(54) Title: APPARATUS AND METHOD FOR PROCESSING GREEN FIBROUS PLANT STALKS

(57) Abstract

A method and apparatus for processing a green plant stalk (90) having a fibrous outer part and an inner hectar. Stalk (90) is split longitudinally with knife-splitter (54) to expose the hectar. Split stalk portion (92) then passes through the nip of externally-fluted conditioner roller (56) and smooth-surfaced anvil roller (58) to divide the exposed hectar into segments, and the fibre is separated from the hectar with decorticator (80).
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APPARATUS AND METHOD FOR PROCESSING GREEN FIBROUS PLANT STALKS

The present invention relates to improvements in or relating to bast crops, and more particularly but not exclusively to the processing of

Cannabis sativa, better known as hemp.

BACKGROUND OF THE INVENTION

Bast crops contain an inner core sometimes called a hurd surrounded by an outer fibrous layer. One such bast crop is hemp. Hemp has a number of commercial uses due to the properties of its fibre, which include strength and resilience. The fibre which can be extracted from the outer fibrous layer of a hemp stalk has a variety of uses and may be a constituent in the production of paper, fibreboard and rope. Hemp fibre also has the capacity to replace cotton as a component of textiles. With the likelihood of gradual relaxation of strict legislative controls over cultivation and processing, hemp is likely to become increasingly attractive to farmers as a valuable cash crop.

The stalk of a hemp plant is generally of substantially circular cross-section, having a fibrous outer layer or bast and an inner core or hurd. The fibre of the plant is generally the more valuable commodity, although the hurd has some uses. It is therefore desirable to separate the fibre from the hurd to yield a value-added commodity.

The principal difficulty in processing hemp has been found to lie in separating the fibre from the hurd. This process is referred to herein as decortication.

A number of proposals have been suggested for separating the fibre from the hurd. The principal category of decortication is mechanical separation. Of the mechanical operations, traditionally scutching has been the most widely used. Scutching involves manually beating the hemp stalk until the hurd is dislodged from the fibre. This is usually followed by a manual mechanical stripping operation using a bladed scutching wheel to strip the outer fibre away from the hurd. As this method of decortication is generally a manual operation, it can be very labour-intensive and time-consuming and hence inefficient. Scutching has therefore not been found suitable for large scale commercial processing of hemp.
Other mechanical decortication methods include the use of ultrasonics, which employ sound waves to generate vibrations to break the bonds between fibre and hurd.

Processing of hemp in a similar manner to that of flax has also been proposed. This method involves retting the hemp, drying and breaking the solidified hurd until the fibre separates from the core. Again this method is time consuming and not generally suited to large-scale commercial operation. There have also been several attempts to develop a method for decortication by processing freshly cut hemp stalks which method by-passes the need for time consuming treatment prior to separating hurd from the fibre. Patent specification GB 1235387 is directed to the processing of green hemp where each plant stalk is passed through rollers, the stalk is split and beaten before the hurd is removed while the stalk is passed between two conveyors. A disadvantage of this method is that uncleaned stalks remain after the process.

Specification GB 2205865 treats plant stalks as soon as they are cut however, the hurd is removed from the stalk by crushing the stalks between cylinders. Specifications GB 693833 and U.S. 5465464 describe methods of processing which, while not requiring time consuming pretreatment of the raw material, are not directed towards the processing of green or freshly cut plant stalks particularly green hemp stalks.

None of such prior art methods is suited to broadacre production involving both the harvesting of the hemp crop and efficiently separating the bast from the hurd of the harvested stalk on a commercial scale.

Patent specification WO 97/45573, the disclosure of which is incorporated herein by reference, describes a method and apparatus for processing the green plant stalk of a bast crop. To encourage the separation of the hurd from the bast, the bonds between the fibre and the hurd are ruptured. The stalk is then subsequently split and the exposed hurd is stripped from the bast by the abrasion of a toothed roller on the hurd. Bond rupturing is effected by passing the green stalks between a complex series of counter-rotating pressing rollers, before the stalk is split and stripped of the hurd. This proposal is somewhat complex and requires significant power to drive the rollers.

The present invention provides an effective alternative to the foregoing proposals for the processing of a bast crop.
SUMMARY OF THE INVENTION

The present invention accordingly provides, in one embodiment, a method for processing a plant stalk having a fibrous outer part and an inner hurd, the method including the steps of:

- splitting the stalk substantially longitudinally whereby to expose the hurd;
- dividing the exposed hurd into segments in a segmenting step; and
- separating the fibre from the hurd.

The present invention provides, in another embodiment, an apparatus for processing a split plant stalk having a fibrous outer part and an inner hurd, said plant stalk being split substantially longitudinally whereby to expose the hurd. The apparatus includes:

- segmenting means to divide the hurd into segments, and
- a separator to separate the fibre from the hurd.

In a still further embodiment the present invention provides an apparatus for processing a plant stalk having a fibrous outer part and an inner hurd, the apparatus including a splitter for splitting the stalk substantially longitudinally whereby to expose the hurd and a decorticator according to the present invention.

The present invention provides, in yet another embodiment, fibre produced from the application of the method and/or the apparatus provided by the present invention and in yet another embodiment, hurd produced from the application of the method and/or the apparatus provided by the present invention.

A plant stalk to be processed according to processing methods and apparatus of the present invention may be a hemp stalk. A particularly preferred hemp is that of the genus Cannabis sativa L and species thereof. Other plant stalks envisaged for processing in accordance with the present invention, include Kenaf, Ramie, sugar cane and other bast crops.

A method according to the present invention may include the additional step of observing the growth pattern of the hemp plant in the field, whereupon harvesting and decortication of the crop may be commenced at a predetermined phase of growth of the plant.
It has been observed that the strength of the bond between the fibre and hurd varies at various stages of growth of the plant. In a preferred embodiment, harvesting and decortication are commenced when the plant is green, also known as freshly cut or fresh green. The fibre of the stalk preferably remains sufficiently fine for textile use, that is to say, prior to pollen formation. The hemp plant stalk may be harvested by cutting and stripped of leaves using known methods. The hemp may be harvested at 50 to 80 days maturity and preferably before lignins form. Preferably the hemp is harvested before the outer fibre thickens and most preferably before the outer fibre forms bundles. Before the adhesives between the hurd and outer fibres harden and most preferably at approximately 60 days maturity or just prior to flowering are particularly preferred indicators of a suitable time to harvest a large crop for use in accordance with the present invention. The cut end of the plant stalk is referred to herein as the butt end.

For best results processing of the stalk is preferably commenced before the adhesive between the fibrous outer layer and the inner core dries. Normally this is within two hours of harvesting but preferably immediately after harvesting. Most preferably processing commences not more than 15 minutes after harvesting. Commencement of processing within two minutes of harvesting is particularly preferred.

An apparatus provided according to the present invention may further include a flatterner.

The flatterner may include means for modifying the cross-section of a plant stalk from a substantially circular cross-section to a substantially elongate cross-section. The flatterner may be located upstream of the decorticator and preferably upstream of the splitter.

In a preferred embodiment the flatterner includes at least one pair of counter-rotating pressing rollers (entry rollers). Each roller may include a cylindrical surface and an axis of rotational symmetry. The surface of each roller is preferably nubbed or toothed without sharp edges on the nubs or teeth. Each roller may rotate around its own axis of rotational symmetry. The pressing rollers are separate from and opposed to each other. The separation between the pressing rollers or nip, may be capable of modifying the cross-section of a plant stalk from a generally circular cross-section to a generally elongate or oval cross-section. The elongate cross-section may be described
as having a major axis at right angles to a minor axis, where the minor axis is shorter than the major axis.

The splitter includes means by which the plant stalk may be split longitudinally. The splitter may be capable of splitting the stalk substantially along or parallel to, the major axis of the elongate cross-section. Splitting the stalk exposes the inner core or hurd of the plant stalk. The splitter may comprise a sharp edge blade or the like poised centrally between the entry rollers. The action of the splitter may create two separated portions of split plant stalk which can be directed into two separate streams for further processing.

A splitter according to the present invention may co-operate with guide means which may be adapted and arranged to guide plant stalks into a position whereby the blade acts to split the stalk. Alternatively, the plant stalks may pass directly from the entry rollers to the splitter without use of a guide. A split stalk may remain in one piece in which case the action of the splitter allows access to the hurd.

Splitters suitable for use in accordance with the present invention are described in more detail in patent specification WO 97/45573, the disclosure of which is incorporated by cross-reference into the present specification.

In another preferred embodiment a directing means, adjacent to the splitter, is capable of directing one stream of a separated split stalk into a first decorticator and the other stream of the stalk away from the first stream and preferably into a second decorticator operating in parallel with the first decorticator.

A decorticator provided in accordance with the present invention may include segmenting means and a separator.

The segmenting means may be located upstream of the separator. The separator may be capable of sweeping the segmented hurd away from the fibrous outer layer, thereby separating the hurd from the fibre. The separator may include a guide and a separating roller.

The segmenting means may include braking means and a conditioner. The segmenting means may be capable of restraining the stalk so that the separating roller can rotate at a speed faster than the speed of travel of a stalk through the segmenting means whereby to sweep the stalk and thereby separate the hurd from the fibre.
The braking means may include a first roller. The first roller may include a cylindrical surface and an axis of rotational symmetry. The first roller may have a smooth or profiled surface. In a preferred embodiment, the first roller has a smooth profiled surface. Alternatively, the braking means may have a toothed profiled surface. The toothed profile surface may include equally spaced ridges extending substantially the length of the first roller. The first roller may rotate about its axis of rotational symmetry. The first roller may be a free to rotate about its axis or it may be driven about its axis by driving means.

The braking means may be arranged to co-operate with a conditioner to divide the hurd into segments, preferably without damaging the fibre. In one preferred embodiment the conditioner includes means for dividing the hurd into segments. The means may be in the form of a toothed profiled surface. The profiled surface of the conditioner may be capable of segmenting the hurd when used in co-operation with the braking means. The profiled surface may be in the form of a profiled cylindrical surface. The surface may comprise the surface of a second roller. The roller may have an axis of rotational symmetry. The second roller carrying such a profiled cylindrical surface is preferably capable of rotating about its axis of rotational symmetry.

The second roller may be driven to rotate at a rate of up to 4000 rpm. In a preferred embodiment, the roller is driven to rotate at a rate of between 2700 and 3100 rpm, most preferably at above 3000 rpm. The toothed profile surface may include equally spaced ridges extending substantially the length of the roller. The profiled surface of the conditioner may co-operate with the braking means to divide the hurd into segments. The conditioner and braking means are preferably set apart to accommodate the outer fibrous layer only so that the tips of the teeth of the conditioner penetrate the soft pith of the stalk against the braking means without cutting the outer fibrous layer so as to divide the soft pit or hurd into segments.

In a preferred embodiment the braking means and the conditioner are in the form respectively of a first roller and second roller. Said rollers may be separate from and opposed to one another. The first roller and second roller may co-operate by counter-rotating. Preferably the braking means is a smooth surfaced anvil roller and the conditioner is a toothed roller. Where both the first and second rollers have a toothed profile the toothed profiled surface of the first roller and toothed profiled surface of the second roller
counter-rotate, preferably without interdigitation. The separation or nip
between the first roller and second roller may approximate the thickness of
the outer fibre layer or bast of the plant stalk. Preferably this separation is
between 0.1 to 0.6mm and most preferably between 0.25 to 0.38mm.

The first and second rollers may be driven to rotate at the same speed
as one another.

The arrangement is preferably such that the braking means and the
conditioner co-operate to direct a stalk being processed toward the separator.

In a particularly preferred arrangement the braking means and the
conditioner are in the form of counter-rotating rollers with a plant stalk
entering the nip of the rollers being urged toward the separator as it emerges
from the nip. In this arrangement the braking means may be effective to
brake the speed of travel of the stalk as it enters the separator.

The guide of a separator provided in accordance with the present
invention may be located upstream from the separating roller. The guide may
comprise a presenting means also referred to herein as a hump for presenting
the plant stalk to the separating roller. The guide may further include a tail
extending from the hump in a direction generally parallel to the direction of
travel of the surface of the separating roller. The surface of the tail which
faces the surface of the separating roller comprises a work face. The
separation or gap between the closest portion of the operating surface of the
separating roller and the work face may be comparable to the size of the nip
between the braking means and the conditioner. The gap is preferably of a
size which is close to the thickness of the outer fibre layer or base of the
plant stalk. Preferably the gap is between 0.1 to 0.6mm and most preferably
between 0.25 to 0.38mm. The work face may be downstream of the hump. In
a preferred embodiment, the hump and the work face are integral units of the
guide.

The guide may include a guiding fence adapted to guide the separated
stalk toward the hump. The guide fence may be pivoted.

The hump may be fixed relative to the separating roller. Alternatively,
the hump may be moveable relative to the separating roller. In a particularly
preferred alternative embodiment, the hump and extending tail is in the form
of a pivoted arcuate member, which may be resiliently poised with respect to
the separating roller. In this embodiment, the hump is adjustably limited to
maintain a gap between the arcuate member and the separating roller to
accommodate the fibre thickness gauge whilst the resilient bias maintains the working pressure for a multiplicity of stalks. Preferably the pivoted hump arrangement also includes a pivoted guiding fence upstream of the hump for guiding the stalk portion to the gap between the hump and the separating roller.

The separating roller may include a profiled cylindrical surface and an axis of rotational symmetry. The profiled cylindrical surface may be effective for sweeping the hurd from the fibre. In a preferred embodiment, the separating roller has a toothed profiled surface. The toothed profiled surface includes equally spaced ridges extending substantially the length of the axis. In another preferred embodiment the width of the ridges of the separating roller is 0.5 mm. The separating roller may rotate about its axis of rotational symmetry. The separating roller may be driven about this axis by a driving means.

The separating roller may rotate in the same direction as the second roller. The circumferential speed of the separating roller, \( V_s \), is the speed [tangential velocity] of a point on the surface of the separating roller. The circumferential speed of the second roller, \( V_c \) is the speed [tangential velocity] of a point on the surface of the second roller. The separating roller may be driven about its rotational axis of symmetry at a rate where \( V_s \) is between \( 1.3 \, V_c \) and \( 3 \, V_c \), preferably \( 2 \pm 0.5 \, V_c \).

The components of a decorticator provided in accordance with the present invention may be mounted in a casing. The casing may include a pair of opposed side walls. The components in the form of one or more rollers including the braking means, the conditioner and the separating roller may be journalled for rotation about an axle. The axle may be carried by the casing. The axle may comprise a unit adapted such as by the provision of a key way for rotation with the corresponding roller. Alternatively the roller may be free to rotate relative to the axle. As will be appreciated by the man skilled in the art, the exact arrangement is dependent upon the nature of the drive train selected.

Components such as the guide of the separator also may be mounted in the casing. Preferably the guide is mounted on at least one wall of the casing. Most Preferably the guide is adjustably mounted so that the gap between the work face and the separating roller can be adjusted.
In a particularly preferred arrangement the rollers comprising the braking means, the conditioner and the separating roller are each fixedly mounted on an axle which extends beyond the casing and includes means for driving the respective axles whereby to drive the braking means, the conditioner and the separating roller. The driving means may be in the form of one or more belts from a remote drive shaft. In a particularly preferred arrangement a gear train is provided so as to control the relative rotation speeds of the braking means, the conditioner and the separating roller. The gear train may include one or more gears co-operable with an external drive whereby to drive the rotation of the braking means, the conditioner and the separating roller.

In a particularly preferred arrangement a drive shaft is used which is not mounted on the casing but operably engages a drive train mounted on the casing whereby the casing and hence the decorticator according to the present invention can be readily removed from the drive shaft for maintenance, cleaning and the like.

The present invention also provides a method for processing a plant stalk which includes splitting the stalk substantially longitudinally to expose the hurd, dividing the exposed hurd into segments and separating the fibre from the hurd. The splitting step may be conducted up stream of the decorticator provided in accordance with another embodiment of the invention. The split stalk may be fed to the decorticator by insertion of the split stalk in the nip between the braking means and the conditioner. In the preferred arrangement where the braking means has a substantially smooth cylindrical surface and the conditioner has a substantially toothed outer surface, the split stalk is preferably presented so that the fibrous outer part faces toward the smooth cylindrical surface of the braking means and the exposed hurd toward the toothed conditioner.

The minimum clearance in the nip between the teeth of the conditioner and the surface of the braking means is preferably adjustable so as to correspond approximately to the thickness of the outer fibre layer. In this arrangement as the split stalk passes through the nip, the teeth of the conditioner divide the hurd into segments which correspond approximately to the spacing between the teeth on the conditioner. If the nip is too narrow some of the fibres may be severed and if the nip is significantly greater than
the width of the fibre layer, the hurd may not be sufficiently segmented as it passes between the braking means and the conditioner.

On exiting the segmenting step the split and segmented stalk is urged by the rotation of the separating roller to travel between the separating roller and the work face. To enter the gap between the work face and the separating roller the stalk passes over the hump. The hump is preferably in the form of a smooth surface which acts to further expose the hurd and present the segments to the teeth of the separating roller. The action of the separating roller to sweep the segmented hurd from the fibre results from the speed of the separating roller which is travelling at a circumferential speed significantly greater than the speed of travel of the stalk as it passes through the conditioner. Thus the braking means is effective to restrain the speed of travel of the stalk and thereby and allow the separating roller to effectively sweep the segmented hurd from the fibrous outer layer and thereby separate the fibre from the hurd.

When the hurd is separated from the fibrous outer layer, it may fall between the conditioner and the separating roller and hence out of the decorticator as it passes over the hump. In an alternative path some of the hurd segments may be swept by the speed of the separating roller past the fibrous outer layer and through the gap to exit the decorticator downstream of the work face. The fibre may be ejected from the decorticator downstream of the separator. The fibre and hurd may be collected for later use.

In yet a further embodiment the present invention provides an apparatus for processing a plant stalk, the stalk having an outer fibrous part and an inner hurd, wherein one side of the apparatus is at least partially open, the apparatus including:

(a) separation means capable of separating the stalk substantially longitudinally thereof to provide separated stalk components;
(b) means for delivering the stalk to the separation means;
(c) a conditioning section including conditioning means for each separated stalk component, each conditioning means including a conditioner roller and an associated conditioning workface;
(d) a decorticating section for separating the core from the fibres including decorticating means for each conditioned stalk component, each decorticating means including a decorticating roller and an associated decorticating workface; and
(e) means for providing an air flow in the device, the air flow being such as to entrain at least part of the separated core and transporting the separated core through the at least partially open side to remove the separated core from the device.

The delivery means may be a set of entry rollers. Preferably the entry rollers have projections at the periphery thereof. The entry rollers may be self-adjusting and self-centring and arranged to come no closer than the diameter of the smallest acceptable stalk. The bearings of each of the roller shafts may be mounted bearing plates which pivot about a rotating idler shaft. This rotation of the pivot shaft has the advantage of eliminating wear from a critical area and reduces friction markedly. The linkage to the bearing plates ensures that the stalks are kept centred and the spring provides adjustable grip on the stalk.

The conditioning section of the device of the invention may include a set of anvil rollers or the like located between the delivery means and the conditioner rollers. The anvil rollers may be of the same diameter as the conditioner rollers, although this is not essential. The anvil rollers may be adjustable to suit various crop thicknesses. For example, the adjustment may be achieved by replacement of the anvil rollers with rollers of a different diameter. Preferably the anvil rollers have a smooth surface.

Each anvil roller is preferably associated with scraper means having a very small clearance between it and the anvil roller. The scraper means may be associated with a workface. Preferably each scraper means is associated with a high velocity airflow between each anvil roller and its associated scraper means to prevent the fibre from wrapping around the anvils and to ensure that fibre and core are conveyed to the workface.

The conditioning and anvil rollers may move with the same surface velocity.

The conditioner rollers and their associated workfaces serve to separate the hurd into short pieces or segments. The conditioner rollers may have outward projections such as teeth, blades, ridges or the like. Preferably the projections are teeth the shape of which is selected to avoid damage to the bast fibre and to keep power consumed to a minimum.

The decorticating rollers preferably move at a greater peripheral speed than that of the conditioning and anvil rollers. Most preferably, the
deorticating rollers move at about twice the peripheral speed of the conditioning and anvil rollers.

The conditioning workface and the deorticator workface may be separate or form part of the one body. The workfaces may be fixed. Each workface may include an arcuate face which is concentric with its respective roller to provide a substantially arcuate path for the stalk component to follow whilst being conditioned by a conditioner roller or when undergoing deorticitation by a deorticitation roller. The axis of each deorticating roller/workface is placed relative to the axis of the respective conditioner roller/first workface to provide a tortuous or serpentine path along which the stem component travels when passing through the conditioning and deorticitation sections.

The transition between the conditioning and deorticating workfaces may be provided by a convex projection or hump at the cusp formed at the intersection of the two workfaces. The purpose of the hump is to cause the separation of the core from the bast fibre. By appropriate selection of the curvature of the hump, the separation of the hurd from the bast can be achieved in the most effective manner at the lowest power.

The workface(s) may be sprung inwardly at an adjustable pressure to control the amount of pressure between the workface and its adjacent roller. The workface(s) may also be pivoted so that the workface can be lifted up to allow ease of cleaning and maintenance.

Preferably all rollers are supported and driven at one end. Preferably one end of each roller is left open and uncluttered to permit core escape through entrainment in the air flow and to allow simple access for maintenance. The rollers may be driven by hydraulic or pneumatic means. The driving means may form part of the device or the device may include means enabling it to be connected to a source of power.

The device may include a vacuum extraction arrangement for extraction of core after it leaves the deorticator.

The separation means may be a knife, splitter blade, saw or any other means capable of separating the stalk longitudinally thereof. Preferably the separation means is fixed.

A particular problem associated with the processing of bast fibre plants is that the bast fibre wraps around the shafts of the rollers. In a preferred form, the device of the present invention provides a solution to this problem.
by including in the device one or more guard means to prevent fibre wrapping around the shaft of the rollers. Preferably the guard means is/are one or more thread guard plates.

Preferably the means for providing air flow provides high velocity air flow to the device. The means for providing air flow to the device may be one or more jets and/or ducts or the like associated with, or capable of being associated with, a source of air. The means for providing air flow may be one or more gaps between components of the device. For example, the means for providing air flow may be the gap between the thread guard(s) and the shaft of one or more rollers. The provision of air flow via the thread guard gap has the added advantage of preventing loose fibres, plant liquids and particles from entering the gap of the thread guard. Alternatively the air flow may be provided via the gap between each scraper means and its associated anvil. The latter option has the further benefit of preventing loose fibres from wrapping around the anvils. The means for providing air flow may be a combination of two or more of the means set out above.

The high velocity air jets may be provided from one or more ducts. The high velocity air jets may be associated with the conditioning and/or decorticating rollers. Preferably the high velocity air jet(s) are located so that it/they clear the conditioning and/or decorticating rollers of any fibres or core particles and/or keep the fibre moving where required. The jet of air expands after it exits the workface. This jet expansion entrains surrounding fluid and this draws the fibre towards the workface. The expanding jet also prevents the fibre from actually contacting the workface. Moreover the entrainment flow prevents the fibre from moving away from the workface and contacting any other surfaces. Because the expanding jet has a velocity much higher than the fibre velocity, this makes sure that the fibre does not decelerate and bunch up. It also facilitates downstream fibre handling.

The projections of the conditioning and/or decorticating rollers preferably have apertures therethrough to permit the high velocity air to pass through the teeth and thereby eject any core. These holes also to provide a parallel flow of air along the workface to keep the exiting fibre moving and prevent its contact with any surface.

The parallel air flow along the workface section past the decorticating roller may also be provided by air from one or more ducts within the workface.
The air jets may carry water droplets, mist or vapour to increase the effect and control moisture content. Release agents such as hemp oil or linseed oil may be added to the air to avoid sticking of the stalk component to parts of the decorticator.

The source of air to the means for providing an air flow may form part of the device of the present invention or it may be separate, in which case the device of the invention may include means for connection to such a source of air. The source of air may be an air blower, compressor or the like.

The device of the invention may be associated with other components for pre-processing the fibre for entry into the device, for example, a primary stripping stage to strip leaves and/or branches from the stalk. The device of the invention may be associated with means for further processing of the fibre produced by the device, for example chemical treatment means.

The device of the invention is suitable for use as a single component in a fibre processing arrangement or a plurality of devices in accordance with the invention may be incorporated into a processing system for parallel processing of a plurality of stalks.

In a further aspect, the present invention provides a decorticating module for decorticating a plant stalk having an outer fibrous layer and an inner core, including:

(a) means for delivering a plant stalk to a separation means for separating the stalk longitudinally thereof to halve the stalk;
(b) a conditioning section for each stalk half, the conditioning section including toothed conditioner rollers and optionally smooth anvil rollers; and
(c) a decorticator section for each stalk half with stationary workfaces and toothed decorticating rollers moving at a peripheral speed greater than that of the conditioner and anvil rollers; the module further including one or more of the following:
(d) thread guard means having one or more gaps for preventing fibres from wrapping around shafts of the rollers;
(e) high velocity air flow through the thread guard gap(s) to prevent loose fibres, plant material and/or particles from entering the gap;
(f) scraper means with a very small clearance and high velocity air flow to keep the fibres from wrapping around the anvils;
(g) high velocity air flows through holes in the conditioner and decorticator roller teeth to eject any core;
(h) one or more high velocity air jets to clear the conditioner and/or decorticator rollers of any fibres or core particles and to keep the fibre moving and to prevent its contact with any surface;

(i) a parallel air flow along the workforce to keep exiting fibre moving and to prevent its contact with any surface; and

(j) one end of one or more rollers, preferably all rollers, is/are open and uncluttered to permit core escape and simple access to the module for maintenance.

In a further aspect, the present invention provides a method for treatment of a plant stalk, the method including use of an apparatus in accordance with the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described with reference to particularly preferred embodiments in which:

Figure 1 is a schematic side view of a decorticator according to one preferred embodiment of the present invention;

Figure 2 is a plan view of the apparatus shown in Figure 1 with the guide removed for clarity;

Figure 3 is a schematic side view of a further embodiment of a decorticator according to the present invention; and

Figure 4 is a further schematic side view showing the spring arrangement of the embodiment shown in Figure 3.

Figure 5 is a top schematic view of the hump used in the embodiment of Example 2.

Figure 6 is a schematic perspective view of the guiding fence used in the embodiment of Example 2.

Fig. 7 is a plan view of yet a further embodiment of the present invention; and

Fig. 8 is a side cross-sectional view of the device of Fig. 7 showing an embodiment of a thread guard plate arrangement in accordance with the invention.
Example 1

Figure 1 and 2 illustrate one preferred embodiment of the present invention. The decorticator 1 includes segmenting means 2, which includes braking means or anvil 10 and conditioner 20. Decorticator 1 also includes separator 3, which includes guide 30 and separating roller 40.

Braking means 10 includes an axis of rotational symmetry 11, shaft 12 and cylindrical surface 13.

Conditioner 20 includes axis of rotational symmetry 21, shaft 22, profiled surface 23, ridges 24 and spacings 25. Conditioner 20 is driven by a driving means associated with drive shaft 22.

The braking means may be driven by a driving means associated with drive shaft 12. The driving means is preferably in the form of a gear train (not shown) in which shafts 12, 22 and 42 mounted on casing 4 act as axles carrying gears which are driven by an external drive shaft carrying a drive gear to engage with the gears mounted on one or more of the axles comprising shafts 12, 22 and 42 whereby to drive braking means 10, conditioner 20 and separating roller 40.

The separation or nip 26 between braking means 10 and the conditioner 20 is close to the value of the thickness of the fibrous outer layer of the plant stalk. Preferably this value is between 0.1 mm to 0.6 mm. Most preferably this is between 0.25 mm to 0.38 mm.

In operation the plant stalk, which is preferably harvested after 60 days maturity, just prior to flowering the plant, may be passed through a flattener to elongate the cross-section of the stalk.

The stalk may be then passed through a splitter which splits the stalk longitudinally along the major axis of the elongate cross-section of the plant stalk. The stalk may be split into separate parts thereby creating two streams of split plant stalk and exposing the hurd.

One stream of the plant stalk is directed into decorticator 1 and the other stream of the split plant stalk may be directed away from the first stream, preferably into a second decorticator (not shown), operating in parallel with decorticator 1.

The split plant stalk enters decorticator 1 at region 5 before passing through the nip 26 of braking means 10 and conditioner 20. The stalks are preferably straight and are led into nip 26 by the butt end.
The split stalk preferably is orientated to enter decorticating 1 in a
position such that the fibrous outer layer of the split plant stalk lies adjacent
cylindrical surface 13 of braking means 10 and the hurd lies adjacent the
profiled cylindrical surface 23 of the conditioner 20.

Braking means 10 and conditioner 20 counter-rotate to urge a stalk
entering the nip to travel towards separating roller 40. Conditioner 20 may
rotate at a rate of up to 4000 rpm, preferably between 2700 rpm and 3100
rpm, and most preferably at 3000 rpm.

Ridges 24 of conditioner 20 divide the hurd of the split plant stalk into
segments as it passes through the nip 20 of braking means 10 and conditioner
20.

After it emerges from segmenting means 2, the split plant stalk is
presented to separating roller 40 and guided between work face 32 and the
profiled surface 43 of the separating roller by hump 31.

Separating roller 40 includes an axis of rotation 41, shaft 42, profiled
surface 43, ridges 44 and spaces 45.

Separating roller 40 sweeps the split plant stalk against work face 32,
separating hurd segments from the fibrous outer layer using ridges 44.

Separating roller 40 is driven by a driving means associated with axle
42 as described above.

In operation, the circumferential speed of the separating roller 40 \( V_s \) is
between 1.3 and 3 \( V_c \), the circumferential speed of conditioner 20. Preferably,
the circumferential speed \( V_s \) of the separating roller 40 is \( 2 \pm 0.5 \ V_c \). The
circumferential speed of the conditioner 20 is \( V_c \).

Freshly harvested hemp processed according to the present invention
separates more efficiently into fibrous ribbons and hurd than hemp in which
glue between the fibrous layer and hurd has begun to dry. As the hemp dries,
more power is required to strip the hurd from the stalk as the glue between
the fibrous outer layer and the inner hurd begins to dry. When the hurd is
separated from the fibrous outer layer, it may fall in a region 6 between
conditioner 20 and separating roller 40 and hence out of the decorticator.

Separating roller 40 ejects the fibrous outer layer out of the
decorticating through region 7. The fibre may be ejected in ribbons which can
be roll baled, square baled, aligned, set in boxes or whatever the user
requires. When the glue begins to dry, hurd may be ejected past separating
roller 40. The hurd may be easily separated from the fibre by collecting the
product over water. The hurd will float while the fibre sinks. The hurd may be collected in boxes and used as a component for particle board, kitty litter, garden mulch, animal bedding, masonite or used in the making of ethanol. The fibre may be collected and used as a component of textiles or as a natural fibre.

Example 2

An alternative embodiment of the present invention is shown in Fig. 3. The decorticator has twin entry rollers 50 having smoothly formed nubs 52 around the periphery thereof to elongate the cross-section of the stalk 90 and to drive it undamaged over a knife splitter 54 poised centrally between the entry rollers to form two split stalk portions 92. Each split stalk portion 92 passes to the nip of counter-rotating externally fluted conditioner 56 and smooth surfaced anvil 58. The conditioner and anvil are set apart to accommodate the fibrous outer layer only so that the tips of the conditioner readily penetrate the soft pith of the stalk against the hard anvil without cutting the outer fibrous layer so as to divide the soft pith or hurd into segments.

The travelling conditioned split fibre is then guided by a guiding fence 60, pivoted at 70, to the variable region 67 of arcuate hump 64 so that the fibre passes over the leading edge 62 and is violently swept between the inner surface 69 of the hump and the teeth of decorticator 80 to thrash out the pith or hurd 94 free of fibre into a delivery area below. The leading edge 62 provides a more aggressive change of direction of the conditioned split fibre than is achieved by the hump arrangement used in Example 1 described above.

The arcuate hump 64 is adjustably limited to maintain an accommodating gap 67 dependent on the fibre thickness gauge. In this embodiment, the entrance to the hump region will not be closer than ten thousandths of an inch. This is achieved by pivoting the hump at 66 and adjustably spring loading the hump so as to maintain a working pressure for a multiplicity of stalks. As best shown in Figs. 4, 5 and 6, the hump 64 is resiliently biased toward the decorticator 80 by a bank of springs 110 pivotally mounted at 112. The springs pass through apertures 111 in the guiding fence 60 and sit over projections 122 on the top surface of the hump 64.
It is envisaged that the apparatus described herein may operate independently or in combination with known harvesting apparatus, such as the harvesting apparatus described in WO 97/45573 incorporated herein by reference. The apparatus of the present invention may also be operated in combination with known post processing means for the fibre product or bast and hurd.

Example 3

Referring to Figure 7, the device 210 has an entry section 2, a conditioning section 5, and decorticator section 7.

The direction of movement of a stalk through the device is shown by arrow 100. The entry section 2 includes two counter-rotating entry rollers 211a, 211b which deliver a stalk (not shown) to fixed splitter blade 213 which splits the incoming stalk longitudinally in half. The entry rollers 211a, 211b are pivoted around point 15 which is the position of an idler shaft (not shown). The entry section also includes air ducts 9 having reverse flow jets 217a, 217b of 0.5 radii on the inside and no radii/chamfer on the outside thereof. These jets are designed to provide approximately 50-150 m/s reverse air flow onto the entry rollers 211a, 211b.

The device includes workfaces 219a, 219b, which are pivoted for easy cleaning. The workfaces are also sprung inwardly at adjustable pressure to control the amount of pressure between the workface and the rollers.

Counter-rotating anvil rollers 225a, 225b which rotate at approximately 4,000 rpm are provided between the entry rollers and the counter-rotating conditioner rollers 221a, 221b. The anvil rollers are readily replaceable to vary the clearance 240 in the range of about 0.2 to 0.5 mm. Each anvil roller has an associated scraper (227a, 227b) provided with a supply of high velocity air between each scraper and its respective anvil. Each scraper is positioned about 50μm from its associated anvil roller.

Conditioner rollers 221a, 221b have teeth 229. Each tooth has a hole 230 of approximately 1-5mm diameter at an axial spacing of 5mm to allow high velocity air flow through the teeth to allow hurd to be dislodged therefrom. That part of the workface in the conditioning section has a face that is coaxial with its associated conditioner roller.
The workface in the conditioning section is substantially coaxial with its associated conditioner roller. The transition between the conditioning workface and the decorticator workface is provided by a hump 231.

Air duct 232 with air jets 233 is positioned in the conditioning section to provide a high velocity air jet (greater than about 100 m/s) towards the two conditioner rollers. This air jet passes through the holes 230 in the teeth of the conditioner rollers.

The decorticating rollers 223a, 223b have teeth 224 with holes 226 therethrough to allow passage of high velocity air through the teeth.

The decorticating rollers run at a peripheral speed approximately two times that of the conditioner rollers, and in this case, run at approximately 8,000 rpm.

The decorticator section also includes an air duct 228 with high velocity air jets 231 to provide high velocity air at a rate of 100-150 m/s.

Further air ducts 233 provide co-flowing air jets at approximately 30-80 m/s to ensure that the bast fibre touches nothing and is attracted towards the co-flowing jet.

All air ducts in the device are supplied with air through the thread guard.

The rollers of the entry, conditioning and decorticator section are all driven at the end on the same side. The other side of the device is open and unobstructed to allow the high velocity air to escape from the top of the device and taking entrained hurd and loose fibres with it thereby clearing the device of hurd particles.

The rollers in each section are cantilevered gear driven rollers. All rollers are driven through a thread guard plate 290 which prevents fibre wrap around. High velocity air flow is provided through the thread guard gap to prevent loose fibres, plant liquids and particles from entering the gap.

A suitable thread guard arrangement is shown in Figure 8. Roller 200 passes through thread guard plate 302, the gap 306 between the periphery of the roller and the thread guard plate being sufficient to allow air flow through the gap. Shaft 310 of the roller passes through an oil separation plate 320 and bearing plate 330. The gap 322 between the shaft and the oil separation plate is sufficient to allow air flow through the gap. The shaft is supported on the bearing plate by bearing 332. An oil flinger 360 is provided on the shaft.
A source of air (not shown) provides air flow 370 between the thread guard plate and the oil separation plate which in turn results in an air flow through gaps 306 and 322. The air flow through thread guard gap 306 prevents fibres and other material from entering the gap. The air flow through gap 322 prevents oil mist from escaping from the gear box 380 and the bearings.

In operation, a hemp plant stalk is fed along direction 9 through entry rollers at 311a, 311b which deliver the stalk to fixed splitter blade 213. The splitter blade splits the stalk longitudinally through the core to produce two stalk halves. Each stalk half moves toward the conditioning section, passing around the anvil to a conditioner roller which separates the hurd into short pieces. The conditioning and anvil rollers move with the same surface velocity. The shape of the teeth of the conditioner rollers is selected to avoid damage to the bast fibre and to keep power consumed to a minimum.

The workforce mounted scrapers 327a, 327b, and the air flow between the anvil and the scraper both ensure that the bast fibre and the hurd are conveyed to the convex hump 331. The curvature of the hump is selected to ensure that the separation of the hurd from the bast fibre is most effective with the lowest power.

The peripheral speed of the decorticating rollers is greater than the conditioner rollers. A ratio of about 2:1 is used although this is to some extent arbitrary, but has been found to work well. The conditioned fibre then passes around hump 331 to the decorticating roller (323a, 323b) which separates the hurd from the bast fibre.

The high velocity air jets supply high velocity air, optionally containing water droplets, or vapour to increase the effect and control moisture content, into the various sections of the device. A release agent such as hemp oil or linseed oil may be added to the air to avoid sticking of the stalk components to parts of the decorticator.

The parallel air flow along the workforce section past the decorticating roller is supplied with air from the ducts 233 in the workforce. The jet of air expands after it exits the workforce and entrains surrounding fluid and draws the fibre towards the workforce. The expanding jet also prevents the fibre from contacting the workforce. The entrainment flow prevents fibre from moving away from the workforce and contacting any other surface. The expanding jet has a velocity much higher than the fibre velocity and this
ensures that the fibre does not decelerate and bunch up. It also facilitates the downstream fibre handling. The holes in the teeth of the conditioning and decorticating rollers allow high velocity air to flow therethrough to eject any hurd that may be lodged therein.

The high velocity air jets operate to clear the conditioning and the decorticating rollers of any fibres/particles which are present and keep the fibre moving as required.

The combined air flow from the air jets and gaps escapes from the open top of the device taking with it entrained hurd pieces and any loose fibre.

This particular embodiment of the device of the invention is capable of sequentially processing about 5 stalks per second.

A decorticating system may include a plurality of apparatus in accordance with the present invention.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.
CLAIMS:

1. A method for processing a plant stalk having a fibrous outer part and an inner hurd, the method including the steps of:
   splitting the stalk substantially longitudinally into separated stalk components whereby to expose the hurd;
   dividing the exposed hurd into segments in a segmenting step; and separating the fibre from the hurd.

2. A method according to claim 1 wherein the cross-sectional of the stalk is modified prior to splitting by application of pressure to the outer surface of the stalk.

3. A method according to claim 2 wherein the cross-section is modified by the stalk passing through at least one pair of counter-rotating pressing rollers.

4. A method according to any one of the preceding claims wherein the exposed hurd is segmented by passing each stalk component between a first roller having outward projections on the surface thereof and a second roller.

5. A method according to claim 4 wherein the first roller and the second roller are separated by a distance approximately equal to the thickness of the fibrous outer part.

6. A method according to claim 4 or claim 5 wherein the second roller is a smooth surfaced anvil roller.

7. A method according to any one of the preceding claims wherein the fibre is separated from the hurd by passing the split stalk between a separating roller and a workforce.

8. A method according to claim 7 wherein the separating roller has a toothed surface.
9. A method according to any one of the preceding claims wherein each stalk component passes over guide means prior to separation of the fibre from the hurd.

10. A method according to claim 9 wherein the guide means is a hump or the like.

11. A method according to claim 10 wherein the hump is followed by a tail, the surface of which provides the workface.

12. A method according to any one of claims 7 to 11 wherein the circumferential speed of the separating roller is between about 1.3 to 3 times the circumferential speed of the first roller.

13. A method according to claim 12 wherein the circumferential speed of the separating roller is \(2 \pm 0.5\) times the circumferential speed of the first roller.

14. An apparatus for processing a split plant stalk having a fibrous outer part and an inner hurd, said plant stalk being split substantially longitudinally to form separated stalk components whereby to expose the hurd wherein the apparatus includes:
   segmenting means to divide the hurd into segments; and
   a separator to separate the fibre from the hurd.

15. An apparatus according to claim 14 further including a splitter for splitting the stalk substantially longitudinally thereof.

16. An apparatus according to claim 15 further including means upstream of the splitter for modifying the cross-section of the plant stalk.

17. An apparatus according to claim 16 wherein the means for modifying the cross-section of the plant stalk is at least one pair of counter-rotating pressing rollers.
18. An apparatus according to claim 17 wherein the pressing rollers each have outwardly extending projections from the surface thereof.

19. An apparatus according to any one of claims 14 to 18 wherein the segmenting means includes a braking means and a conditioner.

20. An apparatus according to claim 19 wherein the braking means includes a roller.

21. An apparatus according to claim 20 wherein the braking means is a smooth surfaced roller.

22. An apparatus according to any one of claims 19 to 21 wherein the conditioner is a toothed roller.

23. An apparatus according to claim 22 wherein the braking means and the conditioner cooperate to divide the hurd into segments.

24. An apparatus according to any one of claims 14 to 23 wherein the separator includes a guide and a separating roller.

25. An apparatus according to claim 24 wherein the separating roller has a profiled cylindrical surface.

26. A method according to claim 25 wherein the surface of the separating roller has a toothed profile.

27. An apparatus according to any one of claims 24 to 26 wherein the guide is located upstream of the separating roller.

28. An apparatus according to claim 27 wherein the guide is in the form of a hump.

29. An apparatus according to claim 28 wherein the guide includes a tail extending from the hump in a direction generally parallel with the direction
of travel of the surface of the separating roller, that part of the tail facing the
surface of the separating roller forming a workface.

30. An apparatus according to claim 29 wherein the hump and workface
are integral units of the guide.

31. An apparatus according to any one of claims 28 to 30 wherein the
hump is fixed with respect to the separating roller.

32. An apparatus according to any one of claims 28 to 30 wherein the
hump is moveable relative to the separating roller.

33. An apparatus according to claim 32 wherein the hump and workface is
in the form of a pivoted arcuate member.

34. An apparatus according to claim 33 wherein the pivoted arcuate
member is resiliently poised with respect to the separating roller.

35. An apparatus according to any one of claims 14 to 34 further including
a pivoted guiding fence upstream of the hump for to guide the stalk
component to the gap between the hump and the separating roller.

36. An apparatus according to any one of claims 14 to 35 further including
means for providing an air flow in the device, the air flow being such as to
entrain at least part of the separated hurd through an at least partially open
side of the apparatus.

37. A decorticator system for processing a plurality of plant stalks the
system including an apparatus of any one of claims 14 to 36 for each plant
stalk.

38. An apparatus for processing a plant stalk having a fibrous outer part
and an inner hurd wherein one side of the apparatus is at least partially open,
the apparatus including:

(a) separation means capable of separating the stalk substantially
longitudinally thereof to provide separated stalk components;
(b) means for delivering the stalk to the separation means;
(c) a conditioning section including conditioning means for each
separated stalk component, each conditioning means including a conditioner
roller and an associated conditioning workface;
(d) a decortication section for separating the hurd from the fibres
including decortication means for each conditioned stalk component, each
decortication means including a decorticating roller and an associated
decorticating workface; and
(e) means for providing an air flow in the device, the air flow being such
as to entrain at least part of the separated core and transporting the separated
core through the at least partially open side to remove the separated core
from the device.

39. A method or apparatus according to any one of the preceding claims
wherein the plant stalk is from a bast crop.

40. A method or apparatus according to any one of the preceding claims
wherein the plant stalk is selected from a plant of the genus Cannabis sativa
L and species thereof.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

Int CG6: D01B 1/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: D01B 1/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT with keywords

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>X</td>
<td>AU 28804/97 A (AUSTRALIAN HEMP CO. LTD) 5 January 1998 Figures 4-5</td>
<td>1-9, 14-27, 36-40</td>
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Further documents are listed in the continuation of Box C

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* Special categories of cited documents:
  **A** document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search: 14 October 1999

Date of mailing of the international search report: 20 OCT 1999

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INTERNATIONAL SEARCH REPORT
Information on patent family members

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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