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Title: Atomization Study of Simplex Injectors

Abstract

Due to the use of centrifugal forces, swirl injectors are inherently more efficient at atomizing liquids than jet injectors at the cost of analytical complexity. To encourage the use of swirl injectors, we propose the creation of a simpler swirl injector design process based off empirical data to make such systems more accessible. To achieve this, as the injector design is matured, droplet distribution data will be collected to serve as the basis of this new model.

Impact and Rationale

Injectors are devices designed to break apart a continuous fluid into small or even microscopic droplets to catalyze reactions, increase thermal transfer, or regulate atmospheric conditions. As such they are critical to many industries from pharmaceuticals, automotive, aviation, to even agriculture (Lefebvre & McDonell, 2017).

Fig 1. Use of injection for irrigation

Intellectual Merits

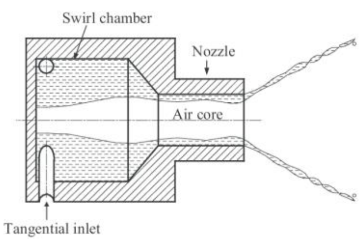

Fig 2. Swirl Injector Diagram

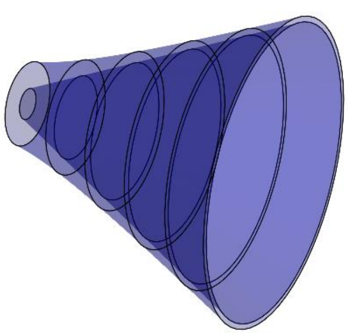

Fig. 3 Isovolumetric thinning of a liquid fan produced by a swirler modeled in python

Currently the most used atomizers are inefficient jet injectors. They work simply by forcing a fluid through a small orifice. While they are simple to design, well-understood and characterized, their overreliance on aerodynamic forces and acceleration to break up a fluid stream makes them quite inefficient. As an alternative, the focus of this research is on swirl injectors. Rather than propelling a fluid purely in the axial direction, swirl injectors first feed fluid tangentially into a vortex chamber. When the fluid exits the vortex chamber, due to the Skobelkin effect, it does so with a radial velocity component that forces the fluid to thin out. (Bazarov, Yang, & Puri, 2004) This stretching complements the other forces involved, enhancing atomization.

The underlying theory of these devices was first developed by G. N. Abramovich in 1944. His principle of maximum flow is still foundational to modern models of swirl injectors. Since then, this his work has been expanded upon by others, notably by G. Taylor in the late 1940s, E. Giffen in 1950s, A H Lefebvre from the 1960s, V G Bazarov and V V. Mikhailov in the 1980s, and D Kim et al in the 2000s. While it may thus seem that this field is matured and well-studied, in

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practice it is not (Lefebvre & McDonell, 2017). Rather than converging on one common engineering approach, this field has since fractured into many various confusing and often contradictory models, with wide variations in efficacy between approaches. This makes it difficult for engineers to implement these devices into their designs.

Expected Outcomes

To help engineers access this technology, we want to use the data we collect to create a Simulink model that will generatively design injection elements and streamline the integration of these devices into engineered designs.

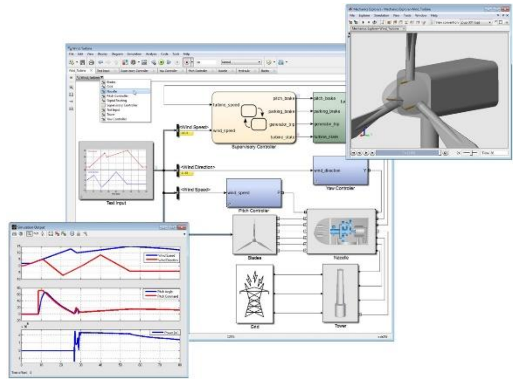

Fig. 4 Simulink Models being integrated into a design

Project Summary

Using the theory of maximum flow and other preexisting models, we will synthesize an initial model of swirl injectors to test. From there we will fabricate the swirler elements predicted by the model out of polymer round stock, construct the testing apparatus, and record the real-world flow characteristics using a combination of conductive probes, cameras, and eventually phase Doppler anemometry to correct discrepancies in the model.

Project Budget	
Plastic Roundstock	$ 150.00
Machining Costs	$ 360.00
Sensing Probes	$ 100.00
Pressure regulator	$ 170.00
fittings and plumbing	$ 100.00
1/2 inch piping	$ 50.00
Pressure Washer	$ 700.00
Pressure Gauge	$ 30.00
Other Consumables	$ 20.00
Research Stipend	$ 320.00
Total	$ 2,000.00

Through this iterative approach, we will then tune the design model in Simulink until the performance of generated injector designs matches the real-world data.

References

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