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Dispersibility of hydroentangled wetlaid nonwovens

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Abstract

Dispersibility in wet wipes made of wetlaid hydroentangled nonwovens is a crucial property and is influenced by factors such as pressure sum during production and the used materials. Different raw materials for nonwovens were produced using a laboratory scale inclined wire paper machine and a hydroentanglement device. In the typical blend of a nonwoven consisting of long regenerated cellulosic fibres and wood pulp the flat viscose fibre seems to be the best according to dispersibility. In the blend the amount of viscose fibres has only a small impact on the dispersive properties, whereas there is also the possibility that the measurement setup is not suitable to test different amounts of long fibres. Next to viscose fibres the tested nonwovens consist of wood pulp which is also able to decrease the dispersive properties when dissolving pulp is used instead of the normally applied bleached kraft pulp. The usage of hydrophobic polyester fibres as the long structure fibres also decreases dispersibility in comparison to regenerated viscose fibres. Here the ability of viscose fibre to swell is a possible reason why these types of fibres in nonwovens easier form well-dispersible nonwovens.

Introduction

The demand of so-called flushable wet wipes as commodity grows with raising comfort. The production process as a combination of a wetlaid process for web formation and water jet hydroentanglement as enforcement measure suits therefore perfect. The paper-production-like wetlaid process allows the usage of biodegradable [1] cellulosic fibres without additional binders that still provide dispersible properties [2].

Before processing the nonwoven material to wet wipes, it solely consists of viscose fibres and wood pulp. In this compound the regenerated cellulose fibres form the ground structure of the nonwoven where the short wood pulp fibres are attached to. This in some publications called ribbon-like [3] in other u-shaped [4] structure is liable for the wet strength properties of wet wipes. The wet strength thereby is strongly enhanced through the hydroentanglement where the areas hit by the water jet are impacted more [5] and the fibres are moved due to the impact [6]. This leads to an even more entangled network thus providing strength properties also in a wet state.

Dispersibility is a crucial characteristic in nonwovens for wet wipes that are designed to be flushable after disposal of via the toilet and the sewer system. Therefore, many publications [7–9] investigated on the dispersible behaviour of these materials in respect to different material characteristics. In the named publications the focus was laid on the production process where it was shown that with enabled hydroentanglement [9] and with increasing pressure [8] in the hydroentanglement the dispersible properties of the nonwovens dropped.

This work will deal less with the influences of the production process but with the raw materials for nonwoven manufacturing. Therefore, different types of regenerated cellulosic fibre and pulps are used to investigate their impact on the dispersible properties of wet wipes.

Materials and Methods

Materials

Three different types of regenerated cellulose fibres (viscose and lyocell types) and one polyester were used as the long structure fibres in the nonwoven production. The fibres and their characteristics are listed in Table 1.

Fibre type	Length [mm]	Linear Density [dtex]
Round viscose fibre	8	0.9
Round viscose fibre	10	1.7
Flat viscose fibre	10	2.4
Polyester fibre	10	1.7
Round lyocell fibre	12	1.7

Table 1 Long structure fibres used in the tested nonwovens

The remaining part in the nonwovens consists of wood pulp. When not marked differently bleached softwood kraft pulp (BSK) was used to produce nonwovens. For identifying the influence of the pulp on the dispersibility of nonwovens additionally two different dissolving pulp grades were used. The properties of the used wood pulps with their cellulose content (R18, DIN 54 355) and length-weighted mean fibre length are listed in Table 2.

Pulp grade	R18 [%]	Fibre length [mm]
BSK	85.9	3.386
Dissolving pulp	93.28	0.749
Dissolving pulp	94.18	1.740

Table 2 Wood pulp characteristics

Nonwoven production

Samples for testing were produced using a pilot-scale inclined wire paper machine depicted in Figure 1. Therefore, the used pulp was disintegrated with a laboratory pulper. The pulp together with the viscose fibres were mixed in a chest (Figure 1 (a)) at a concentration of 1 g fibre material (oven dry) to 1000l tap water. If not stated differently the blend ratio of wood pulp to viscose fibres was 70:30. The suspension is equally distributed on the wire of the paper machine (b) where the nonwoven web is built. In a through-air dryer (c) the fragile web is dried at 125°C and winded afterwards.

Hydroentanglement procedure was used to increase the tensile properties of the material. High pressure water jets were applied on the web in a multi-step concept similar to the one shown in Figure 1 (d). Directly after the hydroentanglement the now tightened nonwoven is again dried and winded.

Sample preparation

For the sloshability test the nonwovens are cut to 175mm x 125mm. To avoid production influences all tested sheets were cut in paper machine direction.

Slosh box test

Sloshability describes the behaviour of nonwovens to disintegrate after being disposed of via the toilet. An industrial applied measurement method, the so-called slosh box test, was used to determine this behaviour. The slosh box test represents one of the many methods to determine dispersible properties and is depicted in Figure 2. Sloshability and dispersibility can be used synonymously. Therefore, the cut nonwovens were placed in a plastic box filled with 2l of water. The box then is tilted for 30 minutes at 26rpm before the residues are separated with a 12.5mm hole sieve stacked on a 200µm sieve.

Sloshability is calculated according to Equation 1, whereas $m_{200\mu m}$ is the oven-dry mass of the residues on the 200µm sieve in grams and $m_{12.5mm}$ is the same for the other sieve.

$$Sloshability = \frac{m_{200\mu m}}{m_{200\mu m} + m_{12.5mm}} \cdot 100\ [\%] \qquad (1)$$

Equation 1 shows that the sloshability is increased the more of the residues pass the 12.5 mm sieve, meaning a higher sloshability indicates a better dispersible behaviour.

All sloshability tests were carried out using the cut nonwovens in a dry condition.

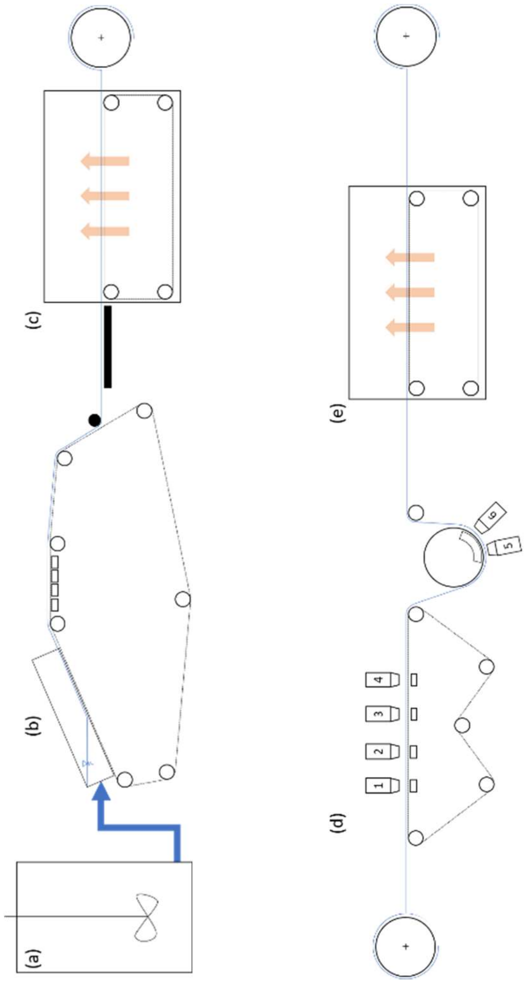

Figure 1 Scheme of the pilot-scale paper machine (left) and a hydroentanglement machine (right)

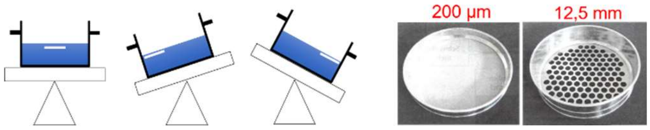

Figure 2 Slosh-Box principle and 200 µm sieve and 12.5 mm sieve

Results

Sloshability is represented for nonwovens produced of different raw materials that are named in the bar diagrams.

Figure 3 demonstrates the influence of the viscose fibre in the dispersibility of nonwovens. Still the majority of the material consists of the same bleached softwood kraft pulp in all nonwovens, it is visible that the flat viscose fibre provides good dispersible properties. For the same pressure sum of 135 bar in the hydroentanglement literature indicates for similar wipes a less distinguishable dispersibility [8]. There, it is also stated that at higher pressure sums the wipes with the lyocell fibres show a better dispersible behaviour than comparable viscose fibres.

However, in our results there is only a small difference in the dispersibility of round viscose fibres and round lyocell fibres. Furthermore, the difference is negligible compared to the difference of the sloshability of the flat viscose fibre to the other round regenerated cellulosic fibres.

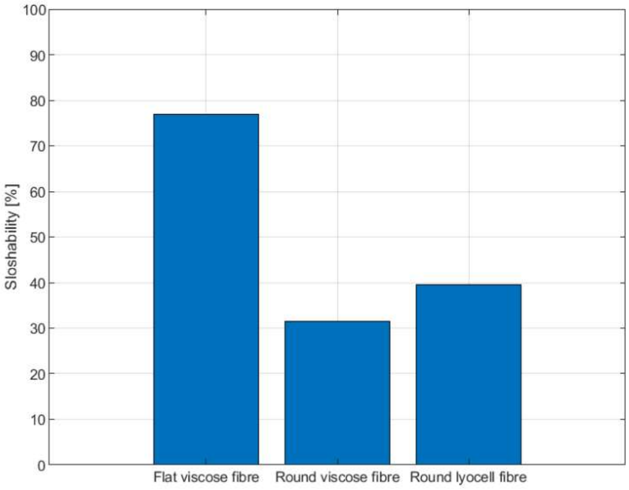

Figure 3 Sloshability for different types of regenerated cellulose fibres. Each bar represents the mean value of three measurements.

The influence of the amount of viscose fibres in nonwovens is depicted in Figure 4. Here the differences between 20% and 30% are very small and only the nonwoven with 70% viscose fibre shows a reduced dispersibility. Not necessarily this must lie in the used materials but in the measurement method. The higher amount of 10mm fibres increases the possibility of the fibres to be retained by the 12.5mm sieve used for the slosh box test. Also other publications found only little influence in the fibre blend ratio [7]. In their findings the biggest influence on dispersibility was found to be the pressure sum during hydroentanglement.

In Figure 5 it is visible that viscose fibres with the same length and linear density (10mm/1.7dtex) as a polyester fibre provide better dispersible properties to nonwovens. This is in contradiction to recent publications[8] where the higher fibre stiffness in the tested polyester fibres seems to be liable for the good dispersible behaviour at low pressure sums. However, the swelling of the cellulosic fibre is able to play a role. The swollen fibre could, once they were dried again and shrunk, form a looser network and allow an easier dispersion during the slosh box test.

Although it was stated that the wood pulp is liable for the dispersible properties of a nonwoven it can be seen in the Figure 3 to 5 that the long structure fibres also define dispersibility. Especially the replacement of cellulosic regenerated fibres with petroleum-based fibres confirms this finding.

Next to the influence of the viscose fibres also the impact of wood pulp is of interest when investigating dispersibility of nonwovens. Therefore, the typically used bleached softwood kraft pulp was compared to two different dissolving pulps. Both pulps are highly purified as it can be seen by the high R18 numbers of 94.18 respectively 93.28. Both pulps consist of rather short fibres which under industrial aspects makes them unsuitable for nonwoven production as during the hydroentanglement these short fibres tend to get torn out of the network due to the high water jet pressures.

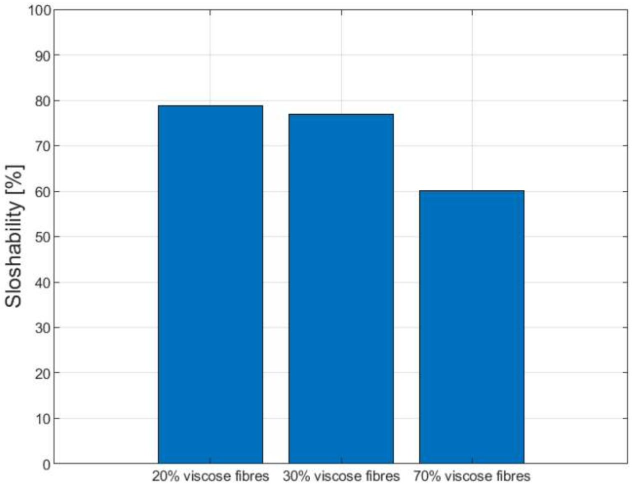

Figure 4 Sloshability for different amounts of the same viscose fibre. The remaining part consists of bleached kraft pulp. Each bar represents the mean value of three measurements.

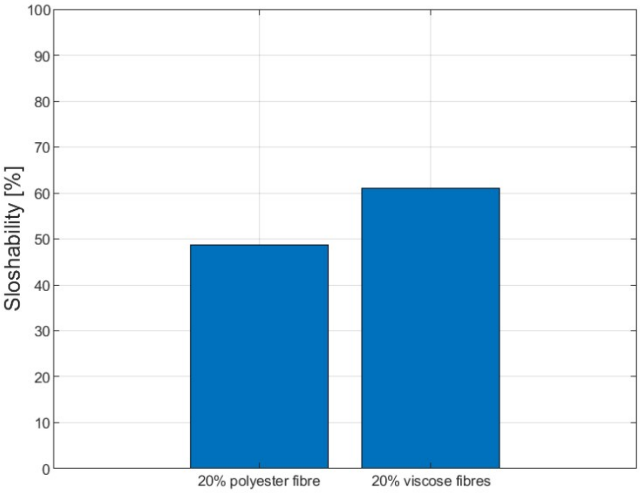

Figure 5 Comparison of synthetic petroleum-based fibres with regenerated cellulose fibres in nonwovens. Length (10mm) and linear density (1.7 dtex) are the same in both fibres. Each bar represents the mean value of three measurements.

Figure 6 shows no clear tendency in dispersibility according to the different pulp grades. One dissolving pulp shows quite acceptable dispersible properties where the other is not. Here the production process is possible to influence these properties. The good dispersibility in one dissolving pulp is most probably accorded to unsatisfying processability of this pulp during the hydroentanglement. This dissolving pulp with its very low mean fibre length is easy to be torn out of the fabric during the hydroentanglement and therefore creating a loose nonwoven with small holes in it. During disintegration either after disposal or in the slosh box test these small holes could initiate an easier disintegration. However, it is still worth considering that when using dissolving pulp instead of bleached kraft pulp the dispersibility is decreased.

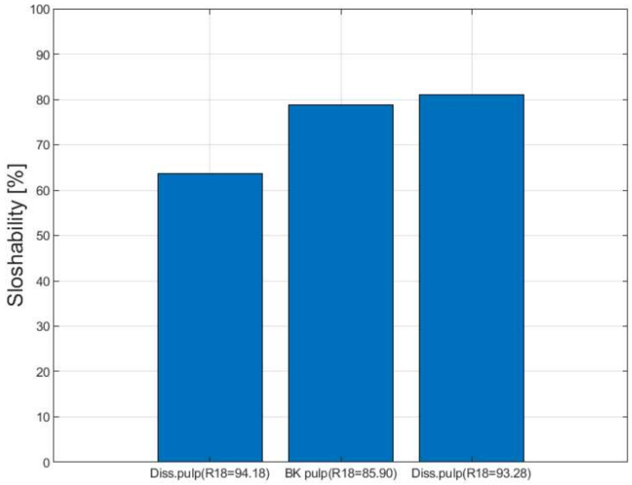

Figure 6 Different grades of pulp and their effect on sloshability. Each bar represents the mean value of three measurements.

Conclusion

Dispersibility as the key parameter of so-called flushable wet wipes was discussed in this work. Different raw materials in nonwovens were tested to investigate on their respective influence. The tests of different types of regenerated cellulose fibre showed that flat viscose fibres when used in nonwovens provide the best dispersible properties among the tested materials. When the shape of the cross-section is similar there is no recognizable difference in dispersibility as the results for round viscose fibres and round lyocell fibres show. The amount of viscose fibres in the blend with wood pulp showed only little effect especially as the measurement setup is likely to attest low sloshability values to wipes with a higher amount of long fibres in it. Dissolving pulp instead of the normally used bleached kraft pulp seems to lower dispersibility even though the two tested pulps behave differently. Also, the usage of cellulosic material for long structure fibres seems beneficial as polyester fibres of same length and linear density show a worse dispersibility as viscose fibre.

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