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PHYSIOLOGICAL INVESTIGATION OF RESIN-TREATED FABRICS FROM TENCEL® AND OTHER CELLULOSIC FIBRES

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Resin–treatment is widely used in textiles to improve crease–resistance of the fabrics and achieve easy–care properties. Extensive work has been performed on this topic, mostly concentrating on cotton fabric by using different resin types, catalysts, treatment time and temperature. In practice, the most commonly used resin is DMDHEU. The changes of the crease angle, tensile properties and air permeability after the resin treatment has been measured, but generally there is not much literature dealing with the physiological properties of the treated fabrics. In this work, TENCEL® and cotton fabric were treated with DMDHEU at different temperatures and reaction times. Wear–comfort relevant properties such as sorption of liquid water and water vapour, drying velocity and thermal absorptivity have been measured in comparison with the untreated fabrics. The results reveal that the resin treatment does hardly affect the water vapour sorption/desorption behaviour whereas the uptake of liquid water is clearly decreased. The layer of DMDHEU on the fabric also causes an increasing in drying velocity. The thermal absorptivity measured with an Alambeta Tester is higher for TENCEL® than for cotton fabric and slightly increases after resin treatment due to a smoother surface.

Keywords: *resin–treatment, cellulosic fibres, wear–comfort, water vapour sorption, thermal absorptivity*

Introduction

Wear–comfort is an important issue in the textile science. It has been extensively explored in the last decade that man–made cellulosic fibres such as TENCEL®, Lenzing Modal® and Lenzing Viscose® show excellent physiological behaviour. All these cellulosic fibres exhibit certain properties that are favourable for the wear comfort such as a high absorbency for water vapour and liquid water and a high heat capacity resulting in a heat buffering effect. These effects are especially pronounced for TENCEL® fibres (generic fibre type Lyocell).

The outstanding wearing comfort of textiles made from TENCEL® fibres is the consequence of the nanostructure of the fibre. The structural features enable a high water absorptivity, which leads to high heat capacity and heat balancing effect for thermoregulation, comparable to the action of phase change materials [1]. The resin treatment of TENCEL® is very important for the fibrillation control. The commercial experiences in the TENCEL® resin finishing process were very inconsistent. In most of the cases the results were excellent, but from time to time the resin process seems to be out of control. The resin suppliers developed their products mainly for cotton and viscose but TENCEL® is not a main target for these companies. Because of that, Lenzing decided to investigate of the resin finishing in detail. Cellulose fibres have a different reactivity in the resin process and of course different product properties.

The curing temperature is not the only an important factor in the resin process but also the type of the resin has a big influence on the performance. The resin concentration itself influences the reactivity and performance of the fabric. The reactivity of the resin system is mainly dominated by the catalyst and curing temperature [2]. Finishing the cellulosic textiles with the resin to improve a crease–recovery has been extensively investigated over the years, but there is not much literature evidence about the effects of such treatments on the physiological properties. Generally it is perceived that the intensive treatment has a negative effect on the wear–comfort [3, 4].

In this research, the influence of the resin–treatment conditions on the physiological properties of TENCEL® and Cotton fabric has been investigated. The fabrics are treated under mild, middle (praxis relevant) and strong temperature and time conditions. The physiological properties, like absorbency of water vapour was measured by dynamic vapour sorption analysis and the absorbency of liquid water was evaluated by measuring WRV. The drying velocity was determined by a very sensitive balance and thermal absorptivity by Alambeta tester.

Materials and Methods

Materials

TENCEL® (1.3/38 fibres) and bleached cotton fabrics were used both with the same textile construction: yarn count Nm 50, plain weave.

Resin Treatment

Fabrics were treated with DMDHEU / catalyst system. The treatment formulation contained 50 gL^{-1} resin Fixapret CP (BASF), 15 gL^{-1} catalyst $MgCl_2x6H_2O$ and 0.5 gL^{-1} surfactant. The resin was applied in a pad–cure process (foulard set at 2.0 bar) under conditions summarized in Table 1.

Table 1. Resin–treatment conditions.

Treatment	Conditions	
	Drying	Curing
Mild	120 °C / 30 min	
Middle	130 °C / 30 s	165 °C / 45 s
Strong	130 °C / 30 s	190 °C / 120 s

The conditions of middle treatment are commonly used in industrial practise. Fabrics which were not treated with resin, were only padded in pure water at middle conditions since elevated temperature can also change the fabric structure and influence on the physiological properties. After the treatment, all samples were washed at 90 °C for 20 min to remove the uncondensed resin.

Physiological Investigation

Dynamic Sorption Analyser

Dynamic water vapour sorption and desorption of the treated fabrics was performed with an automatic multisample sorption analyser SPS11 10µ (Project–Messtechnik, D–Ulm). The system is equipped with an analytical balance and sample chamber which allows the simultaneous gravimetric analysis of 11 samples [5]. The atmosphere in the analyser was set to 25 °C and 0% RH until equilibrium was achieved. Then the moisture sorption cycle was started rising the relative humidity in 10% RH steps. The mass change of the materials was recorded every 8 min and the equilibrium conditions was set to <0.02% total mass change within 40 s. Every time this condition was fulfilled for all samples, the RH was automatically increased by 10% RH up to 90% RH and then stepwise decreased down to 0%. The full sorption/desorption cycle took 14 days and the mass change at each equilibrium condition was used to draw the moisture sorption isotherm. The hysteresis (differences between sorption and desorption) was calculated according to the equation 1 [5].

$$Hysteresis[\%] = \frac{MR(desorption) - MR(sorption)}{MR(sorption)} \times 100 \qquad (1)$$

where is:

MR (sorption) [%] – moisture regain at equilibrium state at sorption process

MR (desorption) [%] – moisture regain at equilibrium state at desorption process

Water retention value

The water retention value (WRV) is a value, which indicates the water amount held back in fibres or textiles after total wetting and centrifuging. The measurements were performed following a Lenzing protocol using a laboratory centrifuge. The fibre sample (0.3 – 0.4 g) were weighed in the centrifuge glass and swollen for 5 minutes in deionised water. The sample was centrifuged for 15 minutes at 3000 Rmin^{-1} and weighed immediately. The samples were dried for 24 h at 105 °C and weighed again. The WRV was calculated out of the measured sample weight at the wet (m_w) and dry (m_d) stage [6].

$$WRV[\%] = \frac{m_w - m_d}{m_d} \cdot 100 \qquad (2)$$

where is:

m_w – mass of wet sample after centrifugation

m_d – mass of sample after drying

Drying Velocity Measurements

A 15x15 cm fabric was placed on a sensitive balance connected to the computer. An amount of 500 mg of an aqueous dye solution is applied with a syringe to the centre of a fabric. The sample was continuously weighted as it dries. The measurement takes two hours where the mass is registered every 60 seconds. The apparatus is shown in Figure 1. For each sample two parallel measurements were performed and the average curve was calculated in the OriginPro 7.5 Software.

Figure 1. Equipment for measuring drying velocity.

Figure 2. Alambeta tester.

Alambeta Tester

The Alambeta Measuring Device (Figure 2), developed at the Technical University of Liberec (Czech Republic) utilizes a new principle in measuring thermophysiological properties of textile fabrics. The instrument allows the measurement of a new (up to now only subjectively evaluated) instantaneous quantity of the warm/cool feeling, i.e. warm or cool sensation at the first contact of the human skin with a textile fabric. The corresponding value (thermal absorptivity) is registered for textile fabrics in interval from 30 $Wm^{-2}s^{1/2}K^{-1}$ (raised knitted fabrics and light webs) to 300 $Wm^{-2}s^{1/2}K^{-1}$ (impregnated or coated woven fabrics). The instruments registers the heat flow through the fabric due to the different temperature of the bottom measuring plate (at ambient temperature) and the measuring head which is heated to 40 °C. The thermal absorptivity of a fabric is a measure of the amount of heat conducted away from the surface of the fabric per unit time. A fabric which does not conduct heat away from its surface will feel warm whereas one that conducts heat away will feel cooler [7].

Results and discussion

Sorption Properties

The water vapour sorption was measured with an automatic sorption analyser recording the mass change as function of the relative humidity at constant temperature. The equilibrium isotherms are plotted in Figure 3 and 4 and show the typical hysteresis loop of cellulose based fibres between the sorption and desorption cycle. One would expect that different coatings close the pores of the fabrics and thus prevent a direct transport of moisture through the fabric resulting in a worse wear comfort of coated textiles. However, the sorption isotherms of untreated and treated fabrics ob both TENCEL® and Cotton fabrics showed that this is not the case. The maximum absorption at 90% RH is much higher for TENCEL® (18.93%) than for Cotton fabric (11.07%). After the very strong treatment, the water uptake of the TENCEL® fabric decreased only by 1.36% at 90% RH (17.27% relative water uptake). At lower humidities (10–40%) the sorption isotherms of the fibre samples overlap which indicates no significant difference in the moisture sorption properties. The differences between untreated and resinated cotton fabrics are slightly more pronounced. Strong treatment decreases the amount of absorbed water vapour by 2%.

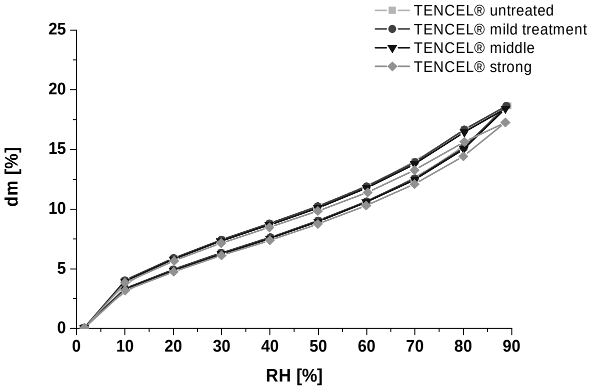

Figure 3a. Sorption isotherms of untreated and resinated fabrics: TENCEL®.

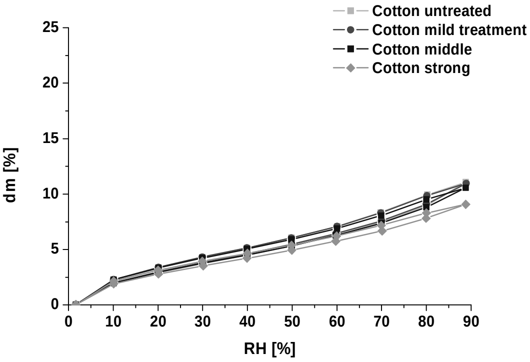

Figure 3b. Sorption isotherms of untreated and resinated fabrics: Cotton.

The hysteresis between desorption and sorption processes is an indicator for structural differences in the materials (Figure 4). Some earlier research on Lyocell and Cotton fibres by Okubayashi et al. showed a similar behaviour although the values for single fibres are higher [5]. The extent of hysteresis clearly decreases with increasing relative humidity, which suggest that the fibre and fabric structure changes when moisture adsorbs on the dry fibre or reversly when all moisture desorbs from the fibre. Obviously, the structural changes become smaller after some moisture has been adsorbed on the fibres. TENCEL® fabrics show a more distinct hysteresis than the cotton fabrics, especially at low RH. This result indicate that TENCEL® (Lyocell) fibre structure is less stable than that of cotton and water can more easily invade the structure. This can be explained by the lower crystallinity, larger pore volume and larger inner surface area of Lyocell [5].

The differences in mild, middle and strong treated fabrics are more pronounced for Cotton fabric which indicated that resination causes a stronger change in the Cotton fabric structure than in TENCEL® fabric.

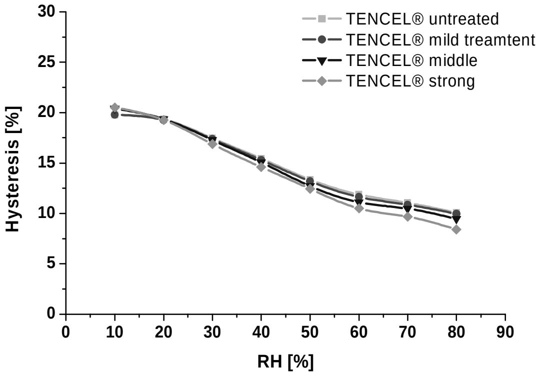

Figure 4a. Calculated hysteresis from the sorption data: TENCEL®.

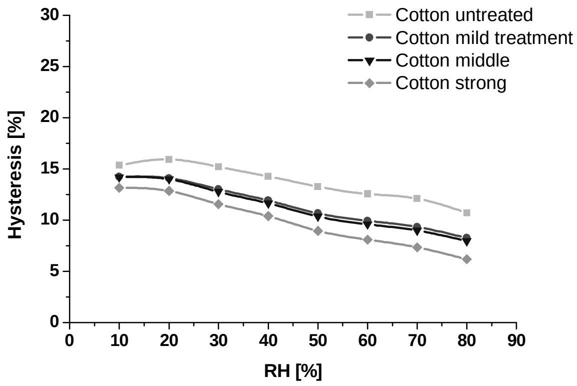

Figure 4b. Calculated hysteresis from the sorption data: Cotton.

The sorption of liquid water was characterised by measuring water retention values of untreated and resinated fabrics respectively, according to the Lenzing Method [6]. The resin–content was evaluated by measuring N–content. The plot in Figure 5 shows the correlation of WRV and N–content. The N–content increases as the fabrics are treated at higher temperature and the water retention value decreases with increasing N-content (amount of resin). The decrease in WRV is stronger for TENCEL® fabric than for Cotton fabric. This indicates again the different bonding ability of resin to the fabric.

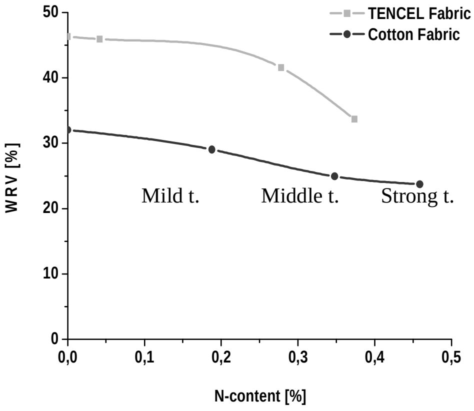

Figure 5. WRV versus N–content.

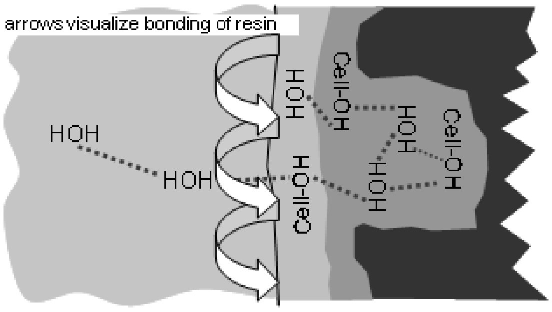

Figure 6. Model of porous cellulose fibre structure proposed by Ibbett, adapted from [8].

Ibbett [8] proposed a model how the resin can be bonded to the cellulose (Figure 6). Macroscopically, the resin is attached to the outer surface of pores so that accessible groups of cellulose molecules remain free for bonding of small water vapour molecules. The resin is attached to the surface of the pores decreasing therefore the Water Retention Values. In Figure 6, the arrows represent the probable distribution of the resin on the surface of pores.

Drying Velocity

The drying velocity was measured on very sensitive balance by adding a droplet of an aqueous dye–solution and measuring the mass decrease. The comparison of the drying velocity of TENCEL® and Cotton fabric is shown in Figure 7. The first part of the curve indicates the drying characteristics and analysed in more details. In the first 10 minutes, 140 mg of water evaporates from untreated and middle–treated TENCEL® fabric while 175 mg evaporated from mild and strongly–treated fabric. After 20 minutes 260 mg of the water evaporates from untreated and middle–treated fabric, 290 mg from mild treated and 320 mg from strongly–treated fabric. From untreated cotton fabric 110 mg evaporate in the first 10 minutes and 150 mg from all other treated cotton fabric. In 20 minutes, the evaporation exceeds to 225 mg for untreated fabric and 300 mg from treated fabric. It is obvious that the drying velocity is higher for all (untreated and treated) TENCEL® fabric than for the cotton fabrics. This behaviour originates from the smoother surface, where water spreading occurs faster resulting in a larger surface and thus a higher evaporation rate.

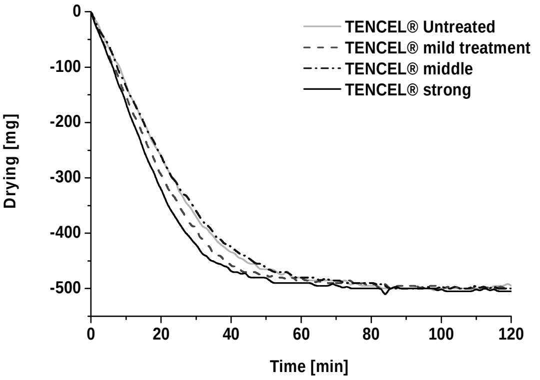

Figure 7a. Drying velocity measurements of: TENCEL® fabric.

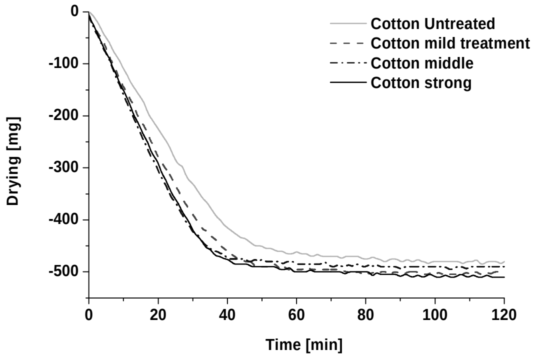

Figure 7b. Drying velocity measurements of: Cotton fabric.

It can be also seen that water evaporation is higher if the fabric is treated with resin. The effect is described in previous work by Firgo et al. dealing with TENCEL® / Polyester sportswear [9]. The spreading of water on hydrophobic surfaces is higher so that evaporation will be also higher to some extent.

Thermal Absorptivity

The thermal absorptivity measurements allow to calculate a so called cool–feeling factor, which represent the first sensation when textile comes in contact with skin. If the thermal absorptivity values are higher, the cool–feeling of the textiles will be better. The fibres were equilibrated before measurements for 24 hours in the laboratory with 55% relative humidity. The results in Figure 9 show that TENCEL® fabric exhibits a higher thermal absorptivity, i.e. provides a better cool–feeling than Cotton fabric. The values increase after the treatment. The fact that the resin fills the pores of the fabric makes the fabric surface smoother and less "hairy" which finally results in higher Alambeta values.

Table 2. Thermal absorptivity results of TENCEL® and Cotton fabric.

Treatment	TENCEL®	Cotton
	Absorp $W\ m^{-2}\ s^{1/2}\ K^{-1}$	Absorp $W\ m^{-2}\ s^{1/2}\ K^{-1}$
untreated	198,40	160,12
mild	199,20	162,80
middle	210,00	173,92

Finally, the crease–recovery was measured for all treated and untreated fabrics in weft and warp directions as standard test procedure in the evaluation of resinated fabrics. As expected, the values significantly increase with increasing treatment conditions.

Conclusions

Physiological properties of resin–treated TENCEL® and Cotton fabrics were investigated. Water vapour sorption was measured by dynamic sorption analyser while sorption of liquid water was characterized by measuring Water Retention Value. Thermal Absorptivity was determined by Alambeta Tester and Drying Velocity with the aid of a very sensitive balance. Fabrics were resin–treated by three different treatment conditions (mild, middle and strong) varying the drying and curing conditions at constant resin and catalyst concentration. The most important result of this investigation is that resin–treatment doesn't change the water vapour sorption ability whereas the sorption of liquid water decreases after the treatment. The data show that water vapour sorption decreased (at 90% RH) by 2% for Cotton fabric and by 1.36% for TENCEL® fabric. At lower RH, the differences in sorption properties between untreated and resinated fabrics are not significantly different. Calculated hystereses indicate different behaviour of resinated TENCEL® and Cotton fabric. The hysteresis of TENCEL® is practically unchanged at low relative humidities but change slightly at high values (90% RH). The hysteresis of Cotton changes stronger after the treatment. The observed decrease in the hysteresis between sorption and desorption occurs due to a structural change of the fabric that affects the invasion of water molecules into the fibres. WRV decreases with the treatment since resin is attached on the outer surface of the pores. Other physiological properties like drying velocity can be improved applying TENCEL® fabric and additionally by resination due to the better surface spreading of water. The cool–feeling factor is also increased by resination due to smoother, less hairy surface of the treated fabrics and is significantly higher in TENCEL® than in cotton.

References

[1] Schuster, K.C., Suchomel F., Männer J., Abu–Rous M., and Firgo H.: Functional and comfort properties of textiles from TENCEL® fibres resulting from the fibres' water–absorbing nanostructure: A Review, Macromolecular Symposia, **244** (2006) 149–165.

[2] Schlangen, J.; Abu–Rous, M., and Liggins, J.: New aspects of TENCEL® resin finishing, Proceedings of International Aachen–Dresden Textile Conference, 28–29 November 2007, Aachen, Germany, (2007).

[3] Schneider, R.: Die Bedeutung von Ausrüstungen in Funktionstextilien, Knecht, P. (Ed.), Deutscher Fachverlag ISBN 3-87150-833-0, (2003).

[4] Mecheels, J.: Körper – Klima – Kleidung, Wie funktioniert unsere Kleidung?, Schiele und Schön Berlin, ISBN 3-7949-0619-5, Berlin, (1998).

[5] Okubayashi, S.; Griesser, U., and Bechtold T.: A Kinetic Study of Moisture Sorption and Desorption on Lyocell Fibres, Carbohydrate Polymers, **58** (2004), 293–299.

[6] Lenzing AG, TIIL – PRÜFANWEISUNG 092/00.

[7] Alambeta Measuring Device: User' Guide Version 2.3, Sensora Instruments Liberec, Company Brochure.

[8] Ibbett, R.N.; Schuster K.C., and Fasching M.: The Study of Water Behaviour in Regenerated Cellulosic Fibres by Low–Resolution Proton NMR, Polymer, **49** (2008) 5013–5022.

[9] Firgo, H., Suchomel, F., and Burrow, T.: TENCEL® High Performance Sportswear, Lenzinger Berichte, **85** (2006), 44 – 50.