ME301 FLUID MECHANICS I

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EXPERIMENT 1. FLOW VISUALISATION AND FLOW TYPE DETERMINATION

A. Objectives

The objectives of this experiment are to visualize the water flow on an open channel by utilising the hydrogen bubble technique and to observe the laminar, transitional and turbulent regions on water flow through a pipe by utilising the dye injection technique.

B. Theory

In the analysis of problems in fluid mechanics, frequently it is advantageous to obtain a visual representation of a flow field. Such a representation is provided by pathlines, streaklines and streamlines. So, various kinematical concepts and relations may be better understood and digested.

In steady flows, three types of lines coincide and the name “streamline” refers to all.

Part 1. Flow Visualisation by Hydrogen Bubble Technique

The technique involves the evolution of small hydrogen bubbles from a *fine* wire cathode which is positioned normal to the fluid flow. These bubbles swept from the wire and because of their small size, they follow the flow accurately. A mass of fine bubbles flowing with the fluid is made clearly visible by the specially developed system of illumination.

Part 2. Determination of Flow Type on An Osborne Reynolds Apparatus

The Reynolds number (Re) is the internationally recognised criterion denoting fluid flow condition. The Reynolds number is defined as

$$Re = \frac{uD}{\upsilon} \tag{1}$$

where u is the mean flow velocity [m/s], D is the pipe diameter [m] and ν is the kinematic viscosity [m^2/s]. The criterion is the ratio of inertial force to the viscous force acting on fluid particles.

The apparatus uses a dye injection technique similar that of Professor Osborne Reynolds’

(British Physicist, 1842-1912) original apparatus to enable observations to be made of laminar, transitional and turbulent flows. These are the most commonly encountered terms describing flow types.

In laminar flows, all streamlines follow parallel paths. There is no mixing between shear planes. The observer will note that under this condition, the dye (indicator) will form an easily identifiable line in the flow.

In turbulent flows, streamlines interact. This interaction causes shear plane collapse and mixing of the fluid. The observer will note that under this condition, the dye will become dispersed as mixing occurs and will no longer remain as a single line in the flow.

If the Re for the flow of a particular fluid in a particular pipe has a value of less than 2000, the flow will be laminar. If the Re is greater than 2800 the flow will be turbulent. Flows with Re between 2000 and 2800 is termed to be transient flow.

Experimental Determination of The Reynolds Number:

The determination of the Reynolds number require velocity of the flow, diameter of the pipe and kinematic viscosity of the fluid. The velocity of the fluid could be determined hy measuring the flow rate Q [m^3/s] from

$$u = \frac{4Q}{\pi D^2} \qquad (2)$$

Substituting Eq. (2) into (1), the Reynolds number reduces to

$$Re = \frac{4Q}{\upsilon \pi D} \qquad (3)$$

For this experiment, the pipe used has a diameter of

D 13mm = 0.013 m

and fluid (which is water) has a kinematic viscosity of

ν=l.2x$10^{-6}m^2/s$

C. Equipment

Part 1.

The Armfield Flow Visualisation Kit, shown in Figure 1, will be used to perform this experiment. The kit comprises the following:

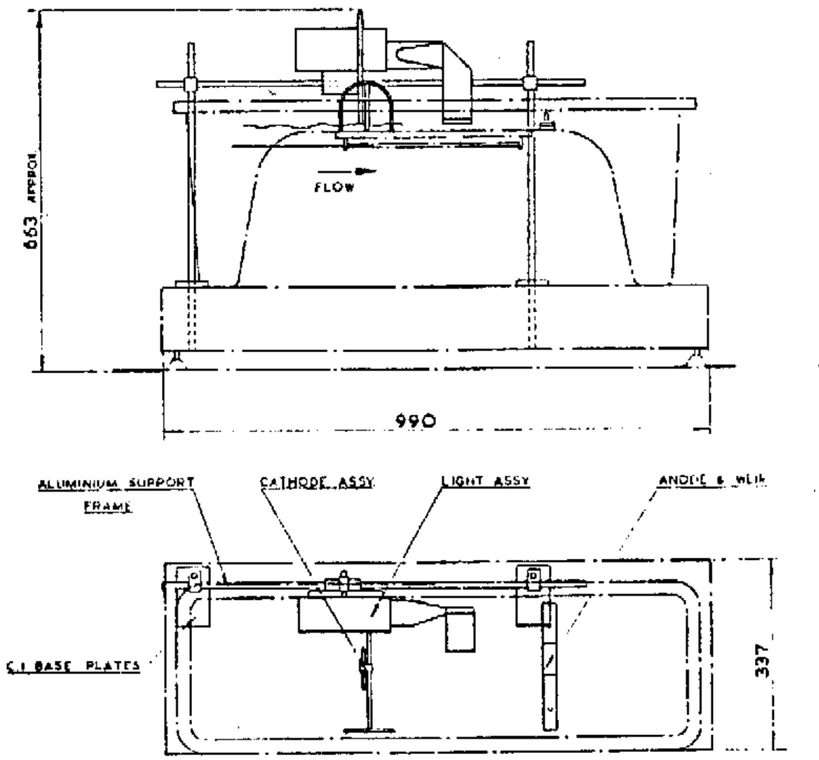

Figure 1. Flow Visualisation Kit

- A flow table comprising a viewing section which is 360 mm long. 250 mm wide and 50 mm deep. Water is circulated by means of a small electric pump and the flow is regulated by a valve located at the pump discharge.

- A hydrogen bubble puls generator which is contained in a compact metal cabinet suitable for bench mounting with all controls clearly anotated on the front face.

- A lamp assembly and light guide. The lamp assembly comprises a 55 W, 12 V, Tungsten Halogen bulb backed by a concave minor. The light guide is made of polished clear acrylic resin which enables abeam of light to be directed below the fluid surface by total internal reflection.

- A cathode assembly consisting of a fine stainless steel wire supported in tension by a forked holder with insulated tips.

- An anode assembly comprising a stainless steel block with terminal connection.
- Accessories: Two circular cylinders (13 mm and 25 mm diameter), an aerofoil model.

Part 2.

The Armfield Osborne Reynolds Apparatus, shown in Figure 2, will be used to perform this experiment. The apparatus is bench mounted and has been designed for the vertical flow of a liquid through a precision bore glass tube. The use of a vertical direction for the fluid flow compensates for the effect of any small deviations of the density of dye relative to that of the working fluid. In the horizontal direction, a dye of density not precisely equal to That of the fluid would lead to vertical deviations of the dye trace.

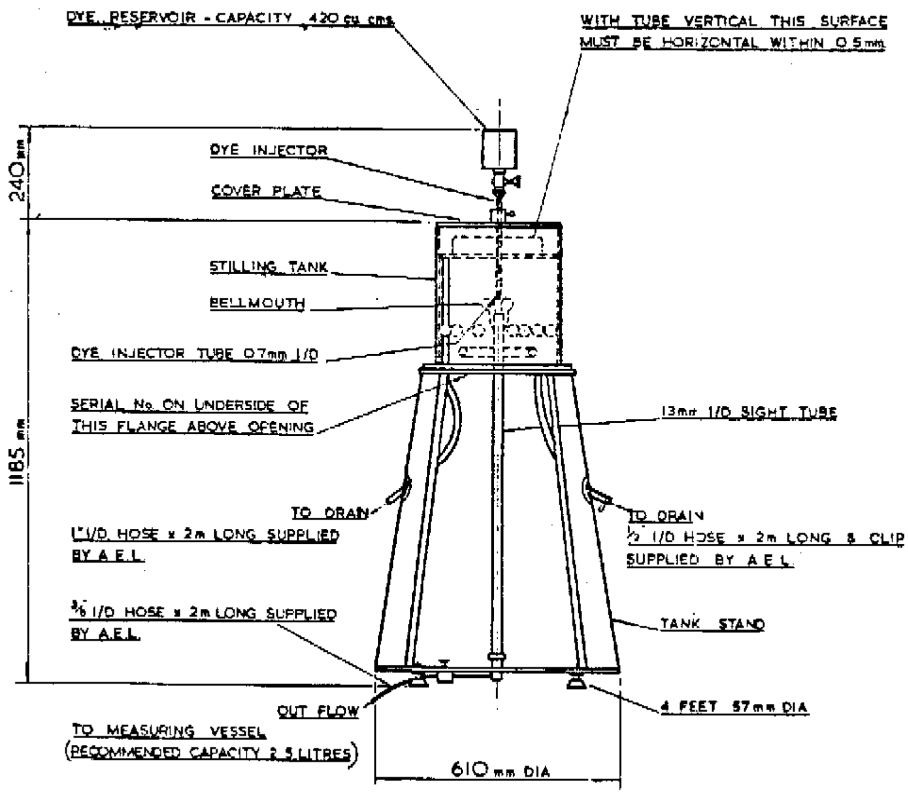

Figure 2. Osborne Reynolds' Apparatus

The operating fluid may be supplied from any small bore supply point by means of the flexible hose providcd. Fluid enters a cylinderical constant head tank through a ring diffuser and then through a particle bed to eliminate any gross variations in the fluid velocity in the head tank. This tank therefore provides uniform, low velocity head conditions upstream of the entry to the vertically mounted pipe test section. Fluid enters this section through a profiled beltmouth, designed to uniformly accelerate the fluid without any spurious inertial effects. Dye solution is admitted to the test section through a fine diameter stainless steel tube, and the rate of flow of dye is controlled by a valve on the outlet of the dye reservoir.

The flow rate of working fluid through the test section is regulated by a needle point globe valve located in the base of the apparatus. The rate may be measured volumetrically.

D. Procedure

Part 1.

1. Adjust the light assembly by means of the clamps until the light guide obtains a desirable position within the channel.

2. Place the anode assembly in position within the working section of the channel immediately downstream of the light guide.

3. Place the cathode assembly in a central position in the channel.

4. Switch on the SUPPLY, PUMP and LAMP switches.

5. Adjust the pump delivery valve to provide a fluid flow which is commensurate with stable two dimensional conditions.

6. Place the object over which the flow will be visualized and observe the streamlines in The flow. (Place each object one by one in the order of cylinders than the aerofoil model.

Part 2.

1. Fill the dye reservoir and lower the dye injection until it is just above the bellmouth inlet.

2. Open the inlet valve and allow water to enter the stilling tank. Maintain a constant level by ensuring a small overflow spillage to waste through the upper drain outlet.

3. Allow the water to settle for five minutes.

4. Fractionally open the flow control valve and adjust the dye control needle valve until a slow flow with dye indication is achieved.

5. See the laminar flow and transitional region flow conditions by adjusting the control valve.

6. Measure the flow rate by timing the discharge from the outlet connection into a calibrated vessel against time.

7. Repeat this process for ascending orders of Q (by progressively opening the flow control valve.)

E. Pre-Lab

After reviewing the experimental procedures, prepare a data sheet on which to record your experimental measurements and observations. Bring this sheet to the lab with you

F. Data Analysis and Reporting Requirements

Part 1.

1.Are the streamlines symmetric about the x axis? (x axis refers flow direction)
   Note: Answer this question by two steps.
   - in front of the body (cylinder or aerofoil model)
   - behind the body
2. Why does the flow pattern change behind the body?
3. What is the most important difference between viscous and inviscid flows?
4. What do we expect about the flow velocity in regions where the spacing between streamlines decreases?

Part 2.

1. Using the measured value of flow rate through the pipe, calculate the Reynolds numbers.
2. What do these numbers tell you about flow type according to the Reynolds number values given in Page 2? What is your observation about the type of the flows in the test section?

G. References

1. Fox, R.W.and McDonald, A.T., **Introduction to Fluid Mechanics**, 4 th edition, John Wiley and Sons, 1994.
2. Holman, J.P., **Experimental Methods for Engineers**, 3 rd edition, McGraw-Hill, 1978.