Determining t=0 in Contact Angle Measurements

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Contact angle measurements are often made on absorbing materials. We must then determine the point in time when the drop came in contact with the specimen. This is difficult because there is no distinct time, measurable to high precision, when this occurs. Instead, contact and stabilization of the drop on the specimen is a gradual process. This application note will use the high speed image capability of the FTÅ200 to illustrate what happens when a drop settles on a specimen.

There will always be some movement of the center of gravity of the drop as it comes in contact with the specimen. This movement implies some kinetic energy in the drop's mass. In turn, this kinetic energy will compete with surface energy and surface tension in determining the drop's shape. What we want to do is minimize the effect of kinetic energy compared to the surface tension force, so we want to "drop" the drop as little as possible. In other words, we want the center of gravity to move as little as possible. This goal is realized by using as small a drop as possible and by having the drop detach from its dispensing needle by touching the specimen, rather than falling off from its own weight. The FTÅ200 system provides four features to facilitate this detachment:

- wide range of disposable needle diameters
- 4:1 range zoom microscope
- rack-and-pinion stage for height adjustment
- fiber optic drop detachment sensor

These let the operator choose a wide range of drop sizes (which have the necessary form factor), magnification to optimally image the desired drop size, convenient mechanics to "touch off" drops, and a fiber optic sensor to trigger image acquisition when the drop actually detaches.

The following five images illustrate these points. The first frame is labeled τ=0 and the others are measured with respect to this time. This τ=0 is not the beginning of absorption--it is simply a reference point.

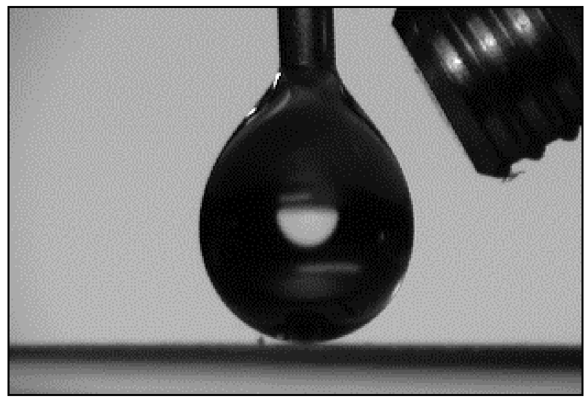

Figure 1. Drop about to detach. τ=0s.

The drop volume is 10µl and the specimen is a thin absorbent paper. The outside diameter of the dispensing needle is 0.71mm; the fiber optic drop detector is seen in the upper right. It signals when its beam reflection is lost.

Figure 2 on the next page shows the situation 17 milliseconds later. The drop detached because its bottom touched the paper and there is a surface tension force pulling the drop down. Under gravity alone, the center of gravity of the drop will move 2mm, a typical detachment distance, in 20 milliseconds. While speeded somewhat by the surface tension attraction, spreading takes a number of milliseconds (the better part of a 60Hz frame) ***and this prevents assigning a precise millisecond time to the beginning of absorption.*** "t=0", the initial contact time, for one part of the surface is not the same as another. At best an averaged value can be assigned within, say, one half a frame period. This can be estimated from the drop shape in the image corresponding to Figure 2 (is the drop early or late?).

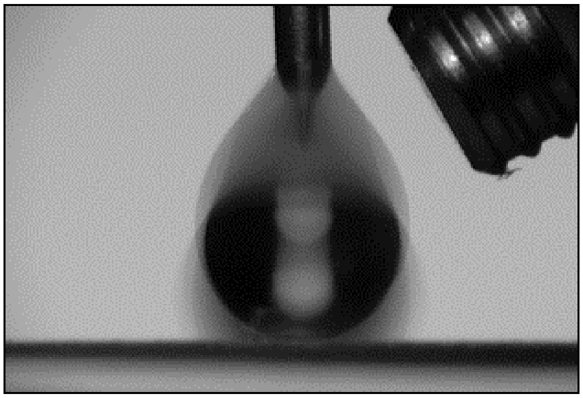

Figure 2. Drop detaching. τ=.017s.

The fiber optic detector can only trigger image acquisition within one frame time (16.6 milliseconds). The transient recorder capability of the FTÅ200 allows it to save images from ***before*** the trigger however. Thus the trigger occurred during the time of Figure 2, but we can still have Figure 1 available.

The next three images show the drop at τ=33, 50, and 100 milliseconds. Blurring in these images shows the drop still in motion.

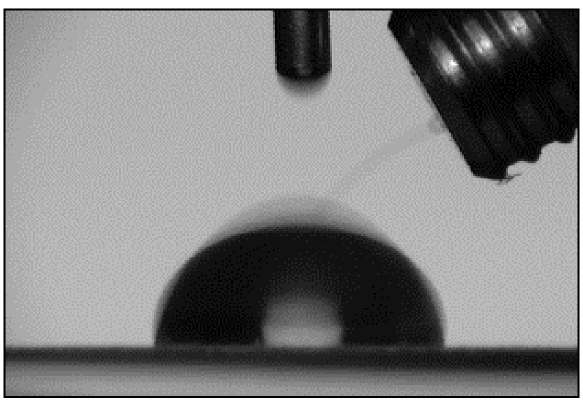

Figure 3. Initial sessile drop--vibrating. τ=.033s.

In addition to the significant motion on the top and at the "bulges" on the sides, notice the small droplet being ejected towards the fiber optic detector. This illustrates the chaotic nature of the detachment process.

The vibration is damped only a little in the next figure at τ=.050s. The drop has finally stabilized in Figure 5 at τ=.100s, fully 83 milliseconds after initial detachment.

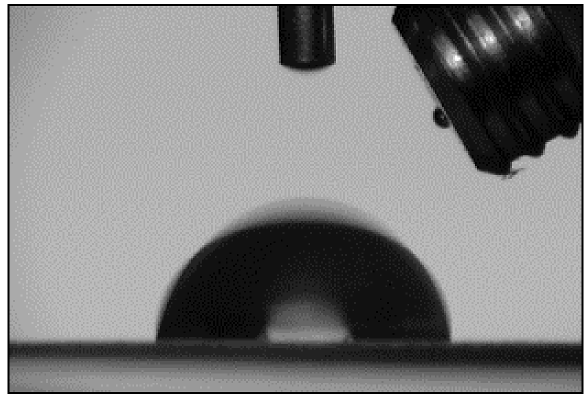

Figure 4. Still vibrating at τ=.050s.

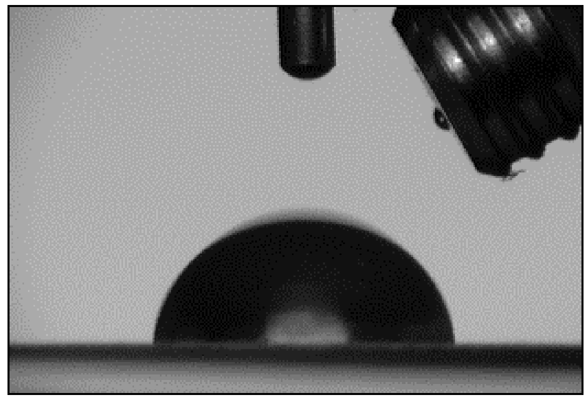

Figure 5. Stabilized at τ=.100s.

These images suggest the following strategy. Start measurements as soon as the drop is fully in contact with the specimen (i.e., Figure 3). Because the drop's image is blurred from motion, a good measurement may not be possible with automatic image analysis. The image can be analyzed, however, using the FTÅ's manual pointing, automatic calculation mode. Irrespective of when measurements can be first made, the time axis should be adjusted back so Figure 2 (τ=.017s) corresponds to t=0. This is done with the FTÅ's "X Offset" in graphing mode. If the drop in Figure 2 were just beginning to touch, a later time, e.g., τ=.025s, might be assigned t=0 for absorption. Thus the τ value for t=0 can be interpolated based on the images.

This note was prepared entirely electronically. Images from the FTÅ software were transferred directly into the manuscript, which was then sent to the printer via e-mail.