Chapter - 2

Experimental Setup and Techniques

This chapter deals with the description of the experimental setup and techniques employed for the measurement of two phase pressure drop and the holdup in tapered batch bubble column using air – non-Newtonian liquid dispersion and the measurement of rheological characteristics of non-Newtonian liquids are being discussed in detail.

2.1 Experimental Setup

A schematic diagram of the experimental setup has been shown in Fig. 2.1. It consists of tapered bubble column, manometers for pressure measurement, distributor (D) to distribute the air, compressor (C), pressure gauge (PG), rotameter (R_G) for flow measures and other accessories. The tapered bubble columns were made of thick perspex and square shaped. Perforated plates made of perspex of different hole diameter were used for air distribution and connected with the column by means of flanges. Air inlet would be provided at the bottom by means of two opposite nozzles of 4 mm diameter and then distributed through the perforated plate and enter into the column. Two tapered bubble columns of different cross-section areas are used for the experiment. Detailed dimension of the columns are shown in Table 2.1. Columns were fitted to vertically by means of clamps to avoid any vibration.

2.2 Rheological properties of Sodium salt of Carboxymethyl Cellulose solutions

It is well known that SCMC is time-independent non-Newtonian pseudo-plastic fluid and its rheology is described by the Ostwald-dewaele model or the power law model (Chhabra, 1988; Chhabra, 2007) as,

$$\tau = K(\frac{du}{dy})^n \quad (2.1)$$

where K and n are constants for the particular fluid and n<1.The constant K is known as the consistency of the fluids; the higher the value of K, the more viscous the fluid. The constant n i.e. the flow index is a measure of the degree of departure from Newtonian behavior; the further n departs from unity, the more pronounced the non-Newtonian properties. The rheological properties of the SCMC solutions were measured by means of pipeline viscometer. Theoretical consideration and detail experimental procedure on the pipeline viscometer are reported in Appendix – 1. DuNouy tensiometer and specific gravity bottle were used to measure surface tension and density of the liquids respectively. The values of n, K and other physical properties of the liquids are shown in Table 2.2.

2.3 Experimental Procedure

A desired amount of sodium salt of carboxymethyl cellulose (SCMC) were dissolved in tap water, a few drops of formaldehyde was added to avoid biological degradation and kept around 12 hours for aging. Four different SCMC concentrations, 0.2 - 0.8 kg/m^3 were used for the experimental liquids.

The clear liquid height used for the experiments were 1.12 m, 1.17 m and 1.22 m for both columns. Air was provided through the air nozzles from the laboratory compressor and air flow rate was measured by using rotameter. The air at a pressure 1 kg/cm^2 gauge was introduced into the column, and under steady state condition, reading of manometers attached to the taping were noted and also the height of liquid column was noted. Manometers were attached to the tapings and it located at different heights in the column. The flow pattern was observed visually and it was bubble and plug according to the increasing air flow rate. The gas holdup for a particular gas flow rate is the fraction of the total gas-liquid volume that is occupied by the gas. This gas holdup is measured experimentally by using the following expression,

$$\varepsilon_g = \frac{V - V_o}{V} \tag{2.2}$$

Where V and V_o are volume of liquid in column with and without gas flow. The liquid volume in the tapered bubble column with respect to the height was calibrated before the experiment for each liquid used in the studies. From the manometer readings the total pressure drop was determined. The diameter of the column was calculated by first calculating the equivalent diameter of the base and at the gas-liquid interface at the top then the log mean diameter, D_c, of the column was calculated. Hence, for each gas flow rate the diameter, D_c, varies according to the height of the gas-liquid interface. The experiments were repeated a number of times to ensure the reproducibility of the data. The temperature was maintained at atmospheric temperature 30±2^{0}C. Range of variables investigated is shown in Table 2.3.

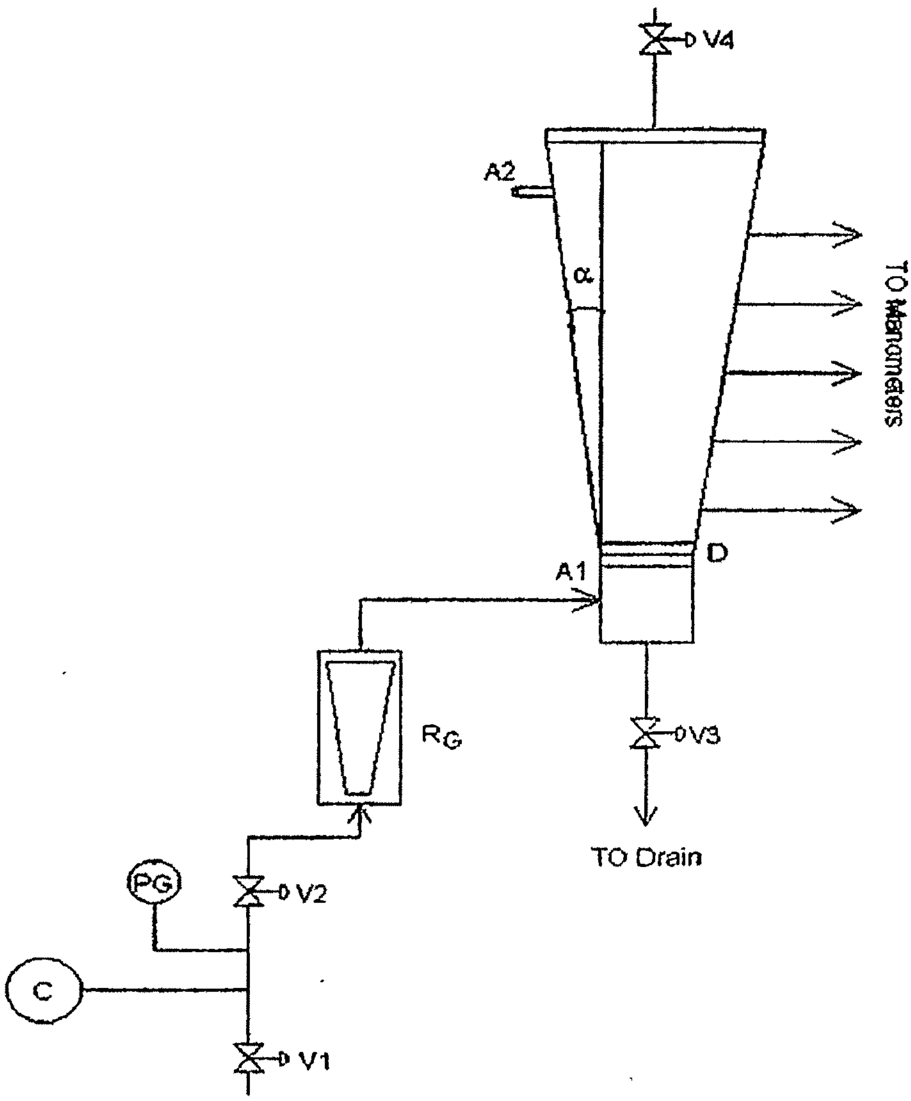
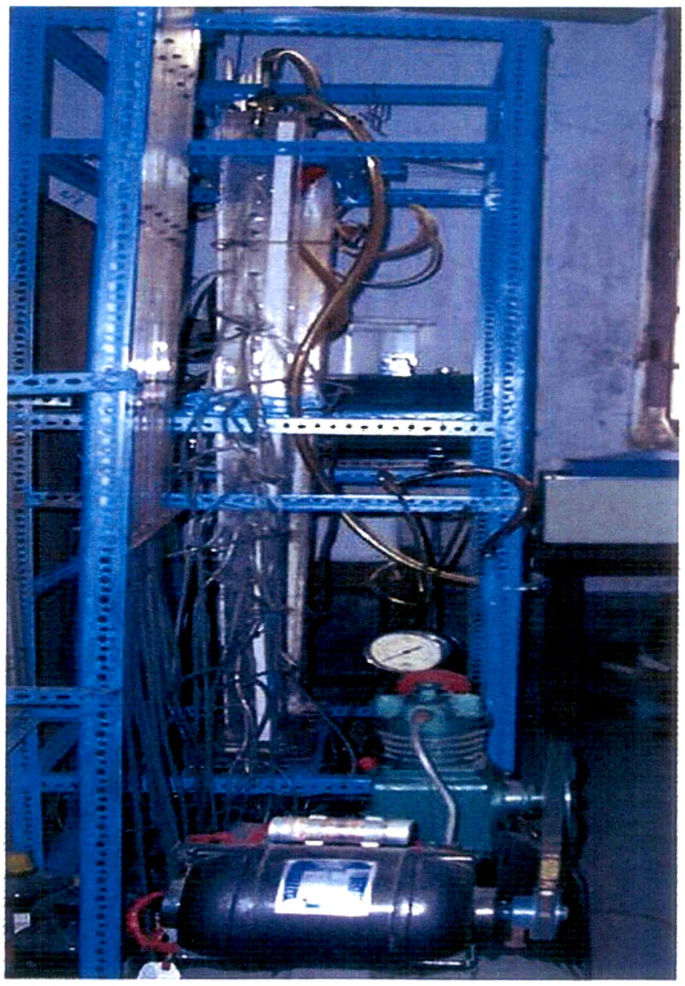
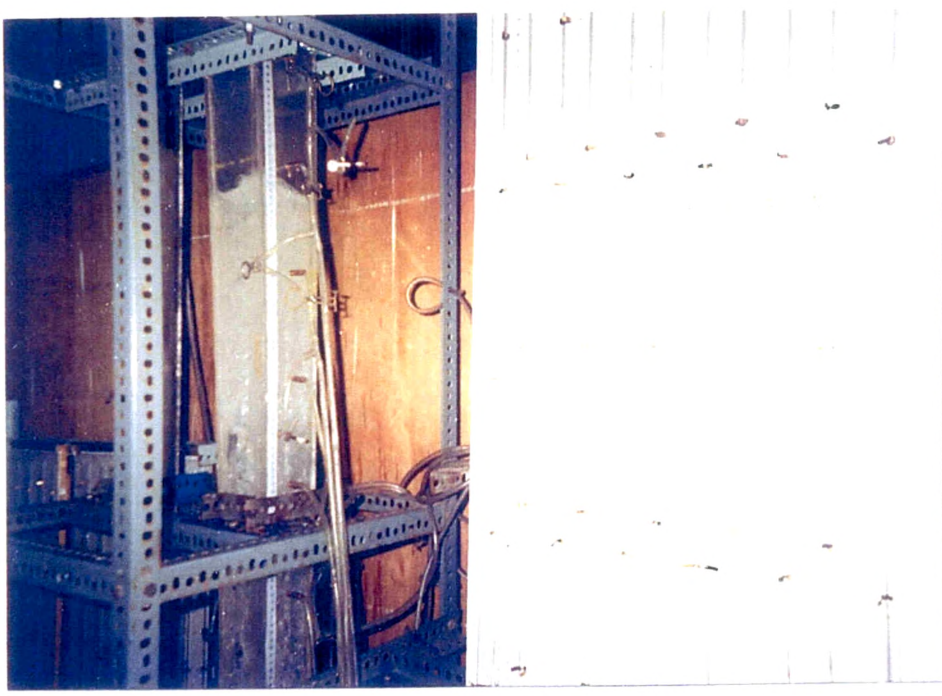


Fig. 2.1 Schematic diagram of experimental setup
A1: Air inlet; A2: Air outlet; Manometers; D: Distributor; C: Compressor; PG: pressure Gauge; R_G: Rotameter for gas; V1-V4: Control valves



P-1 Experimental setup

P-2 Side section of TB1



P-3 Test section and manometers of TB2

Table 2.1 Dimension of bubble columns

Characteristic parameters	Larger Tapered Bubble Column TB2	Smaller Tapered Bubble Column TB1
Thickness of Perspex sheet, m	0.0127	0.0127
Height of column, m	1.83	1.83
Top plate area, m^2	0.1016×0.1016	0.0762×0.0762
Bottom plate area, m^2	0.0508×0.0508	0.0508×0.0508
Equivalent diameter, m	$0.0692 \leq D_c \leq 0.0710$	$0.0605 \leq D_c \leq 0.0614$
Hole diameter of the air inlet and outlet, m	0.0127	0.0127
Taper angle(deg)	0.86	0.44
Hole diameter of different sieve plates used, m	0.00277,0.00357,0.00436	0.00277,0.00357,0.00436
Hole number of sieve plate	50	50
Manometer tapping : distance from the air distributor plate, m		
Taping no .1, m	0.0508	0.0508
Taping no. 2, m	0.2032	0.2032
Taping no. 3, m	0.3556	0.3556
Taping no. 4, m	0.5080	0.5080
Taping no. 5, m	0.6604	0.6604
Taping no. 6, m	0.8128	0.8128
Taping no. 7, m	1.0050	1.0050
Taping no. 8, m	1.1500	1.1500

Table 2.2 Physical properties of the liquids

Concentration Kg/m^3	Flow behavior Index (n)	Consistency index K (Ns ^{n}/m^2)	Density ρ (Kg/m^3)	Surface tension σ (N/m)
0.2	0.9013	0.0142	1001.69	0.07834
0.4	0.7443	0.1222	1002.13	0.08003
0.6	0.6605	0.3416	1002.87	0.08142
0.8	0.6015	0.7112	1003.83	0.08320

Table 2.3 Range of variables investigated

Measurement type	Range
Q_g, Gas flow rate, m^3/s	$0.0000058 \leq Q_g \leq 0.00046154$
ρ_l , Density of liquid, Kg/m^3	$1001.69 \leq \rho_l \leq 1003.83$
σ_l , Surface tension, N/m	$0.07834 \leq \sigma_l \leq 0.0832$
K ,Consistency index, Ns^n/m^2	$0.0142 \leq K \leq 0.7112$
n ,Flow behaviour index	$0.6015 \leq n \leq 0.9013$
D_c, Diameter of column(log mean), m	$0.0605 \leq D_c \leq 0.0710$
D_n ,Distributor hole diameter, m	$0.00277 \leq D_n \leq 0.00436$
H_0, Clear liquid height, m	$1.12 \leq H_0 \leq 1.22$
H_m ,Gas –liquid mixture height in the column, m	$1.13 \leq H_m \leq 1.4$
α, Taper angle(deg)	0.44 and 0.86
ε_g ,Gas hold-up, dimensionless	$0.00813 \leq \varepsilon_g \leq 0.138462$
ΔP, Pressure drop, dimensionless	$0.003937 \leq \Delta P \leq 0.1904986$