Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

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Version of record first published: 18 Oct 2010

To cite this article: F. Munder, Ch. & H. Hempel (2004): Results of an Advanced Technology for Decortication of Hemp, Flax and Linseed, Molecular Crystals and Liquid Crystals, 418:1, 165-179

To link to this article: http://dx.doi.org/10.1080/15421400490479253

Mol. Cryst. Liq. Cryst., Vol. 418, pp. 165/[893]–179/[907], 2004

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400490479253

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RESULTS OF AN ADVANCED TECHNOLOGY FOR DECORTICATION OF HEMP, FLAX AND LINSEED

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The developed processing technology for natural fibre plants is based on a simple mechanical decortication principle. The technology can be operated in a normal agricultural service company. A capacity of 3 t/h of straw, a high available machine time, which is not sensitive to a certain humidity of the straw, and low investment by a simple fibre cleaning in one step permit to manufacture natural fibres at acceptable prices.

Practical applications of the fibres are for automotive industry, geo-textiles, thermal blankets, fibrous insulating material and composites, building boards, coarse yarn, coarse textiles, and reinforcement of several composites and structural parts.

Keywords: fibrous plants, natural fibres, hemp, flax, decortication

1. INTRODUCTION

Natural fibres are gaining progressive account as renewable and environmentally acceptable starting material for industrial applications, as well as for civil engineering and building activities. The first-rate mechanical characteristics of the natural fibres permit the substitution of synthetic, glass and carbon fibres in a wide range of industrial products. Independently of weather conditions and yields, however, the industrial application of natural fibres requires to make high-quality fibres continuously available in large quantities.

Efficient technologies are already being employed for the cultivation and harvest of natural plants. The economic processing and the yield of natural fibres must still be improved to ensure capacities and qualities are acceptable to set up powerful process plants successfully. Therefore, in cooperation with the Kranemann Gartenbaumaschinen GmbH a complete

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new machine line which includes all process stages from pick-up and cutting of straw bales up to the separate cleaning of the final products fibres and shives was established in a pilot plant for testing the developed principles in practical operation. The pilot plant was built on a scale of 50% of a recommended capacity of 3 t/h of straw for a later commercial plant.

Operating the pilot plant makes possible to get ensured operation and economic data of the process under real practical conditions.

2. TECHNOLOGY FOR PROCESSING OF NATURAL FIBROUS PLANTS AND EQUIPMENT CONFIGURATION

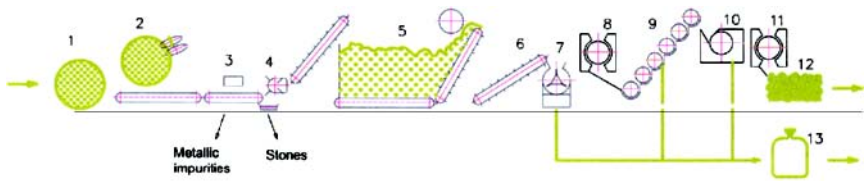
Fibre plants, such as hemp, flax, fibre linen and linseed are processed with the same technology that suits both freshly harvested green and retted plants.

The decorticating machine operates like the principle of a swing-hammer mill [1]. The fibre decortication is effected by rebound stress of the hammers at the surface of the straw stalks [2].

The process presented here includes all stages from the reception of the straw bales to the separated final products, which are fibres and shives ready for shipment. The equipment configuration preferred for the processing of hemp is shown in Figure 1.

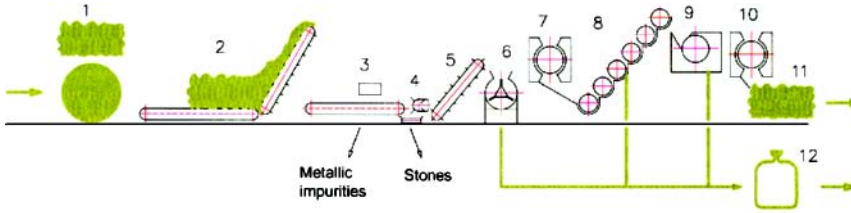
Normally, the hemp straw is harvested in round bales without any pre-cut of the stalks. Thus the stalk length can be up to 3 m. Such straw can not be charged in-to the processing machines without shortening by cutting in-to a defined length of about 400 mm.

The straw of flax and linseed is shorter and is often pre-cut during baling into rectangular bales. Such bales can be opened more easily, which simplifies the machine lines of processing (Fig. 2).



1 – Straw bale
2 - Bale cutting
3 – Metal detector
4 – Stone eliminator
5 – Straw metering system
6 – Conveyor
7 – Decorticating machine
8 – Condenser
9 – Multiple ultra cleaner
10 – Saw tooth opener
11 – Condenser
12 – Fibre baler
13 – Shives

FIGURE 1 Process flow sheet preferred for the processing of hemp.



1 – Straw bale	4 – Stone eliminator	7 – Condenser	10 – Condenser
2 – Straw metering	5 – Conveyor	8 – Multiple ultra cleaner	11 – Fibre baler
3 – Metal detector	6 – Decorticating machine	9 – Saw tooth opener	12 – Shives

FIGURE 2 Process flow sheet preferred for processing flax and linseed, rectangular or round bales.

Both machine configurations were tested in a pilot scale with a capacity of 1.5 t/h of straw to get ensured operation at economical data (Fig. 3).

FIGURE 3 Pilot plant for processing of hemp, flax and linseed.

3. RESULTS OF PROCESSING

3.1. Arising Fractions of Processing

When operating the presented technology, the following components arise in different qualities and quantities (Table 1). However, these data depend on the processed type of plants and variety.

The separate discharging of the components is an essential advantage for the best possible application in the industry for the production of special final products. For instance, the long fibres used for the production of interior panels of the automotive industry should not contain fibres shorter than 20 mm.

A visual impression of the components arising from hemp is given in following photos (Figs. 4–9).

3.2. Fiber Yield

The practical fiber yield depends on the grown variety mainly. Mean yields are shown below (Table 2).

However, it has to be considered that the short fibers contain a certain amount of shives still. The fibre yield is approximately equal, whether not retted or retted hemp is processed. Thus, the fibre yield is independent on the retting rate.

3.3. Mechanical Properties

The natural mechanical properties of the fibers, such as fineness, tear strength, elongation and module are only negligibly changed by the process (Table 3).

TABLE 1 Mass Balance of Processed Hemp and Linseed

	Percentage %	
Fraction	Hemp	Linseed
1. Fibres, long	25.0	18.0
2. Shives	20.7	30.2
3. Shives with short fibres	21.1	20.7
4. Short fibres with shives	6.0	13.0
5. Short fibres from fibre separator	14.2	3.6
6. Short fibres from pre-filter	1.3	3.8
7. Carding waste	0.9	2.1
8. Short straw, leaf, sand, stones, loss a. o.	9.1	8.4
9. dust	1.4	0.4
Input, total	100	100

FIGURE 4 Fibres, long.

The fineness of the hemp fibers can be substantially improved by retting. Also the fibers become more stabile by retting.

3.4. Cleanness of the Fibers

Normally, the required fibre cleanness is met in the two cleaning steps due to the excellent decortication process (Table 4).

The multiple ultra cleaner reduces the shives content of all retted fibers and of not retted hemp to less than 4% and the following saw-tooth cleaner effects a further cleaning down to less than 2% of shives.

However, not retted, freshly harvested flax and linseed have to pass the decorticating machine and the cleaning system twice to get a remaining shives content of less than 2%.

3.5. Fibre Length after Processing

The fibre length of the technical long fibres varies in a wide range. It can be adjusted by the pre-cut length of the straw stalks and the operation data of

FIGURE 5 Shives.

the decorticator. Often fibres shorter than 20 mm are unwanted in the mixtures of the technical long fibres for the technical applications. Therefore, it is an essential advantage of the used technology that the short fibres are separated from the long fibres together with the shives during the cleaning stage of the fibres. The average fibre length required for industrial application is approximately 80 mm. Typical fibre length distributions are shown in Figure 10.

A further shortening of the fibres during the decortication process should be avoided because the fibre loss will be increased in the cleaning stage. However, a separate cut of the fibres is possible after the cleaning, if required for special applications (see below).

3.6. Shives Arising

Approximately 45% of the shives arise at the decorticating machine and another 45% arise at the feeding system of the fibre cleaning stage. The rest is included in the short fibres separated from the long fibres by the multiple ultra cleaner.

FIGURE 6 Shives with short fibres.

All shives as well as the short fibres are a mixture of short fibres and shives with a wide spread range of particle size distribution. These mixtures can be separated in 4 defined fractions by a rotating screening drum with the meshes 6.3 times 6.3 mm, 4.3 times 20 mm and Ø 3.0 mm. The associated 4 fractions are short fibres, rough shives, medium size shives and fine shives. Furthermore a small amount of dust arise during screening.

The particle size of the shives can be adjusted by the operating data of the decorticating machine and the mesh size of the screen to meet the requirements of later shives application. Samples of a practical size distribution are shown in Figure 11.

4. PREPARATION OF FIBRES FOR VARIOUS APPLICATION

The utilization of the natural fibres for various applications, technologies and special products often requires a further cut of the fibres. Modern spinning machines, for instance, require a mean fibre length in the range of 30

FIGURE 7 Short fibres with shives.

to 40 mm. The production of composites need very short fibres in a length range of 2 to 8 mm only. Therefore a specially adapted cutting machine cuts the fibres into a defined nominal length, which is adjustable in the range of 4 to 50 mm. A sample of cut hemp fibres is shown in Figure 12.

The fibre length distribution is in a limited range after cutting (Table 5). It has to be tested still, whether these length distributions are acceptable for the production lines of composites for instance.

The fibre length distribution is illustrated by the following diagram (Figure 13).

5. POSSIBLE APPLICATION OF THE FIBRES PROCESSED

Several fractions arise in the processing of natural fibre plants, when using the technology presented here. For an economical operation of the plant each fraction has to be utilized for the best possible application or product. Samples for the practiced utilization of the components and fractions are given in Table 6.

FIGURE 8 Short fibres from fibres separator.

The samples show that each fraction can be utilized. There is no waste arising.

6. CONCLUSIONS

- The proposed technology is suitable for processing not retted hemp, flax, linseed and other bast fiber plants.
- The rebound stress of the developed decorticating machine effects a complete fiber decortication, which simplified the fiber cleaning.
- When processing of the bast fibre plants, the arising components can be discharged separate for different applications. This is an essential advantage for the best possible application of all components in the industry and for the production of special final products.
- Only a fiber cleaning stage followed by an opening stage reduce the remaining impurity content to $<2\%$ meeting the demands of most industrial fiber applications.
- Efficient fiber yields up to $>29\%$ are possible.

FIGURE 9 Short fibres from pre-filter

- The excellent properties of the natural fibers make it possible to substitute technical fibers like synthetic, glass or carbon fibers in many industrial applications.
- The fibre length after the processing of the bast fibre plants meet already the requirements of many technical applications. Such fibres can be prepared for the application in composites by shortening in an average length of 4 or 8 mm.

TABLE 2 Examples of Fiber Yields

	Fiber yield %	
	Fiber length 20 to 160 mm	Fiber length < 20 mm
Hemp	23 to 27	15.6
Flax	27 to 30	14.4
Linseed	17 to 23	12.7

TABLE 3 Examples of Measured Mechanical Properties [3]

	Fineness tex	Tear force N	Tear strength cN/tex
Hemp, freshly harvested green	14.9	46.9	33.8
Hemp, less retted	8.1	64.3	38.9
Hemp, retted	7.4	72.6	43.2
Flax, freshly harvested green	4.1	63.3	44.3
Flax, freshly harvested green 2 passages	3.3	48.1	32.5
Linseed, freshly harvested green	2.7	57.3	38.4

TABLE 4 Remaining Shives Content of the Fibres after the Two-Step Cleaning Process

	Average remaining shives
Hemp, freshly harvested, green	1.2
Hemp, retted	0.85
Flax, freshly harvested, green	4.4
Flax, freshly harvested green, 2 passages	<0.5
Linseed, freshly harvested green	2.3
Linseed, freshly harvested green, 2 passages	<0.8

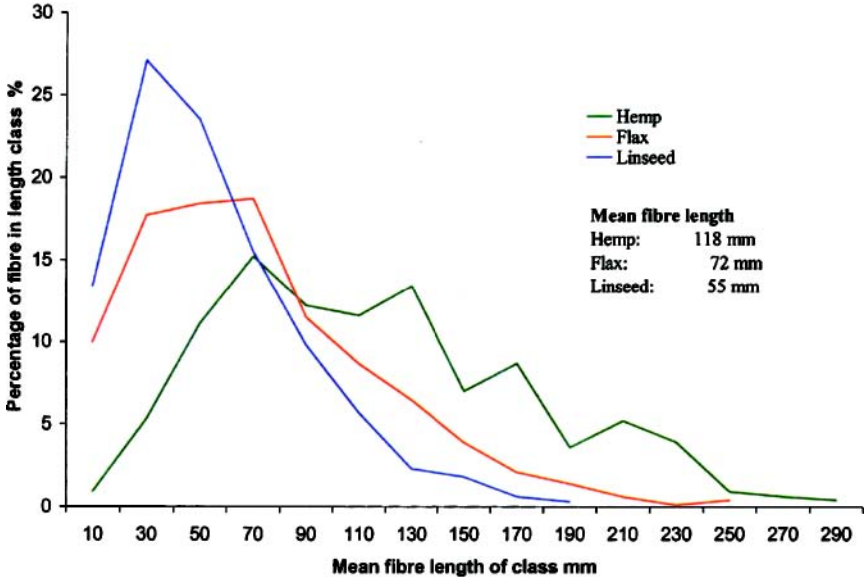


FIGURE 10 Length distribution of long fibres after processing (4).

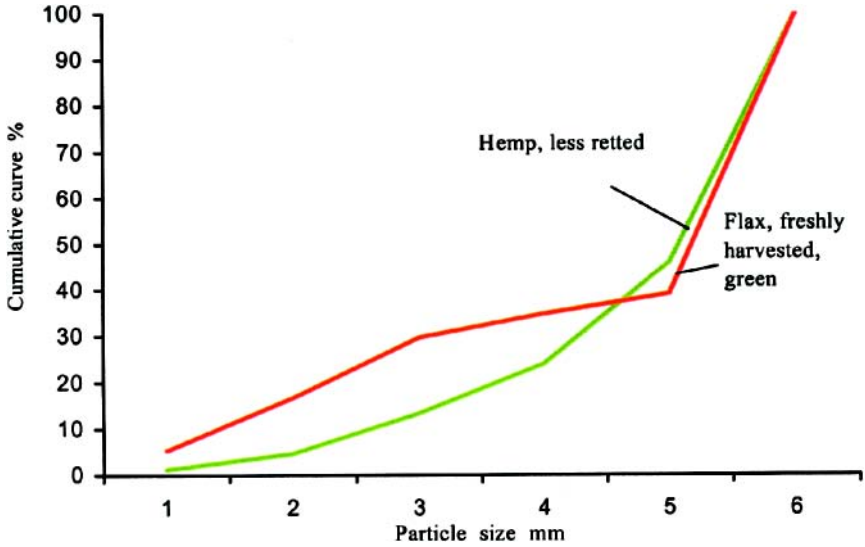


FIGURE 11 Typical particle size distribution of shives.

FIGURE 12 Hemp fibres cut in a theoretical cut length of 8 mm.

TABLE 5 Length Distribution of Cut Fibres [4]

	Hemp Theoretical cut length		Flax Theoretical cut length	
Length class	4 mm	8 mm	4 mm	8 mm
<5	74.7%	51.2%	58.9%	20.4%
5 to 10	16.6%	35.7%	33.1%	58.3%
10 to 15	5.6%	5.5%	3.9%	8.2%
15 to 20	1.8%	4.4%	2.1%	5.8%
20 to 25	1.1%	2.4%	1.3%	2.5%
30 to 35	0	0.1%	0.3%	1.0%
35 to 40	0	0.4%	0.1%	0.9%
Mean length	4.43 mm	6.28 mm	5.35 mm	9.43 mm

– The suitability of the long fibres for mats of the automotive industry, heat insulation mats or textiles has to be check still as well as the suitability of the cut fibres for composites.

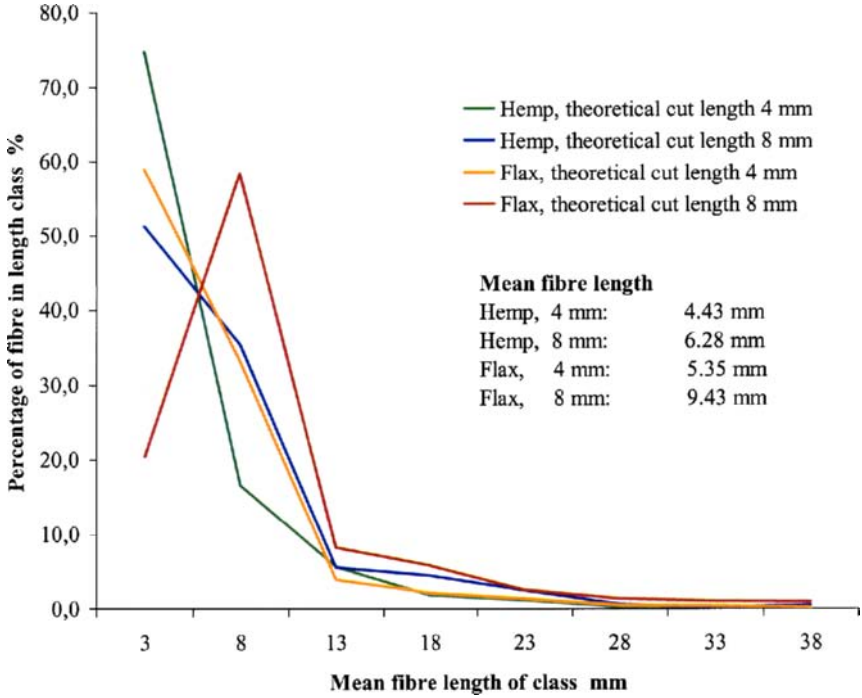


FIGURE 13 Length distribution of the cut fibres.

TABLE 6 Possible Application of Natural Fibres Processed (*See Table 1)

Run. No.*	Fraction*	Examples of application
1.	Fibres, long	- Mats for the automotive industry - Heat insulation mats - Coarse yarn - Textiles - Paper and paperboards, roofing boards - Cellulose - Seals - Composites - Reinforcement of concrete
2.	Shives	- Animal bedding - Pore forming material of clay bricks - Fuel
3.	Shives with short fibres	- Indoor panels - Furniture boards - Heaped heat insulation - Fuel
4.	Short fibres with shives	- Heat insulation panels - Sound insulation panels - Plaster base - Hardboards
5.	Short fibres from fibre separator	- Paper and paperboards, roofing boards - Cellulose - Composites
6.	Short fibres from prefilter	- Paper and paperboards, roofing boards - Cellulose - Composites - Absorbent of construction and chemical industry
7.	Carding waste	- Paper and paperboards, roofing boards - Cellulose
8.	Short, straw, leaf, sand, stones, loss a. o.	- Compost and mixed manure for horticulture - Soil improver
9.	Dust	- Pore forming material of clay bricks - Fuel

– The operational data of the plant are flexible to adjust both fibres and shives data in a wide range meeting the demands of many applications.
– A capacity up to 3 t/h of input raw material ensures an economic and profitable fiber production as well as marketing.
– Research and tests are continued to adjust the mechanical characteristics of fibres and shives for many various applications and to extend the operative range for instance for tropical fibre plants.

REFERENCES

[1] Fürll, Ch. & Hempel, H. (1999). Gewinnung von Naturfasern durch Prallbeanspruchung. *Chem. Technik*, *51*(6), 3.
[2] Fürll, Ch. & Hempel, H. (1999). Optimieren einer neuen Maschine zum Faseraufschluss durch Prallbeanspruchung, Freiberger Forschungsreihe A852 Ökologie.
[3] Krakowska, I. (2002). Report of fibre testing No. LW/04/02, Research Laboratories of the Institute of Natural Fibres, Poznan, Poland, 3.
[4] Blacha, J. & Rawluk, M. (2003). Report of fibre testing No. LW/08/03, Research Laboratories of the Institute of Natural Fibres, Poznan, Poland, 12.