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(54) **FIBROUS NONWOVEN WEB**

(57) The present invention relates to a fibrous nonwoven web, a method for its preparation as well as to uses of the novel fibrous nonwoven web.

EP 3 550 062 A1

Description

[0001] The present invention relates to a fibrous nonwoven web, a method for its preparation as well as to uses of the novel fibrous nonwoven web.

Prior art

[0002] Fibrous nonwoven webs are employed in a wide variety of technical fields, from flushable toilet paper and baby wipes to industrial wipes. These nonwoven fabrics often employ pulps as well as viscose fibers. If a higher mechanical strength is required thermoplastic binders, which may be in powder or fibrous shape as well as reinforcing fibers are employed as it is considered as impossible to ensure the required strength without using these components.

[0003] US 4,755,421 discloses a nonwoven fibrous web, comprising cellulosic fibers as well as pulp fibers, typically in a weight ratio of (5 to 30):(95 to 70). The web is designed to be employed as flushable toilet paper, i.e. the web is intended to be disintegrated in water under mild agitation conditions. The cellulosic fibers are rayon fibers having a titer of from 3.3 to 6.7. The pulp is not specified any further.

[0004] US 6,287,419 discloses a water decomposable nonwoven fabric including first and second regenerated cellulosic fibers and a natural fiber. These different fibers are characterized by means of their fiber lengths and the natural fiber preferably is a pulp fiber. If an increase of mechanical properties is desired, US 6,287,419 emphasizes the importance of employing binder resins.

[0005] EP 2 441 869 discloses a water disintegrable fiber sheet, comprising two different types of pulp, a fibrillated cellulose and a regenerated cellulose fiber. These sheets are intended to be used as simple wipes for one time use and are designed to disintegrate mild agitation conditions, such as the flushing of a toilet, so that they can be easily disposed after use.

[0006] US 2004/0013859 discloses a fibrous nonwoven web material comprising manmade cellulose fibers, natural cellulose fibers and synthetic binder fibers. Again the web is intended to be disintegrated by mild agitation conditions, such as the flushing of a toilet, so that the wipes produced from this web can be easily disposed after use.

[0007] These prior art approaches, while providing serviceable wipes, often suffer from the drawback that at least three different fiber materials are to be employed, or that synthetic binder materials, such as synthetic fibers are required to provided sufficient mechanical strength. The use of such synthetic fibers has a detrimental effect on the sustainability of the product, as for example petroleum based materials are used as binder materials. In addition, the use of synthetic binder materials has a negative effect on biodegradability, as for example not all components of the web are decomposed in a suitable time frame and additional filtration and/or purification steps are required in waste water treatment plants (for example for flushable toilet papers or baby wipes comprising such materials).

[0008] Several types of wipes based on cellulosic fibers are already commercially available. The possible uses extend from baby wipes and moist toilet paper (i.e. low mechanical strength webs typically comprising pulp and viscose fibers) to industrial wipes (i.e. high mechanical strength webs which comprise binder fiber and/or reinforcing fibers, typically synthetic fibers such as olefin based fiber or PET fibers). Commercially available industrial wipes do show basis weights in the range of from 20 to 100 g/m², with tensile strength properties (machine direction, MD) in the range of from 10 to 100 N/5cm (dry and wet, with the wet tensile strength being somewhat lower). For the wipes with less demands for mechanical properties the respective measures are in the range of from 50 to 120 g/m² and from 10 to 80 N/5cm. With such webs water retention values (WRV) and liquid absorption capacities (LAC) of from 10 to 50% and from 350 to 1000 %, respectively, can be achieved. It is however interesting to note that even the low strength webs, used as baby wipes, do employ synthetic fibers, such as polyester fibers, polyolefin fibers etc. so that even those products for which rather low or intermediate levels of mechanical strength properties are required, are not 100% based on materials produced from renewable sources and introduce synthetic non-biodegradable materials into the waste treatment systems. It therefore seems that the market demands in relation with mechanical properties so far cannot be answered by webs bases exclusively on cellulosic materials.

[0009] However, as with the wipes disclosed in the above discussed prior art documents, also the commercially available wipes do suffer from drawbacks, such as the requirement that petroleum based fibers, such as polyolefin fibers or polyester fibers, are essential to achieve high mechanical strength levels, or the use of cellulosic fibers which require a specific fibrillation treatment or are based on regenerated cellulose fibers requiring the use of chemicals which cannot be reused.

Object of the present invention

[0010] It would therefore be preferably if a fibrous nonwoven web material would be available, which ensures high mechanical strength levels without requiring the use of synthetic binder or reinforcing fibers. At the same time it would be advantageous if such a web material could be provided requiring only a minimal number of fibrous materials while

still enabling the preparation of a nonwoven web or fabric suitable as wipe in a wide variety of applications. It also would be advantageous if such as web would require only the presence of decomposable fibers, preferably fibers which do not require any post fiber productions treatments, such as chemical fibrillation treatments, and if the fibers to be employed are either natural fibers or regenerated fibers which can be produced in an efficient as well as environmentally friendly way, for example in a manner enabling a vast degree of re-use of any chemicals required for the regeneration process.

Brief description of the invention

[0011] The present invention achieves this goal with the fibrous nonwoven web as defined in claims 1 to 9, as well as with the process as defined in claims 10 to 15. Further embodiments and illustrations of the present invention are outlined in the following.

Detailed description of the invention

[0012] As outlined in claim 1, one essential component of the web of the present invention is a pulp. This pulp may be of any origin, as long as the requirements as outlined in claim 1 are met, in particular the fiber length of from 1.5 to 5 mm, preferably from 2 to 5 mm, and in particular from 2.2 to 2.8 mm, such as from 2.4 to 2.6 mm. The pulp may be a bleached or unbleached pulp, and preferably the pulp has a fines content (LWL (%)) of from 1 to 5, preferably 2 to 4, more preferably 2.5 to 3.5. In embodiments the pulp may have a coarseness (mg/100m) of from 5 to 25, preferably 8 to 20, more preferably from 10 to 15, such as from 12 to 14. A particular preferred pulp material has a fiber length (LWL, mm) of from 2.2 to 2.8 mm, a fiber coarseness of from 10 to 15 and a fines content of from 2.5 to 3.5. Such a pulp is commercially available at low costs and contributes to the overall commercial feasibility of the fibrous web of the present invention.

[0013] As also outlined in claim 1, a second essential component of the web of the present invention is a lyocell fiber having a length of from 5 to 25 mm. Preferably the length is from 7 to 20 mm, and in particular from 8 to 15 mm, such as from 10 to 12 mm. The lyocell fiber may be a standard fiber, a fiber containing a matting agent, a fibrillated fiber etc. As long as the fiber has a length as indicated above, the type of the lyocell fiber has no relevant influence on the essential product properties discussed further below. Preferably, the lyocell fiber has a titer in the range of from 0.9 to 3.3 dtex, more preferably from 1.15 to 2.5 dtex, most preferably from 1.3 to 2 dtex, such as 1.4 or 1.7 dtex. A particular suitable lyocell fiber has a fiber length of from 8 to 15 mm and a titer of from 1.3 to 2 dtex. Such fibers are commercially available, for example under the tradename LENZING™ Lyocell Shortcut from the company Lenzing AG.

[0014] In a preferred embodiment these two fiber types, i.e. pulp and lyocell fiber, are the only fibrous components present in the web according to the present invention. Preferably, these two fiber components amount to 90 wt.-% or more, more preferably 95 wt.-% or more, even more preferably 98 wt.-% or more of the web (based on the dry weight of the web). In Embodiments of the present invention, the fibrous nonwoven web according to the present invention contains only pulp and lyocell fibers, and any unavoidable processing additives. In embodiments, the web however may also contain additional components, in amounts of typically not exceeding 10 wt.-% in total, such as other types of cellulose based fibers, including viscose fibers, fibers made from cellulose derivatives, such as carboxymethyl cellulose etc., other fibers based on natural and/or renewable resources, such as hemp fibers etc., and in embodiments also synthetic fibers. However, it is preferred that the web comprises only fibers based on natural and/or renewable resources, in particular only cellulose based fibers.

[0015] The weight ratio of pulp to lyocell fiber is as defined in claim 1, with the pulp fibers amounting to at least 35%, preferably at least 40% and in particular 50% or more, based on the weight of pulp and lyocell fibers. Preferably, this weight ratio is from 90:10 to 50:50, more preferably from 85:15 to 55:45. Particularly suitable weight ratios are in the range of from 80:20 to 60:40, in embodiments 70:30. However, in particular when the weight of the pulp amounts to at least 50%, the mixtures of pulp and lyocell enable the preparation of webs with the desired balance of properties, while maintaining cost effectiveness.

[0016] As will be later explained in greater detail in the context of the process for preparing the web of the present invention, pulp and lyocell fibers are mixed thoroughly prior to the preparation of the web, to ensure a uniform admixture and uniform web properties. Such a mixing typically involves mixing in an aqueous medium, preferably in water. Suitable mixing devices and mixing parameters (agitation, shear rate, amount of fibers in the aqueous medium) are known to the skilled person.

[0017] The fibrous nonwoven web in accordance with the present invention typically has a basis weight in the range of from 25 to 200 gsm, such as from 50 to 175 gsm, preferably from 60 to 150 gsm. Such basis weights are usual in the field of fibrous webs employed for wipes, but the webs in accordance with the present invention do provide a unique combination of mechanical properties at these basis weights, without requiring the presence of synthetic reinforcing fibers or synthetic binders for high mechanical strength levels, or without requiring the use of mixtures of three or even more types of fibers, for lower mechanical strength levels.

5 [0018] As will be explained further in relation with the process of the present invention, it is possible, simply by adjusting the weight ratio between pulp and lyocell fibers and, to a lesser extent also by adjusting optionally the fiber lengths, to tailor the final mechanical properties of the resulting web by means of the energy consumption (i.e. energetic impact on the web materials during hydroentangling the fibers) during hydroentangling, to produce either webs with a lower mechanical strength level (lower energy consumption) or with a higher strength level (higher energy consumption), which typically in the prior art are only achievable by means of employing synthetic reinforcing fibers or binders (in powder or fiber shape). Higher strength levels in accordance with the present invention are strength levels represented by tensile strength (MD, dry, N/5cm) of more than 50 and in embodiments up to 150 or more. In comparison to the commercial high strength wipes, which do show a tensile strength of from about 30 up to 100 (MD, dry, N/5cm), the strength levels achieved by the present invention must be considered as extremely surprising, as all the high strength level materials know in the prior art, for similar but still lower strength levels, require the use of reinforcing and/or binder fibers, such as polyolefin or polyester fibers. It was be no means foreseeable that the rather simple fiber mixture in accordance with the present invention as explained and illustrated above, which does not even require the presence of reinforcing or binder fibers, enables the provisions of nonwoven materials with at least equal, but in embodiments even higher strength levels.

15 [0019] Accordingly, the present invention provides a fibrous nonwoven web, which is based in fiber materials which are biodegradable and which are furthermore based on natural, i.e. renewable/sustainable raw materials. The use of petrochemical based materials is not required in accordance with the present invention and the lyocell fiber employed in the present invention is produced by a process which reuses to a great extent all chemicals employed, in particular the solvent required for dissolution and spinning, so that an overall green and sustainable product is provided by the present invention. As the starting materials pulp and lyocell fiber to be employed in the present invention are standard materials, the overall costs of the novel product can be maintained on a highly competitive level. Due to the possibility to tailor product properties by means of raw material composition and energy consumption during hydroentangling, it is possible to produce products specifically adapted to the intended end use, so that the present invention may be regarded as providing a module based system which, using only a small number of variables (see above) enables the production of a wide variety of products, without requiring the use of additional components, such as reinforcing fibers, agents to improve biodegradability etc. These advantages associated with the present invention have to be considered as a vast and unexpected improvement over the prior art.

20 [0020] As already outlined in the claims, it is possible to provide the fibrous nonwoven web in accordance with the present invention with two- or three-dimensional structures, for example by embossing, by providing perforations etc., using methods known to the skilled person in the field of fibrous nonwoven webs. The webs in accordance with the present invention allow the provision of such structures without detrimental effect on the mechanical properties (strength) of the webs. It has been found, as illustrated in the examples, that the provision of such structures improves other properties, such as oil uptake, so that high strength webs in accordance with the present invention do show promise in the field of industrial wipes, where so far only reinforced wipes have shown sufficient mechanical strength to allow the use in practice.

30 [0021] The webs in accordance with the present invention in any case do show very good balance of properties, in particular a good balance of mechanical properties (tensile strength) as well as properties relevant for the use, such as WRV and LAC. Webs in accordance with the present invention do show satisfactory LAC values of clearly above 400, in embodiments exceeding 600, typically in combination with WRV of above 50. This is a balance of use properties roughly equivalent to commercial wipes. Tensile strength values for these webs in accordance with the present invention however are typically higher than the values for the commercial wipes, as these typically show tensile strength values (for baby wipes and moist toilet paper) of up to 25 N/5cm (dry, MD) for low strength products and values of up to 80 N/5cm (dry, MD) for medium strength products. The corresponding values for the webs of the present invention are up to 60 N/5cm (dry, MD) for low strength products and values of up to 150 N/5cm (dry, MD) for medium strength products. Accordingly, the present invention enables, simply by employing two standard products (pulp and lyocell fiber) in the defined weight ratios, the provision of fibrous nonwoven webs with an overall improved balance of use (WRV, LAC) and mechanical (tensile strength) properties. This becomes even more pronounced when considering the high strength webs in accordance with the present invention. These again do show use properties similar to the commercial products, such as WRV and LAC, while achieving the required mechanical properties, in particular tensile strength values without requiring the addition of binder and/or reinforcing fibers. Commercial industrial wipes, which are a prominent example of high strength webs in this field, have tensile strength values of from 30 up to about 100 N/5cm (dry, MD), whereas the present invention achieves, without using reinforcing fibers or binder fibers, values (dry, MD) of up to 250 N/5cm. This is a fully unexpected vast achievement over the prior art.

40 [0022] As indicated above, the present invention enables to tailor properties simply by adjusting the weight ratio of pulp to lyocell fiber as well as by adjusting the energy consumption during hydroentangling. Generally, higher contents of lyocell fibers increase mechanical properties. At the same time, increasing the energy consumption during hydroentangling, even for webs comprising a lower proportion of lyocell fibers, has the same effect. Accordingly, high strength webs in accordance with the present invention typically are webs with a higher basis weight, typically of 150 or more,

with a weight ratio of pulp to lyocell fiber of from 80:20 to 40:60. Webs with lower basis weights and weight ratios of pulp to lyocell fiber of from 70:30 to 90:10 typically are medium or low strength webs.

5 [0023] As indicated above, the use in particular of the lyocell fibers ensures that in combination with the pulp highly cost efficient webs can be provided which can be considered sustainable. However, the use of the lyocell fibers also unexpectedly serves to increase the mechanical properties, in particular the tensile strength properties of the webs in accordance with the present invention. Unexpectedly the inventors have discovered that only the use of lyocell fibers, as for example compared to other regenerated cellulose fibers, such as viscose fibers, ensures the good mechanical properties. Webs produced with viscose fibers instead of lyocell fibers (with the same length and titer) does not enable the production of webs having strength levels achieved with the corresponding webs employing lyocell fibers (under identical production conditions and using otherwise identical mixtures with pulp). Therefore it is evident, that the present invention is based on a specific selection of raw materials, which makes the achievement shown possible.

10 [0024] The present invention will now be described in relation to the process for preparing the fibrous nonwoven webs in accordance with the present invention. It is to be understood that all embodiments as preferences describe above in relation with the webs of the present invention likewise apply to the process disclosed herein.

15 [0025] The fibrous nonwoven web in accordance with the present invention may be produced using a hydroentangling process. Such processes are known to the skilled person and conventional devices used for such processes may be used to prepare the webs of the present invention.

20 [0026] Typically, the process first involves the intimate mixing of pulp and lyocell fiber, which can be carried out in a pulper. Usually water is added to this mixture to ensure proper dispersion. In order to adjust the water content of this initial mixture same can be passed through a station adapted to adjust the concentration, such as a mixing chest. This ensures that the mixture can be pumped to the next stages of the process and that in particular that the mixture can be evenly distributed on a web required for forwarding the not yet entangled web to the hydroentangling station. After mixing, the prepared mixture (slurry) is provided to a distribution station, which distributes the mixture in the desired amount and width onto a moving belt. The amount provided to the belt is adjusted in particular in relation with the target basis weight of the fibrous nonwoven web to be produced. The belt is typically adapted to allow in particular a dewatering step, so that the distributed slurry yields the so called wet laid material. Additional stations which further remove water, such as vacuum stations, may be provided, which also typically ensure an improved uniformity of wet laid material. Subsequently, in typical processes further drying steps are carried out, for example by using steam heated can dryers or other conventional means for drying. After these treatments the dried wet laid webs may be wound onto rolls to forward same to the hydroentanglement step, it is however also possible to directly forward the wet laid webs in accordance with procedures known in the art to the hydroentanglement treatment, and of it is of course also possible to omit some or all of the drying steps, when directly forwarding the wet laid webs to the hydroentanglement. A usual continuous process does not include a drying step before the hydroentangling step. However, a de-watering step, typically including a vacuum de-watering step, is usual for such continuous processes.

25 [0027] Hydroentanglement may be carried out using water beams or jets, which are arranged either on one side of the web to be entangled or on both sides of the web to be entangled. The number of water beams is not critical but two or more beams are conventional. Processes employing in total four water beams, preferably two on each side of the web, have shown to be highly suitable to produce the fibrous nonwoven webs of the present invention. Process conditions during entanglement may be selected among usual conditions known to the skilled person, such as water pressures, etc. It has been found, that in order to reproducibly prepare fibrous nonwoven webs of the present invention, the so called energy consumption (sometimes referred to spunlacing energy consumption) is a good measure to ensure that the desired target values in the fibrous nonwoven webs are achieved. This energy consumption (relating to the water beams) is a theoretical value given in kWh/kg (of dry fibrous nonwoven web) calculated on the basis of water pressure, production speed and basis weight. The calculation can be done based on the principles published in Vliesstoffe, W.Albrecht, H.Fuchs, W.Kittelmann (Ed.), Wiley-VCH 2000, page 329, equation (23).

30 [0028] Typically energy consumption values in the range of from 0.05 to 1 kWh/kg are suitable in the present invention. It should however be understood that higher and/or lower values are not excluded, but that the values given above are typical values, which are given here as means of illustration, taking also the specific conditions as employed in the examples, described below, into account. Suitable ranges for the energy consumption are in particular values of from 0.1 to 0.9 kWh/kg. As already indicated above, an adjustment of energy consumption under due consideration of the basis weight and weight ratio of pulp to lyocell fiber can tailor the mechanical properties of the web produced. Employing for example, as illustrated also in the examples, a basis weight of 170 gsm and a ratio of pulp to lyocell fiber of 40:60, tensile strength values (dry, MD) of above 250 N/5cm can be obtained using an energy consumption of 0.3659 kWh/kg. Lower tensile strength values are obtained with lower energy consumption, for example less than 250 N/5cm at 0.1464 kWh/kg. At the same energy consumption values tensile strength values (dry, MD) of about 170 and about 150 N/5cm, respectively can be obtained with a basis weight of 170 gsm but a ration of pulp to lyocell fiber of 80:20. These experimental results do prove the general feasibility of concept and the modular system provided by the present invention.

35 [0029] Generally, as it is known to the skilled person, the energy consumption may be adjusted easily by changing

production speed (speed of the moving belt moving the wet laid web through the hydroentangling station) and/or by changing the water pressure during hydroentangling. In the present invention it is, when considering these two options, preferred to increase energy consumption by increasing water pressure, compared to increasing energy consumption by decreasing production speed.

5 **[0030]** In accordance with common knowledge the webs, after having been entangled may be subjected to any desired post processing steps, such as de-watering treatments and drying treatments, employing for example vacuum de-watering units and/or through air drying units etc. The web may then be wound on a roll to be shipped to further processing steps, such as cutting to a desired size, application of additives, such as lotions for cosmetic wipes, etc. As indicated above, the webs in accordance with the present invention may be provided with two- or three-dimensional structures by embossing etc. Such processes are known to the skilled person and the respective process steps may be provided at any suitable stage of the process described above.

10 **[0031]** The present invention will now be described further by means of illustrative examples.

Examples

15 Measurement methods

[0032]

20 WRV values were determined according to DIN 53814
 LAC values were determined according to DIN 53923
 Basis weight was determined according to DIN EN 29073 Part 1
 Tensile strength was determined according to DIN EN 29073 Part 3

25 Materials employed

[0033] Pulp (Canfor ECF 90 bleached pulp) having a fiber length of 2.4 to 2.6 mm, a coarseness of 12 to 14 mg/100m and a fines content of 3 wt.-% was mixed in the rations further illustrated below with LENZING™ Lyocell Shortcut fibers 1.7dtex/10mm bright and 1.4dtex/10mm bright. If the Examples do not specifically identify the lyocell fibers employed those identified above with the titer of 1.4dtex were used.

Web production process

35 **[0034]** Substrates were laid using a wet laid line of PILL Nassvliestechnik GmbH (1-schichtige Pilo-Schraggiebanlage NVLA-58), dewatered, dried and wound on a roll. This roll was then unwound to deliver the not yet entangled web material to a spunlacing (hydroentangling) line comprising a pre-wetting unit, two water beams on the top side of the web and then two water beams on the bottom side of the web, vacuum boxes for dewatering and a through air dryer for drying the spunlaced material.

40 Example 1

[0035] The following fibrous nonwoven webs were produced:

- 45 a.) Basis weight 170 gsm, weight ratio pulp to lyocell fiber 40/60
 b.) Basis weight 170 gsm, weight ration pulp to lyocell fiber 80/20
 c.) Basis weight 100 gsm, weight ratio pulp to lyocell fiber 80/20

[0036] The webs were hydroentangled with different energy consumptions of 0.1464 kWh/kg (a'), 0.1746 kWh/kg (b'), 0.2614 kWh/kg (c'), 0.3118 kWh/kg (d'), 0.3659 kWh/kg (e') and 0.4366 kWh/kg (f') respectively.

50 **[0037]** The resulting webs showed the following properties:

Sample	WRV [%]	LAC [%]	Tensile strength (dry/MD) [N/5cm]	(2.5xwet/MD) [N/5cm]
a.)/a')	58	463	~260	~240
a.)/c')	60	427	~250	~250
a.)/e')	59	427	~260	~240
b.)/a')	66	410	~150	~110
b.)/c')	67	407	~160	~110

EP 3 550 062 A1

(continued)

	Sample	WRV [%]	LAC [%]	Tensile strength (dry/MD) [N/5cm]	(2.5xwet/MD) [N/5cm]
	b.)/e'.)	64	419	~170	~110
5	c.)/b'.)	66	592	~60	~30
	c.)/d'.)	65	610	~50	~30
	c.)/f'.)	61	670	~50	~40

10 **[0038]** These results do show, that with high pulp contents and lower basis weights very high values for WRV and in particular LAC can be obtained, while the mechanical properties are still satisfactory. Increasing the basis weight from 100 gsm to 170 gsm leads to a slight decrease in LAC but the mechanical properties increase by the factor of 2 or more. Increasing the content of lyocell by the factor 2 (weight ratio pulp to lyocell fiber 60/40) leads to still high LAC values but increases the mechanical properties to levels even not achieved by commercial webs containing reinforcing/binding fibers.

15 Example 2

[0039] In order to prove that the present invention also provides valuable products at lower basis weight, additional webs were prepared according to the following:

- 20 d.1) to d.3.) Basis weight 60 gsm, weight ratio pulp to lyocell fiber 60/40, 70/30 and 80/20
 e.1) to e.3.) Basis weight 80 gsm, weight ratio pulp to lyocell fiber 60/40, 70/30 and 80/20
 f.1) to f.3.) Basis weight 100 gsm, weight ratio pulp to lyocell fiber 60/40, 70/30 and 80/20

25 **[0040]** The webs were hydroentangled with an energy consumption of 0.4136 kWh/kg (g'.)). The webs did show a favorable combination of high LAC values and highly satisfactory mechanical properties.

	Sample	LAC [%]	Tensile strength (dry/MD) [N/5cm]	(2.5xwet/MD) [N/5cm]
	d.1)/g'.)	920	~54	~33
30	d.2)/g'.)	830	~49	~27
	d.3)/g'.)	880	~40	~20
	e.1)/g'.)	600	~110	~91
	e.2)/g'.)	660	~95	~62
	e.3)/g'.)	700	~77	~43
35	f.1)/g'.)	510	~150	~110
	f.2)/g'.)	550	~143	~93
	f.3)/g'.)	550	~116	~62

40 **[0041]** These results do show, low basis weights and high energy consumption very high values for LAC can be obtained, while the mechanical properties are still satisfactory. Increasing the basis weight leads to a decrease in LAC but the mechanical properties increase drastically, so that even for very high pulp webs (weight ratio of pulp to lyocell fiber of 70/30 and 80/20) very high levels of mechanical properties are obtained, even for the wet webs. From these results it can be concluded that increasing the energy consumption enables the production of low basis weight webs, even with high pulp contents which do show surprisingly high strength levels, although no reinforcing fibers or binders are employed. At the same time these webs only comprise biodegradable materials from renewable sources, so that these webs clearly can be considered as sustainable products.

50 Example 3

[0042] In order to demonstrate the superiority of the fibrous nonwoven webs of the present invention in comparison with webs comprising other types of cellulosic fibers and/or to demonstrate the relevance of fiber titer, additional tests were run using the following webs, which were hydroentangled with an energy consumption of 0.481 kWh/kg.

- 55 g.) Basis weight 80 gsm, weight ratio pulp to lyocell fiber 60/40, lyocell fiber type LENZING™ Lyocell Shortcut 10mm, titer 1.4 (g.1)) and 1.7 dtex (g.2)), respectively, viscose fibers Daiwabo 10mm, titer 1.7 dtex (g.3)), and Viloft 10mm, titer 2.7 dtex (g.4)).

h.) Basis weight 80 gsm, weight ratio pulp to lyocell fiber 80/20, lyocell fiber type LENZING™ Lyocell Shortcut 10mm, titer 1.4 (h.1)) and 1.7 dtex (h.2)), respectively, viscose fibers Daiwabo 10mm, titer 1.7 dtex (h.3)), and Viloft 10mm, titer 2.7 dtex (h.4)).

5 **[0043]** In each case the webs employing the lyocell fibers did show the best mechanical properties. The best results were achieved with the lyocell fibers having a titer of 1.4 dtex, while the viscose fibers lead to a loss of mechanical strength values (dry and wet, MD) almost by the factor 2. The same trend was observed when considering the mechanical strength values in cross direction (CD). These webs furthermore again showed that increasing the amount of lyocell fibers in the web leads to an increase of mechanical properties. Overall, these test runs prove that, as already outlined
10 above, the present invention is based on a specific and unsuggested selection of the raw materials for the fibrous nonwoven webs, namely the pulp component and the fiber component, which specifically is a lyocell fiber component.

Example 4

15 **[0044]** Additional test runs were made in order to prove the influence of the weight ratio of pulp to lyocell fiber at constant basis weights and constant energy consumption and the influence of energy consumption at constant basis weights and constant weight ratios of pulp to lyocell fibers. Fibrous nonwoven webs with basis weights of 60 and 80 gsm respectively were hydroentangled with an energy consumption of 0.5445 kWh/kg and 0.4084 kWh/kg, respectively, while changing the weight ratio of pulp to lyocell fiber from 90/10 to 50/50, with intermediate ratios of 80/20, 70/30 and
20 60/40. Further samples were prepared with 70/30 blends, again with basis weights of 60 and 80 gsm, respectively, while changing the energy consumption from 0.1343 kWh/kg to 0.8084 kWh/kg, with intermediate values of 0.2598 kWh/kg, 0.381 kWh/kg, and 0.5445 kWh/kg for the webs with a basis weight of 60 gsm, and from 0.1007 kWh/kg to 0.6063 kWh/kg, with intermediate values of 0.1949 kWh/kg, 0.2858 kWh/kg, and 0.4084 kWh/kg for the webs with a basis weight of 80 gsm.

25 **[0045]** The results show that the tensile strength values (dry and wet (MD as well as CD)) increase with increasing amounts of lyocell fiber in the webs as well as with increasing energy consumption. A comparison of the blends with increasing lyocell fiber contents shows that the best balance of properties, while considering also costs of the raw material mixture, can be achieved at weight ratios of pulp to lyocell fiber of from 70/30 to 60/40. While the samples with a weight ratio of 50/50 show a slight increase in mechanical properties, the additional costs associated with the higher lyocell
30 fiber content would lead to an unfavorable balance of cost increase to gain in mechanical properties.

[0046] The test runs made with increasing energy consumption show a similar trend, that with increasing energy consumption the mechanical properties increase. In the ranges of energy consumption evaluated each increase in energy consumption did result in a clear increase of mechanical properties, so that no levelling off of the strength increase was observed. At the same time it was observed that at an energy consumption level typically employed for the production
35 of dispersible wipes, which are typically to be employed as flushable wet toilet paper (0.1343 kWh/kg) strength values can be obtained which lead to products being of higher value.

[0047] Also these tests prove again that the present invention, while using simple raw material mixtures based on materials from renewable sources, i.e. pulp and lyocell fibers, fibrous nonwoven webs with highly satisfactory properties can be obtained.
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Example 5

[0048] In order to prove the efficiency of the present invention to provide fibrous nonwoven webs which can serve as sustainable replacement products for dry industrial wipes, which do contain either polyester or polyolefin fibers, additional
45 fibrous nonwoven webs in accordance with the present invention were prepared. These were compared to a high quality industrial wipe with a basis weight of about 95 gsm, tensile strength values of about 96 N/5cm (dry as well as wet, due to the high content of PET fibers in thin industrial wipe a negligible difference between dry and wet state is to be expected). This wipe did show an oil uptake value of approximately 800%.

[0049] Accordingly samples with basis weights of 80, 100 and 120 gsm, respectively were prepared, at blend ratios of pulp to lyocell fiber of 70/30 and 50/50, respectively. These samples were hydroentangled with energy consumptions of 0.3109 kWh/kg, 0.2719 kWh/kg, and 0.2847 kWh/kg and embossed or provided with three-dimensional structures by providing perforations. The results show that with increasing basis weight mechanical properties increase (dry tensile strength, MD as well as CD) to levels similar to the level shown by the commercial reference product. Neither embossing
50 nor perforating leads to a significant decrease of mechanical values and the decrease of strength values when measured in wet state is only about 30%.

[0050] Overall, these fibrous nonwoven webs according to the present invention do show a balance of properties rendering them usable as sustainable replacements for commercial industrial wipes.

[0051] In order to further prove the suitability of the fibrous nonwoven webs of the present invention, the webs with

basis weights of 100 gsm were evaluated in relation with their oil uptake capability. The fibrous nonwoven webs of the present invention did show oil uptakes of more than 800%, with values of about 900% for the embossed webs and values of about 1100% for the perforated webs. These values are even higher than those measured for the high quality commercial industrial wipe, again proving the unexpected superiority of the present invention.

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Claims

- 10 1. Fibrous nonwoven web, comprising pulp and lyocell fibers, wherein the weight amount of pulp is at least 35 wt.% and preferably equal to or greater than the weight amount of the lyocell fibers, and wherein the lyocell fibers have a length of from 5 to 25 mm and the pulp fibers have a length of from 1.5 to 5 mm.
- 15 2. Fibrous nonwoven web according to claim 1, wherein the weight ratio of lyocell fibers to pulp is from 50:50 to 10:90, preferably from 15:85 to 45:55.
- 20 3. Fibrous nonwoven web according to claim 1 or 2, wherein the pulp has a fiber coarseness of from 8 to 20, preferably of from 10 to 15, more preferably of from 12 to 14.
- 25 4. Fibrous nonwoven web according to any one of the preceding claims, wherein the lyocell fibers have a titer of from 0.9 to 3.3 dtex, preferably from 1.15 to 2 dtex.
- 30 5. Fibrous nonwoven web according to any one of the preceding claims wherein the web has a basis weight of from 25 to 200 gsm, preferably of from 50 to 150 gsm.
- 35 6. Fibrous nonwoven web according to any one of the preceding claims, wherein the web is structured by means of providing embossing, perforations and/or three dimensional structures.
- 40 7. Fibrous nonwoven web according to any one of the preceding claims, wherein the web has a dry tensile strength in machine direction (MD) of more than 50 N/5cm and a dry tensile strength in cross direction (CD) of more than 10 N/5cm.
- 45 8. Fibrous web according to any one of the preceding claims, wherein the web has a wet tensile strength in machine direction (MD) of more than 15 N/5cm and a wet tensile strength in cross direction (CD) of more than 5 N/5cm.
- 50 9. Fibrous nonwoven web according to any one of the preceding claims, wherein the web does not contain synthetic thermoplastic binder components and/or synthetic fibers.
- 55 10. Process for preparing a fibrous nonwoven web according to any one of claims 1 to 9, comprising the steps of providing a mixture of pulp and lyocell fibers in an aqueous medium, wherein the weight amount of pulp is equal to or greater than the weight amount of the lyocell fibers, and wherein the lyocell fibers have a length of from 5 to 25 mm and the pulp fibers have a length of from 1.5 to 5 mm, dispensing the mixture on a belt, dewatering the dispensed mixture and hydroentangling the dewatered mixture to obtain a fibrous nonwoven web
11. The process according to claim 10, wherein hydroentangling is carried out using at least two, preferably at least 4 water beams.
12. The process according to claim 10 or 11, wherein a drying step is provided after dewatering and prior to hydroentangling.
13. The process according to any one of claims 10 to 12, wherein the energy consumption during hydroentangling is adjusted to a value of from 0.05 to 1 kWh/kg, preferably of from 0.1 to 0.75 kWh/kg.
14. The process according to any one of claims 10 to 13, wherein all water beams are provided on the same side of the material to be hydroentangled or wherein the water beams are provided on different sides of the material to be hydroentangled.
15. The process according to any one of claims wherein after hydroentangling a de-watering and drying of the hydroentangled web is carried out, preferably by means of vacuum systems and through air dryers, respectively.



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EP 18 16 6170

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EPO FORM 1503 03.02 (P04C01)



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