Title: CROSSLINKED CELLULOSE PRODUCT

Abstract: The present invention provides a bonded cellulosic fibrous product that includes crosslinked cellulosic fibers. Methods for forming the bonded cellulosic fibrous product and personal care absorbent products that include the bonded product are also provided.
CROSSLINKED CELLULOSIC PRODUCT

FIELD OF THE INVENTION

The present invention relates generally to a cellulosic fibrous product and, more particularly, to a bonded cellulosic fibrous product that includes crosslinked cellulosic fibers.

BACKGROUND OF THE INVENTION

Crosslinked cellulosic fibers are advantageously incorporated into a variety of fibrous products to enhance product bulk, resilience, and dryness. Absorbent articles, such as diapers, are typically formed from fibrous composites that include absorbent fibers such as wood pulp fibers, and can additionally include crosslinked cellulosic fibers. When incorporated into absorbent articles, such fibrous composites can provide a product that offers the advantages of high liquid acquisition rate and high liquid wicking capacity imparted by the crosslinked fibers and absorbent fibers, respectively. However, fibrous composites that include relatively high percentages of crosslinked fibers suffer from low sheet strength.

The relatively low strength of sheets that include crosslinked fibers is due to the loss of hydrogen bonding sites that accompanies cellulose crosslinking. As a result of their chemical modification, crosslinked cellulosic fibers have fewer hydroxyl groups that are available for forming hydrogen bonds between fibers. The lower tendency of crosslinked fibers to form interfiber bonds generally precludes their formation into sheets or webs having any significant structural integrity.

Personal care absorbent products, for example, infant diapers, adult incontinence products, and feminine care products, include liquid acquisition and/or distribution layers that serve to rapidly acquire and then distribute acquired liquid to a storage core for retention. To achieve rapid acquisition and distribution, these layers may include crosslinked cellulosic fibers, which impart bulk and resilience to the layers. However, as noted above, webs that include high proportions of crosslinked fibers suffer from a lack of structural integrity. The problem of loss of structural integrity is traditionally addressed by sandwiching webs that include crosslinked fibers between either tissues and nonwoven sheets and secured with an adhesive. Such structures are required to seek to maintain web integrity.
Accordingly, there exists a need for a cellulosic web that possesses the advantageous properties of webs that include crosslinked cellulosic fibers and yet further advantageously maintains its structural integrity. The present invention seeks to fulfill these needs and provides further related advantages.

SUMMARY OF THE INVENTION

In one aspect, the present invention provides a bonded cellulosic fibrous product that includes crosslinked cellulosic fibers. In another embodiment, the product includes a bonding agent. The product can optionally include other fibers alone, absorbent materials alone, or other fibers and absorbent materials.

In another aspect of the invention, methods for forming the bonded cellulosic fibrous product is provided.

In a further aspect, the present invention provides absorbent articles that include the bonded cellulosic fibrous product. The product can be combined with one or more other layers to provide structures that can be incorporated into absorbent articles such as infant diapers, adult incontinence products, and feminine care products.

BRIEF DESCRIPTION OF THE DRAWINGS

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:

FIGURE 1 is a diagrammatic illustration of a representative drum former device and method for forming the product of the invention; and

FIGURE 2 is a diagrammatic illustration of a representative pocket former device and method for forming the product of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In one aspect, the present invention provides a bonded cellulosic fibrous product that includes bonded crosslinked cellulosic fibers. The product possesses the advantageous properties of bulk and resiliency associated with intrafiber crosslinked fibers and the advantage of structural integrity imparted to the structure by the bonding between fibers. The product is a bonded web in which the crosslinked fibers and the bonded structure of the web itself contribute to the resiliency and liquid acquisition performance of the web.
In the present invention, bonding between fibers can be attained by treating the fibers with a crosslinking agent and/or a bonding agent. In one embodiment, the product is formed by treating the crosslinked cellulosic fibers with a crosslinking agent and, if necessary, a crosslinking catalyst. In another embodiment, the product is formed by treating the crosslinked cellulosic fibers with a bonding agent. In a further embodiment, the product is formed by treating the crosslinked cellulosic fibers with a combination of crosslinking agent and, if necessary, catalyst, and bonding agent.

The product can be formed by (1) forming a web of crosslinked cellulosic fibers; (2) treating the web with either (a) a crosslinking agent and, if necessary, a crosslinking catalyst, (b) a bonding agent, or (c) a crosslinking agent and, if necessary, a crosslinking catalyst, and a bonding agent; and (3) heating the web at a temperature and for a time sufficient to effect interfiber crosslinking and bonding between fibers.

In one embodiment, the bonded cellulosic fibrous product includes in situ crosslinked cellulosic fibers. As used herein, the term "in situ crosslinked cellulosic fibers", refers to cellulosic fibers that have been crosslinked during the formation of the web. Therefore, the product is distinguishable from webs that include crosslinked cellulosic fibers that are first formed and then introduced to the web during the web formation process.

For the product includes in situ crosslinked cellulosic fibers, because the fibers are crosslinked during the web formation process (i.e., in situ), the product includes intrafiber crosslinked cellulosic fibers (i.e., fibers having crosslinks within each fiber) that have been interfiber crosslinked (i.e., fibers having crosslinks between fibers). The product has a bonded structure and includes intrafiber crosslinked cellulosic fibers that are further crosslinked to adjacent fibers through interfiber crosslinks. The product possesses the advantageous properties of bulk and resiliency associated with intrafiber crosslinked fibers and the advantage of structural integrity imparted to the structure by the bonding between fibers. The product is a bonded web in which the crosslinked fibers and the bonded structure of the web itself contribute to the resiliency and liquid acquisition performance of the web.

The product can be produced by (1) forming a web of cellulosic fibers, at least some of which having been treated with a crosslinking agent and, if necessary, crosslinking catalyst; and (2) heating the web at a temperature and for a time sufficient
to effect crosslinking. Alternatively, the product can be formed by (1) forming a web of cellulose fibers; (2) treating the web with a crosslinking agent and, if necessary, a crosslinking catalyst; and (3) heating the web at a temperature and for a time sufficient to effect crosslinking.

Suitable fibers useful in forming the product of the invention include cellulose fibers that have been treated with a crosslinking agent and, if necessary, crosslinking catalyst and then dried without curing the crosslinking agent. These dried and treated fibers can be introduced into the forming device for subsequent product formation.

Any one of a number of crosslinking agents and crosslinking catalysts, if necessary, can be used to provide the product of the invention. The following is a representative list of useful crosslinking agents and catalysts. Each of the patents noted below is expressly incorporated herein by reference in its entirety.

Suitable urea-based crosslinking agents include substituted ureas such as methylolated ureas, methylolated cyclic ureas, methylolated lower alkyl cyclic ureas, methylolated dihydroxy cyclic ureas, dihydroxy cyclic ureas, and lower alkyl substituted cyclic ureas. Specific urea-based crosslinking agents include dimethylidihydroxy urea (DMDHU, 1,3-dimethyl-4,5-dihydroxy-2-imidazolidinone), dimethyloldihydroxy-ethylene urea (DMDHEU, 1,3-dihydroxymethyl-4,5-dihydroxy-2-imidazolidinone), dimethylol urea (DMU, bis[N-hydroxymethyl]urea), dihydroxyethylene urea (DHEU, 4,5-dihydroxy-2-imidazolidinone), dimethylolethylene urea (DMEU, 1,3-dihydroxymethyl-2-imidazolidinone), and dimethylidihydroxyethylene urea (DDI, 4,5-dihydroxy-1,3-dimethyl-2-imidazolidinone).

Suitable crosslinking agents include dialdehydes such as C₂-C₈ dialdehydes (e.g., glyoxal), C₂-C₈ dialdehyde acid analogs having at least one aldehyde group, and oligomers of these aldehyde and dialdehyde acid analogs, as described in U.S. Patents Nos. 4,822,453; 4,888,093; 4,889,595; 4,889,596; 4,889,597; and 4,898,642. Other suitable dialdehyde crosslinking agents include those described in U.S. Patents Nos. 4,853,086; 4,900,324; and 5,843,061.

Other suitable crosslinking agents include aldehyde and urea-based formaldehyde addition products. See, for example, U.S. Patents Nos. 3,224,926;
3,241,533; 3,932,209; 4,035,147; 3,756,913; 4,689,118; 4,822,453; 3,440,135; 4,935,022; 3,819,470; and 3,658,613.

Suitable crosslinking agents include glyoxal adducts of ureas, for example, U.S. Patent No. 4,968,774, and glyoxal/cyclic urea adducts as described in U.S. Patents Nos. 4,285,690; 4,332,586; 4,396,391; 4,455,416; and 4,505,712.

Other suitable crosslinking agents include carboxylic acid crosslinking agents such as polycarboxylic acids. Polycarboxylic acid crosslinking agents (e.g., citric acid, propane tricarboxylic acid, and butane tetracarboxylic acid) and catalysts are described in U.S. Patents Nos. 3,526,048; 4,820,307; 4,936,865; 4,975,209; and 5,221,285. The use of C₂-C₉ polycarboxylic acids that contain at least three carboxyl groups (e.g., citric acid and oxydisuccinic acid) as crosslinking agents is described in U.S. Patents Nos. 5,137,537; 5,183,707; 5,190,563; 5,562,740, and 5,873,979.

Polymeric polycarboxylic acids are also suitable crosslinking agents. Suitable polymeric polycarboxylic acid crosslinking agents are described in U.S. Patents Nos. 4,391,878; 4,420,368; 4,431,481; 5,049,235; 5,160,789; 5,442,899; 5,698,074; 5,496,476; 5,496,477; 5,728,771; 5,705,475; and 5,981,739. Polycrylic acid and related copolymers as crosslinking agents are described U.S. Patents Nos. 6,306,251; 5,549,791; and 5,998,511. Polymaleic acid crosslinking agents are described in U.S. Patent No. 5,998,511.

Specific suitable polycarboxylic acid crosslinking agents include citric acid, tartaric acid, malic acid, succinic acid, glutaric acid, citraconic acid, itaconic acid, tartrate monosuccinic acid, maleic acid, polyacrylic acid, polymethacrylic acid, polymaleic acid, polymethylvinylether-co-maleate copolymer, polymethylvinylether-co-itaconate copolymer, copolymers of acrylic acid, and copolymers of maleic acid.

Other suitable crosslinking agents are described in U.S. Patents Nos. 5,225,047; 5,366,591; 5,556,976; and 5,536,369.

Suitable catalysts can include acidic salts, such as ammonium chloride, ammonium sulfate, aluminum chloride, magnesium chloride, magnesium nitrate, and alkali metal salts of phosphorous-containing acids. In one embodiment, the crosslinking catalyst is sodium hypophosphite.

Mixtures or blends of crosslinking agents and catalysts can also be used.
The crosslinking agent is applied to the cellulosic fibers in an amount sufficient to effect intrafiber crosslinking and interfiber crosslinking as described above. The amount applied to the cellulosic fibers can be from about 1 to about 10 percent by weight based on the total weight of fibers. In one embodiment, crosslinking agent in an amount from about 4 to about 6 percent by weight based on the total weight of fibers.

Suitable cellulosic fibers for forming the product of the invention include those known to those skilled in the art and include any fiber or fibrous mixture that can be crosslinked and from which a fibrous web or sheet can be formed.

Although available from other sources, cellulosic fibers are derived primarily from wood pulp. Suitable wood pulp fibers for use with the invention can be obtained from well-known chemical processes such as the kraft and sulfite processes, with or without subsequent bleaching. Pulp fibers can also be processed by thermomechanical, chemithermomechanical methods, or combinations thereof. The preferred pulp fiber is produced by chemical methods. Groundwood fibers, recycled or secondary wood pulp fibers, and bleached and unbleached wood pulp fibers can be used. Softwoods and hardwoods can be used. Details of the selection of wood pulp fibers are well known to those skilled in the art. These fibers are commercially available from a number of companies, including Weyerhaeuser Company, the assignee of the present invention. For example, suitable cellulose fibers produced from southern pine that are usable with the present invention are available from Weyerhaeuser Company under the designations CF416, NF405, PL416, FR516, and NB416.

The wood pulp fibers useful in the present invention can also be pretreated prior to use. This pretreatment may include physical treatment, such as subjecting the fibers to steam, or chemical treatment.

Although not to be construed as a limitation, examples of pretreating fibers include the application of surfactants or other liquids, which modify the surface chemistry of the fibers. Other pretreatments include incorporation of antimicrobials, pigments, dyes and densification or softening agents. Fibers pretreated with other chemicals, such as thermoplastic and thermosetting resins also may be used. Combinations of pretreatments also may be employed. Similar treatments can also be applied after formation of the fibrous product in post-treatment processes.

In addition to natural fibers, synthetic fibers including polymeric fibers, such as polyolefin, polyamide, polyester, polyvinyl alcohol, polyvinyl acetate fibers, can also be incorporated into the product. Suitable synthetic fibers include, for example, polyethylene terephthalate, polyethylene, polypropylene, nylon, and rayon fibers.

Other suitable synthetic fibers include those made from thermoplastic polymers, cellulosic and other fibers coated with thermoplastic polymers, and multicomponent fibers in which at least one of the components includes a thermoplastic polymer.
Single and multicomponent fibers can be manufactured from polyester, polyethylene, polypropylene, and other conventional thermoplastic fibrous materials. Single and multicomponent fibers are commercially available. Suitable bicomponent fibers include CELBOND fibers available from Hoechst-Celanese Company. The product can also include combinations of natural and synthetic fibers.

In one embodiment, the product further includes a bonding agent. The bonding agent serves to further enhance the structural integrity of the product. Suitable bonding agents include thermoplastic materials, such as bicomponent fibers and latexes, and wet strength agents. When the bonding agent is a thermoplastic fiber, the fiber can be combined with cellulosic fibers and then formed into the web to be subsequently heated. When the bonding agent is a wet strength agent, the bonding agent can be applied to the web prior to subjecting the web to fiber crosslinking conditions (i.e., curing).

Suitable thermoplastic fibers include cellulosic and other fibers coated with thermoplastic polymers, and multicomponent fibers in which at least one of the components includes a thermoplastic polymer. Single and multicomponent fibers can be manufactured from polyester, polyethylene, polypropylene, and other conventional thermoplastic fibrous materials. Single and multicomponent fibers are commercially available. Suitable bicomponent fibers include CELBOND fibers available from Hoechst-Celanese Company.

Suitable wet strength agents include cationic modified starch having nitrogen-containing groups (e.g., amino groups) such as those available from National Starch and Chemical Corp., Bridgewater, NJ; latex; wet strength resins, such as polyamide-epichlorohydrin resin (e.g., KYMENE 557LX, Hercules, Inc., Wilmington, DE), and polyacrylamide resin (see, e.g., U.S. Patent No. 3,556,932 and also the commercially available polyacrylamide marketed by American Cyanamid Co., Stanford, CT, under the trade name PAREZ 631 NC); urea formaldehyde and melamine formaldehyde resins; and polyethylenimine resins. A general discussion on wet strength resins utilized in the paper field, and generally applicable in the present invention, can be found in TAPPI monograph series No. 29, "Wet Strength in Paper and Paperboard", Technical Association of the Pulp and Paper Industry (New York, 1965).
In other embodiments, the product can include other fibers. Other fibers include, for example, the cellulosic fibers, particularly the wood pulp fibers described above, as well as hemp, bagasse, cotton, groundwood, bleached and unbleached pulp, recycled or secondary fibers.

For embodiments of the product in which liquid retention is desired, the product can further include absorbent material (e.g., superabsorbent polymer particles). As used herein, the term "absorbent material" refers to a material that absorbs liquid and that generally has an absorbent capacity greater than the cellulosic fibrous component of the composite. Preferably, the absorbent material is a water-swellable, generally water-insoluble polymeric material capable of absorbing at least about 5, desirably about 20, and preferably about 100 times or more its weight in saline (e.g., 0.9 percent saline).

The amount of absorbent material present in the product can vary greatly depending on the product's intended use. Absorbent material can be present in the product in an amount greater than about 0.5 percent by weight based on the total weight of the product.

The absorbent material may include natural materials such as agar, pectin, and guar gum, and synthetic materials, such as synthetic hydrogel polymers. Synthetic hydrogel polymers include, for example, carboxymethyl cellulose, alkaline metal salts of polyacrylic acid, polyacrylamides, polyvinyl alcohol, ethylene maleic anhydride copolymers, polyvinyl ethers, hydroxypropyl cellulose, polyvinyl morpholinone, polymers and copolymers of vinyl sulphonylic acid, polyacrylates, polyacrylamides, and polyvinyl pyridine among others. In one embodiment, the absorbent material is a superabsorbent material. As used herein, a "superabsorbent material" refers to a polymeric material that is capable of absorbing large quantities of fluid by swelling and forming a hydrated gel (i.e., a hydrogel). In addition to absorbing large quantities of fluids, superabsorbent materials can also retain significant amounts of bodily fluids under moderate pressure.

Superabsorbent materials generally fall into three classes: starch graft copolymers, crosslinked carboxymethylcellulose derivatives, and modified hydrophilic polyacrylates. Examples of such absorbent polymers include hydrolyzed starch-acrylonitrile graft copolymers, neutralized starch-acrylic acid graft copolymers,
saponified acrylic acid ester-vinyl acetate copolymers, hydrolyzed acrylonitrile
copolymers or acrylamide copolymers, modified crosslinked polyvinyl alcohol,
neutralized self-crosslinking polyacrylic acids, crosslinked polyacrylate salts,
carboxylated cellulose, and neutralized crosslinked isobutylene-maleic anhydride
copolymers.

Superabsorbent materials are available commercially, for example,
polyacrylates from Clariant of Portsmouth, Virginia. These superabsorbent polymers
come in a variety of sizes, morphologies, and absorbent properties (available from
Clariant under trade designations such as IM 3500 and IM 3900). Other superabsorbent
materials are marketed under the trademarks SANWET (supplied by Sanyo Kasei
Kogyo Kabushiki Kaisha), and SXM77 (supplied by Stockhausen of Greensboro, North
Carolina). Other superabsorbent materials are described in U.S. Patent No. 4,160,059;
U.S. Patent No. 4,676,784; U.S. Patent No. 4,673,402; U.S. Patent No. 5,002,814; U.S.
Patent No. 5,057,166; U.S. Patent No. 4,102,340; and U.S. Patent No. 4,818,598, all
expressly incorporated herein by reference. Products such as diapers that incorporate
superabsorbent materials are described in U.S. Patent No. 3,699,103 and U.S. Patent
No. 3,670,731.

Suitable superabsorbent materials useful in the product include superabsorbent
particles and superabsorbent fibers.

In another aspect of the invention, methods for forming the bonded cellulosic
fibrous product are provided. In one embodiment, the product is formed using a drum
former. In another embodiment, the product is formed using a pocket former.

As described above, the product of the invention is formed by subjecting a web
that includes cellulosic fibers treated with crosslinking agent and, if necessary,
crosslinking catalyst, and bonding agent, if included, to a temperature and for a time
sufficient to effect crosslinking (i.e., curing) and fiber bonding. The curing of the
crosslinking agent to provide the product can be performed by several methods.
Crosslinking typically requires a relatively high temperature (180°C) and long reaction
times (greater than 4 minutes). In one embodiment, the product is formed by heating in
a curing oven in which high temperature and large volumes of air are drawn through
the web. In another embodiment, curing takes place after the webs have been placed in
boxes for shipping. In this embodiment, boxes containing the treated webs are passed through a dryer (e.g., a kiln dryer) to complete the crosslinking reaction.

In one embodiment, the product is produced using pocket forming (mold) technology. In this method, fibers (e.g., crosslinked cellulosic fibers treated with crosslinking agent and, if necessary, catalyst, and optional thermoplastic fibers; or cellulosic fibers treated with crosslinking agent and, if necessary, catalyst, and optional thermoplastic fibers) are introduced into a forming device that includes a pocket or mold that forms the fibers into a desired shape (e.g., the shape of an acquisition zone to be used in an absorbent product such as an infant diaper, adult incontinence product, or feminine care product). For embodiments that do not include thermoplastic fibers and that do include another bonding agent such as a wet strength agent, the bonding agent can be applied to the fibers prior to curing. For embodiments that do not include introducing cellulosic fibers treated with crosslinking agent to the former, the crosslinking agent can be applied to the fibers at a point prior to their curing.

In one embodiment, the product is produced by heating the pockets in which the treated cellulosic fiber web is formed. By such a method, bonded webs having the desired shapes are directly formed. By this method, a continuous web of the desired shape can be formed and packaged into a box ready for shipping and subsequent use by the absorbent product producer.

In one embodiment, the product is formed by airlaying crosslinked cellulosic fibers and bicomponent fibers.

In another embodiment, the product is formed by airlaying crosslinked cellulosic fibers and a wet strength agent.

In a further embodiment, the product is formed by airlaying crosslinked cellulosic fibers and a crosslinking agent and, if necessary, catalyst.

In another embodiment, the product is formed by airlaying cellulosic fibers treated with a crosslinking agent and, if necessary, crosslinking catalyst, and bicomponent fibers, and then heating the airlaid fibers to cure the crosslinking agent and effect fiber bonding.

The product of the present invention can be formed as an extended web or sheet that has structural integrity and sheet strength sufficient to permit the fibrous web to be rolled, transported, and used in rolled form in subsequent processes.
The product of the present invention can be supplied in a fibrous rolled form and readily incorporated into subsequent processes. The product can be advantageously incorporated into a variety of absorbent articles, such as diapers, including disposable diapers and training pants; feminine care products, including sanitary napkins, tampons, and pant liners; adult incontinence products; toweling; surgical and dental sponges; bandages; food tray pads; and the like.

The performance characteristics of a representative bonded web formed in accordance with the present invention (a bonded web including in situ crosslinked fibers) is described below. The acquisition rate (ml/sec) for four liquid insults, rewet (g), median uptake pressure (MUP) capacity (g/g), and median desorption pressure (MDP, cm) for representative bonded webs compared to controls are presented in Table 1.

In Table 1, Control A refers to a commercial infant diaper (Procter & Gamble) having a crosslinked cellulosic fiber acquisition layer; and Control B refers to a commercial infant diaper (PAMPERS) having a dual acquisition layer composed of a 44 gam synthetic layer and 300 gsm crosslinked fiber (citric acid crosslinked fibers) layer. Webs 1A, 2A, 1B, and 2B refer to representative products of the invention. Webs 1A and 1B refer to products formed from 100 percent by weight flash-dried cellulosic fibers treated with citric acid as crosslinking agent (about 6 percent by weight based on the total weight of fibers) and a catalyst. Webs 2A and 2B refer to products formed from 90 percent by weight flash-dried cellulosic fibers treated with citric acid as crosslinking agent (about 6 percent by weight based on the total weight of fibers) and a catalyst and 10 percent by weight bicomponent binder fibers (CELBOND T105). The target basis weight for Webs 1A and 2A was 150 g/m², and the target basis weight for Webs 1B and 2B was 300 g/m².
TABLE 1. PERFORMANCE CHARACTERISTICS OF REPRESENTATIVE PRODUCTS.

<table>
<thead>
<tr>
<th>Web</th>
<th>Density (g/cm³)</th>
<th>Basis Weight (g/m²)</th>
<th>Acquisition Rate (ml/sec)</th>
<th>Rewet (g)</th>
<th>MUP Capacity (g/g)</th>
<th>MDP (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Control A</td>
<td>0.08</td>
<td>300</td>
<td>3.07</td>
<td>1.65</td>
<td>0.80</td>
<td>0.44</td>
</tr>
<tr>
<td>Control B</td>
<td>0.08</td>
<td>344</td>
<td>3.37</td>
<td>1.68</td>
<td>0.91</td>
<td>0.52</td>
</tr>
<tr>
<td>Web 1A</td>
<td>0.046</td>
<td>142</td>
<td>3.38</td>
<td>1.86</td>
<td>0.97</td>
<td>0.50</td>
</tr>
<tr>
<td>Web 2A</td>
<td>0.041</td>
<td>152</td>
<td>3.94</td>
<td>2.08</td>
<td>1.08</td>
<td>0.58</td>
</tr>
<tr>
<td>Web 1B</td>
<td>0.046</td>
<td>275</td>
<td>5.26</td>
<td>2.86</td>
<td>1.48</td>
<td>0.87</td>
</tr>
<tr>
<td>Web 2B</td>
<td>0.042</td>
<td>294</td>
<td>6.60</td>
<td>3.40</td>
<td>1.90</td>
<td>1.02</td>
</tr>
</tbody>
</table>

In a further aspect, the present invention provides absorbent articles that include the bonded cellulosic fibrous product. The product can be combined with one or more other layers to provide structures that can be incorporated into absorbent articles such as infant diapers, adult incontinence products, and feminine care products.

While the preferred embodiment of the invention has 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 making a cellulosic fibrous product, comprising:
   (a) airdrying crosslinked cellulosic fibers to provide a fibrous web;
   (b) treating the web with an amount of a bonding agent effective to provide a bonded product; and
   (c) heating the web to effect bonding between the fibers to provide a bonded cellulosic fibrous product.

2. The method of Claim 1, wherein the bonding agent comprises a latex.

3. The method of Claim 1, wherein the bonding agent comprises a wet strength agent.

4. The method of Claim 1 further comprising airdrying thermoplastic fibers with the crosslinked fibers.

5. The method of Claim 1, wherein the fibrous web further comprises other cellulosic fibers.

6. The method of Claim 1, wherein the fibrous web further comprises absorbent material.

7. A bonded cellulosic fibrous product, comprising airdried crosslinked cellulosic fibers treated with an amount of a bonding agent effective to provide a bonded cellulosic fibrous product.

8. The product of Claim 7, wherein the bonding agent comprises a latex.

9. The product of Claim 7, wherein the bonding agent comprises a wet strength agent.

10. The product of Claim 7, wherein the bonding agent comprises thermoplastic fibers.
11. The product of Claim 7 further comprising other cellulosic fibers.

12. The product of Claim 7 further comprising absorbent material.

13. A method for making a cellulosic fibrous product, comprising:
   (a) airlaying cellulosic fibers to provide a fibrous web, wherein at least a portion of the cellulosic fibers are treated with an amount of crosslinking agent effective to provide a bonded product; and
   (b) heating the web to provide a bonded cellulosic fibrous product.

14. The method of Claim 13 further comprising airlaying thermoplastic fibers with the cellulosic fibers.

15. The method of Claim 13, wherein the fibrous web further comprises other cellulosic fibers.

16. The method of Claim 13, wherein the fibrous web further comprises absorbent material.

17. A bonded cellulosic fibrous product, comprising airlaid cellulosic fibers, wherein at least a portion of the cellulosic fibers are treated with an amount of crosslinking agent effective to provide a bonded product.

18. The product of Claim 17 further comprising thermoplastic fibers.

19. The product of Claim 17 further comprising other cellulosic fibers.

20. The product of Claim 17 further comprising absorbent material.

21. A method for making a cellulosic fibrous product, comprising:
   (a) airlaying cellulosic fibers to provide a fibrous web, wherein at least a portion of the cellulosic fibers are treated with an amount of crosslinking agent effective to provide a bonded product;
   (b) treating the web with an amount of a bonding agent effective to provide a bonded product; and
(c) heating the web to provide a bonded cellulosic fibrous product.

22. The method of Claim 21, wherein the bonding agent comprises a latex.

23. The method of Claim 21, wherein the bonding agent comprises a wet strength agent.

24. The method of Claim 21 further comprising airlaying thermoplastic fibers with the cellulosic fibers.

25. The method of Claim 21, wherein the fibrous web further comprises other cellulosic fibers.

26. The method of Claim 21, wherein the fibrous web further comprises absorbent material.

27. A bonded cellulosic fibrous product, comprising airlaid cellulosic fibers treated with an amount of a bonding agent effective to provide a bonded cellulosic fibrous product, wherein at least a portion of the cellulosic fibers are treated with a crosslinking agent.

28. The product of Claim 27, wherein the bonding agent comprises thermoplastic fibers.

29. The product of Claim 27, wherein the bonding agent comprises a latex.

30. The product of Claim 27, wherein the bonding agent comprises a wet strength agent.

31. The product of Claim 27 further comprising other cellulosic fibers.

32. The product of Claim 27 further comprising absorbent material.

33. A personal care absorbent product comprising the product of any one of Claims 7, 17, or 27.

34. The product of Claim 33, wherein the product is at least one of an infant diaper, adult incontinence product, and a feminine hygiene product.
treated fiber, bonding agent, other ingredients

headbox

pocket

drum pocket former

scavenging device

waste collection

bonded web

FIGURE No. 2