Application Report

Wetting of textiles and fibers

Application report: AR228d

Industry section: Cosmetics, textiles, paper

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Date: 05/2002

Single Fiber Force Tensiometer – K14

Force Tensiometer – K100

Method:  

Keywords: hair, hairspray, surfactant, carbon fiber, aramid fiber, fiber reinforced composite, nonwoven, paper

Characterization of wettability and surface properties of textile fabrics and fibers

Abstract

The woven/nonwoven sector is currently experiencing high demand as a result of the different surface modification options – and the resulting wide range of applications. It is thus seeking ways of optimizing products and processes and quality assurance. Wettability and adhesion as well as water and dirt-repellent properties are determined by surface energy quantities. These play a key role in matters of hydrophilicity/hydrophobicity and the adhesive strength of composite materials. The surface free energy of the topmost monolayers in textile fabrics (woven/nonwoven) or of individual fibers can be determined by means of various contact angle methods. The choice of method depends both on the application-specific question to be answered and on the sample to be investigated itself.

Fig. 1: The K100 – versatile all-rounder for the characterization of fibers, fiber bundles and textile fabrics

Wetting and surface free energy of single fibers

It is always advisable to determine the wetting and de-wetting behavior of single fibers when the monofilament is also to be processed in its own right, when it is present in the process and when it can be looked upon as a closed solid surface. The contact angles (advancing and receding) between the fiber and the liquid formulation (size, finisher, conditioner, finishing solution, adhesive etc.) can be measured directly by means of the Single Fiber Wilhelmy Method, a force measuring technique. The surface free energy (SFE) of the fibers can then be calculated from the contact angles with defined liquids of different polarity. The SFE is used for judging the success of plasma or corona treatments and of the finishing process as well as for adjusting the parameters. It is also used for optimizing the adhesion between fiber and matrix.

Example 1: Assessment of the wetting capability of different hairspray formulations on single, untreated hairs, single fiber tensiometer K14 [J. L. Gormley, G. T. Martino; J. G. L. Pluyter, Q. K. Tong, National Starch and Chemical Company, reprint from Cosmetics and Toiletries Manufacture Worldwide]

Hairspray formulation (15% solid content)	Surface tension [mN/m]	Contact angle [°]
Balance™ 0/55 in demin. water	36.57	87.1
Balance™ 0/55 0.2%DOSS in demin. water	35.29	69.6
Amphomer® in anhy. alcohol	23.05	0

The way in which the poor wetting behavior of an unadditivated, aqueous hairspray can be improved by the addition of dioctyl sodium sulfosuccinate (DOSS) and compared with the excellent behavior of an alcoholic spray has been investigated here by measuring the contact angle on single hairs.

Example 2: Determination of the SFE from contact angles on single fibers [W. Asche, Ermittlung der Oberflächenspannung fadenförmiger Festkörper nach Wilhelmy; Seifen – Öle – Fette – Wachse, 112 (15) 1986 543-545]

Contact angle with	Carbon fiber Thornel 300®	Aramid fiber Kevlar®	Carbon fiber Hercules®
Water	66.0°	64.2°	44.1°
Glycerol	55.1°	52.3°	40.0°
Formamide	-	-	24.9°
Ethylene glycol	31.2°	28.2°	-
SFE according to OWRK [mN/m]*	40.4	42.1	54.0
Dispersive fraction according to OWRK [mN/m]*	25.5	26.4	22.3
Polar fraction according to OWRK [mN/m]*	14.9	15.7	31.7

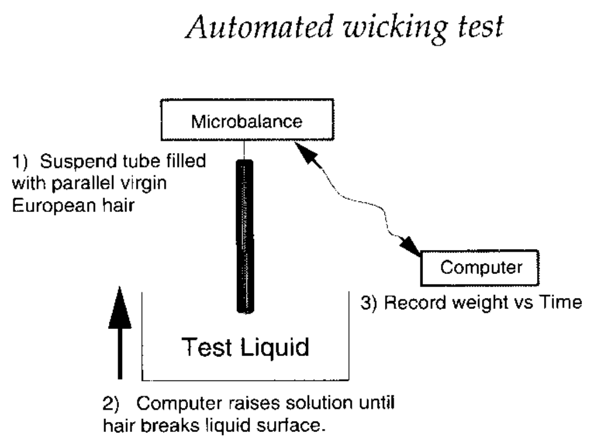
*Own calculations based on literature data for contact angles

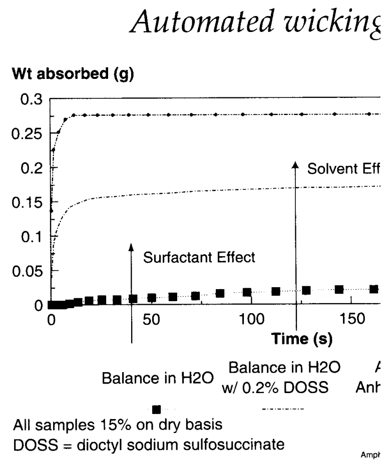
These data clearly show that, although the carbon fiber Thornel 300® and the aramid fiber Kevlar® have entirely different bulk chemistries, they are much more similar with regard to SFE properties than the carbon fiber Thornel 300® and the carbon fiber Hercules®. The surface tension values are used to estimate the wetting and compatibility with matrices and hence serve to optimize the composite materials.

Wetting and surface free energy of fiber bundles

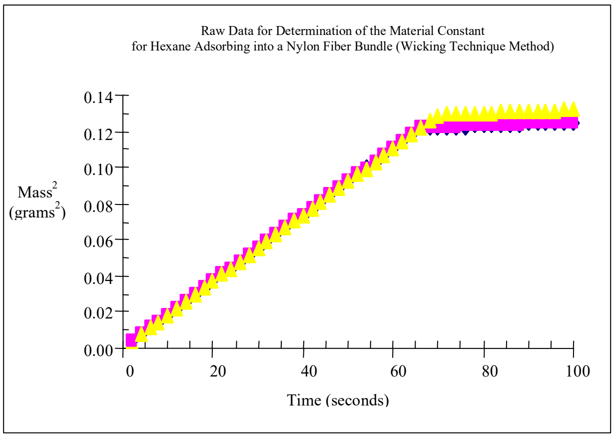
The so-called Wicking technique determines the wetting behavior and the liquid flow in fiber bundles by means of the Washburn adsorption method. The advantage compared with a monofilament lies in the greater representative significance (better statistics) and in the ability to carry out measurements even in porous fibers, such as cotton for example.

Example 3: Experimental setup for the wicking test and results of the adsorption measurement on untreated hair with different hairspray formulations, single fiber tensiometer K14 [J. L. Gormley, G. T. Martino; J. G. L. Pluyter, Q. K. Tong, National Starch and Chemical company, reprint from Cosmetics and Toiletries Manufacture Worldwide]

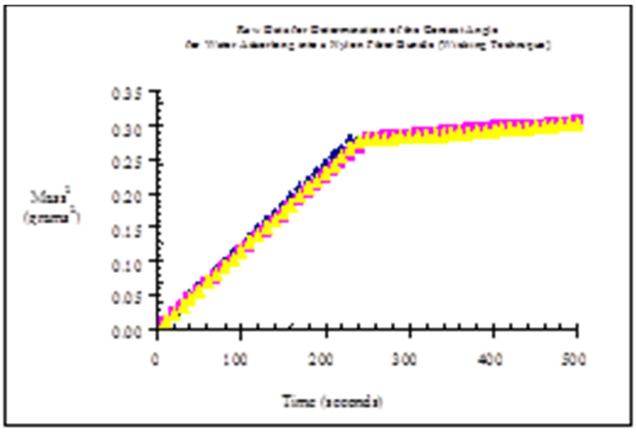




Like Example 1, wicking experiments on hair bundles show the effect of the wetting additive DOSS on wetting. However, due to the use of hair bundles, the capillary transfer of the liquid between hairs and not at the hair monofilament is observed here. This comes closer to the actual application of the hairspray, as it is intended to act in a bridging/wetting manner between hairs.



Example 4: Wetting behavior of nylon 6.6 fibers with water. Comparison of single fiber measurement for the wicking technique, Force Tensiometer – K100 [CR, Contact Angle Determinations by the "Straw" Method and Packed Cell Method: Good Alternatives to Single Fiber Contact Angle Experiments, Krüss Application Note #206]



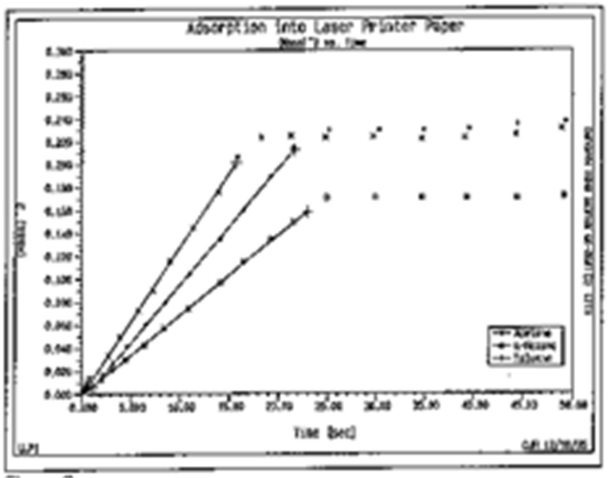
Sample	Contact angle single fiber Wilhelmy technique [°]	Contact angle wicking technique [°]
Nylon 6.6	76.6+/-4.1	77.9+/-0.5

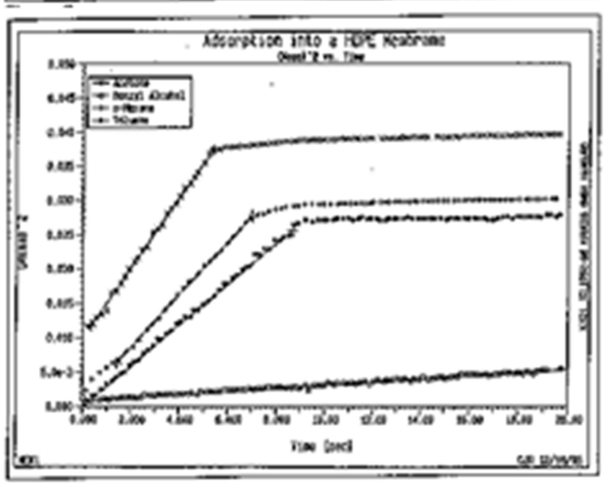
The comparison between Wicking technique and single fiber Wilhelmy technique shows that both methods produce equivalent results; however the generally more applicable conclusion is obtained with the wicking technique. With the tensiometers K100 and K14 both techniques are combined in the same units and complement one another ideally.

Wetting of textiles in the sense of porous solids (woven/nonwoven)

In most cases, fleeces and textiles cannot be regarded as non-porous solid surfaces – particularly when they are also hydrophilic (or highly energetic/polar) and therefore sorptive. The so-called Washburn adsorption method (see above) provides both the contact angle inside the pores and also, as a byproduct, the mean porosity of the textile solid. On the other hand, with optical methods, geometry (capillarity) and energy (contact angle) can only be determined as a total term. However, as well as the liquid parameters of surface tension, viscosity and density, the two solid characteristics (specifically SFE and porosity) determine the assimilation and transfer behavior of textile fabrics in contact with liquids in equal measure, and only the separation of geometric and energy data enables products to be specifically optimized. Examples of applications are the assessment of the wetting behavior of polyester or glass fabrics with resins, the absorption behavior of papers or fleeces with (substitute) bodily fluids for hygiene articles, and the wetting properties of membranes or fleeces as carrier or reinforcing materials.

Example 5: Wetting properties of polyester fabrics, laser printer paper and HDPE membrane support, Force Tensiometer – K100 [CR, Wettability Studies for Porous Solids Including Powders and Fibrous Materials, KRÜSS Technical Note #302]





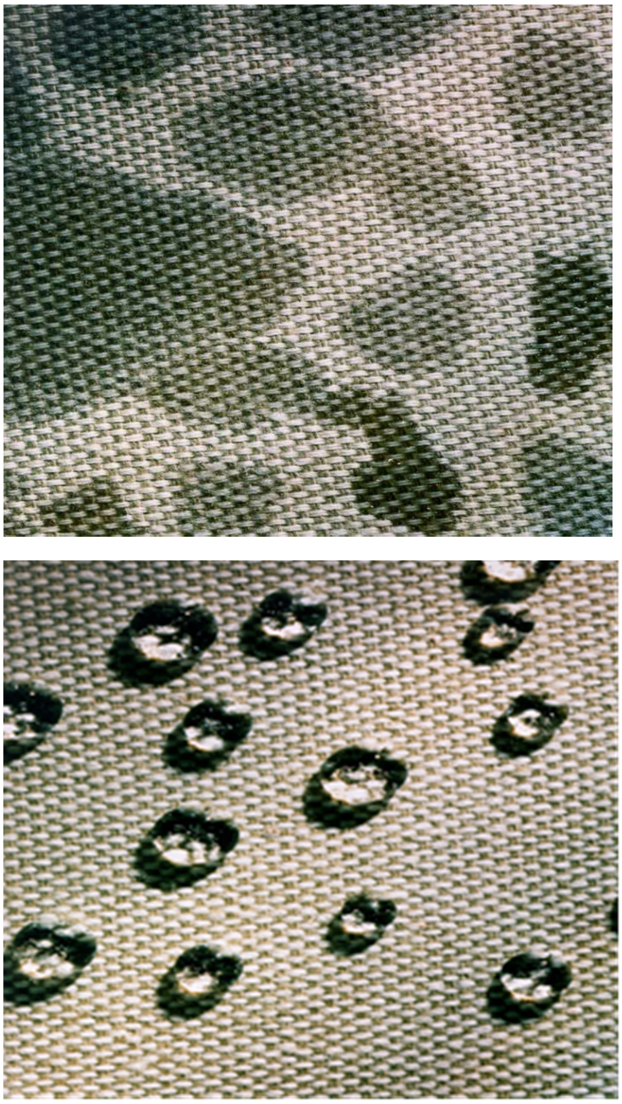
Liquid	Contact angle with laser printer paper [°]	Contact angle with HDPE membrane support [°]	Contact angle with polyester fabric [°]
n-hexane*	$c=2.803x10^{-4}$ cm^5	$c=1.537x10^{-6}$ cm^5	$2.010x10^{-4}$ cm^5
Acetone	0	45.5	-
Toluol	0	57.8	20.2
Benzyl Alcohol	24.5	78.1	-
Ethylene glycol	45.2	-	-
Water	80.1	-	-
SFE according to OWRK	36.6 mN/m	18.1 mN/m	-
Dispersive fraction according to OWRK	29.9 mN/m	18.1 mN/m	-
Polar fraction according to OWRK	6.7 mN/m	0.0 mN/m	-

The Washburn method therefore provides the mean capillarity of the material [c] as well as the contact angle in the pores. Depending on the application of the material, these data can be used for assessing the wetting of the porous materials with any liquids as well as for predicting the compatibility (bonding, adhesion) with further phases.

Wetting of textiles using optical methods

The optical goniometer method – the use of which is these days no longer dependent on the capabilities of the particular user thanks to the advent of digital technology – and the dynamic Wilhelmy method provide a clear description of the wetting behavior of textiles at the surface. If absorption by the surface or – as in the case of DeskJet papers, the impingement of drops on the porous or swellable surface in a timeframe of a few milliseconds – is of interest rather than the isotropic transfer of the liquid in the fabric, the optical method is to be preferred to the Washburn method. If the liquid drops become absorbed in the textile, then the standing time and/or drop volume or contact angle against time are a measure of the liquid repelling/absorbing effect of the surface. Hydrophobic treatments, among others, are clearly and strikingly demonstrated by this means.

However, determination of the SFE using such methods is only meaningful when the measuring liquids do not penetrate the textile (for example in the case of fabrics coated with membranes or extremely low-energy fabrics). It must therefore be decided which measuring technique can provide the required measurements for which textile in the individual case.



Example 6: Wetting of the fabric before and after hydrophobic treatment

Summary

This article is intended to demonstrate that a variety of measuring and evaluation methods are available to the professional for characterizing and optimizing interfacial properties and processes. The choice of method is to great extent determined by the process under observation, the application in practice and the substrates. A careful choice of measuring method and measurement parameters enables reliable conclusions which are directly transferable to practical situations to be reached, optimization to be carried out and processes to be described, all with simple means.

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