Duncan Lowery - 10/12/2018
With the Help of Greg Collins, Bradley Busek, and Brent Eckles
FILM 4200-001 - Group First Visualization Report

This video was created for the Team First project. Our goal was to visualize turbulence within the baffles of a Nikola Tesla one-way valve by feeding a dyed, rheoscopic fluid through it. Greg Collins designed our valve in CAD software, and assembled the pieces of laser cut acrylic plastic into a flat, transparent unit, allowing us to clearly see the fluid inside. He also attached feed and drainage tubes to both ends of the valve, and a fluid reservoir made of the bottom half of a milk jug to the forward-feeding tube. Below is Tesla's original sketch submitted to the U.S. patent office in 1916, that Greg modeled our valve after.

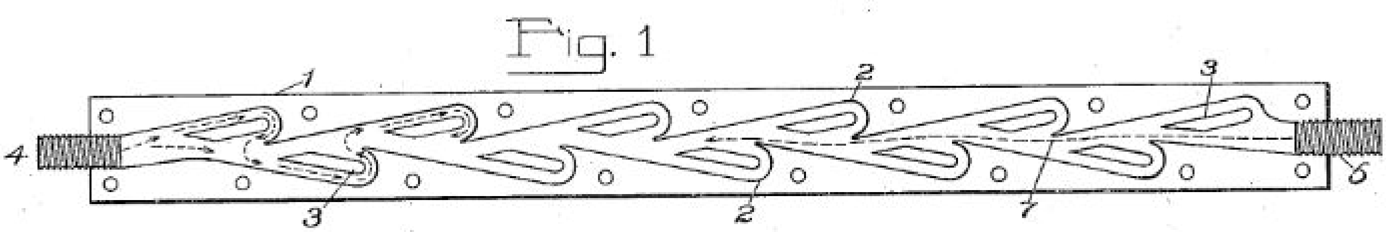

Image Credit: Nikola Tesla; United States Patent and Trademark Office

Brent Eckles held the valve in place for framing in the shot, and blew the fluid in the other direction through the valve to demonstrate the turbulent flow created by the baffles. Bradley Busek held in place and adjusted the orientation of the lights when needed, and helped manage the fluid that leaked out of the valve between shots. I operated the camera, and gave feedback to the rest of my team on the changes that needed to be made to get the best image. The rheoscopic fluid was made by Greg Collins from a gallon of expanded Barbasol shaving cream and ¾ gallon of water mixed together prior to the shoot. The rheoscopic fluid was filtered several times to reduce cloudiness (Collins 2018). For our visualization, eight drops of red food coloring were added the two cups of the fluid we ran through the valve to improve contrast.

Our group used the bottom half of a Hele-Shaw cell (a wooden structure holding a light-diffusing, smooth, translucent surface, with space underneath housing two daylight-temperature LED lights pointed up at the diffusing surface) to place our valve on top of, with hopes that the backlight would make the turbulence within the rheoscopic fluid more visible. The fluid was fed into the valve through tube by force of gravity. The images below (West 2013) illustrate what happens within the valve as fluid passes through in each direction. The colors in these images correspond to the velocity of the fluid as it travels through; the blue signifies areas of lowest velocity, while the highest-velocity areas are represented in red. On the left, the internal turbulence caused by the backfeeding of fluid through the baffles is visible. This happens because the fluid encounters an obstacle when it flows right to left, and can continue on one of two paths. One path leads further into the valve, but the other is separated and redirected, eventually mixing with the rest of the fluid again in the opposite direction, and skewed 20 degrees (Tesla 1920). This creates turbulence at the intersection point, and forces more of the fluid into the next baffle. As a result, the amount of force that needs to be overcome by the fluid to continue in the impeded direction increases with each baffle. The image on the right shows the undisturbed flow through the valve. Because the fluid travels from left to right (the opposite direction), it can follow a path of little resistance, avoiding the obstacles in the valve. This results in unrestricted passage of the fluid in this direction (Tesla 1920; West 2013).

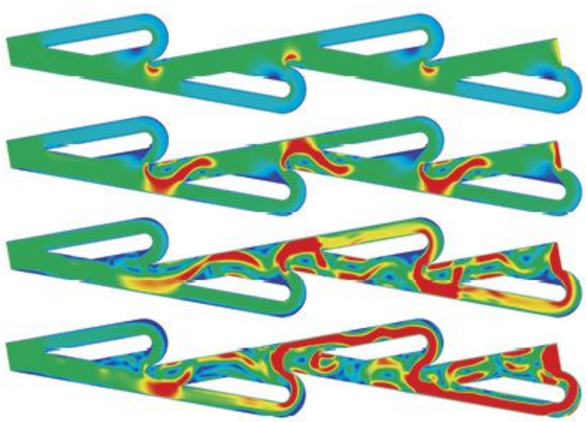

Fig. 2: Flow development in the blocking direction

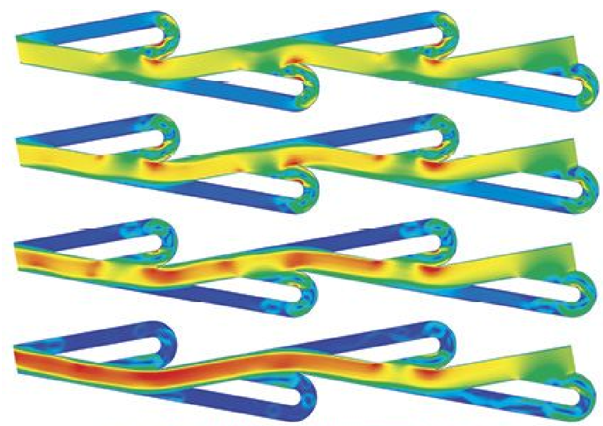

Fig. 3: Flow development in the unimpeded direction

Image Credit: Nathan West, Brigham Young University Idaho

My video was captured with a Blackmagic Pocket Cinema Camera at 1920px by 1080px, through an Albinar variable zoom lens with its focal length set at 200mm. The aperture of the lens was set at f8, and I shot at its minimum focus distance of 4.5 ft. The camera needed to be raised over six feet above the ground to get crisp focus, and my group members were very helpful in arranging and continually adjusting the scene as I watched the camera's LCD preview. The camera's ISO was set at its native value of 800. To minimize motion blur, I set the rolling shutter to 25 degrees. Because I shot at 24 frames per second, the sensor was exposed to light for approximately 0.003 seconds for each frame recorded. I color corrected and edited the video in DaVinci Resolve 15. The colors were inverted, turning the dull red color of the fluid to a vibrant blue-green. I then decreased the lift value until the surface of the Hele-Shaw cell was completely black, then I increased the image gain until the highlights of the image were bright, but not overexposed. I noticed that as my video progresses, some of the fluid leaked onto the surface of the table from the left side of the frame, and creeped to the right. This fluid was much darker than the fluid inside the valve, and was overexposed when the colors were inverted. To mitigate this issue, I ran the color correction to a separate node in DaVinci, where I set the gain value to be a horizontal gradient across the frame. This kept the entire image exposed properly throughout its duration, without the need to compromise the brightness of the fluid flowing through the valve.

In my opinion, the video made for a reasonable, but not ideal portrayal of the way the valve operates. Small bubbles trapped within the fluid got trapped in turbulent and low-velocity areas, and could be seen spinning injust one spot, but the rheoscopic fluid was more or less homogeneous in its color and texture when it was inside the valve. I believe the reason for this was the small size of the valve, because we were only able to see the pearlescent swirls in the fluid when moving inside of larger transparent vessels. Another challenge we faced was the inability of the valve to halt the flow when forced through the direction impeded by baffles. This may have happened because the fluid did not have enough force to cause significant turbulence after being deflected through the baffles, or because too much air was introduced when Bret blew the fluid back into the other side of the valve. If I were to recreate this particular flow, I would use a mechanical pump to supply a more useful amount of force and eliminate any gases from the system. To better demonstrate the turbulence created by the baffles, I would use a larger-scale valve if feeding rheoscopic fluid through it, or I would try to employ Schlieren imaging techniques.

References:

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2. West, Nathan. "Tesla's Valvular Conduit." Fluid Power Journal. October 23, 2013. http://fluidpowerjournal.com/2013/10/teslas-conduit/.
3. Collins, Gregory. "First Team Photo." October 09, 2018. http://www.flowvis.org/2018/09/22/team-first-greg-collins/.