Group Project 3 - The Wetsuit

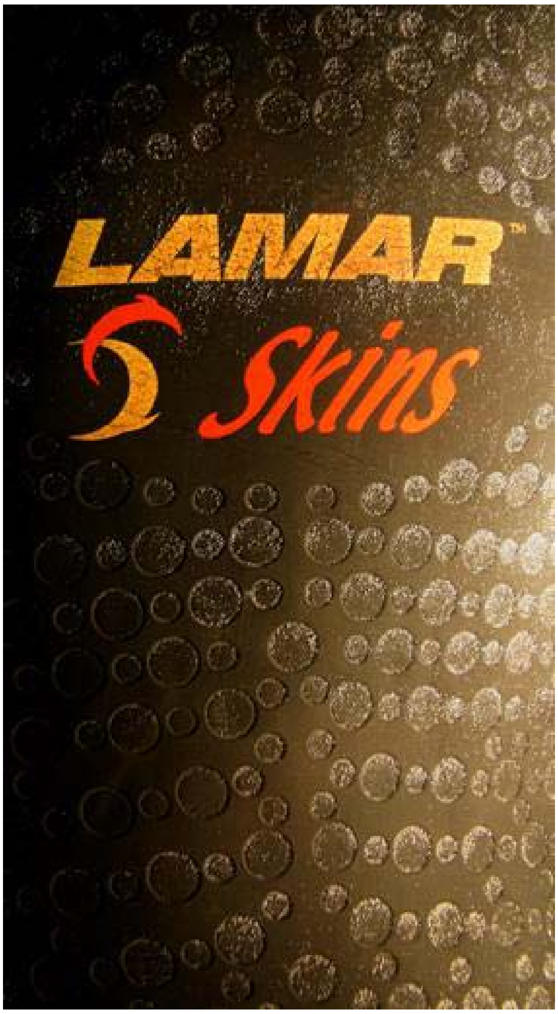

Figure 1: Final image

Flow visualization
MCEN-4228/5228
Date: 05-03-2006

Group members (in alphabetical order):
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Introduction

Lamar designed wetsuits are worn by race-winning swimmers worldwide. Different wetsuit designs have begun to produce record breaking times. The final goal of this final project was to visualize any reason why one Lamar wetsuit design would produce faster race times than two other designs. The initial wetsuit design is a smooth surfaced neoprene suit. The second wetsuit tested was the same smooth surfaced suit with raised painted circles ranging from three eights to three quarters of an inch. The final, and the fastest race proven, suit design consisted of flat recessed dimples with diameters ranging from three eights to three quarters. To determine why one suit is faster than others, we photographed different designs' boundary flow characteristics in a stream of water.

Experimental Setup

Figure2: (a) The water flume setup, (b) Side view of the Flume

A picture of the open channel water flume is shown in Figure 2, which is located at the civil engineering department basement, with the permission to use by Professor John Crimaldi. The water flume has a 2 ft x 3 ft x 15ft channel bed with the water level in the working section of the flume approximated to about 5 inches high. Pictures were taken from the bottom of the flume through a clear layer of glass. In order to get sufficient light, one set of high-powered 500 watt halogen lamp is used to illuminate the environment in addition to fluorescent ceiling lights. A foam insert is enclosed by the wetsuit in order to simulate a human body form. The foam insert also provided buoyancy so that the wetsuit did not sink down to the bottom of the flume. The speed of the flow was set to 40 Hz, and it is estimated to be about 2.3 ft/s.

Fluid Dynamics

According to [1], the flow characteristic can be determined by calculating the Reynolds number for the system which is given by:

$$Re = V*D/\nu$$

Where V is the velocity of the water, D is the length of the wetsuit, and ν is the kinematics viscosity of water. The velocity of the water is estimated to be about 2.3 ft/s. With $\nu = 1.08x10^{-5}$ ft^2/s, V = 2.3 ft/s, and D = 2.5 ft, the Reynolds number is calculated to be $Re = 4.9x10^5$ which is less than the critical point $Re_L < 5x10^5$, and therefore, the flow is laminar.

The recessed dimples of the third wetsuit, which is shown in figure 4, are trapping the air bubbles flowing in the stream of water. The bubbles being trapped increase the buoyancy of the wetsuit. This increase in buoyancy is equivalent to the mass of water the bubbles are displacing. Assuming the wetsuit was to trap 0.1 Liters of air underneath the suit, the buoyant force would be as follows [2,3]:

The mass of air displacing the water is equal to the volume of air multiplied by the density of air:

$$M_{air} = V*\rho_{air} = 0.1L*1.3kg/m^3*0.001m^3/L = 0.00013\ kg$$

The mass of water displaced equals the volume of air multiplied by the density of water:

$$M_{water} = V*\rho_{water} = 0.1\ L * 998\ kg/m^3 * 0.001\ m^3/L = 0.01\ kg$$

The buoyant force is equal to the difference in masses multiplied by the acceleration of gravity:

$$F_b = [M_{water} - M_{air}] * g = [0.01\ kg - 0.00013\ kg] * 9.8\ m^2/s = \mathbf{0.097\ N}$$

This force is the buoyant force helping lifting the swimmer out of the water. The more the swimmer is out of the water the faster the swimmer can swim since water is more viscous than air, and the lighter the swimmer, the faster he can swim.

Figure 3 shows a comparison of the three different types of wetsuit. The image on the left corresponds to the smooth surfaced neoprene suit, while the middle image is the smooth surfaced suit with raised painted circles, and the last image is the flat recessed dimples, which is the fastest one. The images clear illustrated that no bubbles were trapped on both of the smooth surfaced suits while a lot of bubbles were trapped on the receded dimples on the third image.

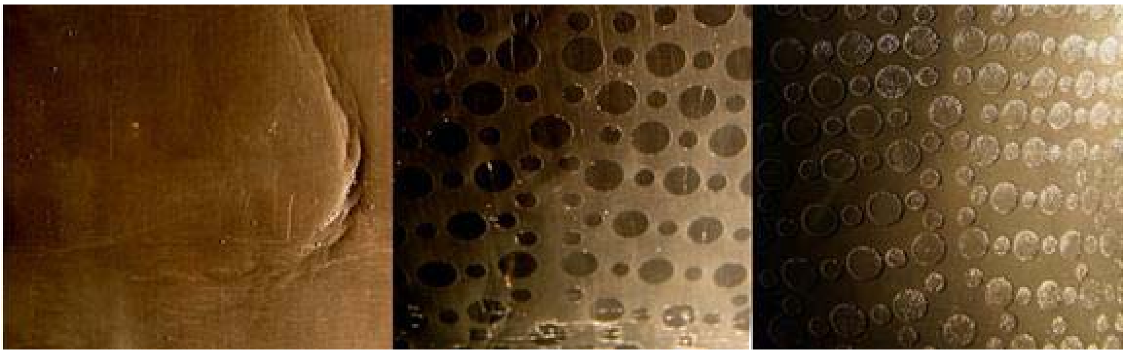

Figure 3: Comparison of three different types of wetsuit.

Visualization Techniques

By placing the wetsuit in fast flowing water, air bubbles inherently found in the water stream across the wetsuit and help to illustrate how the water flows over the wetsuit. Our pictures illustrate this by showing air bubbles caught in the recessed dimples of one wet suit and few bubbles caught on the wetsuit with no dimples and even fewer bubbles with no dimples at all.

Photographic Techniques

The camera used to take the image was a Canon EOS Digital Rebel XT with 8.0 Megapixel. Some of the details of the photographic techniques are listed below:

- Field of view – 18 in by 10 in
- Distance from object to lens – 1 ft
- Lens focal length and other lens specs:
  - Focal length – 26 mm
  - ISO light sensitivity of 400
- Type of camera – Canon EOS Digital Rebel XT
- # pixels –2304 x 3456
- Exposure specs

- Aperture – 4.6
- Shutter speed – 1/40 sec
- F-Number – F/5.0
- Exposure time – 1/40 sec

Adobe Photoshop CS is used to process the image shown in figure 1, which is the final image. The image was cropped to isolate the desired image. Some adjustments have been made to create a more dramatic image, and they are:

- Contrast and brightness – Contrast level is increased to +20 to bring out the contrast of the clouds and the brightness level is increased to +10

Conclusion

The images shown in the above sections clearly demonstrated the different boundary layer of the three different types of wetsuit under water flows. The images also illustrated the reason why the wetsuit design consisted of flat recessed dimples is faster than the others, and that is, due to the buoyancy effect of the air bubbles that were trapped underneath of the dimples of the wetsuit. The most we like about the image is that it is easy to visualize the air bubbles that were trapped on the wetsuit as well as the water streamline. The most we dislike about the image is the lighting gradient across the wetsuit, and it was impossible for us to get a uniform gradient of light all across the wetsuit. Is the air bubble the only reason why the wetsuit is faster than the other ones is the equation that we would like to ask. Overall, we are able to visualize the reason why one Lamar wetsuit design would produce faster race times than two other designs, therefore, our intent is fulfilled. One improvement can be done is injecting dye into the water and produces a better view of the water streamline as well as the air bubbles.

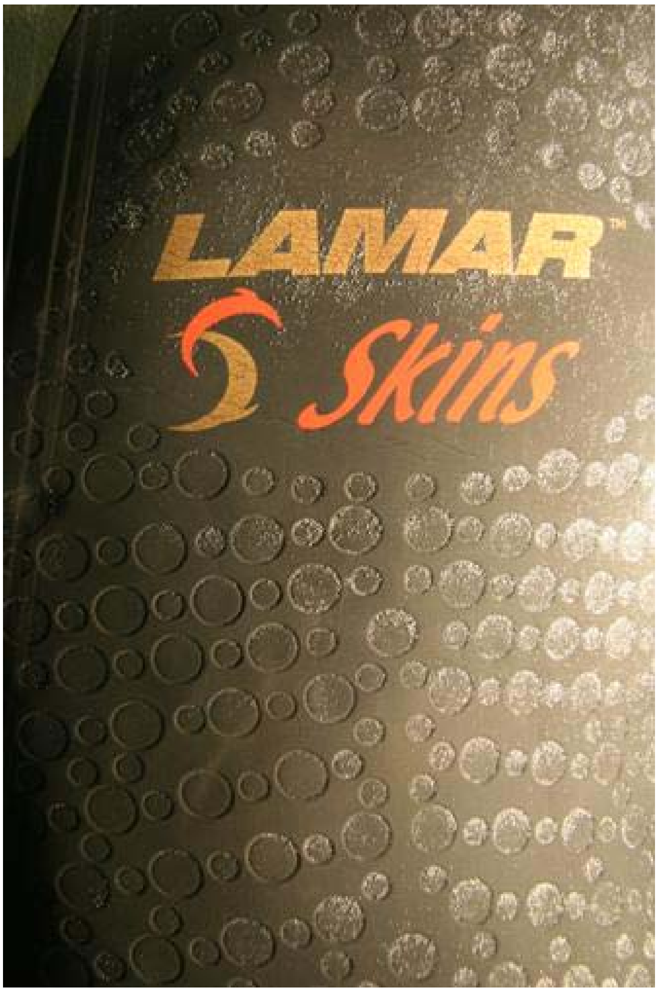

Figure 4: Original image

References

[1] Principles of Heat Transfer, by Frank Kreith, Mark S. Bohn.

[2] Brujan, "Buoyant bubbles close to a rigid boundary and near the null final Kelvin impulse state". International Journal of Multiphase Flow Vol. 31 2005

[3] Fundamentals of Fluid Mechanics, Bruce R. Munson.

Image Assessment Form
Flow Visualization
Spring 2006

Names: Nigel Gorbold, Lok Kin Lee, Christopher McCray, Taylor Simonson, Melissa Talmage

Assignment: Group 1 Date: 03/15/2006
Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Instructor assessment
Intent was realized	√	
Effective	√	
Impact	√	
Interesting	√	
Beautiful	√	
Dramatic	√	
Feel/texture	NA	
No distracting elements	√	
Framing/cropping enhances image	√	

Flow	Your assessment	Instructor assessment
Clearly illustrates phenomena	√	
Flow is understandable	√	
Physics revealed	√	
Details visible	√	
Flow is reproducible	√	
Flow is controlled	√	
Creative flow or technique	√	
Publishable quality	√	

Photographic technique	Your assessment	Instructor assessment
Exposure: highlights detailed	√	
Exposure: shadows detailed	√	
Full contrast range	√	
Focus	√	
Depth of field	√	
Time resolved	√	
Spatially resolved	√	
Clean, no spots	√	
OK, simple print	√	
Mat	√	
Mounting	√	

Report		Your assessment	Instructor asssessment
Describes intent	Artistic	√	
	Scientific	√	
Describes fluid phenomena			
Estimates appropriate scales	Reynolds number etc.	√	
Calculation of time resolution etc.	How far did flow move during exposure?	√	
References:	Web level	√	
	Refereed journal level	√	
Clearly written		√	
Information is organized		√	
Good spelling and grammar		√	
Professional language (publishible)		√	
Provides information needed for reproducing flow	Fluid data, flow rates	√	
	geometry	√	
	timing	√	
Provides information needed for reproducing vis technique	Method	√	
	dilution	NA	
	injection speed	NA	
	settings	√	
lighting type	(strobe/tungsten, watts, number)	√	
	light position, distance	√	
Provides information for reproducing image	Camera type	√	
	Camera model	√	
	Field of view	√	
	Focal length	√	
	aperture	√	
	shutter speed	√	
	film type and speed	√	
	# pixels (width X ht)	√	
	Photoshop techniques	√	
	Print details	√	
	"before" Photoshop image	√	