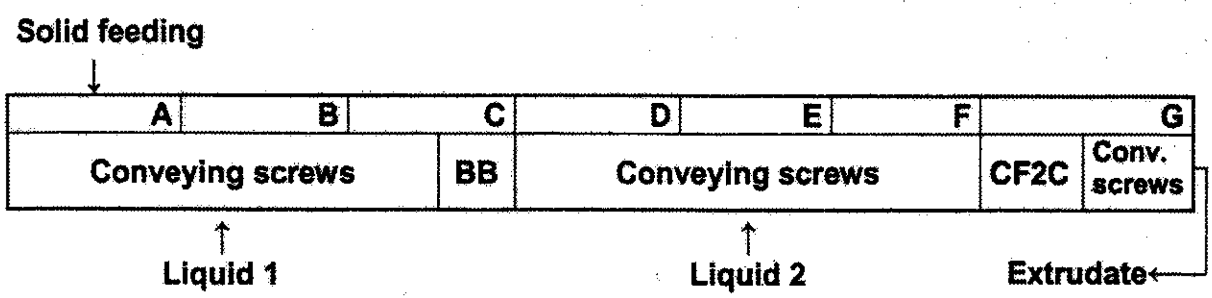
3. Generation of methane and carbondioxide in dumps, which can be considered as anaerobic reactors. Methane contributes to the green house effect eighty times more than carbondioxide (1 t methane is equivalent to 88 t of carbondioxide in global warming of the atmosphere).

4. Polluted leaching water from dumps may penetrate in the earth crust and contaminate surface and underground water.

5. In the dumps energy content of wood and wood-based panels is wasted and no utilization is made of the organic biomass.

Fig. 1

Configuration and the profile of the extruder



BB: bicam kneading discs
CF2C: screw elements with reverse pitch
Liquid 1 is either water or soda and liquid 2 is always water
The screw rotation speed is 200 rpm

Fig. 2a

Temperaturprofile in the twin-screw extruder

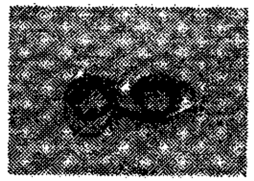
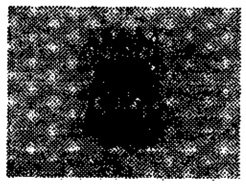
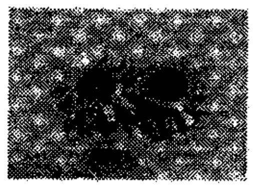
A	B	C	D	E	F	G
70°C	80°C	110°C	100°C	100°C	100°C	60°C

Fig. 2b

Chemical characterization of waste uncoated particle- and fibreboards

CHEMICAL DATA	PARTICLE-BOARDS PB	FIBRE BOARDS MDF
Lignin content [%]	27.51	25.82
Nitrogen content [%]	3.73	6.15
pH value of cold water extract (particle size ≥ 0,5 < 1 mm)	4.89	5.36
Buffering capacity of cold water extract [mmol NaOH/ 100 g o.d. sample]	1.37	0.64
pH value of hot water extract (particle size ≥ 0,5 < 1 mm)	6.96	7.80
Buffering capacity of hot water extract [mmol NaOH/ 100 g o.d. sample]	0.28	Not determinable
Ash content [%]	0.81	0.30
Silica content [%]	0.058	0.00
Formaldehyde Emission (Flask method, acc. to EN 717-3, after 24 h) [mg / 1000 g o.d. board]	93.4	37.3

Fig. 3

Screw elements	Pictures	Description
T_2F 66		Twin flight trapezoidal (Pitch of 66mm) Strong action of conveying
C_2F X		Twin flight self wiping (Pitch of x mm) Action of conveying
Mal_2		Bilobal paddles Strong action of shearing Very strong action of mixture
CFC_2 -25		Twin flight reverse pitch self wiping (Pitch of 25 mm) Very strong action of shearing Strong action of conveying Strong action of mixing
MEL		Mixing paddles Shearing

Description of the screws used for the screw profile in the extruder

Fig. 2c

Chemical characterization of fibres produced from waste particleboards, waste fibreboards, and wood chips by extruder technique

Sample No.	1	2	3	4	5	6	7	8	9	10	11
Raw material	**PARTICLEBOARD**				**MEDIUM DENSITY FIBREBOARD**				**PINE WOOD CHIPS**		
Liquid 1 in conveying Screw	Water	Water	NaOH	NaOH	Water	Water	NaOH	NaOH	Water	Water	NaOH
Lignin content [%]	29.49	28.57	28.67	28.65	26.27	26.03	26.01	26.21	30.40	30.57	30.39
Nitrogen content [%]	3.74	3.75	3.66	3.64	6.02	6.00	5.85	5.66	0.2	0.06	0.07
pH value of cold water extract	5.75	5.57	5.73	5.90	6.26	6.38	6.63	6.81	6.55	4.99	5.70
Buffering capacity of Cold water extract [mmol NaOH/ 100 g o.d. sample]	0.80	0.87	0.78	0.81	0.46	0.71	1.5	1.05	1.2	2.4	2.7
Ash content [%] / Silicate content [%]	0.82 / 0.18	0.8 / 0.16	1.03 / 0.19	0.98 / 0.13	0.31 / 0.004-0.028	0.31 / 0.007-0.026	0.57 / 0.01	0.59 / 0.01	0.34 / n.d.	0.32 / 0.05	0.53 / 0.04-0.07
Formaldehyde emission (Flask method, according to EN 717-3, after 24 h) [mg / 1000 g o.d. fibres]	157.3	141.4	129.8	49.2	113.5	96.9	119.6	76.2	Not detectable		

Fig. 4

Comparison of chemical data of fibres produced from pinewood, waste particle- and fibreboards by refiner technique with the fibres from extruder technique and with the basic raw material

Analysis	**Basic raw material**			**Defibration by**					
				Extruder technique			[illegible]		
	Pine wood	**PB**	**MDF**	**Pine wood**	**PB**	**MDF**	**Pine wood**	**PB**	**MDF**
Lignin content [%]	28.5	27.51	25.82	30.57	28.57	26.03	29.70	28.44	27.24
Nitrogen content [%]	0.07	3.73	6.15	0.06	3.75	6.00	0.14	3.29	4.75
Formaldehyde emission (Flask method, after 24 h) [mg/1000g o.d. fibres]	16.2	93.4	37.3	Not detectable	141.4	96.9	89.19	67.48	99.29

Fig. 5

Parameters of Board Production

Pressure (N/mm²)	**35**
Press temperature (°C)	**190**
Press time (s/mm)	**15**
Target density (kg/m³)	**800**
Resin types:	**UF110 & UF110+cross linker**
Glue factor (%)	**12**
Hardener (% on dry resin, Ammonium sulfate	**2**
Board dimensions	**43cmx43cmx16mm**

Fig. 6

Properties of MDF produced from extruded fibres

Sample No.	**1***	**2**	**3***	**4**
Sample mix (waste feedstock)	**PB**	**PB**	**MDF**	**MDF**
%hardener	2	2	2	2
Density, kg/m³	810	803	812	799
MOR, N/mm²	18.6	22.6	17.6	19.7
IB, N/mm²	**0.44**	**0.41**	**0.52**	**0.48**
Thickness, mm	15.7	15.6	15.8	15.7
24h swelling, %	**14.3**	**11.4**	**15.0**	**14.9**
HCHO, mg/100g	6.3	8.5	7.1	9.6
Moisture content, %	6.9	6.5	7.1	6.9

*** with cross linker**

Fig. 7

Physical-mechanical properties of UF-bonded MDF prepared from pine fibres and panel residues

Board No.	Press time	Fibres from	Board properties							
			Density	Bending strength	Internal bond strength	Thickness swelling		Water absorption		Moisture content
						2h	24h	2h	24h	%
	s/mm		kg/m³	N/mm²	N/mm²	%	%	%	%	
1a/1	15	Pine wood (33%) / Particleboard (33%) / MDF (33%) Mixed during hammermilling before extruded	805	21.67	0.54	5,0	17,5	18,7	67,5	7.7
1b/1	15	Pine wood (33%) / Particleboard (33%) / MDF (33%) Each material is extruded before being mixed together	837	21.09	0.41	7,7	22,2	37,7	72,9	7.7

Fig. 8

Formaldehyde release of UF-bonded MDF prepared from pine fibres and panel residues

Press time	Fibres from	Formaldehyde release [1] (flask method) EN 717.3 mg/1000 g d. board		Formaldehyde content [2] (perforator method) EN 120 mg/100 g d. board		Moisture content %
s/min		3h	24h	A	B	
15	Pine wood (33%) / Particleboard (33%) / MDF (33%) Mixed during hammermilling	5.9	52.8	7.0	7.0	6.5
15	Pine wood (33%) / Particleboard (33%) / MDF (33%) Each material is extruded before being mixed together	4.6	49.1	5.4	5.8	5.9

1) EN 717 – 3
2) EN 120, A: perforator value determined based on the moisture content of the board
B: perforator value determined and corrected to a moisture content of 6.5%

Fig. 9