ME 302 FLUID MECHANICS II

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EXPERIMENT 1. FLOW VISUALISATION ON LAMINAR FLOW TABLE

A. Objectives

The objective of this experiment is to visualize the streamlines of basic potential flows and flows formed by combining the basic potential flows.

B. Theory

Potential flows are governed by Laplace's equation, which is a linear partial differential equation. It therefore follows that the various basic velocity potentials and stream functions can be combined to form new potentials and stream functions. Whether such combinations yield useful results remains to be seen. It is to be noted that *any streamline in an inviscid flow field can be considered as a solid boundary*, since the conditions along a solid boundary and a streamline are the same - that is, there is no flow through the boundary and the streamline. Thus, if we can combine some of the basic velocity potentials or stream functions to yield a streamline that corresponds to a particular body shape of interest, that combination can be used to describe in detail the flow around that body. This method of solving some interesting flow problems, commonly called the *method of superposition.*

The simplest plane flow is one for which the streamlines are all straight and parallel, and the magnitude of the velocity is constant. This type of flow is called a *uniform flow*. A *uniform flow* of constant velocity parallel to the x-axis satisfies the continuity equation and the irrotationality condition identically.

A simple *source* is a flow pattern in the x-y plane in which flow is radially outward from the z axis and symmetrical in all directions. The strength of the source is the volume flow rate per unit depth.

In a simple sink, flow is inward. Sink is a negative source. A source or sink represents a purely radial flow.

Another basic potential flow to be considered is one that is formed by combining a source and sink in a special way is called doublet. This flow is produced mathematically by superposing a source and a sink of numerically equal strengths which are located at an infinitesimally small distance from each other.

To study the flow around a closed body a source and a sink of equal strength can be combined with a uniform flow. Since the body is closed, all of the flow emanating from the source flows into the sink. These bodies have an oval shape and are termed *Rankine ovals*.

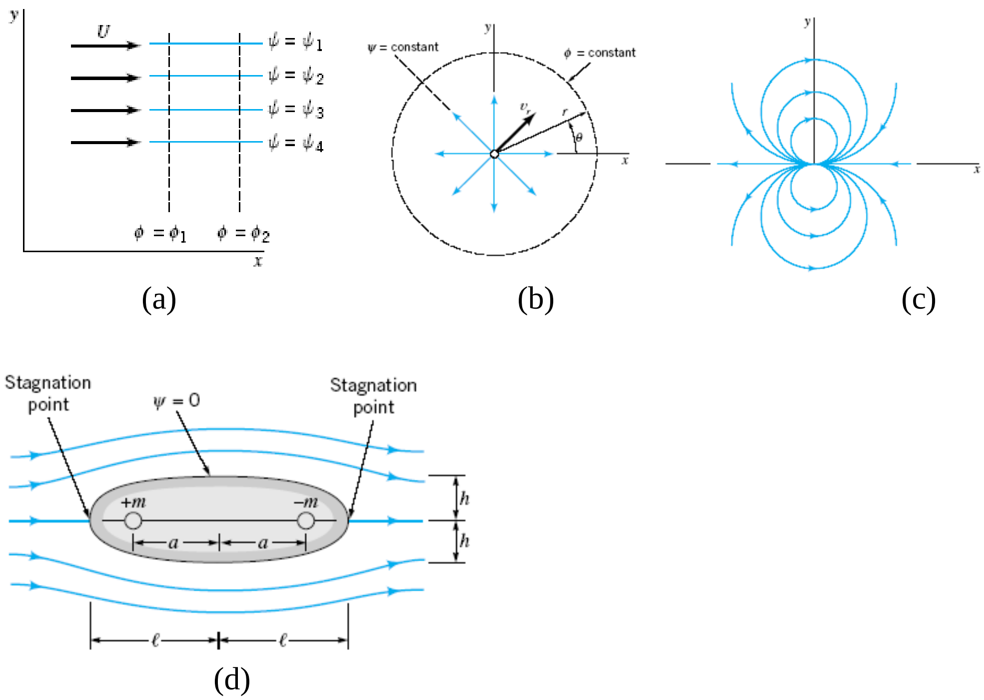

Figure 1. (a) The streamline pattern for a uniform flow in the x-direction,
(b) The streamline pattern for a source,
(c) The streamlines for a doublet
(d) Rankine oval.

The Armfield Laminar Flow Table is designed to simulate ideal fluid flow. The table creates two-dimensional laminar flow between two glass plates by the combination of low fluid velocity and the narrow gap between the plates. The resulting flow is free from turbulence and gives the behavior of an ideal fluid. Because the flow is controlled by potential, (i.e. a pressure gradient that exist between two points of interest) the apparatus can be used to model any physical system that obeys Laplace's Law.

C. Equipment

The flow table consists of two closely spaced sheets of laminated glass, which are arranged horizontally on a glass fiber moulding. The table also has an inlet and outlet tank incorporated in the moulding that is supported on a metal frame. In the centerline of the lower glass plate, eight miniature tappings are arranged in a cruciform configuration that may be used as sinks or sources. A doublet, which is a sink and source located in close proximity, is located at the center of the pattern. A system of pipes and manifolds are utilized to enable any combination of sinks and sources. Control valves are mounted above the flow table to adjust the flow through each individual source. Also, a set of control valves is mounted below the table to adjust the flow through each individual sink.

Patterns or streamlines generated by the flow can be visualized by use of dye injection. A row of evenly spaced hypodermic needles is attached to the manifold at the inlet edge of the glass plates. Blue dye is injected into the flow to visualize the streamlines. A grid is printed on the table to aid in the visualization of streamlines.

In order to promote a uniform flow of water, a diffuser is located in the inlet tank, and an adjustable weir plate is located in the discharge tank. An inlet control valve controls the flow of water.

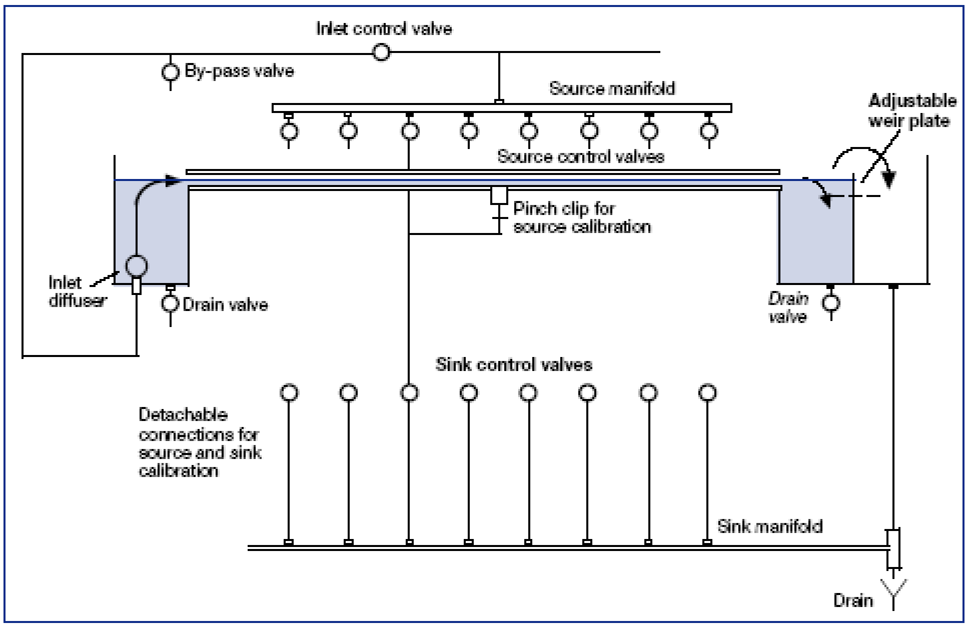

Figure 2. Schematic diagram of laminar flow table

D. Procedure

1. Open water inlet control valve fully.
2. Allow time for water inlet reservoirs to fill with water and for water to flow across table.
3. Fill the ink source container. Open the ink valve. The injector rake should be submerged in the inlet reservoir to allow the air bubbles in the line to be released.
4. Place the injector rake between the table and the glass. Keep the needles submerged so that the air is not caught under the glass.
5. Turn on the "sink" or "source" or "doublet" tapping.
6. Allow time for the streamlines to form. When the streamlines are satisfactory, use the digital camera to take a picture or draw the streamlines.
7. Estimate the volumetric flow rate of water through the slot by discharging the sump pump effluent into a bucket for a specified amount of time. Divide this volumetric flow rate by the cross sectional area of the slot normal to the direction of flow to determine the average fluid velocity.

F. Data Analysis and Reporting Requirements

1. What is the most important difference between viscous and inviscid flows?
2. Calculate the stream function and velocity profile for a uniform flow.
3. Calculate the stream function and velocity profile for a half body. Are there any differences between calculation and visualization? Why?
4. Calculate the stream function and velocity profile for a Rankine oval. Are there any differences between calculation and visualization? Why?

G. References

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3. Armfield Laminar Flow Table Specification Sheet, Armfield Limited, Hampshire, England.
4. Laminar Flow Table Experiment, Chemical and Petroleum Engineering Department,University of Pittsburgh.