Floating Granite Sphere at CU Boulder

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Abstract

This report accompanies a video showcasing the floating granite sphere located at the Engineering Center Courtyard, CU Boulder. The video was created for the first assignment of the Flow Visualization class, "Get Wet," which focuses on capturing and analyzing fluid flow in artistic and scientific contexts. The purpose of this image was to explore the fascinating fluid mechanics behind the levitation and movement of the granite sphere as it rotates atop a thin film of water. Capturing this phenomenon allowed me to highlight the motion and flow patterns that sustain the sphere's levitation. The video can be accessed at the following link: https://vimeo.com/manage/videos/1008666657.

1 Introduction

A granite sphere floating in a Kugel fountain is a fascinating demonstration of fluid mechanics, specifically lubrication theory. The image in the video shows the sphere levitated by a thin water film, which supports the weight of the granite by balancing forces across the contact area. This report analyzes the underlying physics and the methods used to capture the motion of the floating sphere.

2 Flow Apparatus and Phenomenon

The granite sphere, weighing several tons, levitates atop a thin water film pumped from beneath. The mechanism can be described using lubrication theory, where water pressure supports the sphere. According to Snoeijer and van der Weele (2014) [1], this system works due to a balance between pressure and the forces acting on the fluid. The thickness of the water film is approximately less than a millimeter, which enables the sphere to spin freely.

Lubrication theory is critical in understanding the dynamics of this system. It describes the flow of a thin fluid layer between two surfaces, and the resistance to movement it provides is largely due to viscous forces. In the case of the floating sphere, water is injected into the small gap between the sphere and its base. This water flows radially outward, creating a pressure distribution that lifts the sphere. The pressure is highest at the center where the water enters and decreases toward the edge. The balance between the weight of the granite sphere and the hydrodynamic pressure generated by the water flow enables the sphere to float stably.

Figure 1: The floating granite sphere at the Engineering Center Courtyard, CU Boulder.

The governing physics can be described as follows: the hydrodynamic pressure generated in the thin water film counters the weight of the sphere. This thin film of water behaves as a lubricant, reducing friction between the sphere and the base. The viscous forces dominate the flow due to the low Reynolds number, indicating that inertia is negligible, and the motion of the water is smooth and steady. As the water flows beneath the sphere, it creates a squeeze film effect. The water is compressed as it flows out from the central point of injection, resulting in the generation of lift, which keeps the sphere hovering.

The laminar nature of the flow is evident from the Reynolds number calculation, which, being significantly below 100, confirms that the flow is slow and controlled by viscosity. The balance between the viscous forces in the water film and the external forces acting on the sphere ensures its near-frictionless rotation and levitation.

$$Re = \frac{UL}{\nu} = \frac{0.1 \times 0.0003}{1.004 \times 10^{-6}} \approx 30$$

The Reynolds number is calculated based on the velocity of the sphere $U = 0.1\, m/s$, the characteristic length of the thin film $L = 0.0003\, m$, and the kinematic viscosity of water $\nu = 1.004 \times 10^{-6}\, m^2/s$. A value of around 30 confirms the flow is laminar, typical of lubrication flow, where viscous forces dominate. The estimation taken into account to calculate the Reynolds number were taken from [1] .

3 Visualization Technique

The video focuses on the floating granite sphere without using external visualization methods like dye or smoke. The reflective properties of the sphere, illuminated by natural lighting, allow for the flow of water around the base to be observed. No significant post-processing was applied to the footage other than minor exposure and contrast adjustments. The video was converted to monochrome to get rid of distracting bright colours in the frame.

4 Photographic Technique

The video was captured using a Canon M50 Mark I with a Canon EF 50mm STM prime lens, shooting at 120 frames per second (FPS) in 720p resolution. The settings were adjusted to an aperture of f/10, shutter speed of 1/160, and ISO of 200. These settings were chosen to optimize depth of field and minimize noise in the available light. The distance from the sphere to the camera was approximately 1.5 meters, and the sphere's horizontal size in the frame was 10 cm.

5 Image Analysis

The final video highlights the smooth, nearly frictionless motion of the granite sphere, illustrating the forces at play in the thin water film. The flow is predominantly laminar, with no noticeable turbulence, which aligns with the low Reynolds number. An improvement to the video could involve capturing a more detailed visualization of the water flow to better observe the fluid dynamics at the contact points.

6 Acknowledgments

I would like to thank Snoeijer and van der Weele for their detailed work on the physics of the granite sphere fountain, which was instrumental in understanding the fluid mechanics involved [1].

References

[1] Jacco H Snoeijer and Ko van der Weele. Physics of the granite sphere fountain. *American Journal of Physics*, 82(5):486–490, 2014.