Superhydrophobic surfaces: tilt angle and friction coefficient

Equipment

- red rose petals
- strips of parafilm, plastic, glass, filtering paper, alluminium, aerogel, superhydrophobic textiles , magic sand
- incline
- Pasteur pipette
- micropipette (optional)
- food coloring (optional)
- glass of water
- paper towels
- videocamera + tripod
- goniometer
- screen
- Tracker[1] software
- Computer
- adhesive tape

In some applications of both hydrophobic and superhydrophobic materials the aim is not to repel water to keep the surface clean (see dirt repellant textiles) but rather to transport the drops from one point to the other of the substrate without leaks and contamination, applying the smallest force and as fast as possible. It's therefore fundamental that the drops are able to flow easily on the surface. In the following activities you will test different materials to see which are suitable for this.

Procedure

Video n°1- Evaluation of the static friction coefficient and the contact angle hystheresis .

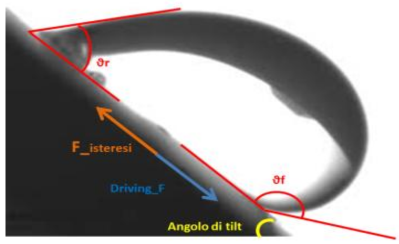
1. Cut out strips of the different materials. Choose appropriate dimensions to cover the entire length of the incline with just one piece.
2. Put one of the strips on the incline. Tape it with adhesive tape: the resulting surface should be very smooth and taut.
3. Set up for videorecording the drops motion. You should be particularly interested in catching the very moment the drop starts moving as it reaches the right angle of inclination.

TIPS

[1] Free download at *www.cabrillo.edu/~dbrown/**tracker**/*

- *Put the video camera quite near the top of the incline so as to obtain a clear and focused picture of the "starting" drop.*
- *If there's too little contrast drop/background you may use colored drops obtained mixing water and food coloring.*
- *Put the video camera on a tripod (or any other support or fixed stand). The camera should be at level with the drop surface interface.*
- *Put a screen behind the incline and choose its color in order to enhance the contrast between the drop and the incline.*

1. Start videorecording.
2. With a Pasteur pipette deposit a single drop at the top end of the incline. Then slowly begin to increase the incline tilt angle till the drop starts moving.
3. Stop the recording and write down the angle (this is the **rolling angle** : $\Theta_{incline}$ = …… If the incline has not a goniometer embedded you may decide to calculate it through trigonometry.
4. Extract from the video the picture of the drop just before it starts moving and calculate the **contact angle hystheresis** $\Delta\Theta$ (difference between the drop contact angle at the front Θ_f and at the rear Θ_r).
5. Repeat the whole procedure with the other strips of different materials. Write down your observations and fill in a table.(See *Table 1*)



L'isteresi dell'angolo di contatto è data da $\theta_f - \theta_r$

Advanced

For each of the above tested materials you may answer to the following additional questions seguenti quesiti

1. Could you estimate the **static friction coefficient** μ_s?
2. Which is the **minimum force** F_μ you have to exert to move the drop?
3. Which is the minimum value for the static friction coefficient between drop and inclined surface so that the drop will roll down the plane without actually sliding? **Table 1**

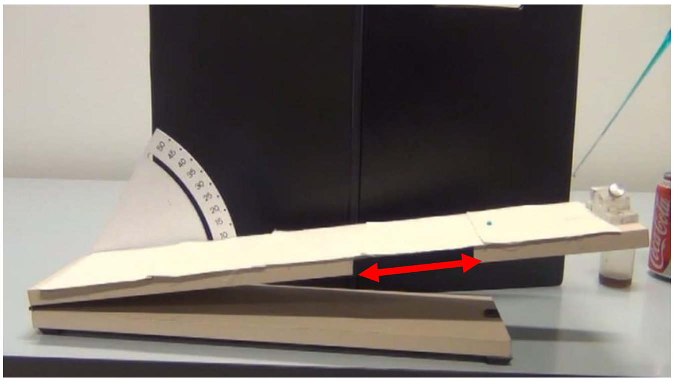
Material	Θ_f (°)	Θ_r (°)	$\Delta\Theta$ (°)	$\Theta_{incline}$ (°)	μ_s	F_μ (N)

Data Analysis

1. Compare the tilt angles with the contact angles (vedi Esp.1) for the same sample. Would you agree or not that a high contact angle always implies a better mobility of the drop on the surface? Why?
2. Is there any relationship between friction coefficient and contact angle hystheresis?

3. And between these two parameters and the tilt angle of the incline?
4. What changes when the drops dimensions vary?

Video n°2- Investigating drop motion on different surfaces.



1. Tape a 10 cm long colored strip on the side of the incline (see red double arrow in the picture): you will use it as a reference for calibration of Tracker software.
2. Video record the motion of the drop down the incline covered with the superhydrophobic material to be investigated .

Tips : Put the videocamera at a proper distance to discern the drops clearly in the video (this is particularly important if you want to exploit the autotracking functionality of Tracker) and check that the whole incline is framed in. once you attain this two features do not move the frame during videorecording.

3. Try to change the following parameters

   a) Drops dimensions You may use the micropipette regulating it on different volume capacity, then from the volume you can calculate the radium with the simplifying hypothesis that drops are perfectly spherical. If you don't have such a tool you may use syringes with different needles and pipettes. You shoul at least have two different sizes for the drops. (You may also try to obtain the radium with Tracker from pictures in the video)
   b) Incline tilt angle

   Repeat the procedure with some of the other materials

Data analysis

1. With Tracker from video n°2 obtain the drop motion s=s(t), v=v(t),a=a(t)
2. Compare results obtained with different materials and note down the different types of motion (rolling, sliding, stick and slip,…).

You may fill in a table similar to this:

Material	R (mm)	M (g)	Distance (mm)	Time (s)	Final speed (mm/s)	Average speed (mm/s)	Θ_{piano} (°)
…….							

- Are you able to transport liquid without any leek?
- Can you do it fast?
- Is it better to use many small drops or rather one big drop? Why? gocce piccole od una sola goccia di grandi dimensioni? Perché?

Further research

In case of superhydrophobic materials the drop moveent is a rolling one and the corresponding model is the one about a solid sphere rolling freely down the incline.

1. Find out the dynamic friction coefficient μ_d..
2. Which is the minimum force to exert to keep the drop moving?
3. Which are the limits of this model?.

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