Methods for blending first and second fibers to provide fiber blends that include blended fiber flocs composed of a substantially homogeneous blend of first and second fibers.
FIRST FIBERS

SECOND FIBERS

BLENDING

FIBER BLEND

Fig. 1.

FIRST AND SECOND FIBER MIXTURE

SECOND AIR STREAMS

BLENDING ZONE

COLLECTION ZONE

FIBER BLEND

Fig. 2.

FIRST AND SECOND FIBER MIXTURE IN AIR STREAM

SECOND AIR STREAM

BLENDING ZONE

COLLECTION ZONE

FIBER BLEND

Fig. 3.
Fig. 4B.
Fig. 4C.
Fig. 8B.
Fig. 8C.
Fig. 8D.
Fig. 9A.
Fig. 9C.
Fig. 9D.
METHODS FOR BLENDING DRIED CELLULOSE FIBERS

BACKGROUND OF THE INVENTION

[0001] Crosslinked cellulose fibers are difficult to blend with other fibers due to their low density, high bulk, their tendency to aggregate to form flocs, rigid nature and their fragile nature. Because of their tendency to form flocs, crosslinked fibers also resist flowing as individual fibers making their mixing and blending with other more freely flowing fibers difficult.

[0002] To effectively blend crosslinked cellulose fibers with other fibers, crosslinked fiber flocs need to be disrupted. Floc disruption releases individual crosslinked fibers that can then associate with secondary fibers to form fiber blends. A challenge in blending crosslinked fibers with secondary fibers relates to floc disruption. Floc disruption requires imparting stresses sufficient to crosslinked fiber flocs to release crosslinked fibers from the floc for blending with secondary fibers without damaging the relatively fragile crosslinked fibers.

[0003] A need exists for methods for blending crosslinked fibers with secondary fibers to provide homogeneous fiber blends. The present invention seeks to fulfill this need and provides further related advantages.

SUMMARY OF THE INVENTION

[0004] The present invention provides methods for blending fibers to provide fiber blends that include blended fiber flocs composed of a substantially homogeneous blend of first and second fibers.

[0005] In one aspect, the present invention provides a method for blending a mixture of first and second dried cellulose pulp fibers, comprising:

[0006] (a) introducing a mixture of first and second dried cellulose pulp fibers into a blending device, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs; and

[0007] (b) blending the mixture of first and second dried cellulose pulp fibers in the blending device to provide a blend of first and second dried cellulose pulp fibers, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

[0008] In one embodiment, the method for blending first and second fibers is a pneumatic blending method that utilizes opposing intermingling air jets. In this embodiment, a mixture of first and second dried cellulose pulp fibers is blended by:

[0009] (a) introducing a mixture of first and second dried cellulose pulp fibers into a first air stream to provide a stream of mixed first and second dried cellulose pulp fibers in air, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs;

[0010] (b) impinging the stream of mixed first and second dried cellulose pulp fibers with a plurality of second air streams in a blending zone to provide a stream of blended first and second dried cellulose pulp fibers in air, wherein the plurality of second air streams impart stresses sufficient to disrupt a plurality of the first and second fiber flocs thereby blending the first and second dried cellulose fibers from the first and second fiber flocs; and

[0011] (c) conducting the stream of blended first and second dried cellulose pulp fibers from the blending zone to a collection zone to provide a blend of first and second dried cellulose pulp fibers, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

[0012] In this method, the plurality of second air streams are provided by an interlaced configuration of nozzles on opposing surfaces of the blending zone.

[0013] In another embodiment, the method for blending first and second fibers is a pneumatic blending method that utilizes air jet impact on fibers circulating in a loop. In this embodiment, a mixture of first and second dried cellulose pulp fibers is blended by:

[0014] (a) introducing a mixture of first and second dried cellulose pulp fibers into a first air stream to provide a stream of mixed first and second dried cellulose pulp fibers in air, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs;

[0015] (b) circulating the stream of mixed first and second dried cellulose pulp fibers into a loop blending zone and impacting the circulating stream of mixed first and second dried cellulose pulp fibers with one or more second air streams to provide a stream of blended first and second dried cellulose pulp fibers in air, wherein circulating and impacting the stream of mixed first and second dried cellulose fibers impart stresses sufficient to disrupt a plurality of the first and second fiber flocs thereby blending the first and second dried cellulose fibers from the first and second fiber flocs; and

[0016] (c) conducting the stream of blended first and second dried cellulose pulp fibers from the blending zone to a collection zone to provide a blend of first and second dried cellulose pulp fibers, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

[0017] In a further embodiment, the method for blending first and second fibers is a mechanical blending method that utilizes mechanical mixers. In this embodiment, a mixture of first and second dried cellulose pulp fibers is blended by:

[0018] (a) introducing first and second dried cellulose pulp fibers into a mechanical blending device to provide a mixture of first and second dried cellulose pulp fibers, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs;

[0019] (b) mechanically blending the mixture of first and second dried cellulose pulp fibers to provide a blend of first and second dried cellulose pulp fibers, wherein mechanical blending imparts stresses sufficient to the mixture of first and second dried cellulose pulp fibers to disrupt a plurality of the first and second fiber flocs thereby blending the first and second dried cellulose fibers from the first and second fiber flocs, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and
wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

DESCRIPTION OF THE DRAWINGS

[0020] The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same become better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

[0021] FIG. 1 is a schematic illustration of the fiber blending methods of the invention;
[0022] FIG. 2 is a schematic illustration of a first representative pneumatic fiber blending method of the invention;
[0023] FIG. 3 is a schematic illustration of a second representative pneumatic fiber blending method of the invention;
[0024] FIGS. 4A-C are images of stained pads formed by fibers blends prepared by a representative pneumatic blending (loop) method of the invention; FIG. 4A is an evaluation image where bright white areas correspond to crosslinked fibers, dark black areas correspond to cellulose fluff pulp fibers, and grey regions correspond to blends of crosslinked and fluff fibers; FIGS. 4B and 4C identify crosslinked fiber features and fluff pulp features, respectively, where features correspond to flocs and gray features correspond to nits;
[0025] FIGS. 5A and 5B compare images of a stained pad made from a control fiber mix (CA) and a stained pad made from a fiber blend prepared by a representative pneumatic blending (interlaced nozzles) method of the invention (51B);
[0026] FIGS. 6A and 6B compare images of a stained pad made from the control fiber mix (6A) and a stained pad made from a fiber blend prepared by a representative pneumatic blending (loop) method of the invention (6B);
[0027] FIGS. 7A and 7B compare images of a stained pad made from the control fiber mix (7A) and a stained pad made from a fiber blend prepared by a representative pneumatic blending (interlaced nozzles) method of the invention (7B);
[0028] FIG. 8A compares the floc area/night ratio for crosslinked fiber flocs for a pad made from a control fiber mix (Air Off) and a pad made from a fiber blend prepared by a representative pneumatic blending (interlaced nozzles) method of the invention (Air On);
[0029] FIG. 8B compares the floc area/night ratio for crosslinked fiber flocs for a pad made from a control fiber mix (Feed) and a first pad made from a fiber blend prepared by a representative mechanical blending method of the invention in which the fibers were blended for 1 minute (1 min) and a second pad made from the same fiber blend prepared by the same method except that the fibers were blended for 5 minutes (5 min);
[0030] FIG. 8C compares the floc area/night ratio for crosslinked fiber flocs for a pad made from a control fiber mix (Feed) and a first pad made from a fiber blend prepared by a representative mechanical blending method of the invention in which the fibers were blended by a single pass through the blending device (1 Pass) and a second pad made from the same fiber blend prepared by the same method except that the fibers were passed through the blending device four times (4 Pass); two blending device configurations are compared, vertical pin mixer and horizontal pin mixer;
[0031] FIG. 8D compares the floc area/night ratio for crosslinked fiber flocs for a pad made from a control fiber mix (simple fan method, SFM) and a pad made from a fiber blend prepared by a representative pneumatic blending method of the invention (pneumatic loop, PL);
[0032] FIG. 9A compares the floc area/night ratio for fluff pulp fiber flocs for a pad made from a control fiber mix (Air Off) and a pad made from a fiber blend prepared by a representative pneumatic blending (interlaced nozzles) method of the invention (Air On);
[0033] FIG. 9B compares the floc area/night ratio for fluff pulp fiber flocs for a pad made from a control fiber mix (Feed) and a first pad made from a fiber blend prepared by a representative mechanical blending method of the invention in which the fibers were blended for 1 minute (1 min) and a second pad made from the same fiber blend prepared by the same method except that the fibers were blended for 5 minutes (5 min);
[0034] FIG. 9C compares the floc area/night ratio for fluff pulp fiber flocs for a pad made from a control fiber mix (Feed) and a first pad made from a fiber blend prepared by a representative mechanical blending method of the invention in which the fibers were blended by a single pass through the blending device (1 Pass) and a second pad made from the same fiber blend prepared by the same method except that the fibers were passed through the blending device four times (4 Pass); two blending device configurations are compared, vertical pin mixer and horizontal pin mixer; and
[0035] FIG. 9D compares the floc area/night ratio for fluff pulp fiber flocs for a pad made from a control fiber mix (simple fan method, SFM) and a pad made from a fiber blend prepared by a pneumatic fiber blending method of the invention (pneumatic loop, PL).

DETAILED DESCRIPTION OF THE INVENTION

[0036] The present invention provides methods for blending first and second fibers to provide fiber blends that include blended fiber flocs composed of a substantially homogeneous blend of first and second fibers.

[0037] In one aspect, the present invention provides a method for blending a mixture of first and second dried cellulose pulp fibers, comprising:

(a) introducing a mixture of first and second dried cellulose pulp fibers into a blending device, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs; and

(b) blending the mixture of first and second dried cellulose pulp fibers in the blending device to provide a blend of first and second dried cellulose pulp fibers, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

[0038] As used herein, the term dried cellulose pulp fibers refers to cellulose pulp fibers (e.g., crosslinked cellulose fibers, cellulose fluff pulp fibers) that have been air dried and that have a moisture content of from about 5% to about 10% by weight of fibers.

[0039] The methods of the invention are illustrated schematically in FIG. 1. Referring to FIG. 1, first fibers and second fibers are introduced into a blending device where the fibers are mixed and blended to provide fiber blends.

[0040] In the methods of the invention, the first and second dried cellulose pulp fibers can be introduced into a blending zone or device as a mixture prepared by low intensity mixing of the first and second fibers. Low intensity mixing can be
achieved by, for example, combining a stream of first dried cellulose pulp fiber in air with a stream of second dried cellulose pulp fiber in air. The air streams carrying the fibers can be combined in any suitable device, such as elbow junction.

[0043] In the methods of the invention, first and second dried fibers are mixed and blended. Mixing refers to simple combination of the first and second dried fibers. Due to their tendency to self-associcate (i.e., aggregate), the first and second dried fibers each include fiber floccs. First fibers include first fiber floccs and second fibers include second fiber floccs. Floccs are defined herein to include fiber aggregates greater than or equal to 2.0 mm². As noted above, the methods of the invention reduce flocc size and provide fibers blends having blended fiber floccs. The first and second dried fibers may also each include fiber nits, which unlike floccs, typically are tightly bound and are difficult to separate into individual fibers. Nits are defined herein to include fiber aggregates smaller than 2.0 mm².

[0044] The methods of the invention provide for blending the first and second fibers. In the methods, first and second fibers are blended in a blending device. Representative pneumatic and mechanical blending devices useful in the methods are described in detail below. As used herein, blending refers to the process by which flocc size is reduced and blended fiber floccs are formed. In the methods, the first and second fiber floccs are subjected to conditions that impart stresses (i.e., energy) sufficient to disrupt the first and second fiber floccs. In this process, the first and second fiber floccs are reduced in size, individual first and second fibers are released from their respective floccs (i.e., fiber singulation), resulting in blending of the released fibers and blending (e.g., homogenation) of the resulting fiber floccs (i.e., blended fiber floccs). As used herein, blended fiber floccs refer to the floccs formed by the method of the invention that include a blend of first and second fibers.

[0045] As noted above, the methods of the invention provide a blend of first and second dried cellulose fibers that includes blended fiber floccs, wherein at least a portion of the blended fiber floccs include a substantially homogeneous blend of first and second fibers. As used herein, substantially homogeneous blend of first and second fibers refers to the composition of the blended fiber floccs produced by the method of the invention. Substantially homogeneous blend refers to the blend of fiber floccs. A plurality of the blended fiber floccs include substantially the same amount of first and second fibers (e.g., 80:20) and the first and second fibers are distributed substantially homogeneously throughout the flocc.

[0046] Cellulose fibers that are characterized as twisted, curled, rigid, and kinked fibers that are relatively highly self-associative and tend to flocc are advantageously blended with secondary fibers by the methods of the invention. Among those fibers that are advantageously blended by the methods of the invention are crosslinked cellulose fibers, such as chemically crosslinked cellulose fibers (e.g., polyacrylic acid crosslinked fibers), flash dried fibers, and anfractuous fibers. Secondary fibers useful in the blending methods of the invention include cellulose fluff pulp fibers.

[0047] The methods of the invention advantageously provide fiber blends that include crosslinked cellulose fibers, for example, fiber blends of chemically crosslinked cellulose fibers and cellulose fluff pulp fibers. For fiber blends that include crosslinked cellulose fibers and cellulose fluff pulp fibers, the initial mixture of fibers can include from about 75 to about 85 percent by weight crosslinked fibers (first fibers) and from about 15 to about 25 percent by weight fluff pulp fibers (second fibers). By the methods of the invention, these fiber mixtures provide fiber blends having blended fiber floccs that can include from about 75 to about 85 percent by weight crosslinked fibers (first fibers) and from about 15 to about 25 percent by weight fluff pulp fibers (second fibers). In the methods of the invention, the fiber blends are provided by pneumatic and mechanical blending techniques, as described in detail below.

[0048] In one embodiment, the method for blending first and second fibers is a pneumatic blending method that utilizes opposed intermeshing air jets. In this embodiment, a mixture of first and second dried cellulose pulp fibers is blended by:

[0051] (a) introducing a mixture of first and second dried cellulose pulp fibers into a first air stream to provide a stream of mixed first and second dried cellulose pulp fibers in air, wherein the first dried cellulose pulp fibers comprise first fiber floccs, and wherein the second dried cellulose pulp fibers comprise second fiber floccs;

[0052] (b) impinging the stream of mixed first and second dried cellulose pulp fibers with a plurality of second air streams in a blending zone to provide a stream of blended first and second dried cellulose pulp fibers in air, wherein the plurality of second air streams impart stresses sufficient to disrupt a plurality of the first and second fiber floccs thereby mixing the first and second dried cellulose fibers from the first and second fiber floccs; and

[0053] (c) conducting the stream of blended first and second dried cellulose pulp fibers from the blending zone to a collection zone to provide a blend of first and second dried cellulose pulp fibers, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber floccs, and wherein at least a portion of the blended fiber floccs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

[0054] In this method, the plurality of second air streams are provided by an interlaced configuration of nozzles on opposing surfaces of the blending zone.

[0055] A representative pneumatic blending method of the invention that utilizes opposing intermeshing air jets is illustrated schematically in FIG. 2. Referring to FIG. 2, a mixture of first and second fibers in an airstream are introduced into a blending device where the first and second fiber mixture is impinged with a plurality of second airstreams to effect fiber blending. The blended fibers exiting the blending zone are conducted to a collection zone where the fiber blend is collected.

[0056] The approach used for pneumatic blending was characterized by impairing very high shear stress to the air stream conveying the mixture of floccs where each flocc consisted of either the first dried cellulose pulp fibers or of the second dried cellulose pulp fibers, and a 4-inch by 4 inch duct of square cross section. The high shear stress was generated by arranging high pressure air nozzles on opposing walls of the duct in an interlaced configuration. Several different interlaced nozzle configurations (blending sections) were considered. In addition, various repeating combinations of blending sections of interlaced nozzles arranged sequentially in the duct were investigated. The number and geometrical arrangement of the jets in the blending sections are not limited to the examples described herein.
Three nozzle window sets were tested: 2-3, 2-2, and 3-3 intermeshing nozzle configuration sets. Each window had 4 vertical nozzle sets with alternating pattern sides. The 2-3 refers to 2 vertical nozzles on one side of the square duct and 3 vertical nozzles on the other side in an intermeshing pattern. The first set of nozzles would have a 2-3 pattern and the next set would have a 3-2 pattern and would continue alternating the pattern for the 4 nozzle sets in the window. Different nozzle combinations were used with different vertical nozzle sets on and off. Some nozzle sets were switched on and off to perform a "Z" pattern through the nozzle exposure window that forced the flocs towards opposite walls of the duct. Patterns of 4 to 15 converging nozzles (nozzle diameter 0.352 in.) were tested and were limited with the amount of air volume to maintain pressure. The total nozzle airflow ranged from 75 to 581 cfm, with pressures from 11 to 55 psig. The flow was under expanded at the nozzle exit and exceeded machining inside the duct. The fiber feed rate was from 2.4 to 21.2 lb/min. The flow velocity in the duct ranged from 40 to 190 ft/s.

A representative pneumatic system useful for carrying out a representative method of the invention had the following characteristics:

- **Square Duct ID**: 3.86 inches
- **ID of Nozzles**: 0.352 inches
- **Number of Nozzles**: 10
- **Ambient Temperature**: 
- **Nozzle Pressure**: 20 psig
- **Fiber Feed Rate**: 7.7 lb/min
- **Air Mass Flow Rate**: 69.9 lb/min
- **Solids Loading Ratio**: 0.11
- **Total Nozzle Airflow**: 501 cfm
- **The following information was derived from high speed video of a trial run using the above characteristics:**
  - **Average Particle Length**: 0.8 inch
  - **Average Floc Speed**: 72.4 mph
  - **Average Air Speed**: 88.5 mph
- **The shear stress required to break apart the flocs into individual fibers was found to be inversely related to the floc size. Large flocs were readily broken up into smaller flocs. However, significantly greater stress (i.e., energy) is required to break up the smaller flocs into individual fibers. The level of shear stress required to break up the flocs can be analytically determined if the floc strength is known. The required shear stress can then be generated using the appropriate air nozzle arrangement, air pressure and flow rates.**
- **The images and results presented herein are exemplary of the fiber blends produced by the methods of the invention. In the representative methods, the first fibers were dried crosslinked cellulose fibers (polyacrylic acid crosslinked fibers, 9% by weight applied based on total weight of fibers) and the second fibers were dried cellulose fluff pulp fibers. The ratio of crosslinked fibers: fluff pulp fibers was 80:20.**

FGS. 4A-C are images of stained pads formed from fibers blends prepared by a representative pneumatic blending method (pneumatic loop air jet impact blending method) of the invention described above. FIG. 4A is an evaluation image where bright white areas correspond to crosslinked fibers and dark black areas correspond to cellulose pulp fibers. FIGS. 4B and 4C identify crosslinked fiber features and fluff pulp features, respectively, white features correspond to flocs and gray features correspond to nits.

The image analysis is done for the crosslinked fiber (XL) features looking at the white images at a specific threshold level and sensitivity as shown in FIG. 4A. A second image analysis for the fluff pulp fiber (Fluff) features looking at the black images at a second specific threshold level and sensitivity as shown in FIG. 4B. The gray material intermediate the white and black features in FIG. 4A represent the blended fibers. The smoother or more even the gray, the more homogeneous the blend. A pad that is uniformly gray represents a highly homogeneous blend having no features.

FIGS. 5A and 5B compare images of a stained pad made from a control fiber mix (5A, nozzles off) and a stained pad made from a fiber blend prepared by a representative pneumatic blending method (pneumatic opposed intermeshing air jet blending method) of the invention (5B, nozzles on).

FIGS. 6A and 6B compare images of a stained pad made from a control fiber mix, low intensity blending (simple fan method, two pneumatic fiber streams coming together in an elbow junction) (6A) and a stained pad made from a fiber blend prepared by high intensity blending (pneumatic loop air jet impact blending method) (6B) representative pneumatic blending method (pneumatic opposed intermeshing air jet blending method).

FIGS. 7A and 7B compare images of a stained pad made from a control fiber mix (7A, nozzles off) and a stained pad made from a fiber blend prepared by a representative pneumatic blending method (pneumatic opposed intermeshing air jet blending method) of the invention (7B, nozzles on).

The homogeneity of fiber blends produced by the method of the invention can be assessed by the floc area/nit area ratio for crosslinked fiber flocs and the floc area/nit area ratio for fluff pulp fiber flocs. The floc area/nit area ratio compares the floc area to the nit area by dividing the total floc area by the total nit area. The methods of the invention reduce total floc area and therefore reduction of the floc area/nit area ratio corresponds to increased fiberization (i.e., singulation of fibers from the floc). The floc area/nit area ratio is a calculated value determined by optical analysis and numerical integration of the respective areas of interest from the images, as described below.

As used herein, the term control fiber mix refers to a fiber mix prepared by a simple fan method in which two pneumatic fiber streams are combined in an elbow junction (pre-mixed) before entering a blending zone used in the methods of the invention.

FIG. 8A compares the floc area/nit area ratio for crosslinked fiber flocs for a pad made from a control fiber mix (Air Off) and a pad made from a fiber blend prepared by the representative pneumatic blending method of the invention (pneumatic opposed intermeshing air jet blending method) described above (Air On). It can be seen that the area occupied by the flocs in the blended material is reduced by 32.8% relative to that of the non blended fiber mixture. FIG. 9A compares the floc area/nit area ratio for fluff pulp fiber flocs for a pad made from a control fiber mix (Air Off) and a pad made from a fiber blend prepared by the representative pneumatic blending method of the invention described above (Air On). The mixture is well blended to stain with. This figure shows that when the mixture is well mixed to start with, further blending is not very effective.

Material was feed through the representative pneumatic blending method without air on to collect a representative feed material without air jet action and is shown in FIGS. 8A and 9A as air off. The XLink floc area to nit area
ratio boxplot in FIG. 8A shows a 32.8% reduction in the floc area/nit area ratio compared to the feed. The Fluff floc area to nit area ratio boxplot in FIG. 9A shows nearly no change on the Fluff features.

(a) introducing a mixture of first and second dried cellulose pulp fibers into a first air stream to provide a stream of mixed first and second dried cellulose pulp fibers in air, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs;

(b) circulating the stream of mixed first and second dried cellulose pulp fibers into a loop blending zone and impacting the stream of mixed first and second dried cellulose pulp fibers with one or more second air streams to provide a stream of blended first and second dried cellulose pulp fibers in air, wherein circulating and impacting the stream of mixed first and second dried cellulose fibers imparts stresses sufficient to disrupt a plurality of the first and second fiber flocs thereby blending the first and second dried cellulose fibers from the first and second fiber flocs; and

(c) conducting the stream of blended first and second dried cellulose pulp fibers from the blending zone to a collection zone to provide a blend of first and second dried cellulose pulp fibers, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogenous blend of first and second dried cellulose pulp fibers.

In this embodiment, the stream of mixed first and second dried cellulose pulp fibers is circulated one or more times in the blending zone.

A representative pneumatic blending method of the invention that utilizes air jet impact on fibers circulating in a loop is illustrated schematically in FIG. 3. Referring to FIG. 3, a mixture of first and second fibers in a first air stream are introduced into a loop blending device and impacted with a second air stream such that the first and second fiber mixture is circulated to effect fiber blending. The blended fibers exiting the blending zone are conducted to a collection zone where the fiber blend is collected.

Representative pneumatic loops useful for carrying out the methods of the invention include devices known as jet driers (e.g., THERMAJET, Fluid Energy Process and Equipment Co., Telford, Pa.). Jet driers are characterized by a pipe configured in a closed loop of a relatively annular shape (similar to that of a doughnut). In these devices, air is introduced tangentially into the closed loop, accelerates in a curved path around the loop and exits the loop in a radially inward direction in the center of the device. A mixture of first and second dried cellulose pulp fibers is introduced into the loop by a first stream of air. The flocs are carried around in the loop in the air stream and exposed to stresses as a tangential (second) air stream impacts them and they collide against the interior surface (pipe wall) as they accelerate around the curved path. The flocs break apart and exit the loop in the radially inward direction with the air when their size has been sufficiently reduced.

Fig. 8D compares the floc area/nit area ratio of crosslinked fiber flocs for a pad made from a control fiber mix (simple fan method, SFM) and a pad made from a fiber blend prepared by the representative pneumatic loop blending method of the invention (pneumatic loop air jet impact blending method) (pneumatic loop, PL) described above. It can be seen that in the mixture formulated by simply combining the two streams of fibers together in an elbow junction, the area occupied by the flocs is almost three times the area occupied by the nit. After blending by the pneumatic loop, the area occupied by flocs of crosslinked fibers is reduced by 57.8% and is only 1.17 times the nit area. FIG. 9D shows the floc area/nit area ratio of fluff and fiber flocs for a pad made from a control fiber mix (simple fan method, SUM) and a pad made from a fiber blend prepared by the representative pneumatic loop blending method of the invention (pneumatic loop, PL) described above. It can be seen that in the mixture formulated by simply combining the two streams of fibers together in an elbow junction that the area occupied by the flocs is over two times the area occupied by the nit. After blending by the pneumatic loop, the area occupied by flocs of crosslinked fibers is reduced by 53.5% and is less than the nit area.

The SUM blended material was used as a feed material to the pneumatic loop. The Xlink floc area to nit area ratio boxplots in FIG. 8D shows the PL has a 57.8% reduction of over the feed SFM. The Fluff floc area to nit area ratio boxplot in FIG. 9D shows the PL has a 53.5% reduction over the feed SFM. Usually the Fluff component has smaller flocs and is easier to break apart. The floc area to nit area ratio is nearly 1 or less and usually indicates effective blending.

Mechanical Blending Method

In a further embodiment, the method for blending first and second fibers is a mechanical blending method that utilizes mechanical mixers. In this embodiment, a mixture of first and second dried cellulose pulp fibers is blended by:

(a) introducing first and second dried cellulose pulp fibers into a mechanical blending device to provide a mixture of first and second dried cellulose pulp fibers, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs;

(b) mechanically blending the mixture of first and second dried cellulose pulp fibers to provide a blend of first and second dried cellulose pulp fibers, wherein mechanical blending imparts stresses sufficient to the mixture of first and second dried cellulose pulp fibers to disrupt a plurality of the first and second fiber flocs thereby blending the first and second dried cellulose fibers from the first and second fiber flocs, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

Mechanical blending can be performed with continuous or batch mixers.

In one embodiment, the methods of the invention are carried out using a batch mixer. Batch mixers can include those having a rotating drum in which blades (called plows) are installed on the inside surface of the drum. In addition to the plows, the drum contains a high speed rotating blade (called a chopper) similar to that used in a kitchen blender. The fiber mixture is loaded into the drum in the desired ratio of the first cellulose fibers and the second cellulose. The plows in the rotating drum direct the fiber mixture to the high
speed chopper blade, which imparts sufficient stress to break apart the flocs and accomplish the blending.

[0099] Suitable batch mixers include batch mixers from Littleford Day (FM130D, Florence, Ky.). The batch mixer was tested at various conditions: plow speeds at 80 and 160 rpm at ambient conditions; mixer fiber loads of 500, 800, 1000, and 1300 grams; chopper speeds of 0, 720, 1440, 2160, and 3600 rpm; and retention times of 1, 2, 5, and 10 minutes. Representative conditions for operation of the batch mixer included a plow speed of 160 rpm, at ambient conditions, at 1000 g loads, and a chopper speed of 3600 rpm. The blending retention time was 1 to 5 minutes, depending on the degree of blending desired. The desired plow configuration does not tend to trap material between mixer wall and plow, and between plows and plow arm.

[0100] FIG. 8B compares the floc area/nit area ratio for crosslinked fiber flocs for a pad made from a control fiber mix (Feed) and two pads (1 minute blend and 5 minutes blend) made from a fiber blend prepared by the representative mechanical blending method of the invention described above. FIG. 9B compares the floc area/nit area ratio for fluid pulp fiber flocs for a pad made from a control fiber mix (Feed) and two pads (1 minute blend and 5 minutes blend) made from a fiber blend prepared by the representative mechanical blending method described above. Both the mixture and blend appear to be well blended. There appear to be more flocs after 1 min in the device and only 3.5% less floc area after 5 mins. This figure also shows that when the mixture is well blended to start with, further blending is not very effective.

[0101] Boxplots are shown in FIGS. 8B and 9B with circles indicating the 8 values measured and the horizontal line representing the mean value of the boxplot. Missing circles indicate no features were found in the stained pad image. The XLink floc area to nit area ratio on FIG. 8B at 1 minute retention time shows a 53.1% reduction in mean value over the original feed material. The 5 minute retention time shows a 67.1% reduction in mean value over the original feed material. The Fluff floc area to nit area ratio on FIG. 9B shows mean boxplot values nearly unchanged. The floc area to nit area ratio is nearly 1 or less and usually indicates effective blending.

[0102] In another embodiment, the methods of the invention are carried out using a continuous mixer. Suitable continuous mixers useful in the methods of the invention include pin mixers in which radial pins are attached to parallel shafts. These non-standard pin mixers use shafts with long pins instead of pin/stud mills containing rotating disks with short pins/studs. These pin mixers have pins/studs moving in selected directions causing shear that tears the flocs apart with high impact. Shear stresses are generated in the flocs between the pins due to differences in the tangential velocity of the pins when the shafts are rotating. These devices can be used with shafts oriented in a vertical position (vertical pin mixer) or in the horizontal position (horizontal pin mixer). These mixers can be used in series (e.g., four units) for inline blending in a duct depending on the degree of blending desired. Both positions were tested at various conditions with 1, 2, 3, and 4 passes at ambient conditions. The fiber feed rate was at 3.8, 7.8, and 11.7 lb/min. The airflow was at 646, 841, and 1025 cfm. The rotor speed was at 3600 rpm with different shaft turning directions. Good performance was obtained when the shafts were in the vertical position, both rotating in the same direction causing shear at 3500 rpm shaft speed and tip speed of 119 ft/sec. The fiber feed rate at ambient temperature was 11.7 lb/min at 646 cfm of airflow in a nominal 6 inch duct.

[0103] FIG. 8C compares the floc area/nit area ratio for crosslinked fiber flocs for a pad made from a control fiber mix (Feed) and a first pad made from a fiber blend prepared by the representative mechanical blending method of the invention described above in which the fibers were blended by a single pass through the blending device (1 Pass) and a second pad made from the same fiber blend prepared by the same method except that the fibers were passed through the blending device four times (4 Pass); two blending device configurations are compared, vertical pin mixer and horizontal pin mixer. FIG. 9C compares the floc area/nit area ratio for fluid pulp fiber flocs for a pad made from a control fiber mix (Feed) and a first pad made from a fiber blend prepared by the representative mechanical blending method described above in which the fibers were blended by a single pass through the blending device (1 Pass) and a second pad made from the same fiber blend prepared by the same method except that the fibers were passed through the blending device four times (4 Pass); two blending device configurations are compared, vertical pin mixer and horizontal pin mixer. The vertical pin mixer results show blending effectiveness and a trend with the number of passes through the device. The first pass reduces the floc area/nit area by 56.8%, and four passes reduce this ratio to 69.7% of the feed.

[0104] FIG. 8C shows the vertical and horizontal pin mixer Xlink floc area to nit area ratio for feed, 1 pass, and 4 passes through the pin mixer. The vertical pin mixer shows a 37.7% reduction of mean values over the feed for 1 pass and a 57.6% reduction of mean values over the feed for 4 passes. The feed passes parallel with the shafts and perpendicular to the pins for the vertical position. The horizontal pin mixer shows a 16.0% reduction of the mean values over the feed for 1 pass and a 45.7% reduction of mean values over the feed for 4 passes. The feed passes perpendicular with the shafts and parallel to the pin set plane for the horizontal position. The XLink floc area to nit area ratio shows a higher percent reduction in mean values in the vertical position over the horizontal position.

[0105] FIG. 9C shows the vertical and horizontal pin mixer Fluff floc area to nit area ratio for feed, 1 pass, and 4 passes through the pin mixer. The vertical pin mixer shows a 47.8% reduction of mean values over the feed for 1 pass and a 69.7% reduction of mean values over the feed for 4 passes. The horizontal pin mixer mean values are about the same for the feed, 1 pass, and 4 passes. This indicates no further blending was observed for the Fluff in horizontal pin mixer.

[0106] Another suitable mixer is a standard pin/stud mill commercially available under the designation CONTRA-PLEX (Hosokawa Alpine, Natick, Mass.). Pin/stud mills have opposing rotating disks, some disks are stationary like a stator, and others are separately driven counter rotating. The outer portion of the disks has pin/studs protruding in multiple alternating rolls. Higher speeds cause higher impacts and classification of size by retaining larger materials for more impacts.

[0107] Image Analysis of Fiber Blends

[0108] As noted above, the methods of the invention provide fiber blends that include blended fiber flocs made up of a substantially homogeneous blend of first and second dried cellulose pulp fibers. The homogeneity of a fiber blend of crosslinked cellulose fibers and cellulose fluff pulp fibers can
be determined by image analysis techniques. The image analysis technique described below provides a quantitative measure of the degree of blending of fibers by the methods of the invention. Image analysis was conducted on fiber pads made from fiber blends produced by the methods of the invention. The image analysis is based on the selective absorption of a dye by cellulose fluff pulp fibers. The selective dyeing of cellulose fluff pulp fibers in the pads including those fibers and crosslinked fibers allows for analysis of the pads by standard imaging techniques.

Fiber blend pads were prepared by collecting 10 grams of fiber blend into a ball with little pressing and no mixing. The fiber ball was then opened by hand without mixing and then pressing the fibers into a pad by applying pressure in the amount of about 5,000 psig. The resulting pad is then trimmed into a 4-inch x 4-inch square. In the image analysis, four 4 x 4-inch square pads were prepared from each fiber blend sample. The pads were then sprayed with Graft's "C" Stain (Integrated Paper Services, Appleton, Wis.), a stain that selectively stains cellulose fluff pulp fibers. Four pads were stained per sample and each pad was sprayed on both major surfaces. After spraying, the pads were dried at 105°C for 30 minutes and then each pad was placed on a flatbed scanner and its image scanned. The scanner was an Agfa Duoscan 2500 (Agfa, Taiwan), operating in an 8-bit grayscale format, having an image area of 76.2 x 76.2 mm, with a pixel resolution of 100 μm per pixel, providing a density range (histogram) of from 0 to 255.

Image analysis using MATLAB software selected Xlink and Fluff features from the 8 images for each condition. The Xlink and Fluff features have different set thresholds and sensitivity values and are held constant for all the analysis. The features selected are those with areas of each standard statistical values of the areas are made. These values are used to prepare a blending evaluation with standard boxplots (i.e., box-whisker plots) of Floc Area to Nit Area Ratio. These primary boxplots and stained images are used together to judge the degree of blending. The floc area and nit area is based on the total areas of that feature. Pads with highly effective blending may have no features and all even gray areas and is difficult to attain due to the stresses needed to break up small nits.

Images of pads made from representative fiber blends produced by the methods of the invention are illustrated in FIGS. 4-7. In these figures, bright white images correspond to crosslinked fibers, dark black images correspond to fluff pulp fibers, and gray areas correspond to blended areas. The image analysis does not look at the gray blended areas. For the purposes of image analysis, features greater then or equal to 2.0 mm² are defined as flocs, and features smaller than 2.0 mm² are defined as nits. A nit is defined as an agglomerates of fibers that cannot be readily individualized (i.e., cannot be readily separated into individual fibers). The ratio of floc area to nit area (floc area/nit area ratio) compares the floc area to the nit area by dividing the total floc area by the total nit area. The methods of the invention reduce total floc area and therefore increased crosslinked fiber fiberization (i.e., crosslinked fiber floc disruption and individualization of crosslinked fibers) increases as the floc area/nit area ratio decreases.

While illustrative embodiments have been illustrated and described, it will be appreciated that various changes can be made therein without departing from the spirit and scope of the invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for blending a mixture of first and second dried cellulose pulp fibers, comprising:
   (a) introducing a mixture of first and second dried cellulose pulp fibers into a blending device, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs; and
   (b) blending the mixture of first and second dried cellulose pulp fibers in the blending device to provide a blend of first and second dried cellulose pulp fibers, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

2. The method of claim 1, wherein the first dried cellulose pulp fibers are crosslinked cellulose fibers.

3. The method of claim 1, wherein the first dried cellulose pulp fibers are flash dried cellulose fibers.

4. The method of claim 1, wherein the first dried cellulose pulp fibers are anhydrofusible fibers.

5. The method of claim 1, wherein the second dried cellulose pulp fibers are cellulose fluff pulp fibers.

6. The method of claim 1, wherein the mixture includes from about 75 to about 85 percent by weight first fibers.

7. The method of claim 1, wherein the mixture includes from about 15 to about 25 percent by weight second fibers.

8. The method of claim 1, wherein the blended fiber flocs comprise from about 75 to about 85 percent by weight first fibers.

9. The method of claim 1, wherein the blended fiber flocs comprise from about 15 to about 25 percent by weight second fibers.

10. The method of claim 1, wherein blending imparts stresses to the mixture sufficient to disrupt a plurality of the first and second fiber flocs.

11. The method of claim 1, wherein blending comprises mechanical blending.

12. The method of claim 1, wherein blending comprises pneumatic blending.

13. A method for blending a mixture of first and second dried cellulose pulp fibers, comprising:
   (a) introducing a mixture of first and second dried cellulose pulp fibers into a first air stream to provide a stream of mixed first and second dried cellulose pulp fibers in air, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs; and
   (b) impinging the stream of mixed first and second dried cellulose pulp fibers with a plurality of second air streams in a blending zone to provide a stream of blended first and second dried cellulose pulp fibers in air, wherein the plurality of second air streams impart stresses sufficient to disrupt a plurality of the first and second fiber flocs thereby mixing the first and second dried cellulose fibers from the first and second fiber flocs; and
   (c) conducting the stream of blended first and second dried cellulose pulp fibers from the blending zone to a collection zone to provide a blend of first and second dried cellulose pulp fibers, wherein the blend of first and second dried cellulose fibers comprises a plurality of
blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

14. The method of claim 13, wherein the one or more air streams are provided by an interlaced configuration of nozzles on opposing surfaces of the blending zone.

15. A method for blending a mixture of first and second dried cellulose pulp fibers, comprising:
   (a) introducing a mixture of first and second dried cellulose pulp fibers into a first air stream to provide a stream of mixed first and second dried cellulose pulp fibers in air, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs;
   (b) circulating the stream of mixed first and second dried cellulose pulp fibers into a loop blending zone and impacting the circulating stream of mixed first and second dried cellulose pulp fibers with one or more second air streams to provide a stream of blended first and second dried cellulose pulp fibers in air, wherein circulating and impacting the stream of mixed first and second dried cellulose fibers imparts stresses sufficient to disrupt a plurality of the first and second fiber flocs thereby blending the first and second dried cellulose fibers from the first and second fiber flocs; and
   (c) conducting the stream of blended first and second dried cellulose pulp fibers from the blending zone to a collection zone to provide a blend of first and second dried cellulose pulp fibers, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

16. The method of claim 15, wherein the stream of mixed first and second dried cellulose pulp fibers is circulated more than once in the blending zone.

17. A method for blending a mixture of first and second dried cellulose pulp fibers, comprising:
   (a) introducing first and second dried cellulose pulp fibers into a mechanical blending device to provide a mixture of first and second dried cellulose pulp fibers, wherein the first dried cellulose pulp fibers comprise first fiber flocs, and wherein the second dried cellulose pulp fibers comprise second fiber flocs;
   (b) mechanically blending the mixture of first and second dried cellulose pulp fibers to provide a blend of first and second dried cellulose pulp fibers, wherein mechanical blending imparts stresses sufficient to the mixture of first and second dried cellulose pulp fibers to disrupt a plurality of the first and second fiber flocs thereby blending the first and second dried cellulose fibers from the first and second fiber flocs, wherein the blend of first and second dried cellulose fibers comprises a plurality of blended fiber flocs, and wherein at least a portion of the blended fiber flocs comprise a substantially homogeneous blend of first and second dried cellulose pulp fibers.

18. The method of claim 17, wherein mechanically blending the mixture of first and second dried cellulose pulp fibers comprises blending in a pin/stud mixer.

19. The method of claim 17, wherein mechanically blending the mixture of first and second dried cellulose pulp fibers comprises blending in batch mixer.

20. The method of claim 17, wherein mechanically blending the mixture of first and second dried cellulose pulp fibers comprises blending in continuous mixer.

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