An Experimental Approach to Two-Dimensional Horizontal Flow Phenomena in Thin Films

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There exists a sharp divide in fluid mechanics between theoretical modeling of flow behavior and the flow behavior found in natural environments or engineered applications. This disconnect is due to an idealized approach to theoretical models associated with fluid flow. One of the chief obstacles to workable theory is the action of viscosity to which a destabilizing effect occurs within the fluid. This effect gives rise to a disorderly, random phenomena called turbulence. Theory of turbulent flow is heavily supported by experimental analysis as idealized models do not account for the chaotic fluctuations in flow behavior. Restricting our flow to two-dimensions simplifies the analysis of flow behavior while retaining practical estimations for its three-dimensional counterpart. Experimental studies of 2-dimensional flow have significant implications on vortex dynamics related to oceanic and atmospheric analysis, 2-dimensional turbulence, and transition mechanisms in shear flow.

This experimental approach utilizes horizontal soap films as physical approximations to the concept of a 2-dimensional fluid to analyze flow phenomena relating to turbulence. Soap film tunnels provide an ideal candidate for experimental analysis regarding fluid-structure interaction and two-dimensional flow phenomena by providing conditions for various boundary situations and its effect on flow behavior. The soap film tunnels act as a tool to investigate two-dimensional flow by propelling soap films using electro-motion in a guide wire system to create uniform flow within the film. We utilize a monofilament fishing line running through a set of motorized pulleys for our horizontal guide wires and a braided polymer line for the injection and exit channels. The injection and exit lines are connected to suspended hooks to create a closed network to establish the film. The film is maintained by a precise control of the flow rate as to prevent local thinning due to evaporation or fluctuating pressures.

For this experiment we will test parameters with both moving and stationary boundaries as well as pressure-driven, couette, and hybrid flow systems. The couette flow system is designed to remove flow effects created by pressure differences to isolate a shear driven flow created by a moving boundary system. Using various measurement techniques, including Schlieren Imaging and Laser Doppler Velocimetry, we can analyze thickness variations throughout the film and the corresponding velocity fields to better understand turbulent behavior within two-dimensional flow.

Experimental verification of flow behavior will be used to support advanced numerical models used to simulate flow behavior under various conditions. Computational fluid dynamic (CFD) modeling using machine learning systems will require extensive experimental data to train the system to identify data relationships.

This experimental study will provide the data needed to design an efficient system used to simulate flow behavior in an attempt optimize design parameters for future systems. This area of study has a wide range of applications on both the micro and macro scales such as two-dimensional analysis of oceanic and atmospheric behavior, infrastructure relating to the storage and transportation of fluids, downstream flow to natural bodies of water, as well as creating efficient microfluidic systems associated with manufacturing and bioengineering.