First Ten Ångstroms

Tilting Plate Example

3 February 2004

The tilting plate method is to slowly tilt a contact angle sample until the sessile drop on it begins to move in the downhill direction. At that time, the downhill contact angle is the advancing angle and the uphill angle the receding contact angle. Strictly speaking, you should use the measurement immediately before actual motion takes place, because once motion starts, the system is no longer in thermodynamic equilibrium.

The principal alternative to the tilting plate method is having the dispense needle remain immersed in the sessile drop and pumping in until the drop expands in base area and pumping out until the drop contracts in base area. For a further discussion of this approach, see the FTA paper "Contact Angle Measurements Using the Drop Shape Method" The tilting plate method has two comparative advantages:

- there is no problem of the dispense needle distorting the drop shape, and
- both the advancing and receding angles are obtained at the same time.

Often the tilting plate measurement is carried out on an instrument with a mechanical platform that tilts the stage and the camera together. This is true with the FTA2000 and when using the instrument tilt option with the FTA188 and the FTA200. This arrangement has the further advantage that the drop appears to stay horizontal in the image, even as its two sides distort, which makes image analysis much easier.

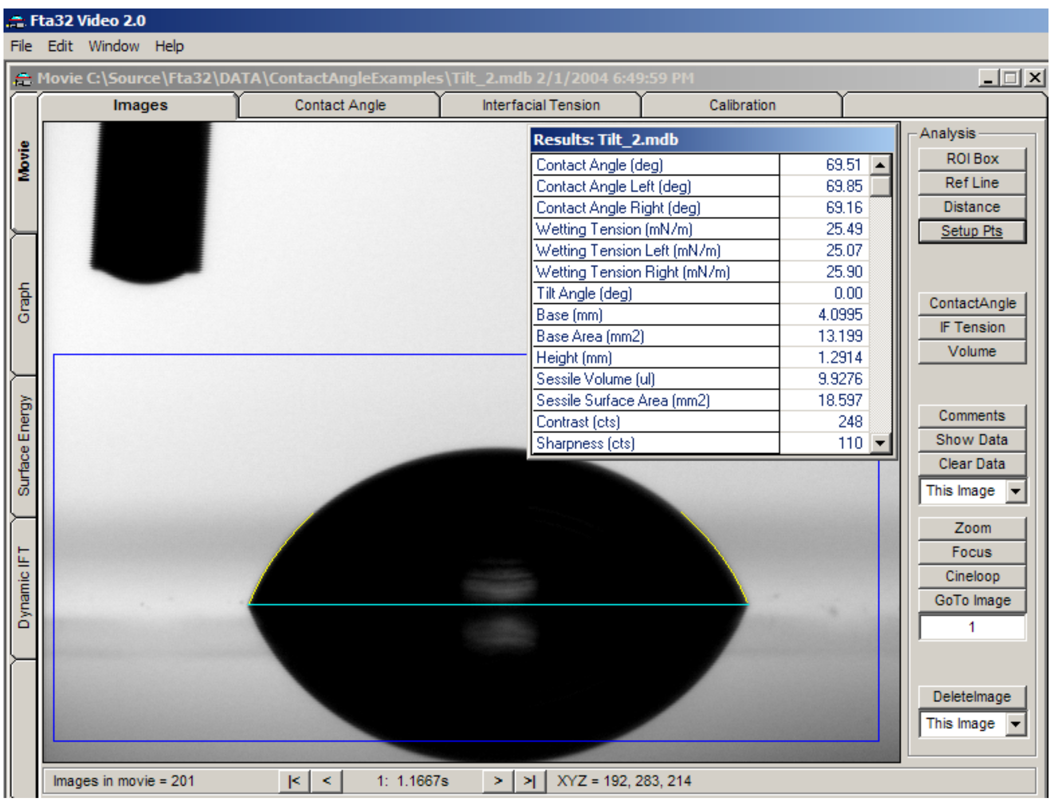
Conversely, there are two requirements on the tilting plate experiment:

- the tilt rate must be a compromise between tilting slowly, to minimize any vibration in the apparatus, and tilting quickly enough that evaporation of the drop is not an issue. Rates like 1°/s are normally satisfactory.
- you must determine when drop motion is just ready to begin (incipient motion) so you can use the angles at that time. The graph of the time variation of measured base diameter is helpful here.

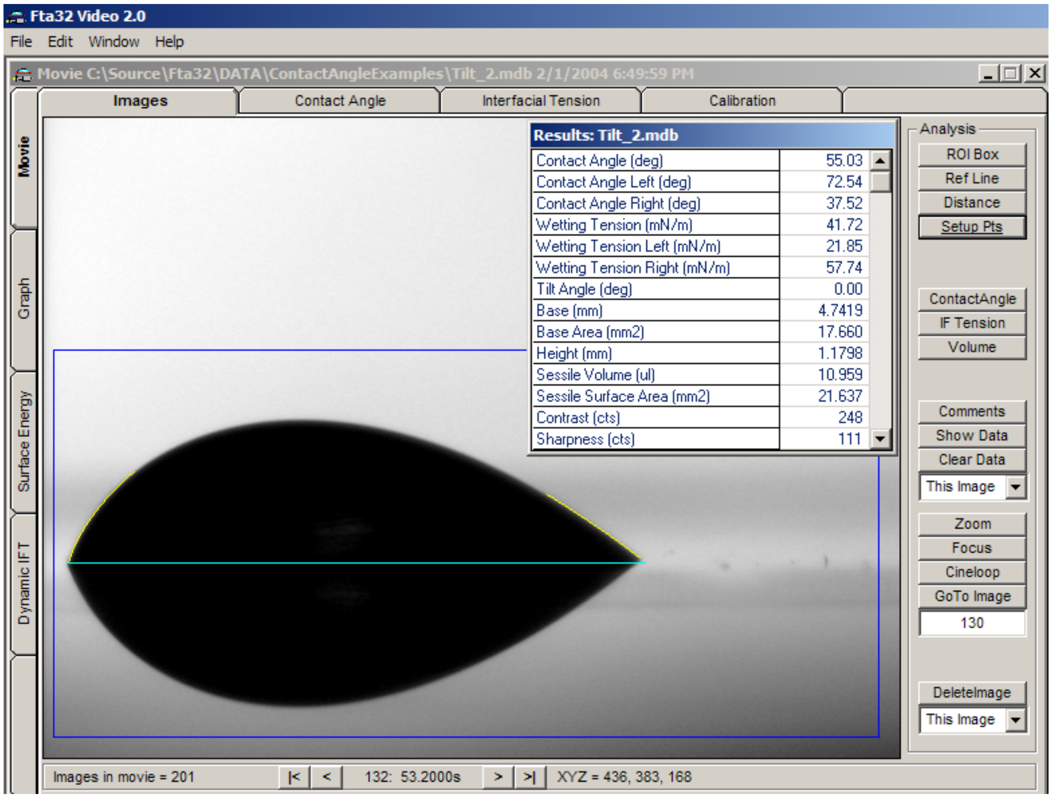
There is a subtle detail that must now be discussed. The sessile drop does not keep a circular profile when viewed from above as the drop tilts. Instead it looks more like a tear drop from above. The downhill side will always move first, before the uphill side. Thus the advancing angle three phase line begins motion first, before the receding angle three phase line moves. Again, when viewed from above, the locus of motion starts at the most downhill point and gradually moves around the drop to the most uphill point. All of this is saying that the wetting process, that which the advancing angle measures, preceeds the dewetting process that the receding angle measures. This means that the time of incipient motion differs for the advancing and receding angles. However, when the time varying angles are plotted against drop base width, it is not difficult for the operator to pick out when the respective angles should be taken. The example which follows will illustrate this.

Finally, as a practical matter, large volume drops work better than small drops. This is because the downhill force is from gravity and increases in proportion to volume, whereas the restraining force is proportional (among other things) to the length of the three phase line (Tate's law). Therefore a large drop will start moving downhill with less overall tilt than will a small drop. Thus the larger drop will reside on the surface for a shorter time before moving, and also will suffer less from evaporation than will a small drop.

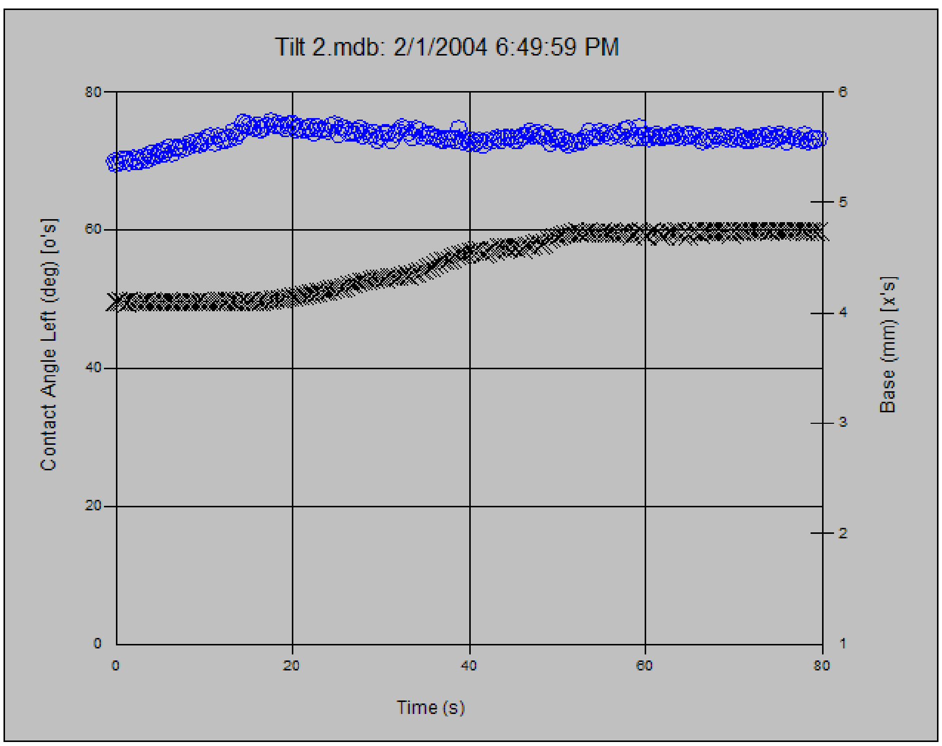
The following images show an actual experiment.



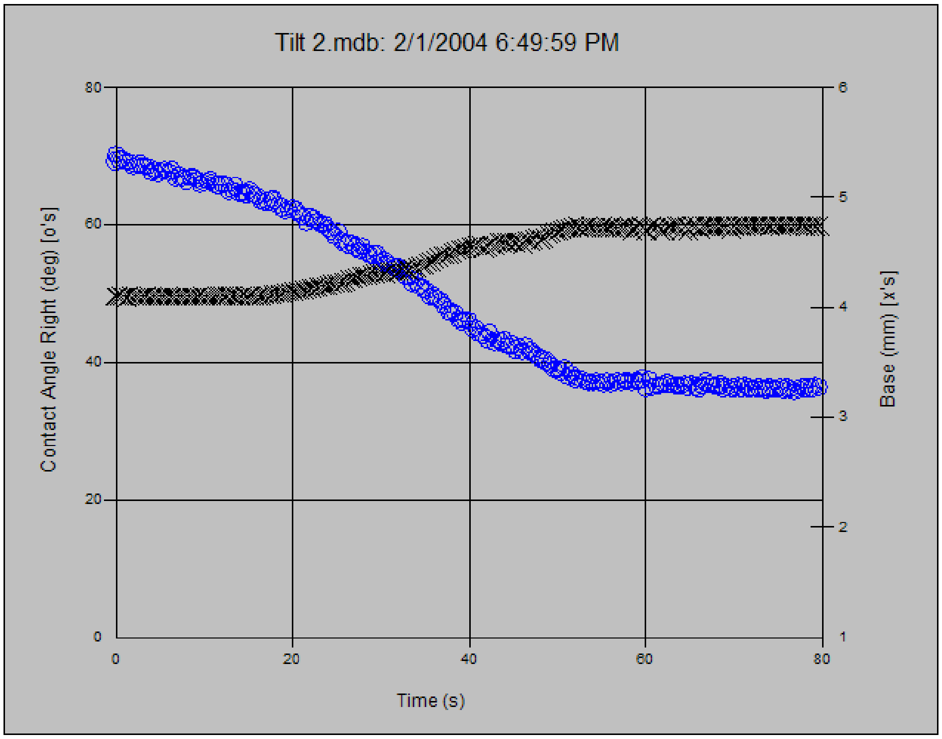
Just starting to tilt. On this FTA2000, the dispense needle does not tilt so it moves out of the image as the table starts. The drop appears level in the image. The ROI box prevents the analysis from considering the dispense needle as an indicator of where the drop is located horizontally.



Drop at point of full motion. Tilting stopped soon thereafter in this experiment.



Upper curve is the downhill advancing angle. It reaches a more or less stable plateau as the lower base width starts to expand at 17s. This expansion is the motion of the wetting three phase line.



The base width curve is the same as in the previous graph. The uphill receding angle starts high and then decreases until it reaches a plateau around 53s.

We would conclude from these graphs that the advancing angle is approximately 73°. We could use the last value, 72.54° in the image at 53.2s, or some average over the plateau region, or the initial value back at t=17s. Remember the three phase line is actually moving over new surface so we should not expect it to be absolutely constant during this time.

The receding angle is approximately 37°, from the graph plateau, or 37.52° from the above image at 53.2s.

465 Dinwiddie Street • Portsmouth, Virginia 23704 • 1.757.393.1584 Fax: 1.757.393.3708
http://www.firsttenangstroms.com