CHAPTER III
EXPERIMENTAL

3.1 Material Preparation

- Air from a compressor (Taiwan, Fu Sheng HTA-100H).
- SodiumDodecylSulphate ($C_{12}H_{25}NaO_4S$, SDS) (Riedel-de Haen, 90% purity) mixed with water is used as working fluids.

3.2 Experimental Apparatus

3.2.1 Design and Experimental Setup of Two-phase Flow

Air, water, and SDS solution (1 CMC) are used as the working fluids. The main components of the system consist of the vertical test section, an air supply, and instrumentation. The pipe with 1.9 cm inside diameter and the length of 300 cm made from transparent acrylic glass to permit visual observation of the flow patterns is used as the test section. The scheme of the experimental set up is shown in figure 3.1. All connections of the piping system were designed to change very easily. At the bottom of the main column is the inlet for the compressed air from compressor and flow rates will be measured by a calibrated air-rotameter (Cole-Parmer, A-32466-68, U.S.A.). Liquid is pumped from the storage tank through the rotameter and mixed with air at the bottom of the main column. The flow rates of the liquid are measured by a calibrated liquid-rotameter (Cole-Parmer, U.S.A, A-32461-42). Liquid flow upward through main column together with air and then flows back to the storage tank. Two static pressure tabs were installed at two axially locations with the spacing of 0.4 m and connected with a custom made manometer which was used to measure the pressure drops along the test section.

Experiments are conducted by varying air and liquid flow rates. The air flow rate was increased by small increments while the liquid (pure water or SDS solution) flow rate was kept to constant. The experimental conditions were as follows: superficial air velocity j_{air}: 0.0026~58.81 m/s, superficial water velocity

j_{water}: 0~0.123 m/s, superficial SDS solution (1 CMC) velocity $j_{SDS\ solution}$: 0~0.1359 m/s respectively. Air and liquid temperatures varied between 31~32°C. The system was allowed to approach the steady condition before any data were recorded. The pressure drops across the test section were detected at different flow rates of air and liquid. The flow regimes were observed and identified by visual observation, a video camera (Panasonic, NV-M3000) and software program (Win DVD). Bubble size, slug size and void fraction of Taylor bubble were measured by software program (Scion Image). Bubble velocity was measured by timing bubble at a known distance.

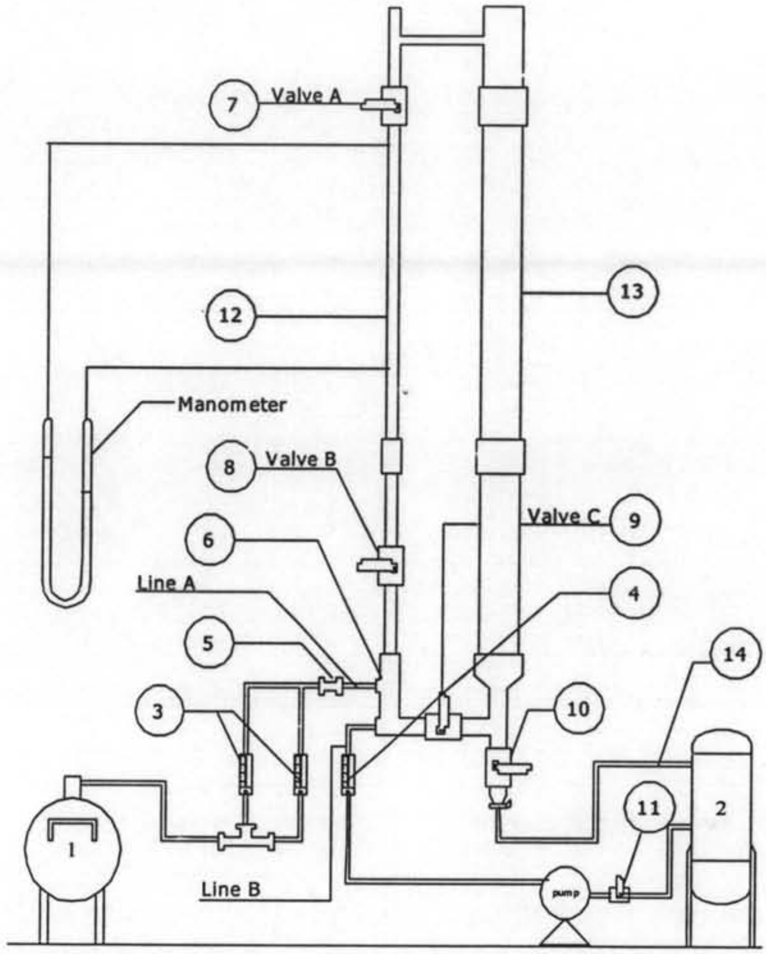

Figure 3.1 Schematic diagram of the experimental setup: 1) air compressor; 2) liquid reservoir tank; 3) air rotameter; 4) liquid rotameter; 5) check valve; 6) air injection tee; 7) isolating ball valve A; 8) isolating ball valve B; 9) isolating ball valve C; 10) draining ball valve; 11) control valve for reservoir tank; 12) vertical tube with the diameter of 0.019 m and the length of 3 m; 13) overflow tube with the diameter of 0.054 m and the length of 3 m; 14) liquid return line to reservoir, Line A for air injection line, and Line B for liquid injection line.

Table 3.1 Physical properties of liquids used in the experiment

Liquid	ν_L (m^2/s)	μ (Pa.s)	ρ_L (kg/m^3)	σ ($\mu S/cm$)	Γ (mN/m)
Water	0.85×10^{-6}.	8.48×10^{-4}	994.7	1.7	71.272
SDS solution (0.5 CMC)	9.34×10^{-7}	9.3×10^{-4}	994.8	1016	22.02
SDS solution (1 CMC)	1.02×10^{-6}	1.01×10^{-3}	994.97	1939	21.813
SDS solution (2 CMC)	1.09×10^{-6}	1.09×10^{-3}	995.58	2692	21.606

ν_L: kinematic viscosity, μ: viscosity, ρ_L: density, σ: electrical conductivity,

Γ: surface tension

System temperature, T = 31°C (± 1°C)

1 CMC = 2.75 g/L

3.3 Methodology

3.3.1 Parameters

3.3.1.1 Controlled Parameters of Two-Phase Flow

- Dimensions of both columns.
- Temperature of working fluids was controlled at 31°C by putting ice around the reservoir fluid tank.
- Outlet pressure of air compressor by using air pressure regulator. The air pressure regulator was connected with

air compressor's outlet to control the system pressure. The inside pressure of air compressor is 10 bars.

3.3.1.2 Variable Parameters of Two-phase Flow

- Volumetric flow rates of air in main column (0.0444-1000 l/min).
- Volumetric flow rates of liquid in main column (0-2.091 l/min for pure water and 0-2.310 l/min for SDS solution at 1 CMC).
- SDS solution concentration (0.5, 1 and 2 CMC).

3.3.1.3 Measured Parameters of Two-phase Flow

- Boundaries of flow regimes by video camera or still photographs.
- Critical Reynolds numbers of air at each flow regime.
- Liquid lcvels difference in manometer for pressure gradient.
- Bubble size.
- Bubble velocity.
- Slug size
- Void fraction.

3.3.2 Experimental Procedures

3.3.2.1 Determination the Density of Surfactant (SDS) Solution by Pycnometer (volume = 25.499 cm^3).

1. Weigh the empty dry pycnometer and record the mass.

2. Fill the pycnometer with SDS solution and take the mass of the filled pycnometer.

3. The difference between the mass of the empty pycnometer and the pycnometer when it is full yields the mass of the SDS solution that is within the pycnometer.

4. Knowing the mass of the SDS solution and the volume of the pycnometer, the density of the SDS solution can be calculated using the equation:

$$\rho = \frac{M}{V} \tag{3.1}$$

3.3.2.2 Determination the Viscosity of Surfactant (SDS) Solution by Cannon-Ubbelohe Viscometer.

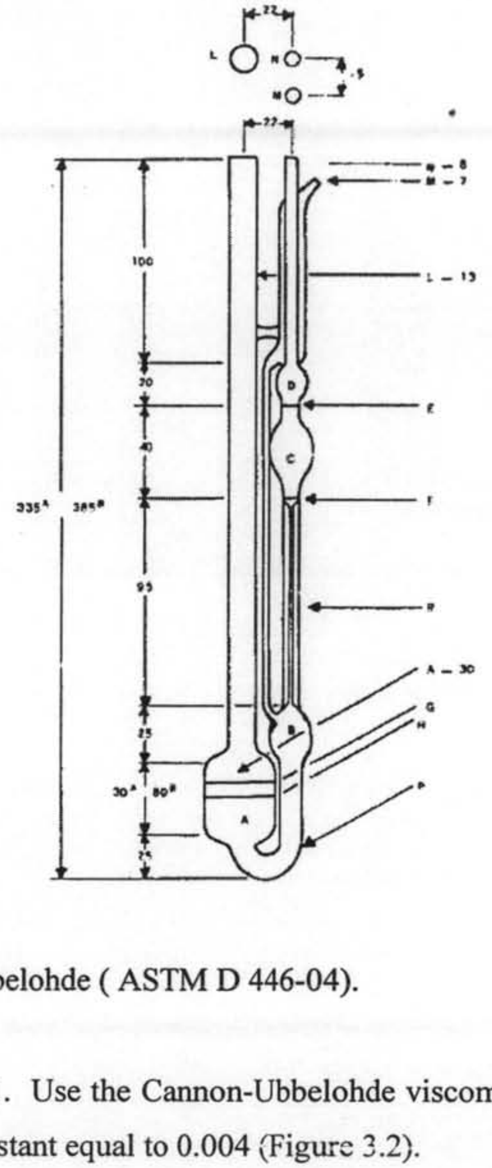

Figure 3.2 Cannon-Ubbelohde (ASTM D 446-04).

1. Use the Cannon-Ubbelohde viscometer size no. 50 which has the approximate constant equal to 0.004 (Figure 3.2).

2. Fill the SDS solution into Cannon-Ubbelohde viscometer.

3. Mount the Cannon-Ubbelohde viscometer in the constant-temperature (31±0.3 °C) bath and keeping the tube vertical.

4. Apply vacuum to tube N and closing tube M by a finger or rubber stopper to make the SDS solution filling upper bulb D.

5. Let the SDS solution flow by gravitation and timing the level of SDS solution from mark E to mark F. Use the time average value for calculating the kinematic viscosity.

6. Calculate the kinematic viscosity (ν) by using equation:

Kinematic viscosity (ν), mm^2/s = Time(s) × approximate constant ($(mm^2/s)/s$)

7. Calculate the viscosity (μ) by using equation:

$$\mu = \upsilon\rho \tag{3.2}$$

3.3.2.3 Determination of Pressure Drops in The Main Column

Two static pressure tabs were installed at two axially locations with the spacing of 0.4 m at the main column and connected with a manometer were used to measure the pressure drops along the test section. The system was allowed to approach the steady condition before any data was recorded. The manometer was filled with water. We measured the water levels difference in the manometer and calculated the pressure gradients for each flow regimes by following equation:

$$\left(-\frac{dp}{dz}\right) = \frac{\rho_L\, g\, h}{dz} \tag{3.3}$$

where ρ_L = liquid density (kg/m^3), g = gravitational acceleration (m/s^2), h = water levels difference in the manometer (m), and dz = pressure taps difference (m).

The pressure drops across the test section were recorded and calculated by this method. And the values of pressure drops from the experiments were compared with the theory.

3.3.2.4 Determination of Bubble and Slug Size in The Main Column

Make a movie of bubble and slug flow regime by a video camera (Panasonic, NV-M3000) then convert it to DVD file. Use the software program (Win DVD) to capture the bubble and slug picture from the movie. Bubble size, slug size and void fraction of Taylor bubble were identified by software program (Scion Image).