Air Flow in between Two Layers

Introduction

The context of this image is to visualize the air flow underneath the paper in a printer while printing. The purpose of capturing the image is to understand how the air flows in between two layers of surface, in this case, the two layers of surface represent the paper and the printer preheat pattern. Various phenomena can be identified from the image such as the motion of the fluid flow and the interference between two air flows. Several experiments have been done for various studies, and the best shot is used as the final image for the discussion in the rest of this paper. In the experiment, two air-flows are coming out from the two holes simultaneously and interference with each other and going to all directions. A stagnation line, which is due to interference of the two air-flows, is then formed in between the air-flows as shown in figure 1 below.

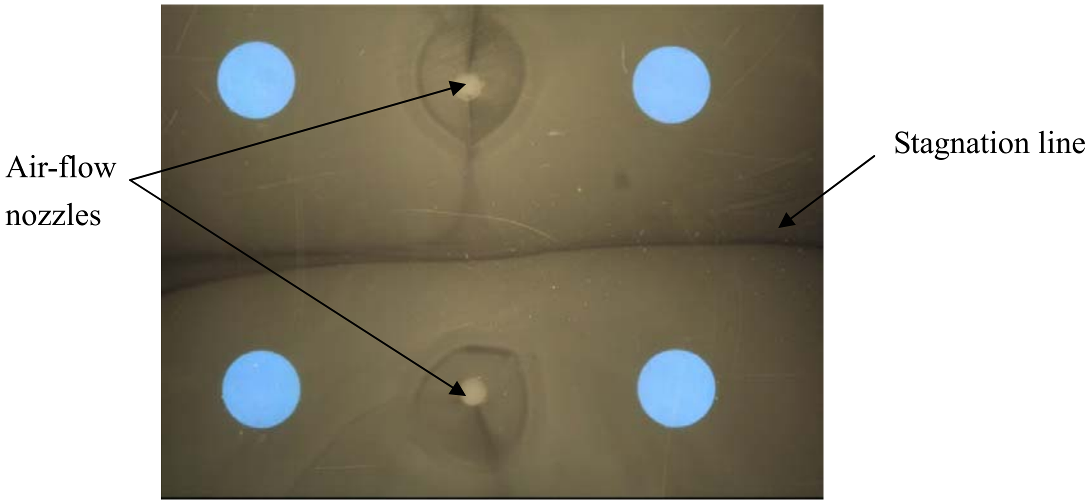

Figure1: Stagnation line formed by two air flows.

Experimental Setup and Discussion

The experimental setup and their quantities are as follows: two air-flows are coming out from the two holes on a black plastic platen and flow in between the platen and a transparence cover on top, which is showed in the schematic in figure 2.

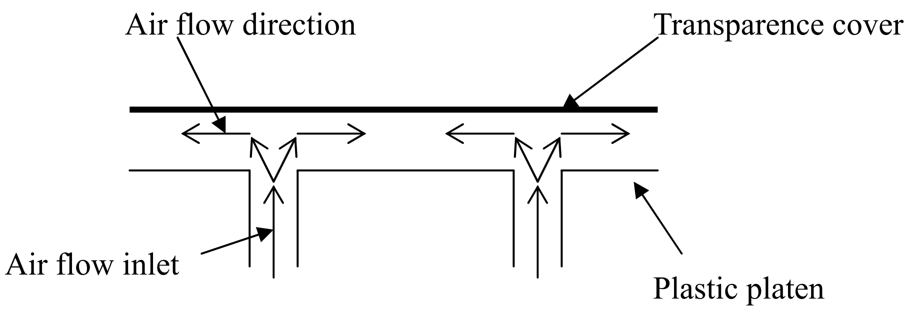

Figure2: Side view of the two air-flows.

The distance between the two holes is about 5 cm, along with 1 cm spacing in between the platen and the cover. A circular flow is formed around the two holes on the platen which is mostly caused by the imperfect spacing in between the platen and the cover around the holes as shown in figure 1. As discussed in [1], for lower velocities, fluid flowing over a smooth surface that is relatively short and flat will only develop a very thin boundary layer. The flow inside the boundary layer will be smooth and orderly, meaning that the layers will basically stay in layers, without mixing [2]. This condition is called laminar boundary layer. According to [3], this can be proved by calculating the Reynolds number for the system which is given by:

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

Where V is the free-stream velocity, D is the distance from leading edge, and ν is the kinematics viscosity of the fluid. The velocity of the flow is estimated by finding the distance of the fluid moves (3.8 cm) divided by the time it takes (0.5 s). With $\nu = 15.7 \times 10^{-6}\ m^2/s$, V = 7.6 m/s, and D = 0.5 cm, the Reynolds number is calculated to be $Re = 2.42 \times 10^5$ which is less than the critical point $Re_L < 5 \times 10^5$, and therefore, the flow is laminar.

Visualization Techniques

In order to visualize the air flow, a Silver Rain Lighting Manufactory fogger machine is used to generate fog for the flow visualization process. To get sufficient light, two set of high-powered halogen lamps are used to illuminate the environment beside room light as shown in figure 3.

Figure3: Experimental setup.

Photographic Techniques

Since the speed of the air flow is relatively fast, an Olympus i-speed high-speed digital camera with Nikon lens is used to capture a video clip for the whole process. Size of the field of view is about 100 cm^2. The distance from object to lens is about

100 cm. Photoshop is applied to the image in order to remove any unnecessary scratches and spots on the image. A comparison of the images before and after Photoshop is shown in figure 4.

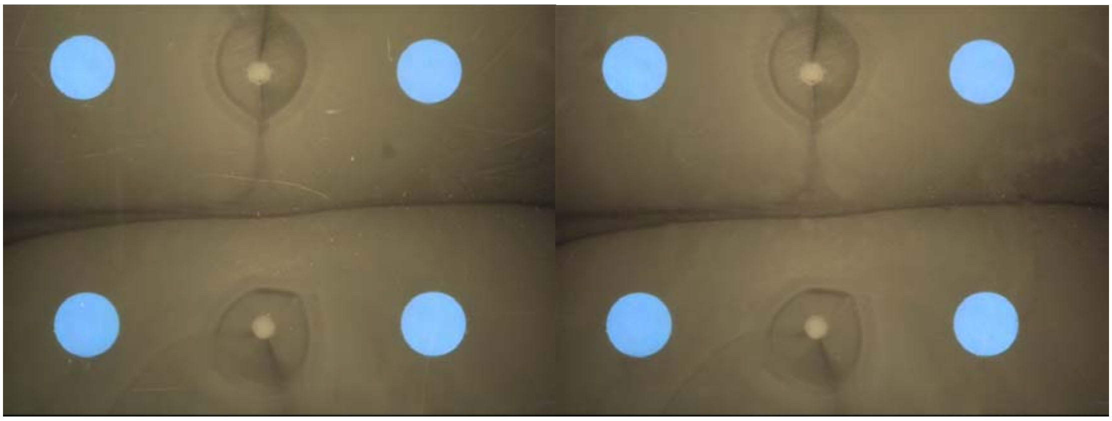

Figure 4: Image a) before Photoshop and b) after Photoshop.

Conclusion

This image reveals how two air-flows interference with each other and form a stagnation line in between them. The most I like from the image is that it clearly shows the behavior of a very laminar air flow, in which we are not able to see normally with dry air. The combination of white fog with black background highly enhanced the visualizability of the air flow. To develop this idea further, more different combination of air flow can be done and investigate the different behavior.

Reference

[1] Cislunar Aerospace, Inc. 2-11-1999.
http://www.fi.edu/wright/again/wings.avkids.com/wings.avkids.com/Tennis/Book/laminar-01.html
[2] Jaywant H. Arakeri, P. N. Shankar. "Ludwig Prandtl and Boundary Layers in Fluid Flow". Resonance. 1999.
[3] Principles of Heat Transfer, by Frank Kreith, Mark S. Bohn.