Get wet

Flow Visualization

Ray (Hsin-Jui) Wu

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Prof. Hertzberg and Prof. Sweetman

Introduction

The purpose of the first flow visualization assignment is "Get wet". That is to say, getting started in capturing images of flow phenomenon. There are many flow phenomenons around us in everyday life, involving air, water, and any fluid or combination of fluids. But the questions are how to capture the flow in good visual images and how to set up the equipment in the experiment. That is the goal of the first assignment in the flow visualization course.

Image purpose

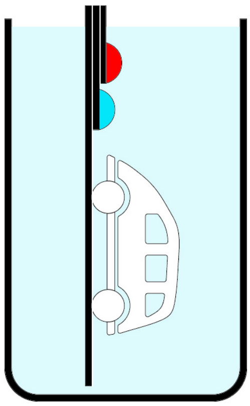
The purpose of my "Get wet" assignment is to get the images of capturing the streamlines over a small toy car. In the automotive industry, lots of testing for Aerodynamic Drag is done. This usually requires a wind tunnel designed for a test model to obtain the frontal drag force on the car and also to see the streamlines of the air flow around the car. Therefore, my imaging objective is to simulate the streamlines of food coloring dyes around the car in the water as a visual observation of the liquid flow.

Apparatus

First of all, I prepared several components including a beaker, a small toy car, few slides, and food colorings to assemble (see Figure 1). Because wind tunnels usually use the pumped air flow to make visible streamlines around the car in the horizontal plane, I used different color dyes that were moved downwards by gravity in the vertical plane to be visible streamlines in the water. The steps are as follows:

1) Filling up the beaker with water and then waiting about ten minutes to make the water more stable.

2) Using adhesive tape to assemble three slides, and placing a car, blue coloring, and red coloring on the three different levels.
3) The Height of beaker is 12cm; the toy car length is 2cm.



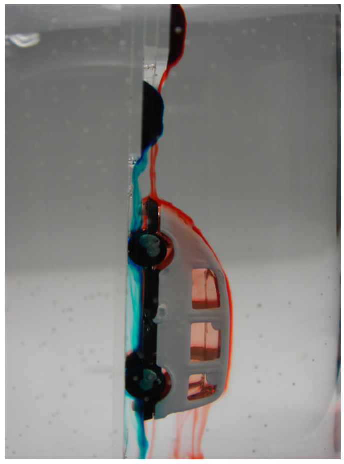


Figure 1: Experimental Setup Schematic

Description

After the water in the beaker is stable, the fixture of the car and two colorings are placed into the water. The colorings move down to approach the front of the car, then smoothly go over the car's shape. The red coloring moves around the top side of the car and another blue coloring move around the bottom side (see Figure 1). We can successfully observe the streamlines in the images as well as in images of wind tunnel experiments.

Estimating the approximate Reynolds number

$$Re = \frac{\rho v_s^2/L}{\mu v_s/L^2} = \frac{\rho v_s L}{\mu} = \frac{v_s L}{\nu} = \frac{\text{Inertial forces}}{\text{Viscous forces}}$$

v_s - mean fluid velocity, [m s^{-1}] , L - characteristic length, [m]

μ - (absolute) dynamic fluid viscosity, [N s m^{-2}] or [Pa s]

ν - kinematic fluid viscosity: $\nu = \mu / \rho$, [m^2 s^{-1}]

ρ - fluid density, [kg m^{-3}].

The speed of the colorings measured approximately 1 cm/sec. Because the colorings look like the human blood, we assume the coloring density is 1.1 (human blood density is 1.05~ 1.06). The colorings have little more viscous than water, so we assume the viscosity of coloring is 1.2 X10^{-3}N s/ m^{-2}. The characteristic length is 0.1 m.

	viscosity [Pa·s]	viscosity [cP]
liquid nitrogen @ 77K	0.158×10^{-3}	0.158
acetone*	0.306×10^{-3}	0.306
methanol*	0.544×10^{-3}	0.544
ethanol*	1.074×10^{-3}	1.074
water	0.894×10^{-3}	0.894

In this case,
v_s : 0.01 m/s,
L: 0.1 m,
μ: $1.2 X10^{-3}$N s/ m^2
ρ: 1.1 kg/ m^3
Therefore, the estimated approximate of the Reynolds number is 1; so there is the laminar flow shown in my experiment.

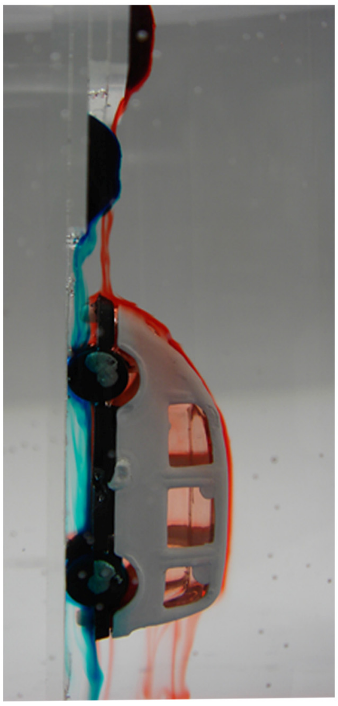
Photographic technique

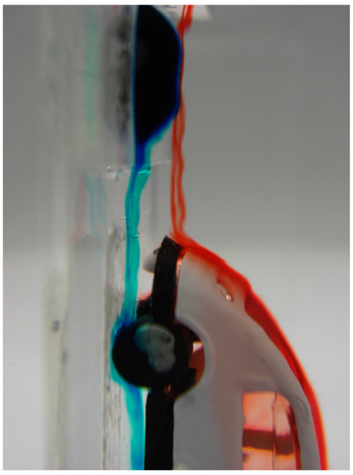
1) Size of the field of view is 12cm X
2) Distance from object to lens is 3cm
3) Lens focal length and other lens specs are [Automatic Macro] [exposure 1/60 sec] [Focal length 6.3 mm] [Max Aperture value f/3.5] [No flash]
4) Type of camera: Make: Sony DIGITAL CAMERA; Model: DSC-T9; Pixels W X H: 2112 X 2816.

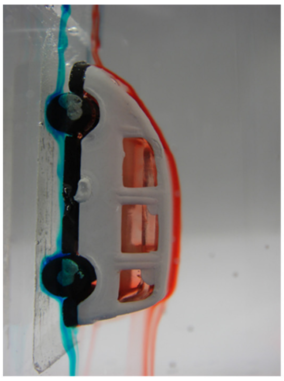
Discussions

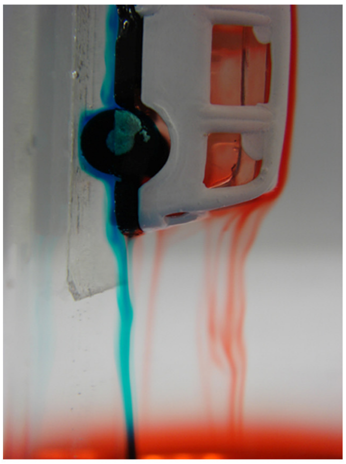
For the camera selection, I tried to use the Canon XTI camera with 18-200mm lens to capture the image, but it did not work because the lens doesn't have function of the micro. So that I took another digital camera "Sony DSC-T9" that has a micro function that can capture the target at a very small distance. All images not only reveal the obvious streamlines of the laminar flow around the car, but also are good representations of Aerodynamic phenomenon, using simple food coloring and equipment. The streamline depends on several conditions such as the shape of the body, and the Reynolds number. For my experiment, I did not see any turbulent flow in my all images (See Appendix). Even when I used a differently shape small car instead, there were no signs of turbulent flow. The reason is that the Reynolds number is very small, inducing the laminar flow in my experiment.

Appendix









References:

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