WATER DROPLETS ON A HYDROPHOBIC SURFACE
(FLOW VISUALIZATION FALL 2016)

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ABSTRACT

This paper describes the art and physics of the interaction between a hydrophobic surface and water droplets. The experiment was performed for the Flow Visualization course at the University of Colorado at Boulder for the Fall 2016 semester. The project was performed as a team (Team 2) that includes: Sierra Castillo, David Leng, and Kate Gresh. On October 25, 2016 Team 2 met at Professor J. Hertzberg's laboratory at the University of Colorado at Boulder (Figure 8). Images were taken of water dropped on to a hydrophobic gortex surface.

The images were captured using equipment courtesy of Professor T. Truscott of Utah State University. The equipment consisted of a Phantom v2011 camera. The Phantom v2011 camera is a high-speed camera with over 22,000 frames-per-second at 1 megapixel resolution. Post-processing was performed by T. Mironuck to add music by A. Englehart.

INTRODUCTION

The second team image for the Flow Visualization course at the University of Colorado at Boulder was completed using a high-speed digital camera (Phantom v2011). The goal was to show the fluid interaction between water dropped on to a hydrophobic surface. The water was dropped from a height of approximately 18" on to a hydrophobic surface consisting of a gortex coat. The images created a movie that shows how the fluid interacts on a hydrophobic surface and how dispersion, or the puddle effect typical for water on a surface, is eliminated.

Figure 1: Water Droplet on a Hydrophobic Surface- Created by Team 2

Figure 2: Team 2 Image Showing the Puddle Effect vs Water on a Superhydrophobic Surface – Courtesy of D. Leng

Camera Set-Up

The Phantom v2011 camera [Ref 4] was set-up in the laboratory of Professor J. Hertzberg at the University of Colorado at Boulder. The camera was provided, and the images were taken, courtesy of Professor T. Truscott of Utah State University.

The camera was mounted on a tripod and focused on the gortex surface at the point of the water droplet impact (Figure 3).

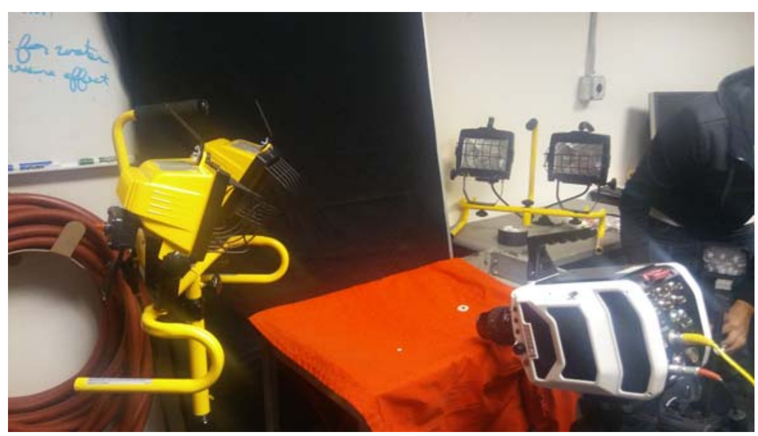

Figure 3: Phantom v2011 Camera Set-Up

Water was dropped on to the surface using a plastic syringe from a height of approximately 18". A tripod was utilized to provide a consistent height and point at which to drop the water (Figure 4). Several water droplets were initially dropped to obtain camera focus.

Figure 4: Water Droplet Syringe and Tripod Set-Up

Fluid Physics

Fluid interaction with a hydrophobic surface is an area of current research studies. Team 2 chose to investigate the fluid physics interaction, and visually captured the unique fluid phenomena for the second team project. The wetted surface interactions with the fluid is well demonstrated in the video with the hydrophobic surface and water droplet clearly showing a well formed droplet which spreads upon impact and then re-forms so the puddle effect does not occur.

The contact angle (θ) on a wetted surface is given by Young's Equation (1805) as [Ref 1]:

$$\cos\theta = (\gamma_{SV} - \gamma_{SL}) / \gamma_{LV}$$

γ_{SV} = Solid Surface Energy
γ_{SL} = Solid-Liquid Interfacial Energy
γ_{LV} = Liquid Surface Tension

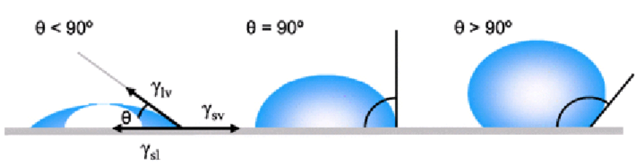

Figure 5: Contact Angles – Formed by sessile liquid drops on a smooth homogenous solid surface [Ref 2]

The contact angle (θ) on a rough surface is defined by Wenzel's Equation where roughness is determined by the roughness factor and has a value greater than one [Ref 3]:

$$r = A_{rough} / A_{flat}$$

r = Roughness Factor
A_{rough} = Area of the rough surface
A_{flat} = Area of the flat surface

The contact angle (θ) on a rough surface is given by Wenzel's Equation [Ref 3]:

$$r \cos\theta = r (\gamma_{SV} - \gamma_{SL}) / \gamma_{LV}$$

γ_{SV} = Solid Surface Energy
γ_{SL} = Solid-Liquid Interfacial Energy
γ_{LV} = Liquid Surface Tension

A hydrophobic surface exhibits a fluid interaction with a contact angle greater than 90 degrees [Ref 2]. Fully wetted surfaces exhibit a contact angle of 0 degrees with water and show a puddle, as shown in Figure 2 [Ref 2].

The video clearly demonstrates the water droplet impacting the hydrophobic surface and reforming in to a droplet with theta greater than 90 degrees. The droplet was observed reforming in to smaller droplets and also reforming in to the original single droplet. Note: during the camera set-up and focusing, the hydrophobic surface became wetted if water was left on the surface, but the fluid phenomena of a wetted surface was not observed during the water droplets being dropped on to the surface and removed after the images were taken.

Photographic Technique

The photographic technique included the following equipment:

-Phantom v2011 High-Speed Camera (Figure 6):

Figure 6: Phantom v2011 [Ref 4]

Phantom v2011 Specifications [Ref 4]:
-22,000 frames-per-second
-1.0 Megapixel resolution
-1280 x 800 resolution
-28 micron pixel size, 12-bit depth

-Color 10,000T; 6,400D
-305ns minimum exposure with the FAST option
-Up to 666,000 fps standard

Post-processing included:
-reducing the file size
-choosing music by A. Englehart
-video editing and the addition of music by T. Mironuck
-conversion to MP4 format

Figure 7: Team 2 Project 2 Video – K. Gresh
http://www.flowvis.org/2016/10/22/team-2-project-2-k-gresh/ [Ref 5]

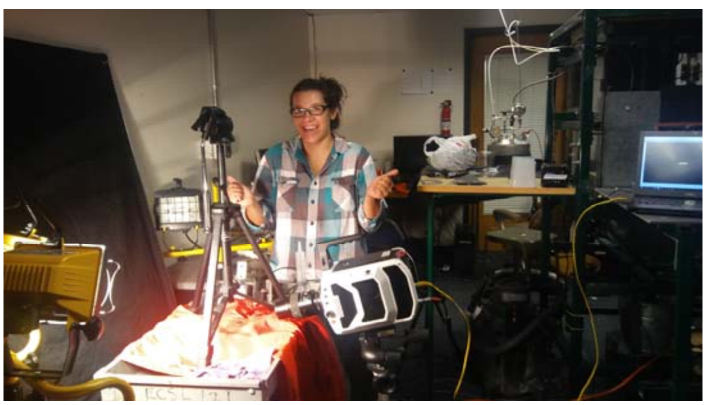

Figure 8: Team 2 at Professor Hertzberg's Laboratory at the University of Colorado at Boulder – S. Castillo pictured

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