Team 3 - Coffee

MCEN 5151

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1 Introduction

I took a picture of espresso being made (Figure 1). When espresso is made, water is brought to a high pressure and the steam is forced through ground coffee beans. The steam condensed as it passes through the coffee beans, and exits the apparatus through a nozzle [1]. The espresso appears to bounce off the exit of the nozzle, preferring a narrow path when the picture was captured. A buoyant plume can be seen rising from the brewed espresso.

Figure 1: Final image of espresso being poured.

2 Photographic Technique

The espresso maker was positioned in direct sunlight for the picture. I cleaned all the surfaces carefully. Unfortunately, some espresso spilled on the espresso cup while I was shooting. I held the camera in my hands, which resulted in a small amount of motion blur and a slight tilt to the image. A high shutter speed was used to prevent motion blur and a low ISO was used to prevent image quality corruption. The camera settings used are shown in Figure 2.

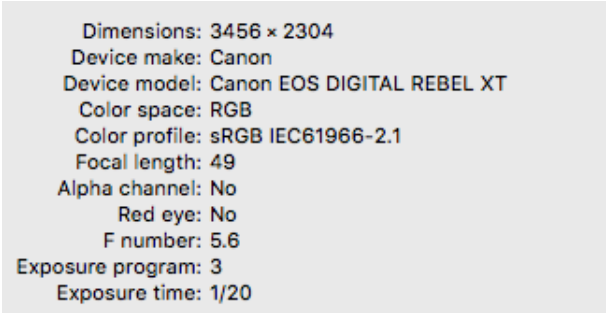

Figure 2: Settings used to capture image

3 Relevant Physics

There are two interesting flow phenomena in the image: the dynamics of the coffee leaving the nozzle and the shape of the steam made by the plume. The flow from the nozzle is a little mysterious–it was not clear to me why a low-pressure nozzle would act that way. The stream of espresso becomes thinner as it falls, indicating that it is being accelerated by gravity. The plume of steam is an example of a Rayleigh-Taylor instability [2], where the difference in densities between the ambient air and steam produce the curling motion. Some researchers have cast this as a KelvinHelmholtz instability, arguing that the rolling motion is primarily caused by the difference in velocities between the ste4am and ambient air. [3, 4]). I argue that this affect is a combination of the Rayleigh-Taylor and Kelvin-Helmholtz instabilities. The vorticity created by the plume interacts with the ambient air, causing vortices to roll out.

4 What the image reveals

The image reveals the wonderful dynamics of a buoyant plume. The difference in density and viscosity between the steam and ambient air creates vorticity, causing the lovely shape to appear in the steam. I hypothesize that the reason the espresso curves is because surface tension dominated the flow near the nozzle exit.

References

[1] S. Rao. *The Professional Barista's Handbook: An Expert's Guide to Preparing Espresso, Coffee, and Tea*. RAO, 2008.

[2] Xi Jiang and K Luo. Direct numerical simulation of the puffing phenomenon of an axisymmetric thermal plume. 14:55–74, 05 2000.

[3] Ahmed Ghoniem, Issam Lakkis, and M.C. Soteriou. Numerical simulation of the dynamics of large fire plumes and the phenomenon of puffing. 26:1531–1539, 12 1996.

[4] Baki M. Cetegen and Kent D. Kasper. Experiments on the oscillatory behavior of buoyant plumes of helium and heliumair mixtures. *Physics of Fluids*, 8(11):2974–2984, 1996.