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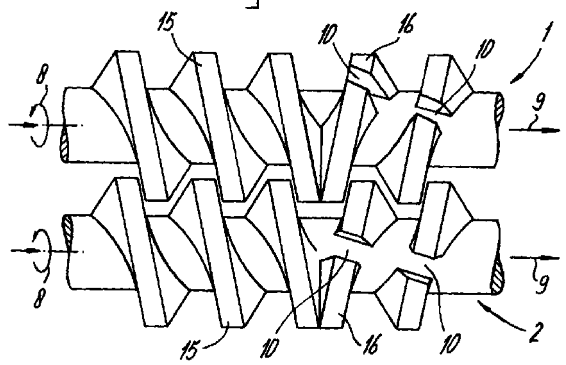
(54) Method and device for refining fibres

(57) A fibre shortener comprises at least two extrusion screws (1,2) having each:

- a rotational axis for rotation in a positive direction (8),
- at least two transport sections provided with transporting screw threads (15) of positive pitch; and
- at least one reversed screw section provided with a reversed screw thread (16) of negative pitch and being arranged between said transport sections; the extrusion screws being arranged in parallel relation for intermeshing corotation: and each reversed screw thread being provided with at least one window (10) providing a passage through the respective reversed screw thread. In the reference plane defined by the respective reversed screw thread, each window has an essentially rectangular cross section. The width of the cross section of each window is chosen in dependency of the desired fibre length of fibres to be obtained, wherein said width decreases if the desired fibre length decreases.

Fig-2



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Description

[0001] The present invention relates to a device, its use and a method for the cutting of wood and vegetable fibres.

[0002] More specifically the present invention concerns a fibre shortener comprising at least two extrusion screws having each:

- a rotational axis for rotation in a positive direction,
- at least two transport sections provided with transporting screw threads of positive pitch; and
- at least one reversed screw section provided with a reversed screw thread of negative pitch and being arranged between said transport sections; the extrusion screws being arranged in parallel relation for intermeshing corotation; and each reversed screw thread being provided with at least one window providing a passage through the respective reversed screw thread.

[0003] The terms positive and negative as used here with respect to the rotational direction and pitch directions are intended to indicate opposed directions with respect to each other, positive can thus mean clockwise while negative means anti-clockwise. However positive can just as well mean anti-clockwise while negative means clock-wise.

[0004] In the manufacture of mechanical pulps from wood and vegetable fibres extruders of the type having two corotating extrusion screws, so-called twin screw extruders, have been introduced as a process in which several process and impregnation steps can be integrated in one continuous process. A process for the production of chemimechanical pulp including a twin screw extruder is described in US 4,983,256, US 4,088,528, EP 0336842 and in the French patents 2 319 737, 2 436 844, 2 426 769 and 2 618 811. The extruders in those processes have been developed in order to achieve defibrated and fibrillated fibres, using simultaneous impregnation, pulping and washing. The effective parts of twin screw extruders are the so-called reversed screw sections having threads, whose direction of winding is the reverse of the threads undertaking the transfer of the material. These reversed threads reduces the material velocity in this zone and a compression effect upstream. The reversed threads are provided with windows, through which the fibres can eventualy pass forward, resulting in a controlled downstream passage, at least it is believed to be controlled, of the flow of material. The fibres are said to be homogenised, which improves the impregnation of the fibres and a first phase of breaking is attributed to this zone.

[0005] Important disadvantages of known twin screw extruders are that the shortening of the fibres during the process is uncontrolled and that the fibres leaving the extruder show a relatively large fibre length distribution.

[0006] The object of the present invention is to provide a fibre shortener allowing the production of fibres with a relatively snail fibre length distribution.

[0007] According to the invention, this object can be achieved in a surprisingly easy manner by providing a fibre shortener comprising at least two extrusion screws having each:

- a rotational axis for rotation in a positive direction,
- at least two transport sections provided with transporting screw threads of positive pitch; and
- at least one reversed screw section provided with a reversed screw thread of negative pitch and being arranged between said transport sections; the extrusion screws being arranged in parallel relation for intermeshing corotation; and each reversed screw thread being provided with at least one window through the respective reversed screw thread, characterized in that, considered in the reference plane defined by the respective reversed screw thread, each window has an essentially rectangular cross section.

[0008] It is assumed that it is the, considered in the direction of evolution of the thread, essentially constant width of the window, which results from its rectangular cross section, contributes to the shortening into fibres having a relatively small fibre length distribution.

[0009] According to a preferred embodiment of the invention, the rectangular cross section of each window has a length extending essentially in radial direction of the respective extrusion screw and has a width extending in a direction essentially transverse to its length. It has been found that such an orientation of the windows on the one hand contributes in minimizing the fibre length distribution, and on the other hand simplifies the manufacturing of the window by for example a milling operation.

[0010] According to the invention, it further appeared to be possible to influence the fibre length of fibres leaving the extrusion screws by adjusting the width of the cross-section of the window. Therefore, according to a further preferred embodiment of the invention, the width of the cross section of each window is chosen in dependency of the desired fibre length of fibres to be obtained, wherein said width decreases if the desired fibre length decreases. It is however to be noted that the width of said cross-section is not the only parameter influencing the obtained fibre length. Also the type of fibres to be shortened will play a role. Taking into account different types of fibres and different desired fibre lengths, the width of said cross-section will in practice generally lie between about 1 and 25 mm, preferably between about 3 and 20 mm.

[0011] A reduction of the energy consumed by the rotating extrusion screws is obtained if the passages of the windows (or some of the windows) extend through the respective reversed screw thread along an essentially helical line having positive pitch. This reduction of energy consumed appeared to be possible without significantly changing the obtained fibre length, when considered in the plane defined by the respective reversed screw thread, the width of the window is kept essentially constant.

[0012] In practice the pitch of the helical line of alignment of the windows will be at least 10 mm, preferably at least 25 mm, and/or smaller than 800 mm, preferably smaller than 350 mm.

[0013] According to a further preferred embodiment, the reduction of energy consumed becomes remarkable, the absolute value of the pitch of said essentially helical line being larger than the absolute value of the pitch of the reversed screw thread, preferably at least twice as large.

[0014] According to the invention, a reduction of the energy consumed by the rotating extrusion screws can also be obtained or can be further improved when two or more of said windows are helically aligned with respect to each other, preferably on the same helically line along which, according to an above mentioned preferred embodiment, the passage of the windows extend. This has been worded in claim 9.

[0015] According to further embodiments of the invention, the reversed screw section can be provided with a plurality of windows, as further worded in claim 10, and/or each extrusion screw can have three transport sections and two reversal screw sections (claim 11).

[0016] According to a further aspect, the invention concerns the use of a fibre shortener according to claims 12 and 13.

[0017] According to still a further aspect, the invention concerns a method for shortening vegetable fibres or wood fibres into fibres of a desired fibre length, using a fibre shortener, wherein the width of the cross section of the window is chosen in dependence from the desired fibre length.

[0018] An important advantage of the invention, is that it is made possible to obtain from longer fibres shorter fibres having a predetermined or controlled length. A further important advantage is that the energy consumed can be reduced while maintaining the length of the obtained fibres essentially unchanged.

[0019] The invention provides the possibility to shorten fibres of a relatively long fibre type to the length belonging to another type of fibres having a relatively shorter fibre length. If the characteristics of the shorter fibre type and longer fibre type are further comparable, this means that fibres of a relatively longer fibre type, for example coniferous or softwood, can after shortening be used as a substitute for fibres of a relatively shorter fibre type such as for example deciduous or hardwood, in the manufacturing of further products, such as paper.

[0020] The invention will be explained in more detail in the form of a non limiting exemplary embodiment, with reference to the following figures, in which:

Figure 1 shows schematically, partially in cross-section, a sideview of a fibre shortener according to the invention.

Figure 2 shows in elevational view a detail of the extrusion screws of the fibre shortener according to figure 1.

Figure 3 shows a schematically end view, partially in cross section, of the fibre shortener according to figure 1 and 2.

Figure 4 shows schematically the arrangement of the windows in the reversed screw section.

Figures 5a and 5b show schematically the axial transport distance in case of a helical window respectively axial window.

Figure 6 shows the weight average fibre length versus the window width, as numerically depicted in table 1.

Figure 7 shows the specific power consumption versus the window width, as numerically depicted in table 1.

Figure 8 shows the weight average fibre length versus window width P in case of kraft of wood pulp, a weight average initial fibre length of 2,7 mm, and T = 100 °C.

Figure 9 shows the specific power consumption versus window width P in case of kraft of wood pulp, a weight average initial fibre length of 2,7 mm, and T = 100 °C.

Figure 10 shows schematically the test set up of example 3.

Figure 11 shows, referring to example 4, the tear strength versus power input for flat extrusion pulps.

Figure 12 shows, referring to example 5, the results of hemp extrusion trials using reversed screw elements with different slot width.

Figure 13 shows, referring to example 6, a cumulative frequency curve (by weight).

[0021] Figures 1, 2 and 3 show in sideview, topview and endview, respectively, and on schematic manner an embodiment of a fibre shortener according to the present invention.

[0022] This fibre extruder consists of two extrusion screws 1 and 2, each provided with five intermeshing screw sections. Those screw sections are the transport sections 3, 5 and 7 and the reversed screw sections 4 and 6.

[0023] In operation, the extrusion screws rotate in the same rotational direction, called the positive direction, indicated with arrows 8. The screw threads 13, 15 and 17 of the transport sections 3, 5 and 7, respectively, evolve in the same rotational direction and thus are said to have a positive pitch. The screw threads 14 and 16 of the reversed screw sections 4 and 6, respectively, evolve in the opposed rotational direction and thus are said to have a negative pitch.

[0024] The reversed screw sections 4 and 6 are relatively short. The screw threads 4 and 6 evolve over about 2,5 revolutions. The direction in which the reversed screw sections 4 and 6 act is in the opposed direction of that of the transport sections. As a result of this, the reversed screw sections cause a compression of the material present in the space between the transport screw thread and the reversed screw thread. In order to ensure a throughgoing transport of the extrusion screws in the main transport direction 9 of the transport sections, windows 10, at least one per thread revolution, are provided in the screw threads 14 and 16 of the reversed screw section.

[0025] As described thus far (in the foregoing four paragraphs), the fibre shortener in essence corresponds to commonly known co-rotating, intermeshing twin screw extruders having reversed screw sections.

[0026] The present invention itself is, in a manner of speaking, directed to the configuration, shape and/or arrangement of the window(s) in the reversed screw of the reversed screw section(s).

[0027] According to the invention the window(s) 10 has (have) an essentially rectangular cross-section (see figure 3) considered in a plane transverse to the rotational axis of the respective extrusion screw. As projection of this rectangular cross-section on a reference plane defined by the reversed screw thread (from which the window is cut out), results in an essentially rectangular cross section again, it can also be said that according to the invention the window(s) 10 has (have) an essentially rectangular cross-section considered in the reference plane defined by the respective reversed screw of the reversed screw section.

[0028] When passing the window(s), fibres will undergo a cutting action shortening the fibres. It has been found that this cutting action can be controlled in the sense that the resulting shortened fibres have a surprisingly small fibre length distribution. Applicant presumes this effect can be attributed to the essentially constant window width considered in the direction of evolution of the thread. This essentially constant window width inherently follows from the rectangular cross-section of said window. In this respect the characterizing part of claim 1 can also read "that, considered in the direction of evolution of the reversed thread, the width of the window is essentially constant".

[0029] On the one hand a small fibre length distribution and on the other hand simplification of the forming and machining of the window is obtained when its length L extends essentially in radial direction of the respective extrusion screw and its width W or W' extends essentially in a direction transverse to its length.

[0030] Figure 4 shows very schematically in top view two parts of a reversed screw thread 16, each provided with a window 10. As will be clear W indicates the width of the window as considered in the direction of evolution of the reversed thread. This width W is also the width of the cross-section of the window as considered in the reference plane 20 defined by the reversed screw thread.

[0031] In figure 4, the axial direction of the extrusion screw itself is indicated with arrow 9, also indicating the transport direction. From figure 4 it will be clear that the passage of window 10 does not extend in axial direction, but under an angle to the axial direction 9. This means that the width P of the passage of the window 10 is smaller than the width W. The passage defined by the window 10 extends in a direction opposite to the pitch direction of the reversed screw thread 16. It could be said that the passage extends along an helical line 21 having a pitch direction opposite to the pitch direction of the reversed screw thread, if slight inaccuracies, for example resulting from forming the window itself along a straight line instead of a helically curved line, are disregarded.

[0032] Figure 4 also shows that two subsequent windows 10 can advantageously be aligned to each other preferably helically aligned on a helical line 21, which is preferably the same helical line along which the passage of the window extends.

[0033] Referring again to figures 1-3, it is noted that the extrusion screws 1 and 2 are essentially identical, at least with respect to the transporting screw threads 3, 5 and 7 and the reversed screw threads 4 and 6. As indicated in figure 3, the positions of the windows is however not per se identical, read symmetrical. The positions of the window can however be identical or symmetrical if desired. In that case, for example, window 10 of the right extrusion screw 1 is to be shifted from the 2 o'clock position to the 12 o'clock position.

[0034] It has now been found that the twin-screw extruder is especially useful in chemimechanical processing of wood and annual fibres including flax, oilseed flax, hemp, cotton, switch grass, straw and other fibrous crops. The main feature of the mechanical treatment of this process is the ability to process relatively long cellulosic fibres and fibre bundles (of up to 150 cm) to a pulp with a controlled fibre length and narrow fibre length distribution. The invention implies use of reversed screw elements in which windows are made which extend preferably helically. By adjusting the width and direction of the windows vegetable fibres as well as wood fibres can be shortened to controlled lengths. When windows are machined helically with positive pitch, material pressed through the windows is transported less far in z-direction, Δz_1 (figure 5a), in comparison with windows which are machined axially, Δz_2 (figure 5b). Fibres pressed through the windows enter the second canal of the reversed element and are transported in negative z-direction because of the reversed pitch of this element at will be compressed again in the space between the transport screws and reversed screw elements. If helical windows are used, material is easier transported backwards and is therefore processed longer to get a more even fibre length distribution. Use of reversed elements with helical windows appeared to require less energy in processing than when reversed elements with axial windows of the same width W are used.

Extrusion process:

[0035] Wood at vegetable fibres are possible raw materials for extrusion pulping. The fibres can be fed dry or pretreated, depending on the extent of defibration or chemical modification required for the application.

[0036] The raw material is prepared in such way that manual or automatic feeding to the cutting twin screw extruder is possible. The fibres can be pretreated with chemicals, and impregnation liquids can be fed to the extruder depending on the end use of the fibrous product. The screw configuration is set before each experiment. The extruder can be set to a specific desired temperature, depending on the end use of the fibrous product

The raw material needs to be fed in regular portions to allow a stable process. The system requires to stabilise for a few minutes until the motor power consumption remains constant, so a constant flag of fibres reaches the reversed screw element.

Possible excess of liquid, squeezed out by the generated pressure in the reversed screw element, can be allowed to drain from the machine through a filter located in the top of the barrel.

[0037] Screw speed and throughput do not significantly influence the fibre length of the product, but might influence degree of defibration and fibrillation. The heat rate produced by internal friction of the fibres will be higher with a higher throughput, and throughput thus has to be adjusted to the temperature control to be able to keep the material at constant temperature. Moreover the load (amperage) of the extruder is restricted to a maximum. Hence, both throughput and screw speed have to be adjusted to avoid a load or temperature overflow. Temperature does not influence fibre length distribution but influences the specific energy consumption. A higher temperature results in a lower specific energy consumption.

[0038] In the process of the present invention not only a controlled defibration, fibrillation and chemical treatment can be achieved, but also a controlled fibre length distribution and reduced power consumption, the latter two being controlled by the screw configuration. This results in an economic process yielding defibrated fibres with lengths appropriate for several applications, like short fibres for composites or long fibres of vegetable origin, which are particularly suitable for the production of specialty products (e.g. tea bags, reinforcement pulp and non-woven materials).

[0039] With respect to the examples following next, the following is noted. In those examples the used width is the width P of the window passage. The width W (figure 4) as projection on the reference plane of the reversed screw thread can be calculated using the following formulas:

for an axially extending window

$$W=\frac{\sqrt{\pi^2 D^2+U^2}\ P}{\pi D}$$

for an helically extending window with positive pitch

$$W=\frac{d \sin \beta}{\sin (\pi-\beta-\alpha)}$$

for an helically extending window with negative pitch

$$W=\frac{d \sin (\pi-\beta)}{\sin (\beta-\alpha)}$$

in which:

$$\alpha = \arctan \left(\frac{U}{\pi D}\right)$$

$$d = \frac{\sqrt{q^2 + \pi^2 D^2}}{q}\ P$$

$$\beta = \arctan\left(\frac{q}{\pi D}\right)$$

U = pitch of reversed screw thread
q = pitch of the helical line along which the passage of the window extends
p = width of the window passage
D = outer diameter of the extrusion screw

[0040] Further with respect to the examples, it is noted that there is a relation between the tear strength and the fibre length:

The tear strength is proportional to (fibre length)^a [Clark, 1962 #458; Seth, 1988 #463; Page, 1994 #313]. The dependence of tear strength on fibre length changes with the degree of sheet consolidation. In a poorly-bonded sheet a is larger than 1, in a well-bonded sheet a is smaller than 1 [Seth, 1988 #463]. A higher degree of beating results in a higher paper bonding.

Example 1

[0041] Northern bleached softwood kraft pulp (NBSK-pulp) sheets were sliced into strips of 4 cm wide and 30 cm long to allow manual feeding to the cutting extruder Clextral BC45. The strips were soaked in tap water to a dry matter content of 40 ww%.
[0042] In order to study the effect of window direction and window width, the screw configuration at each experiment consisted of transport screws and one reversed screw element, which was changed after each experiment. The following reversed screw elements were used:

1) pitch: 25 mm, axial windows, window width: 6 mm
2) pitch: 25 mm, axial windows, window width: 10 mm
2) pitch: 25 mm, helical windows, width of window passage: 6 mm, positive window pitch: 69 mm
4) pitch: 25 mm, helical windows, width of window passage: 10 mm, pos window pitch: 69 mm
5) pitch: 25 mm, reversed helical windows (i.e. windows having a negative pitch) window width 12 mm, negative window pitch: 145 mm

[0043] The extruder screw speed was set to 150 rpm. The extruder was preheated to 100 °C by means of heating elements on the extruder using magnetic induction. During the cutting process the temperature control system was set on 100 °C. By preparing stacks of strips with known weight and feeding them one by one at regular time intervals, a constant feed rate of 40 % dry matter pulp to the extruder was obtained.
[0044] The system was allowed to stabilise for a few minutes until the motor power consumption, evaluated by on-line data-acquisition, remained constant, so a constant flow of pulp would reach the RSE-element.
[0045] The extrusion cut pulps and two controls (untreated NBSK-pulp) were submitted to the following laboratory evaluation. The samples were soaked in water at room temperature for 4 hours before standard disintegration in a Messmer laboratory disintegrator at 75,000 revolutions at room temperature. The fibre length distribution of the disintegrated samples were tested on Kajaani FS-200 fibre length distribution. The results of the first four experiments are shown in table 1. The reversed elements with the reversed helical windows did hardly allow the fibres to pass through, resulting in a very high power consumption. A weight average fibre length of 0.65 mm was obtained.

Window geometry	Axial		Helical (pitch = 69 mm)				
Pitch of reversed screw thread, U (mm)	25	25	25	25	25	15	15
Window width, P (mm)	6	10	8.3	10.2	12	6	12
Window width, W (mm)	6.1	10.1	10.7	13.1	15.4	8.6	17.1
Weight average fibre length (mm)	0.8	1.35	1.54	1.97	2.06	1.1	2.09
Power consumption (kWh/ton)	>2000	694	396	190	146	972	154

Table 1: influence of window geometry of reversed elements on weight average fibre length (initial fibre length 2.56 mm)

[0046] Figures 6 and 7, which are based on table 1, show in graphical form that the window width W determines the fibre length, respectively, that axially extending windows have a higher power consumption.

Example 2

[0047] Northern bleached softwood kraft pulp sheets were sliced into strips of 4 cm wide and 30 cm long to allow manual feeding to the cutting extruder Clextral BC45. The strips were soaked in drinking water to a dry matter content of 40 ww%.
In order to study the effect of window width, the screw configuration at each experiment consisted of transport screws and one reversed screw element with a pitch of 25 mm, containing helical windows with positive pitch of 69 mm. The width of the window passage was changed after each experiment:

1) window width: 4 mm
2) window width: 6 mm
3) window width: 8 mm
4) window width: 10 mm
5) window width: 12 mm

[0048] The extruder screw speed was set to 150 rpm. The extruder was preheated to 100 °C by means of heating elements on the extruder using magnetic induction. During the cutting process the temperature control system was set on 100 °C. By preparing stacks of strips with known weight and feeding them one by one at regular time intervals, a constant feed rate of 40 % dry matter pulp to the extruder was obtained.
[0049] The system was allowed to stabilise for a few minutes until the motor power consumption, evaluated by on-line data-acquisition, remained constant, so a constant flow of pulp would reach the RSE-element. The average pulp

throughput is measured by weighing the product after a known processing time. The dry matter content of the pulp is determined at 105 °C for 16 hours. The specific power consumption is calculated from the dry matter throughput and the motor power, adjusted for the motor power with transport screws only.

[0050] The extrusion cut pulps were submitted to the following laboratory evaluation. The samples were soaked in water at room temperature for 4 hours before standard disintegration in a Messmer laboratory disintegrator at 75,000 revolutions at room temperature. The disintegrated samples were tested on Kajaani FS-200 fibre length distribution. The results of the experiments are shown in figure 8 and 9. The initial weight average fibre length was 2.57 mm.

[0051] Smaller windows in the reversed screw threads result in a smaller average fibre length and an exponentially increased specific power consumption.

Example 3:

[0052] Flax was extracted from a 1994 batch of dew-retted flax lints. Hemp fibre was extracted from a batch of untreated, dried stalks of variety Futura 96 of harvest 1996. The bast fibres are guillotine cut to a length of 9.5 mm. The fibres were impregnated with a sodium hydroxide solution. The impregnation is carried out overnight (16 hours) at room temperature. After the impregnation the liquid was allowed to drain through a perforated screen for 30 minutes. After draining the impregnated fibres were preheated with saturated steam at atmospheric pressure.

[0053] The pulps are extruded in one or two passes. The impregnated, preheated fibres were introduced into a modified Clextral BC45 extruder manually. Different screw configurations were used to obtain different cutting degrees under different power consumption (table 2 and 3). The system was allowed to stabilise for a few minutes until the motor power consumption, evaluated by on-line data-acquisition, remained constant, so a constant flow of pulp would reach the reversed elements. The pulp mass output was recorded every 30 seconds together with the motor power, thus giving an almost continuously reading of the specific energy consumption of the pulp. For all trials we virtually divided the extruder in three successive sections. Referring to figure 10, the first section consists of the inlet of the extruder, transport screws (TZ) and a reversed screw element (RSE) to defibrate and cut the fibres. Upstream of the reversed screw element (RSE1) an outlet for excess water is placed. The second section consists of a steam inlet, transport screws (TZ2), a reversed element (RSE2) and a filter. The filter is placed downstream from the reversed screw element (RSE2) to remove excess water. The third section consists of transport screws (TZ3) and a reversed element (RSE3). At the end of the third section self-wiping (SW) screws transport the pulp to the outlet of the extruder. The used reversed elements are given in table 2.

[0054] The codes used for the reversed elements are the pitch (mm) of the element in mm, the orientation of the windows (H = helical) and the width of the passage of the window (mm).

[0055] The extruder screw speed was set to 150 rpm. The extruder was preheated to 100 °C by means of heating elements on the extruder using magnetic induction. During the cutting process the temperature control system was set on 100 °C.

[0056] The extruded fibres were submitted to the following laboratory evaluation. The pulps were desintegrated in a valley beater during 30 minutes. The disintegrated samples were tested for beating degree using ISO standard 5267. Handsheets were formed using a 'l homargy sheetformer and pressed twice at 4 bar for 5 minutes. The sheets were conditioned and tested at 23 °C, 50% RH. The tear strength is determined according to ISO 1974: 1974(z).

[0057] The results of the experiments are shown in table 2 and 3.

[0058] Extrusion with reversed elements with smaller windows appears to result in a pulp with higher beating degree and paper with lower tear strength. Lower tear strength at a higher beating degree implies a lower average fibre length.

Trial	Material	Pass 1	Pass 2	tear strength $mN.m^2/g$	Beating degree (°SR)
1	Hemp	-25H10 -15H8 -15H12	-25H10 -15H8 -15H12	16.1	50
2	Hemp	-25H10 -15H8 -15H12	-25H10 **-15H6** **-15H8**	11.9	61

Table 2: influence of screw configuration during hemp extrusion on paper tear strength and beating degree

Trial	Material	Pass 1	Pass 2	tear strength $mN.m^2/g$	Beating degree (°SR)
3	Flax	-25H10 -15H8 -15H12	-25H10 -15H8 -15H12	18.6	28
4	Flax	-25H10 -15H8 -15H12	-25H10 **-15H6** **-15H8**	8.4	42

Table 3: influence of screw configuration during flax extrusion on paper tear strength and beating degree.

Example 4:

[0059] Flax was taken from a 1994 batch of dew-retted flax lints. For the extrusion trials the lints were used at their full length. Prior to extrusion pulping the bast fibres were impregnated by immersion for 2 hours in a sodium hydroxide solution. After impregnation the liquid was allowed to drain through a perforated screen for 30 minutes. After draining the impregnated fibres were preheated with saturated steam at atmospheric pressure.

[0060] The impregnated, preheated fibres were introduced into a modified Clextral BC45 pulping extruder manually. Each sample was passed through one single run, with one reversed element fitted in the screw configuration. Different window widths were used to obtain different cutting degrees. The used reversed elements are given in table 4. The codes used for the reversed elements are the pitch (mm) of the element in mm, the orientation of the windows (H =

helical) and the width of the passage of the window (mm). All reversed elements have three windows evenly distributed in each screw flight revolution, except for the -25H8/1, which has only one window per revolution. The pitch of each window passage was 69 mm.

[0061] The system was allowed to stabilise for a few minutes until the motor power consumption, evaluated by on-line data-acquisition, remained constant, so a constant flow of pulp would reach the reversed elements. The pulp mass output was continuously recorded together with the motor power, thus giving a continuous reading of the specific energy consumption of the pulp. The average pulp throughput is measured by weighing the product after a known processing time.

[0062] 60 Grams of the samples were disintegrated for 75.000 revolutions in a Messmer standard laboratory desintegrator at 70°C. The disintegrated samples were tested for beating degree using ISO standard 5267. Handsheets were produced on a 'I Homargy sheetformer, and pressed twice before conditioning at 23 °C, 50% RH. The tear strength is determined according to ISO 1974: 1974(z). The results are shown in table 4 and figure 11.

[0063] The power consumption and degree of beating show a clear increase with decreasing window width. The tear strength shows a high level due to the high fibre length of the pulps, but decreases with the tightening of the window width of the reversed elements and increased power input. A smaller window of the reversed element results in a higher power consumption and a lower average fibre length.

Trial	Material	reversed element	Power consumption (kWh/ton)	beating degree (°SR)	Tear strength (mN.m^2/g)
1	Flax lints	-25H12	139	11	42.2
2	Flax lints	-25H10	252	14	43.4
3	Flax lints	-25H8/1	912	15	17.5
4	Flax lints	-25H8	332	16	49.1
5	Flax lints	-25H6	1260	32	16.5

Table 4: Results of flax fibre extrusion.

Example 5

[0064] Hemp bast fibres are cut to 6 mm. Prior to extrusion pulping the bast fibres were impregnated by immersion for 16 hours in a sodium hydroxide solution. After impregnation the liquid was allowed to drain through a perforated screen for 30 minutes. After draining the impregnated chips were preheated with saturated steam at atmospheric pressure.

[0065] The fibres are introduced into a modified Clextral BC45 pulping extruder by a hydraulic feeder. Each sample was passed through one single run, with two reversed elements fitted in the screw configuration. Different window widths were used to obtain different cutting degrees. The system was allowed to stabilise for a few minutes until the motor power consumption, evaluated by on-line data-acquisition, remained constant, so a constant flow of pulp would

reach the reversed elements.
The extruder screw speed was set to 200 rpm.

[0066] 60 Grams of the samples were disintegrated for 75.000 revolutions in a Messmer standard laboratory desintegrator at 70°C. The disintegrated samples were tested for beating degree using ISO standard 5267. Handsheets were produced on a 'l Homargy sheetformer, and pressed twice before conditioning at 23 °C, 50% RH. The tear strength is determined according to ISO 1974: 1974(z). Figure 12 shows the relation between tear strength, beating degree and window width of the used reversed elements.

[0067] A decreasing width of the passage of the window appears to result in increasing beating degree and decreasing tear strength.

[0068] The tear strength depends on the average fibre length and on the degree of fibrillation. A smaller window width results in a higher compression of the fibre mat, which results in a higher degree of fibrillation. The tear strength however decreases with decreasing width of the window passage, suggesting a smaller average fibre length.

Example 6

[0069] Flax was taken from a 1994 batch of dew-retted flax lints. For the extrusion trials the lints were used at their full length.

[0070] Prior to extrusion pulping the best fibres were impregnated by immersion for one night in a sodium hydroxide solution. After impregnation the fibres were washed with water (50 °C) until the pH was decreased to 9.4.

[0071] The impregnated fibres were manually introduced into a modified Clextral BC45 pulping extruder. Each sample was passed through one single run, with one reversed element fitted in the screw configuration. Different window widths were used to obtain different cutting degrees. The used reversed elements are given in table 5. The codes used for the reversed elements are the pitch (mm) of the element in mm, the orientation of the windows (H = helical) and the width of the passage of the window (mm). The pitch of the windows is 69 mm.

[0072] The system was allowed to stabilise for a few minutes until the motor power consumption, evaluated by on-line data-acquisition, remained constant, so a constant flow of pulp would reach the reversed elements.

[0073] After extrusion the flax fibres were placed in 200 litres of water (40 °C) for 20 minutes. Afterwards the fibres were washed with cold water on a cascade sieve. The fibres were not subjected to any disintegration.

[0074] The fibre length distribution of the samples was analysed with computer image analysis, according to the following procedure:

[0075] A representative sample (0.1 grams of fibre) was taken into 20 ml of water. The fibres were carefully stirred and separated by hand, using tweezers. The fibres were taken out of the water, dispersed in a 2% Carboxymethyl Cellulose (CMC) solution and stirred for of maximum of 15 minutes on magnetic stirrer at 300 rpm. A series of slides is prepared by pouring a small amount of the CMC solution on each slide. The slides were dried overnight at room temperature, protected from dust. The slides were then projected on a white screen (magnification 40x, calibrated with a standard slide). The fibres were manually copied on a set of white A4 paper sheets using a dark coloured fine liner. All A4 pages were scanned at 300 DPI and Image Pro Plus was used to measure the fibre length in these scans.

[0076] The results are shown in table 5. The cumulative frequency curves (by weight) of these samples are shown in figure 13.

		142A	142B
RSE (length 50 mm)		-25H12	-25H8
Number of fibres		595	628
Arithmetic average	mm	5.26	2.88
Length weighted average	mm	8.26	4.59
Median	mm	4.33	2.42
Minimum	mm	0.15	0.04
Maximum	mm	19.91	13.31
Range	mm	19.75	13.27

Table 5: Influence of screw configuration during flax extrusion on the fibre length distribution of the product.

Claims

1. Fibre shortener comprising at least two extrusion screws having each:

   - a rotational axis for rotation in a positive direction,
   - at least two transport sections provided with transporting screw threads of positive pitch; and
   - at least one reversed screw section provided with a reversed screw thread of negative pitch and being arranged between said transport sections; the extrusion screws being arranged in parallel relation for intermeshing corotation; and each reversed screw thread being provided with at least one window providing a passage through the respective reversed screw thread, characterized in that, considered in the reference plane defined by the respective reversed screw thread, each window has an essentially rectangular cross section.

2. Fibre shortener according to claim 1, characterized in that, the rectangular cross section of each window has a length extending essentially in radial direction of the respective extrusion screw at has a width extending in a direction essentially transverse to its length.

3. Fibre shortener according to claim 2, characterized in that, the width of the cross section of each window is chosen in dependency of the desired fibre length of fibres to be obtained, wherein said width decreases if the desired fibre length decreases.

4. Fibre shortener according to claim 2 or 3, wherein the width of said cross section is between about 1 and 25 mm, preferably between about 3 and 20 mm.

5. Fibre shortener according to one or more of the preceding claims, characterized in that, the passage of each window extends through the respective reversed screw thread along an essentially helical line having positive pitch.

6. Fibre shortener according to claim 5, in which the pitch of said essentially helical line is at least 10 mm, preferably at least 25 mm.

7. Fibre shortener according to claim 5 or 6, in which the pitch of said essentially helical line is smaller than 800 mm, preferably smaller than 350 mm.

8. Fibre shortener according to one or more of the claims 5-7, in which the absolute value of the pitch of said essentially helical line is larger than the absolute value of the pitch of the reversed screw thread, preferably at least twice as large.

9. Fibre shortener according to one or more of the preceding claims, characterized in that, the reversed screw threads extend over one or more than one evolution, preferably over about 2-4 evolutions, such as 2,5 evolutions, and in which each said reversed screw thread is provided with two or more of said windows which are helically aligned with respect to each other.

10. Fibre shortener according to one or more of the preceding claims, in which the reversed screw section is provided with a plurality of windows, preferably a plurality of windows per thread revolution, said windows preferably being equally spaced.

11. Fibre shortener according to one or more of the preceding claims, in which each extrusion screw has three of said transport sections and two of said reversed screw sections.

12. Use of a fibre shortener according to one or more of the preceding claims, for cutting vegetable fibres, such as flax, oil seed flax, hemp, ramie, switch grass, reed canary grass, straw, bagasse, cotton, lienal, abaca or sisal bast fibres, into shorter fibres.

13. Use of a fibre shortener according to one or more of the claims 1-11, for cutting wood fibres, such as softwood fibres or wood chips, into shorter fibres.

14. Method for shortening vegetable fibres or wood fibres into fibres of a desired fibre length, using a fibre shortener according to one or more of the claims 1-11, wherein the width of the cross section of the windows is chosen in dependence from the desired fibre length.

fig-1

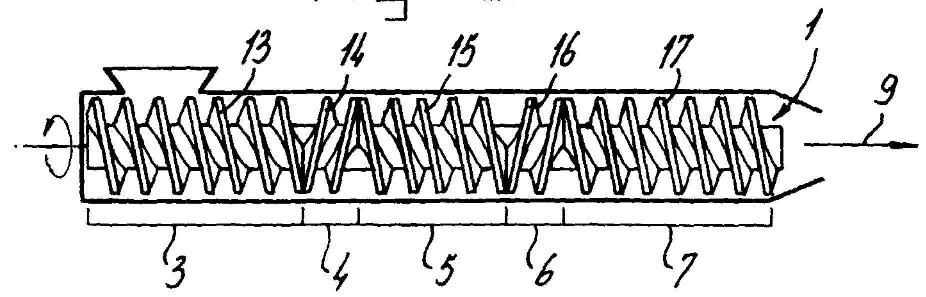


fig-2

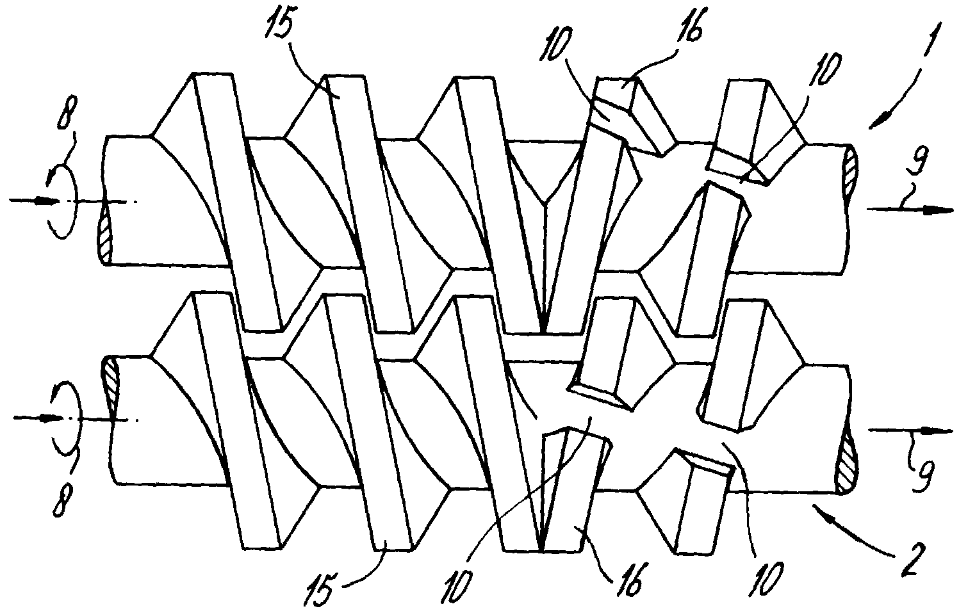


fig-3

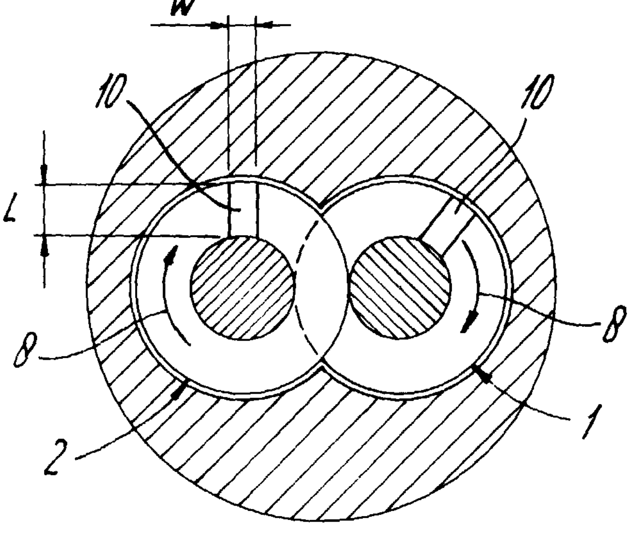


Fig-4

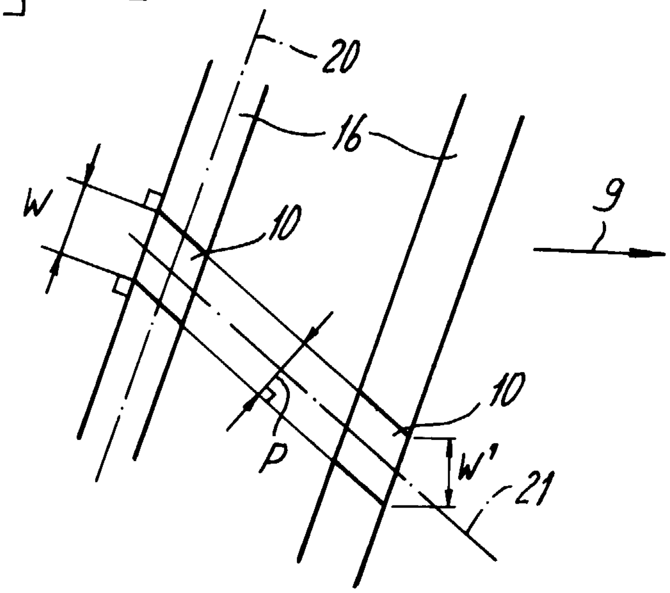


Fig-5a

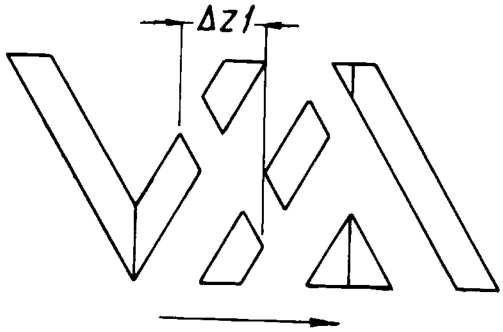
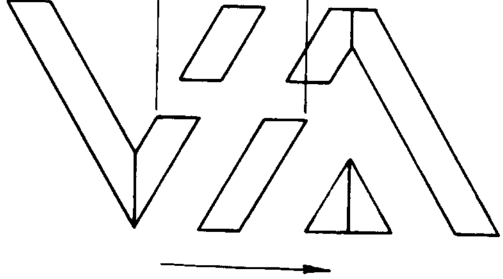


Fig-5b



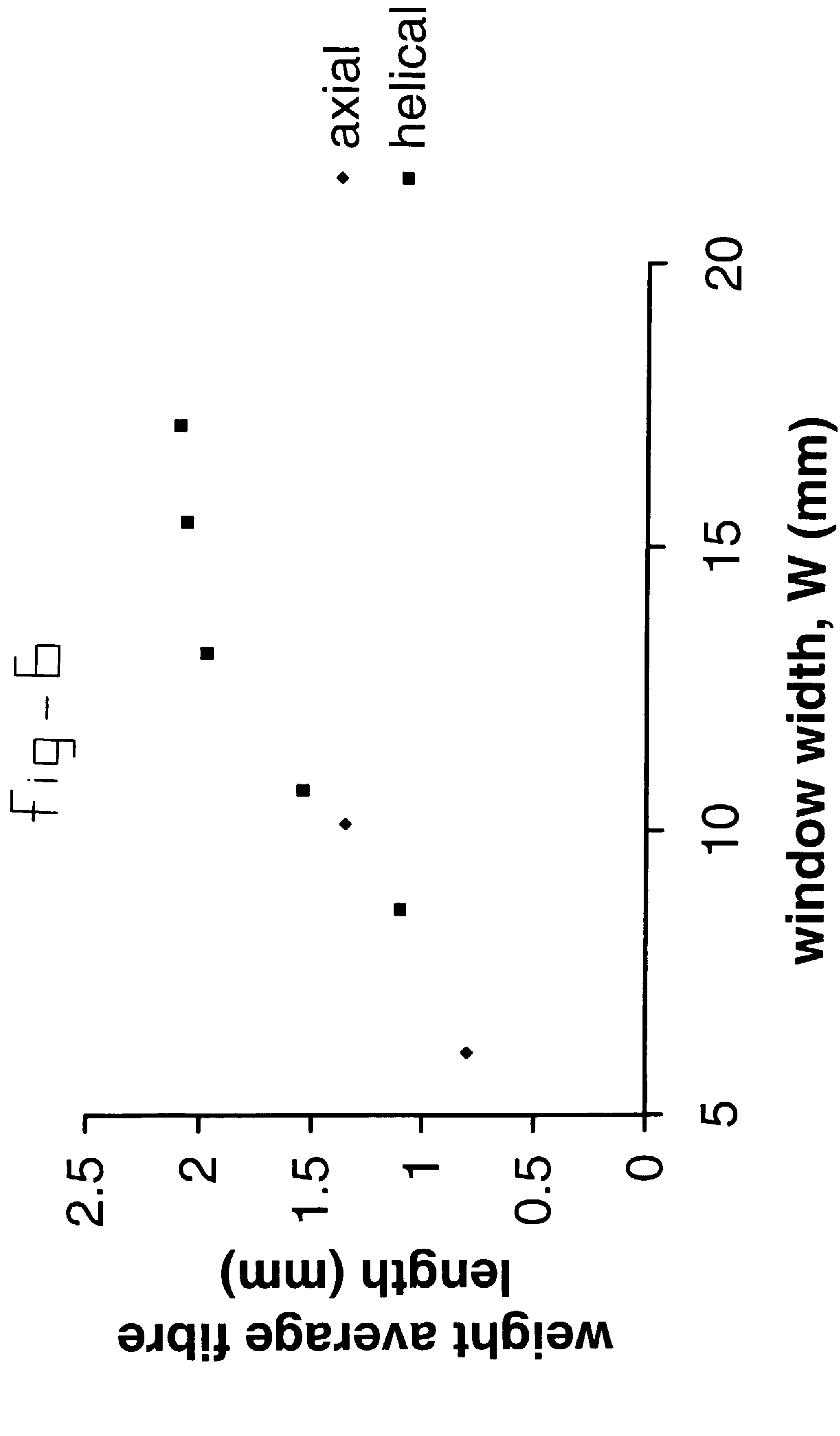
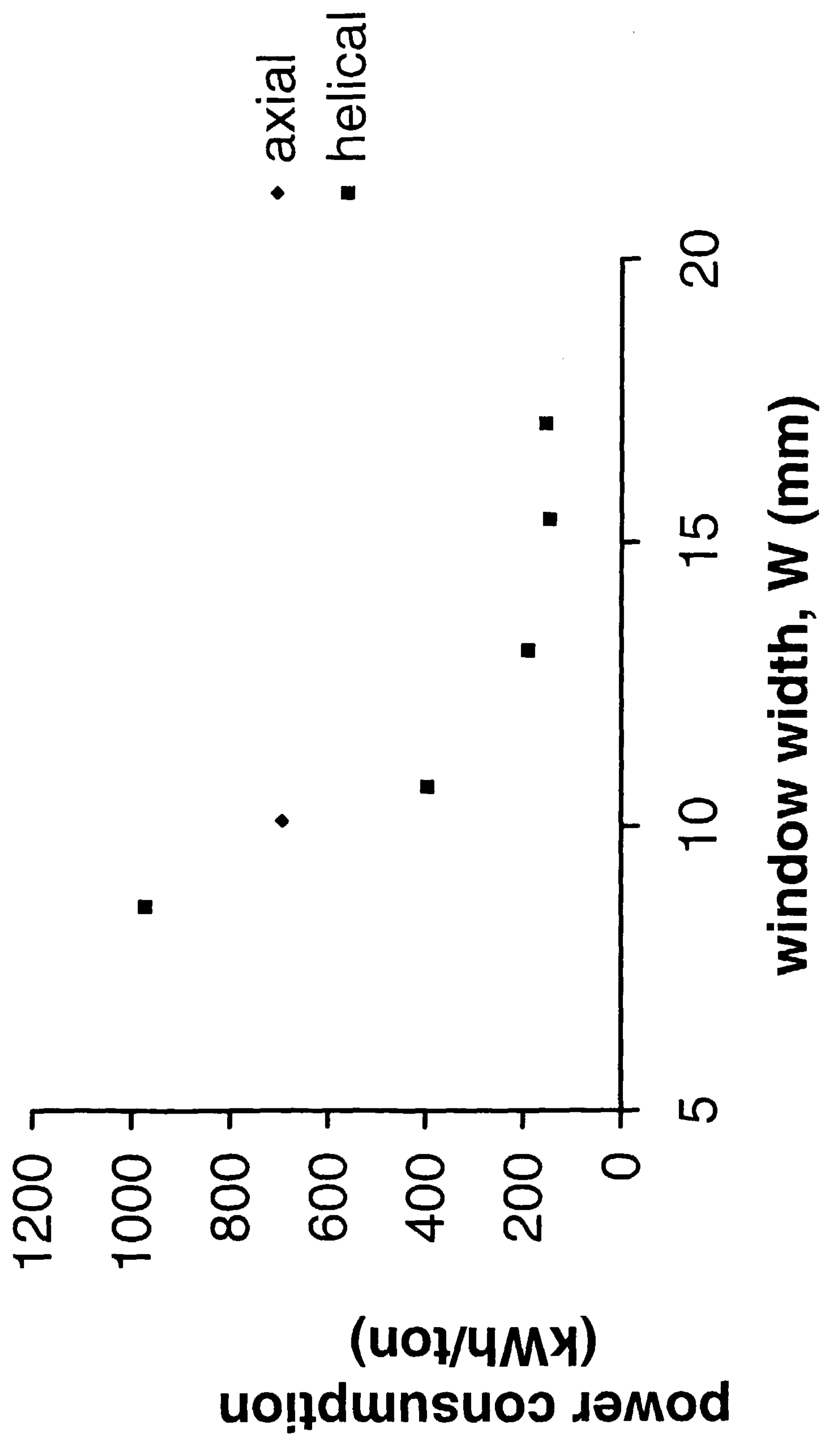

axial
helical
weight average fibre length (mm)
0
0.5
1
1.5
2
2.5
5
10
15
20
window width, W (mm)

Fig - 6

fig-7


axial
helical
power consumption (kWh/ton)
0
200
400
600
800
1000
1200
window width, W (mm)
5
10
15
20

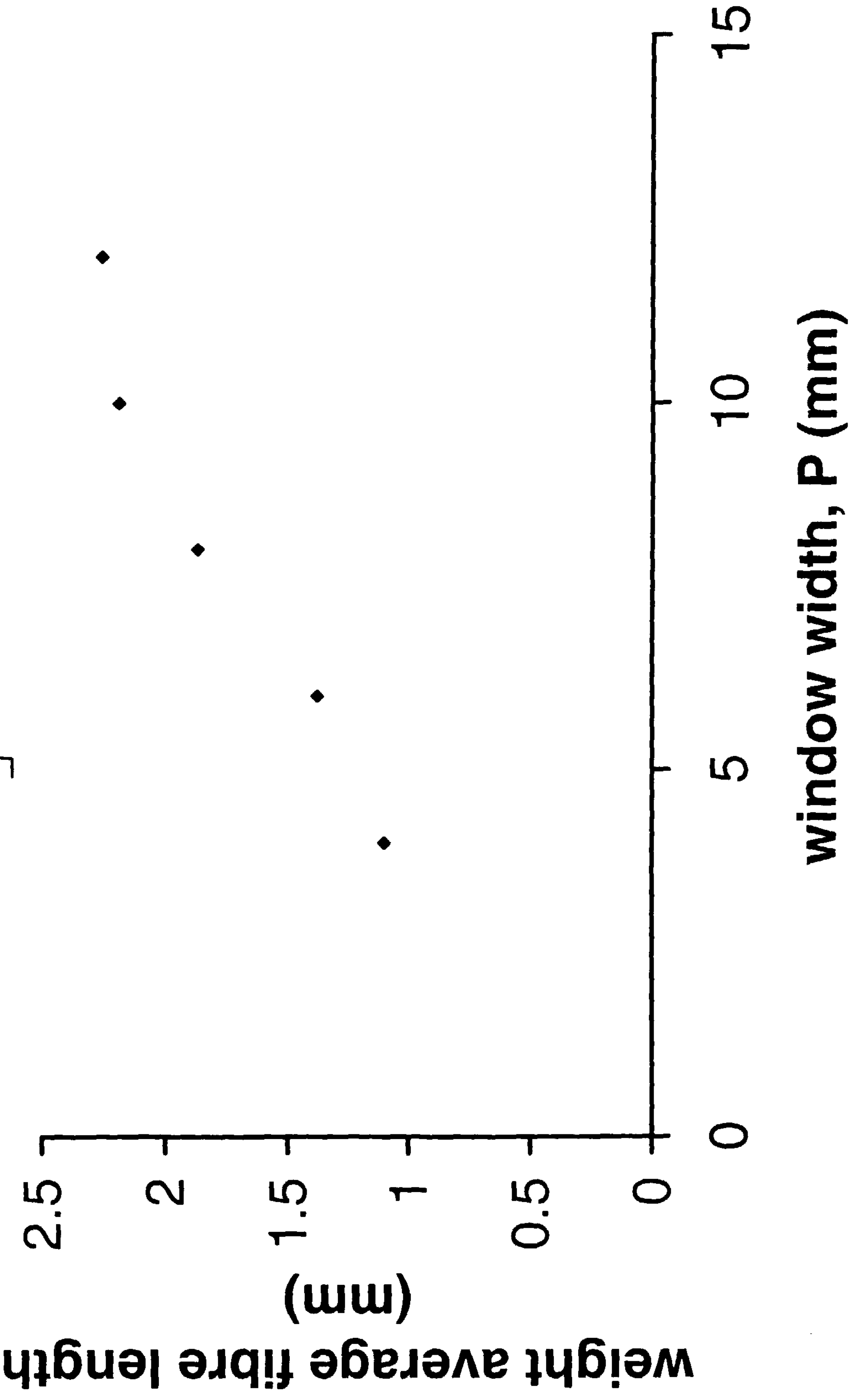

weight average fibre length (mm)
2.5
2
1.5
1
0.5
0
0
5
10
15
window width, P (mm)

fig-8

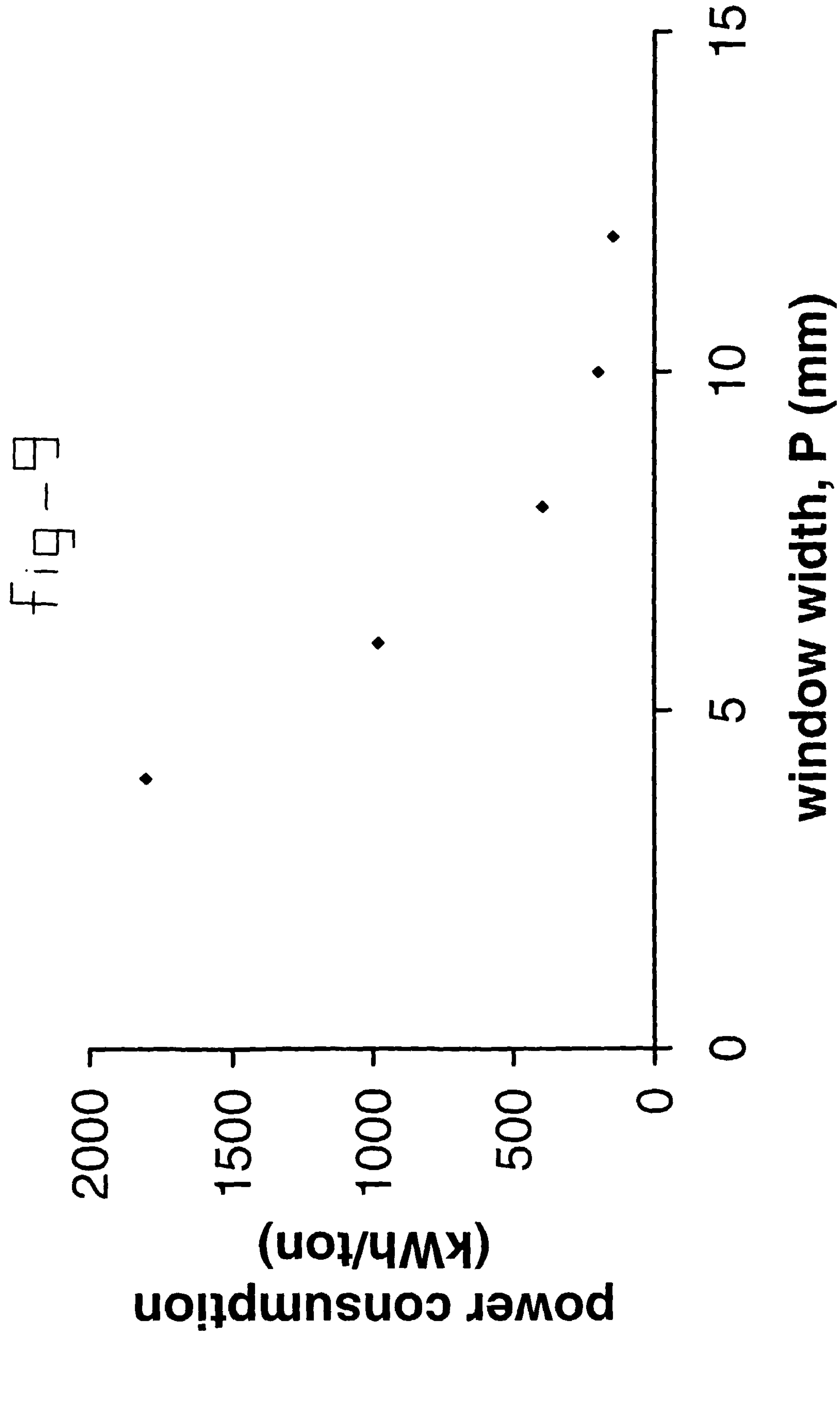


Fig-9
power consumption (kWh/ton)
0
500
1000
1500
2000
0
5
10
15
window width, P (mm)

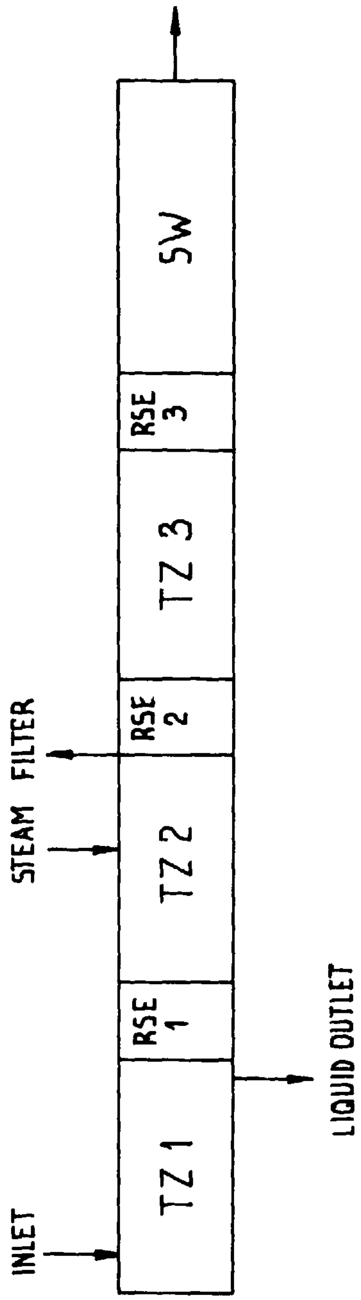
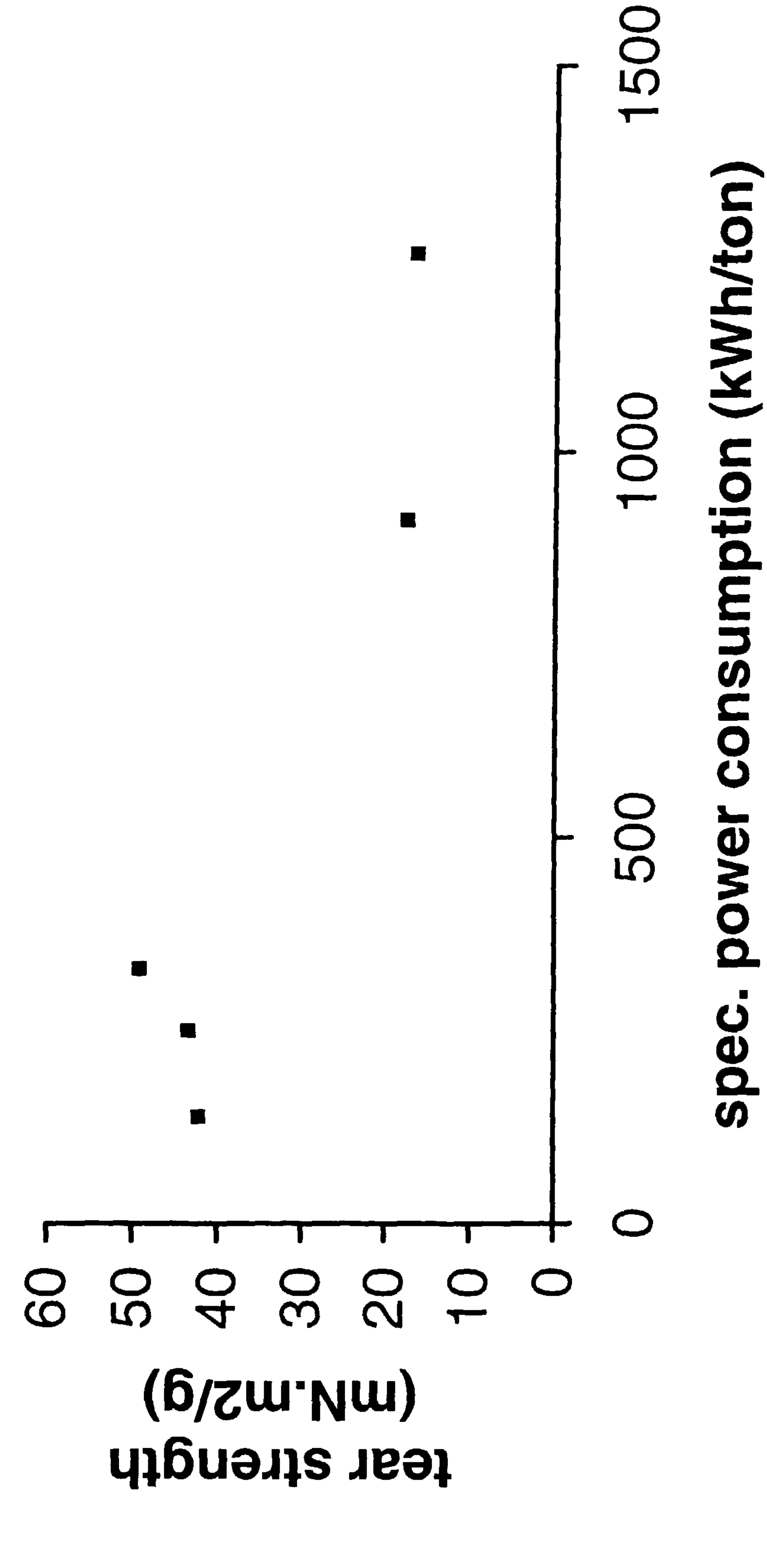

INLET
TZ 1
RSE 1
LIQUID OUTLET
STEAM
TZ 2
FILTER
RSE 2
TZ 3
RSE 3
SW

fig - 10

fig - 11


tear strength
(mN.m2/g)
60
50
40
30
20
10
0
0
500
1000
1500
spec. power consumption (kWh/ton)

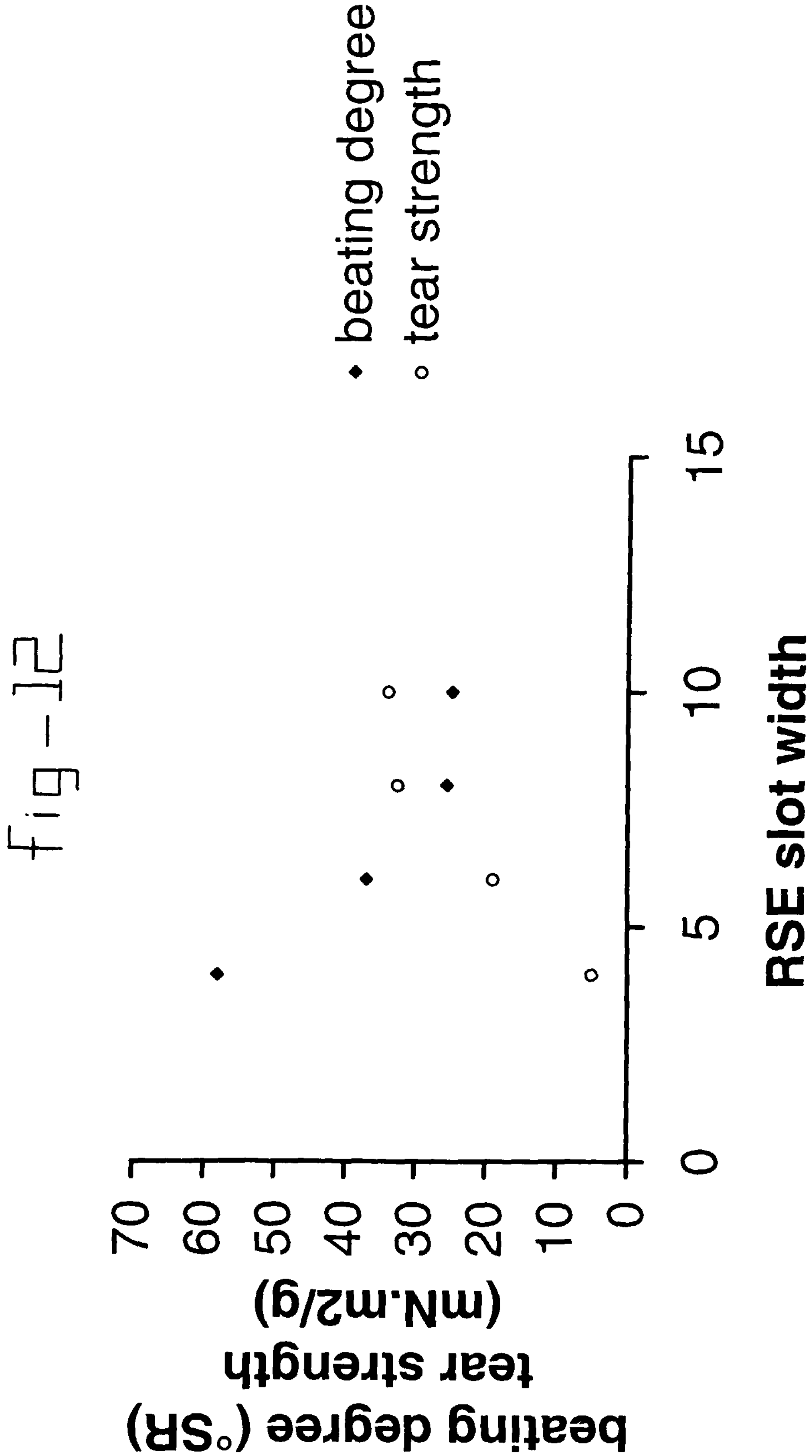
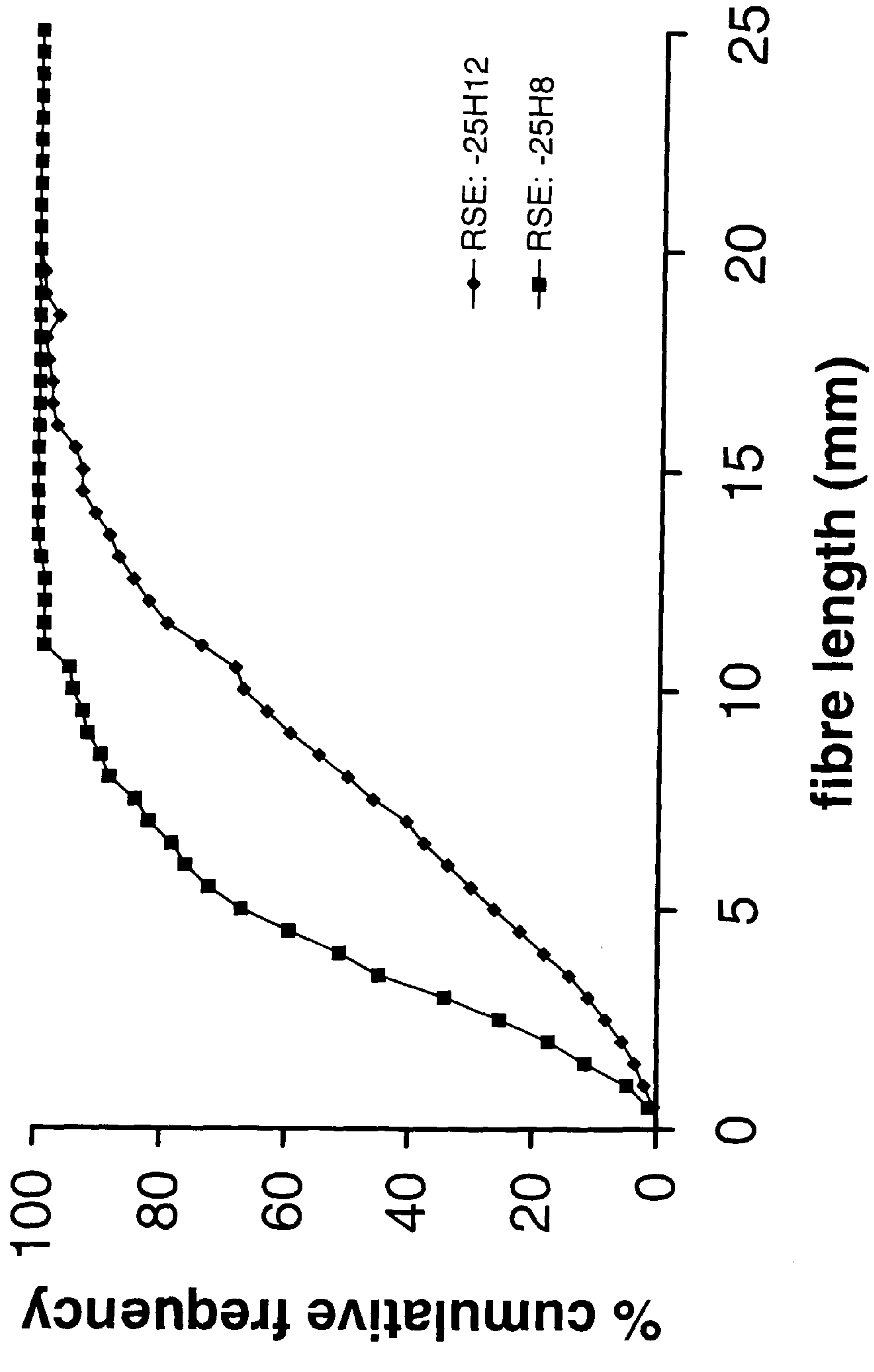


fig-12
beating degree
tear strength
beating degree (°SR)
tear strength
(mN.m2/g)
70
60
50
40
30
20
10
0
0
5
10
15
RSE slot width

fig-12

Fig-13


% cumulative frequency
100
80
60
40
20
0
0
5
10
15
20
25
fibre length (mm)
RSE: -25H12
RSE: -25H8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 20 2705

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,X	US 4 088 528 A (BERGER PIERRE ET AL) 9 May 1978 * abstract; figures * * column 3, line 24 - line 68 *	1-3,10, 12-14	D21B1/30
X	EP 0 017 544 A (CREUSOT LOIRE) 15 October 1980 * page 3, line 31 - page 5, line 30; figures *	1-3,5, 9-14	
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TECHNICAL FIELDS SEARCHED (Int.Cl.6)

D21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 January 1999	Helpiö, T.

CATEGORY OF CITED DOCUMENTS

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