

Contact angle measurements on single fibers

This application note illustrates how the Attension Tensiometers can be used to study fiber wettability.

Introduction

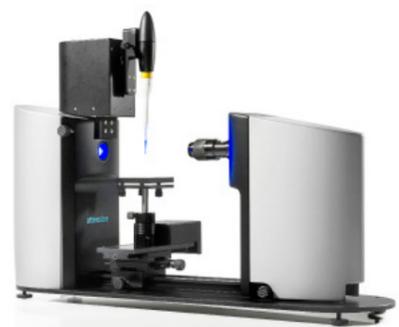
Contact angle measurements on single fibers are used in different industrial areas to characterize the adhesion and wetting behavior of the fibers. Wetting properties of fluids on fibers can also be studied by measuring the contact angle formed by the liquids on the fibers. It can be important for example in textile industry when studying water repellency of textiles. In addition, treatments of human hair (e.g. with shampoos, coloring etc.) require knowledge on the wettability of the hair. Fibers are also used as reinforcement material in composites and material properties can be assessed by measuring contact angles with given liquids. Wettability of fibers can be studied with both optical and force tensiometry.

In force tensiometry, the fiber sample is hung on the balance of the tensiometer and brought in contact with the test liquid. The tensiometer measures advancing and receding contact angles formed by the liquid on the fiber. When the fiber comes in contact with the liquid, the change in forces acting on the fiber is detected and the tensiometer registers this elevation as zero depth of immersion. As the solid is pushed into the liquid, the changes in mass are recorded and forces acting on the solid can be measured. The tensiometer calculates and automatically subtracts the effects of the buoyancy force and the weight of the probe. The only remaining force measured by the balance is the wetting force. The graph shows wetting force versus depth of immersion as the data is obtained.

In optical tensiometry, a drop is placed onto the surface of the solid with a dispenser. With standard dispensers the drop volume is typically a few microliters and therefore the diameter of the droplet is several millimeters. This kind of drop is too large to be placed on a thin fiber. To create smaller drops, a dispenser that is able to create nano and picoliter sized drops is required (e.g. Attension Theta picoliter dispenser). Taylor et al.¹ showed that contact angles measured from picoliter volume drops of water are equivalent to contact angles measured from microliter sized drops on six common polymers, opening the way for further research in the field.



Sigma force tensiometer



Theta optical tensiometer

Case Study 1: Fiber wettability with force tensiometry

Fu et al.² studied the influence of oxidation of carbon fibers with ozone for reinforcing cement. The filament diameter of these fibers was $15\pm 3\ \mu\text{m}$. Among other properties, wettability of the fiber with water was measured with a Sigma 70 force tensiometer from Attension (former KSV Instruments) before and after treatment. An example of this kind of measurement is shown in Figure 1. Fu et al. untreated carbon fiber gave an advancing angle of $84,7^\circ$ whereas the receding angle was $29,0^\circ$. After the treatment, the receding and advancing contact angles decreased to zero. This was due to the fact that the oxygen containing functional groups improved the wettability on the fiber surface. Since the cement paste used is a water based mixture, the wettability between fiber and water can be used to estimate the wettability between fibers and cement paste.

Case study 2: PTFE coated wire contact angle measurement with optical tensiometry

Theta optical tensiometer combined with picoliter dispenser was used to measure contact angles between water and a PTFE coated wire. The wire had a diameter of 0.18mm and the volume of the drop placed on its surface was 180pl. Pictures were taken with a high speed camera (1550fps) and the drop shape was fitted with the Young-Laplace method. Figure 2 shows the drop on the surface of the wire.

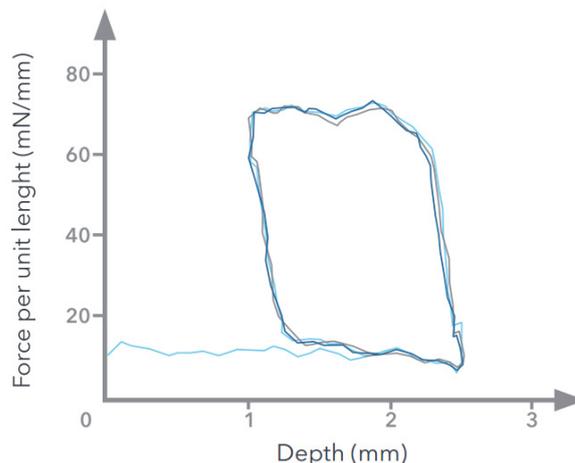
Water contact angles obtained from the coated wire are shown in Figure 3. As it appears, the coating of the wire can be defined as hydrophilic, as the contact angles are less than 90° . This method allows the characterization of different coatings used for fibers and wires.

Conclusion

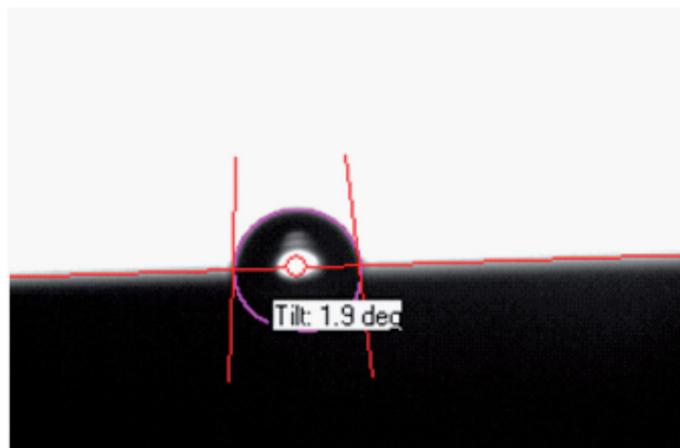
The surface properties of single fibers are relevant in many fields such as in the textile and construction industries. Contact angle measurement is a suitable method to characterize the surface and adhesion properties of a fiber. Fiber contact angles can be measured with either a force tensiometer by immersing the fiber in a liquid or with an optical tensiometer by placing a liquid drop onto the fiber.

References:

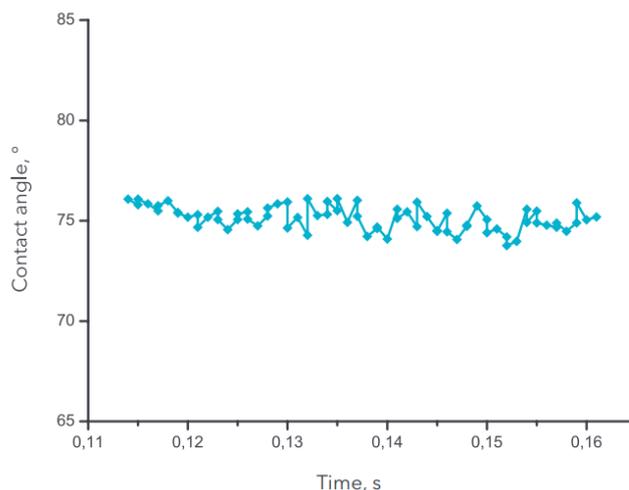
- [1] M.Taylor, A. J. Urquhart, M. Zelzer, M.C. Davies and M.R. Alexander, Picoliter Water Contact Angle Measurement on Polymers, *Langmuir* 23 (2007), 6875-6878.
- [2] X. Fu, W. Lu and D.D.L. Chung, Ozone Treatment of Carbon Fiber for Reinforcing Cement, *Carbon* 36, 9 (1998), 1337-1345.



[Figure 1]: Wetting force per unit length of fiber versus immersion depth measured by Sigma force tensiometer.



[Figure 2]: A picosized drop on a PTFE coated wire.



[Figure 3]: Water contact angle of PTFE coated wire measured with Theta optical tensiometer combined with a picoliter dispenser.