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Jet Bounce in Low Gravity

Caleb Turner
Portland State University

Maseeh College of Engineering and Computer Science
PORTLAND STATE UNIVERSITY

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Caleb Turner , Karl Cardin, Mark Weislogel

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Introduction

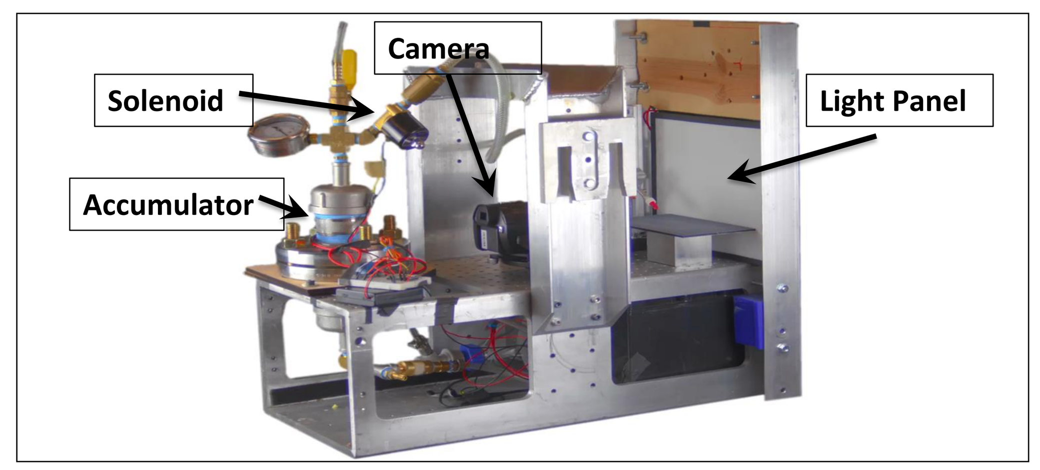
Liquid jets rebound ('bounce') from superhydrophobic surfaces when they impinge at oblique angles. We call this interesting phenomena 'jet bounce' and in this work we investigate the phenomena at large length scales in a reduced gravitational environment. For example, for water at Reynolds numbers $0 < Re < 3500$ and surface normal Weber numbers $0 < We < 60$ we characterize the response of the jets on the hydrophobic surface in the brief 2.1s micro-gravity environment achieved using a drop tower. It is observed that by varying jet velocity, flow rate, jet diameter, and incident angle we observe up to four distinct regimes of behavior. The various regimes may be targeted for specific applications and we demonstrate a variety of unique jet bounce behaviors for applications such as no-touch, no-contact fluid-thermal transport for spacecraft unit operations such as contaminated water processing, device cooling, and cryogenic fluids transport and management

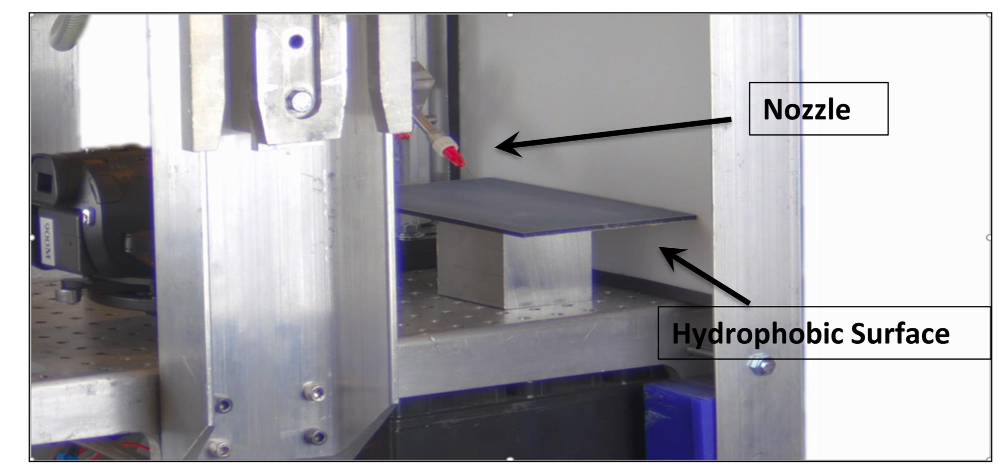
Problem

Terrestrial characterization of the fluid jet bounce phenomena has been well understood for small diameter jets (sub millimetric). We seek to analyze jet rebound's from super hydrophobic surfaces with an increase in fluid jet diameters as well as characterizing the jet response when a step reduction in gravity is introduced.

Materials and Method

The Dryden Drop Tower allows for high volume micro-gravity experimentation of fluidic, combustion, and material science investigation. With a total tower height of 31.1 meters the drag shield, where experiment rigs are interfaced, experiences a free fall distance of 22 meters allowing for 2.1 seconds of a low gravity environment. Using Arduino technology to set a logical sequence for controlling the actuation of the jet we were able to exploit maximum microgravity time during free fall for study of the jet bounce response.





Hydrophobic surfaces were constructed using commercial grade 400 grit sandpaper with a follow on PTFE (Teflon) spray coating as the hydrophobic material mounted to a flat plate to provide the necessary impact geometry. Varying the needle jet diameter, impingement angle, and driving pressure we were able to characterize the jets response based on two dimensionless coefficients, the Reynolds and Weber number.

Results

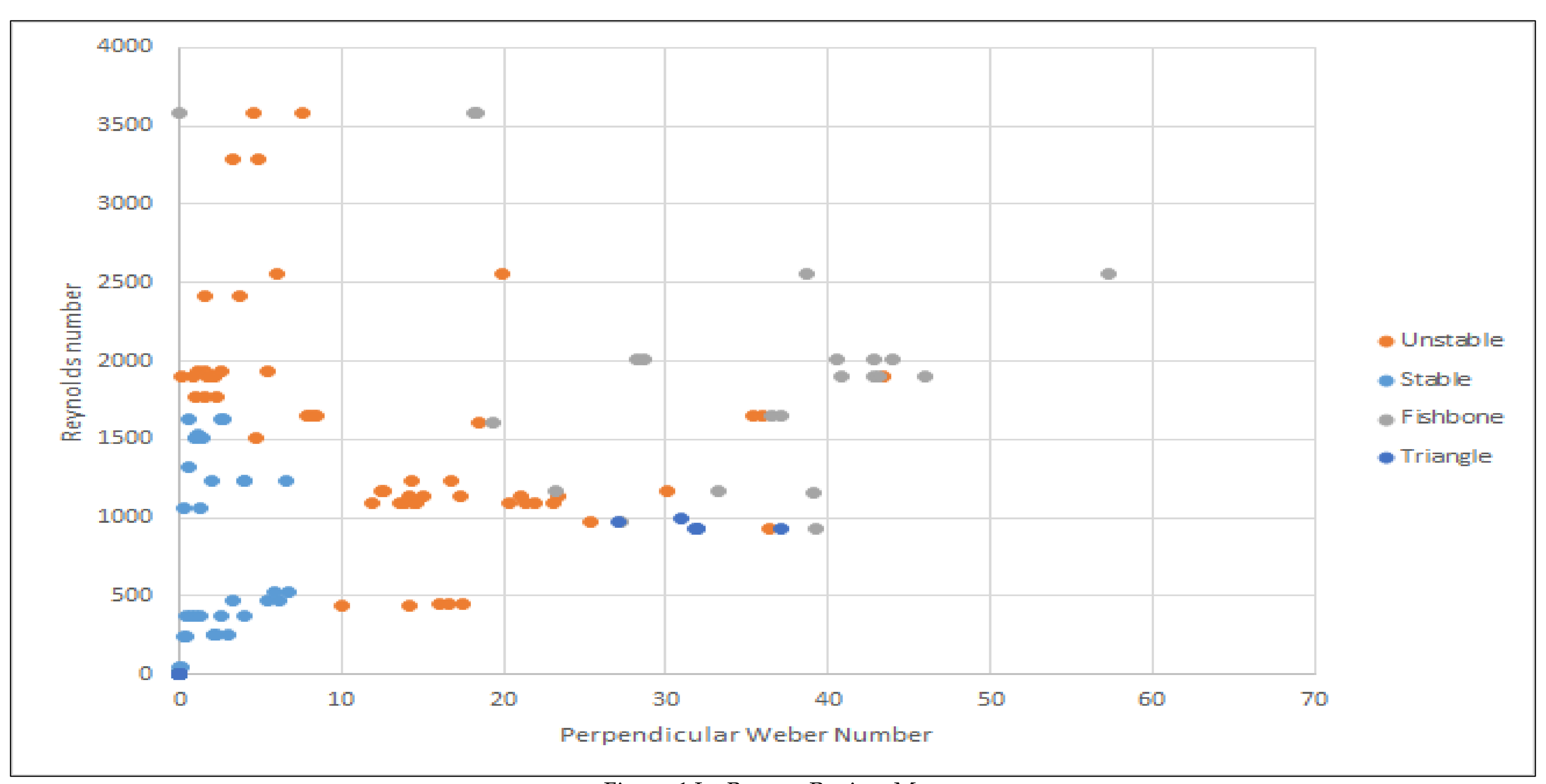
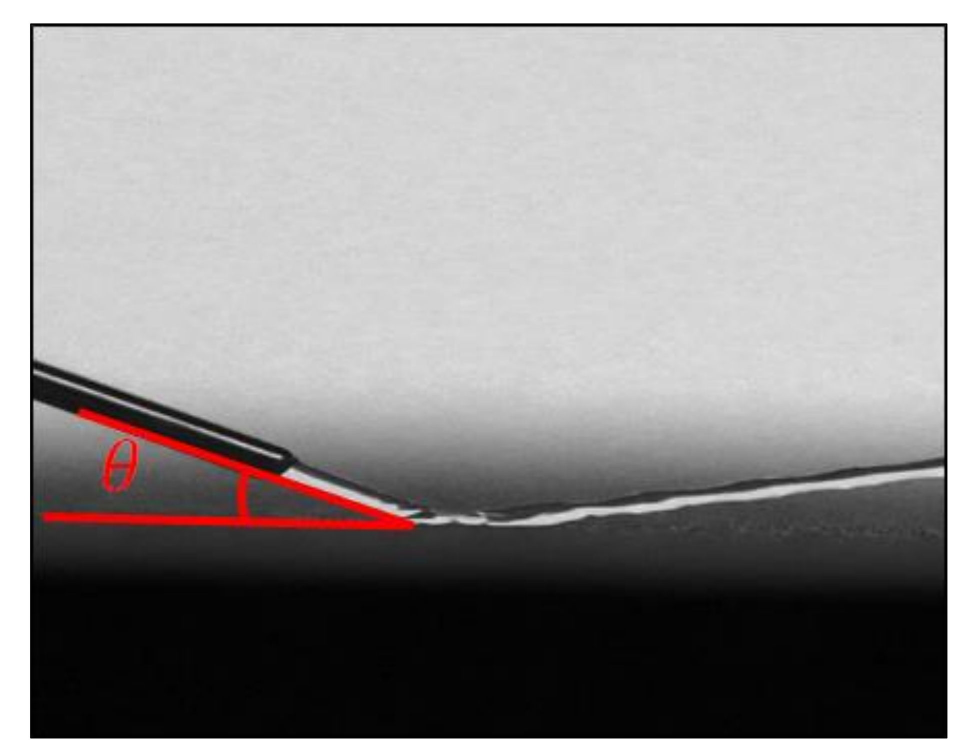


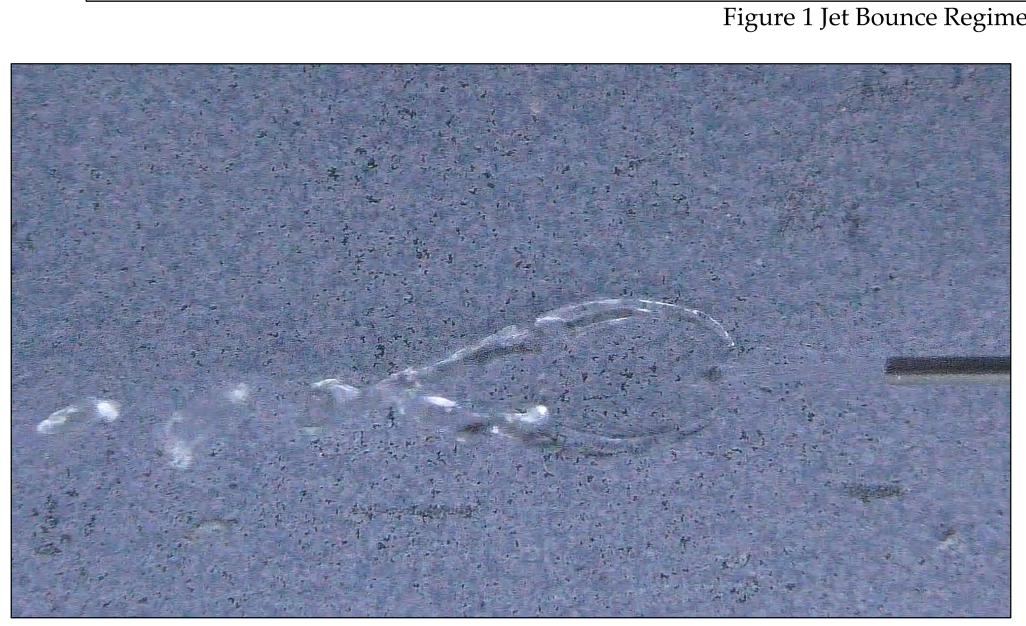
Figure 1 Jet Bounce Regime Map

$$W_e = \frac{\rho(u\sin(\theta))^2 r}{\sigma}$$

$$R_e = \frac{\rho u r}{\mu}$$

ρ: fluid density
u: axial velocity
r: inner radius of jet
μ: dynamic viscosity
σ: surface tension
θ: impact angle

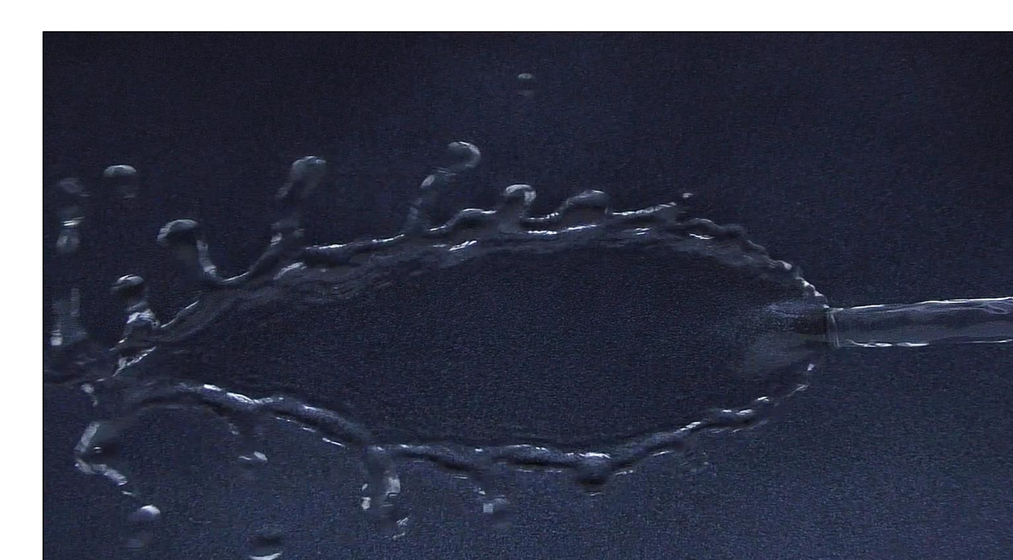




Top view of Triangle Jet Bounce

Top view of Stable Jet Bounce

Top view of Unstable Jet Bounce



Top view of Fish Bone Jet Bounce

Conclusion

Moving forward it is planned to continue refinement of the regime map, gather statistics on previous data points, and gain clarity into where the borders lie between regimes. We also hope to be able to characterize these jet responses from impacting more dynamic geometries.

Research here can be applied to no touch, no contact fluid transfer of caustic fluids in medical or space environments and cryogenic fluid management. The hydrophobic substrates used provide similar fluid reactions as that of the Leidenfrost effect such that jet bounce research can be used in potential cooling system or other environments where fluid jets are impacting surfaces with large temperature gradients.

Acknowledgments

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