دراسة تحليلية وعملية لتغير الضغط ونسبة الفراغ لجريان العمود النازل ثنائي الطور لانبوب كبير القطر

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الخلاصة:

لقد تم اجراء دراسة تجريبية ورياضية تحليلية على الجريان الثنائي الطور في الانبوب العمودي وفي الاتجاه النازل لغرض ملاحظة معدل الجريان وقياس نسبة الفراغ (Void Fraction) والمتغير في الضغط (الخسارة في الضغط) في منطقة (Annular) ومقارنتها مع النتائج النظرية التي انجزت لهذا الغرض .
تمت الدراسة العملية وذلك بأمرار الماء والهواء داخل انبوب زجاجي شفاف ذو قطر 7.35 سم وارتفاع 3.25 م . وتحت ظروف تشغيلية محصورة بين (129) كيلو باسكال و (143) كيلو باسكال بالنسبة للضغوط وتحت درجة حرارة ثابتة (36-42) م° . تم قياس نسبة الفراغ بأستعمال تقنية الحث الذاتي الجديدة (Auto-transformer) . وحساب التغير في الضغط عند مدى واسع من تغير نسبة الفراغ . وقد لوحظ تطابق واضح بين نتائج الطريقتين العملية والنظرية .

Experimental and analytical investigation of pressure Drop and void fration for vertical downward Two - phase (Annular) flow in large diameter pipe

Abstract :-

An experimental and an analytical in co-current downward two-phase (Annular) flow was preformed . The results of observation of flow rates , void fraction and pressure drop in annular flow pattren were presented. Air-water mixture were used in transport test-section of 7.35 cm I.D. and 3.25 m length with operation condition of 36-42 C° temperature and 129 Kpa and 143 Kpa pressure .Void fraction was measured locally by using a new method which is Auto-transformer technique .The experimental

results of pressure drop was compared very well with analytical results presented .

Introduction :-

Two-phase flow phenomena have been studied for the last five decades because of importance especially in major industrial fields like chemical , petroleum and nuclear industries .

There is large technological need for information in two-phase flow and this has resulted in a rapid expansion in research over the last decades , particularly in gas-liquid two-phase flow .

In chemical industry the two-phase flow applications occurs as example in boilers , condensers , reactors , distillation plants and evaporators .

In petroleum industry the two-phase flow occurs during the production and transportation of oil and gas [Abdul-Majeed , 1997] .

In nuclear reactor engineering there are many examples of two-phase flow such as flow rate in turbines and flow rate during loss of coolant accident-LOCA- or evaporation of coolant due to high rates of heat flux . [Rivard and Travis , 1979] .

Because of little usage of downward flow , only a few number of studies and experiments of limited ranges have been conducted concerning flow pattern , void fraction and pressure drop , in contrast to comprehensive studies of upward flow . Downward flow as opposed to upward flow , has been suggested as a method to improve the characteristics of heat transfer to high quality steam water mixtures in the core of nuclear reactors [Oshinow and charles , 1974] .

Most of the experimental data where carried out in small diameter vertical tubes , usually less than 5 cm I.D. , while the designs involving much larger diameter tube , and because of lack of data for such vertical tube size , scaling up is usually adopted . This is a doubtful procedure since , for example , bubbles do not scale up with tube size .

However , no other methods are available , at present , and large errors can not be avoided . The need for data in large diameter vertical tube is thus obvious .

Orkiszeewski (1967) presented accurately method to calculate pressure drop of two-phase flow over a wide range of conditions through vertical pipe .

Yamazaki and Yamaguch (1979) , made an experimental study in a co-current downward flow air-water system in 2 m long and 2.25 cm inside diameter flow pattern , void friction and pressure drop were investigated . Salcudean and leung (1988) , measured local pressure drop for single and two-phase flow along vertical and horizontal channels . The relation between the pressure drop and obstructed flow momentum has been investigated .

The present research will concentrate on vertical co-current downward two - phase annular flow through large diameter pipe using air-water mixture as a component under test . A new method is used to calculate a void fraction locally , which is Auto-transformer technique which presented firstly by kendoush an Sarkis (1996) for non-flow .

The experimental results of pressure drop is compared with a simple analytical results presented ,

Experimental system :-

The schematic diagram of the experimental system is shown in Fig (A1) . It consists of an air compressor , a reservoir - separator tank , an air-water mixer , a circulating pumps , a 7.35 cm I.D. and 3.25 m long glass tube pipe as a test-section and various other accessories . Tap water was circulated from the reservoir - separator tank by means of four centrifugal recalculating pumps to the test-section through the air-water mixer. The reservoir-separator tank was opened at the top and contained one vertically fixed baffles and two fixed framed wire-mesh filter to completely execute the air separation before water entering the pump section line . Care was taken to ensure the evaluation of entrapped air bubbles from the water flowing system . Air was supplied by the compressor , and its flow rate was measured by a couple of calibrated Rota meters connected in parallel .

Water flow rate was measured by a calibrated turbine flow meter . The two-phase flow patterns were visualized for a wide range of flow rates of (6-26 m^3/hr) water and (0.2 - 11 m^3/hr) air . Absolute and differential pressure reading were taken by two pressure gauges located on the ends of the test-section . The water and air used in the experimental were at ambient temperature of (36 to 42 C^o) and 136 Kpa outlet system pressure .

The void fraction (α) was measured by using an Auto-transformer technique which is a new method [kendoush and sarkis , 1996] . By the calibration of the Auto-transformer was found that the optimum operating frequency is 675 KHz and the optimum operating voltage ($V_{p.p}$) is 18 V.

The calibration of Auto-transformer was achieved with stationary (no flow) system consisted of a finite length glass test tube of the same diameter of test-section Fig (2) known geometrical size of empty plastic tube were inserted into filled test tube with tap water to simulate the bubbles .

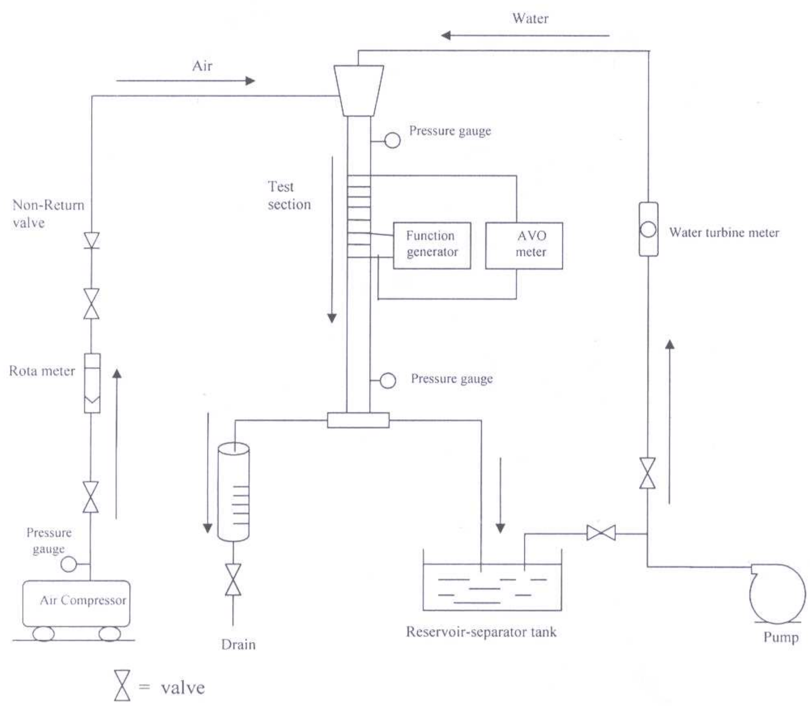

Fig.A1. The Experimental system

<u>Void fraction measurement theory</u> :

A new method was used to measure the void friction which is Auto-transformer technique show in Fig (A2) . It consists of wire winding around the glass tubular test-section . The basic principle of the this technique is that when the primary (input) ceil [point AB] is connected to an alternating current supply , an alternating magnetic flux is setup inside the core which represents the test-section for each turn of the cell . This flux induces an electromotive force (emf) of self-inductance in the secondary (output) cell [point AC] .

If a two-phase medium is occupying the test-section , measurement of (emf) will indicate a particular value for the void fraction (α) .
The presence of gas-liquid two-phase medium in the test-section (which is the core of the magnetic field) , produces a net change in the magnetic flux a cross the medium. This change induces the measured (emf) .

Steel tube test-section can not be employed here because of the magnetic field tends to concentrate in the metal and prevents the magnetic flux line from crossing the two-phase medium due to the well-known magnetic shielding phenomenon . [Al-Judi, M. M. 1997] .
All of the experimental results of the void fraction measurement were presented using the equation given by Kendoush and Sarkis (1996) .

$$L^*=[(V_1(\alpha)_m - (V_1(\alpha=1)_m)] / [(V_1(\alpha=0)_m- (V_1(\alpha=1)_m)$$

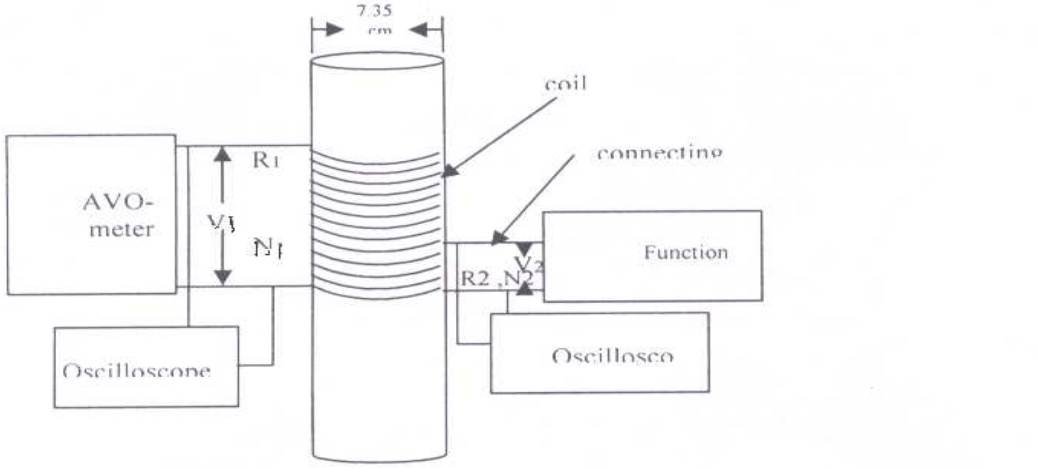

Fig.A2. Experimental arrangement of the Auto-Transformer

Analytical Results:

Consider an equilibrium annular flow as shown in Fig (A3) , a momentum balance on each phase (gas and liquid phase) yield :

$$-A_L\left(\frac{dP}{dz}\right)-\tau_L S_L+\tau_i S_i+\rho_L A_L g=0 \quad -----(1)$$

$$-A_G\left(\frac{dP}{dz}\right)-\tau_i S_i+\rho_G A_G g=0 \quad ---------(2)$$

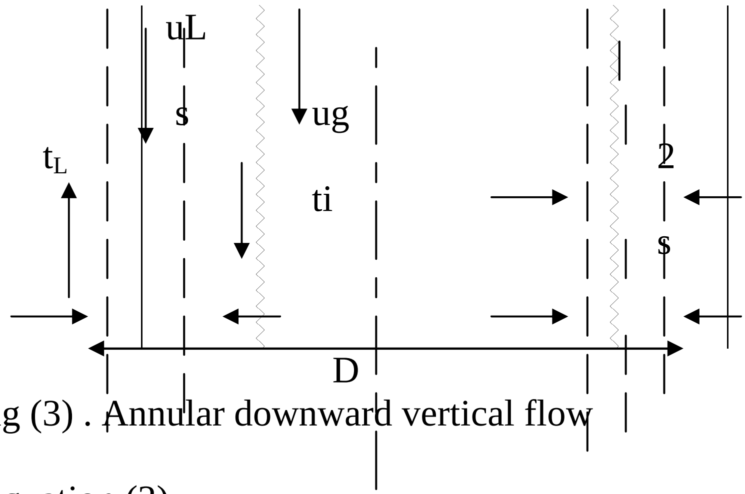

Fig (3) . Annular downward vertical flow

From equation (2)

$$\tau_i S_i = -A_G\left(\frac{dP}{dz}\right) + \rho_G A_G g \quad ---------- (3)$$

Substituting equation (3) into equation (1) yield

$$-A_L\left(\frac{dP}{dz}\right) - \tau_L S_L - A_G\left(\frac{dP}{dz}\right) + \rho_G A_G g + \rho_L A_L g = 0 --- (4)$$

$$-\left(\frac{dP}{dz}\right)(A_L + A_G) - \tau_L S_L + \rho_G A_G g + \rho_L A_L g = 0 ---- (5)$$

Now , the first term in above equation

Represented the total pressure drop over total cross-sectional area . since :

$A_L + A_G = A$

Substituting into equation (5) yield

$$-A\left(\frac{dP}{dz}\right) - \tau_L S_L + \rho_G A_G g + \rho_L A_L g = 0 \quad ----- \quad (6)$$

$$-\left(\frac{dP}{dz}\right) - \left(\frac{S_L}{A}\right)\tau_L + \left(\frac{A_G}{A}\right)\rho_G g + \left(\frac{A_L}{A}\right)\rho_L g = 0 ---- (7)$$

From the diffention of void fraction (α)

Substituting into equation (7) yield

$$\alpha = \frac{A_G}{A} \Lambda\ (8a) \quad and \quad (1-\alpha) = \frac{A_L}{A} \quad ------- \quad (8)b$$

$$\left(\frac{dP}{dz}\right) = \alpha\,\rho_G g + (1-\alpha)\rho_L g - \left(\frac{S_L}{A}\right)\tau_L \quad ------ \quad (9)$$

Using $S_L = \pi D$ ----------------------- (10)

The shear stresses of liquid (τ_L) is evaluated in the conventional

$$and \qquad A = \frac{\pi}{4} D^2 \quad ---------- (11)$$

$$Henc, the\ \ term \qquad \left(\frac{S_L}{A}\right) = \frac{4}{D} \quad ------ (12)$$

substitutng int*o* *equot* (9) *yield*

$$\left(\frac{dP}{dz}\right) = g\left(\alpha\rho_G + (1-\alpha)\rho_L\right) - \frac{4}{D}\tau_L \quad --------(13)$$

$$\tau_L = f_L \frac{\rho_L U_L^2}{2} \quad ---------- \quad (14)$$

manner

With the liquid friction factor evaluated from :

$$F_L = C_L \left(\frac{D_L U_L}{V_L} \right)^{-n} \quad ------------ (15)$$

Since , it is difficult to calculate liquid diameter (D_L)

Therefore

$$D_L = \frac{4A_L}{S_L} \left(\frac{A}{A} \right) = 4 \left(\frac{A_L}{A} \right) . \left(\frac{A}{S_L} \right) \quad --------- (16)$$

Substituting equation (8b) and equation (12) in to equation (16) yield

The following coefficients were used in equation (15) take the value of:

$$D_L = 4(1-\alpha) \left(\frac{D}{4} \right) \quad ------------ \quad (17)$$

$$and \;\; \therefore \;\; D_L = (1-\alpha) D \quad ------------ \quad (18)$$

$$D_L = \frac{4A_L}{S_L} \quad ------------------ (19)$$

C_L=0.046 and n=0.2 for the turbulent flow and
C_L=16 and n=1.0 for the laminar flow [Barinea , 1982]

Where

$$So \quad \nu_L = \frac{\mu_L}{\rho_L} \quad ------------- \quad (15b)$$

Results and Discussion

From the experimental , there are three flow patterns were observed , bubbly , slug and annular which is the research concentrated on it .

The air bubbles in downward two-phase flow are affected by two dominating force , the first force which is the drag tends to descend the bubble in the downward direction . The second force is the buoyancy force which tends to lift the bubble upward . These opposing two-forces try to deform the bubble from spherical to ellipsoidal .

Co-current downward two-phase flow takes place when the drag force overcomes the buoyancy force . The reason for the slip ratio was less than one may be raised from the fact that the main flow and buoyancy are in the opposite direction .

The transition between one flow pattern and another occurs , as observed gradually . The transition between bubbly and slug occurs when void fraction (α) equal or more the 0.26 , which is approximately in agreement with the analysis of Mishima and lshil (1984) and also with Kendoush and Al-khatad (1994) . The annular flow appeared at void fraction (α) equal or more than 0.68 and the slug flow range was $0.26 < \alpha < 0.68$. The transition between annular and slug flow nearly agrees with the prediction of Barnea et al . (1982) , as well as kendoush and Al-khatad (1994) .

The pressure drop in downward flow in pipe occurs due to hydrostatic difference and the friction between the gas-phase and the liquid phase as well as the friction at pipe wall .

The hydrostatic pressure effected by the bulk density , this is clearly shown in the analytical presented-and for this reason , the pressure drop decreases when the gas flow rate increases with constant water flow rate .

By further increasing the air flow rate with keeping constant water flow rate , the liquid slug between the large bubbles virtually disappears with significant amount of liquid entrained in the gas phase . In this state the liquid flow in a film around the inside wall of the pipe and the gas flows at a higher velocity in the central core depending on the gas flow rate .

This is a fairly stable state which is represents the annular flow . The water film thickness becomes thinner by further increasing the air flow rate . At higher air flow rate . The interface between air and water film is disturbed by waves traveling in the downward direction of the flow .

The pressure drop is less in annular region flow than the other regions were observed. This is coming due to the bulk density effect as we discussed abrasively.

At last a good agreement between the experimental results and an analytical calculation results as show in the figures plotted.

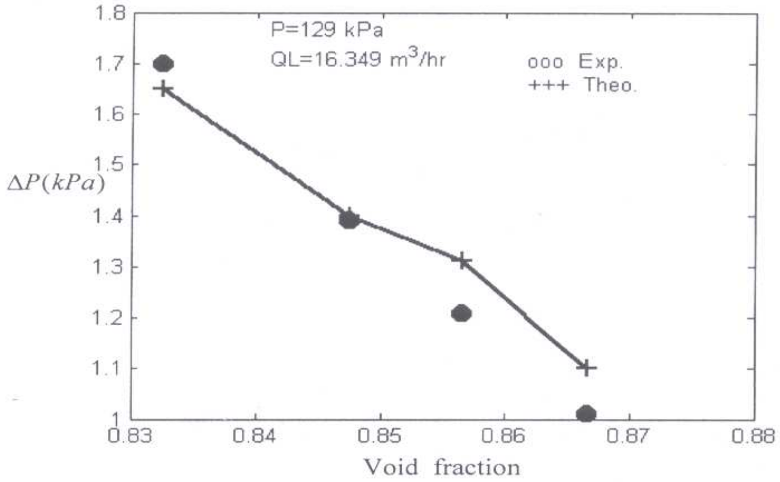

Fig.1.Variation of pressure drop with void fraction at constant liquid flow rate.

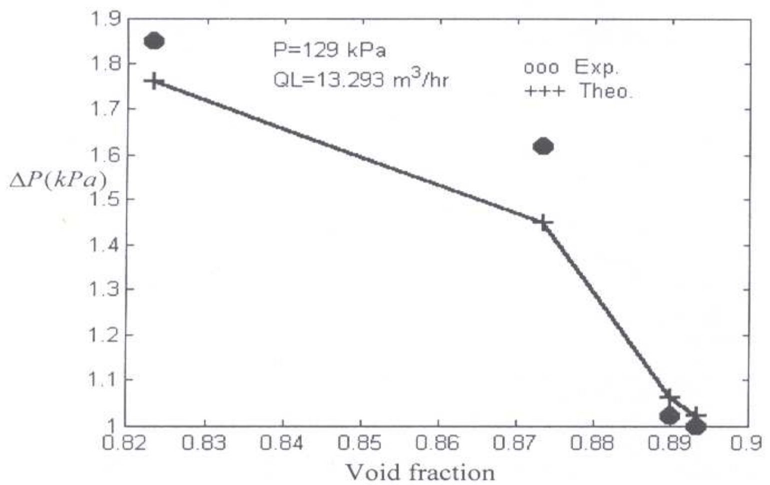

Fig.2.Variation of pressure drop with void fraction at constant liquid flow rate.

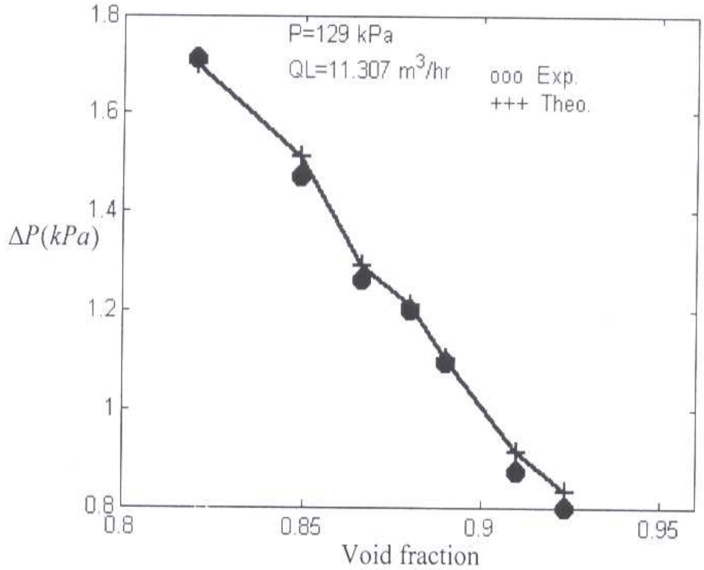

Fig.3.Variation of pressure drop with void fraction at constant liquid flow rate.

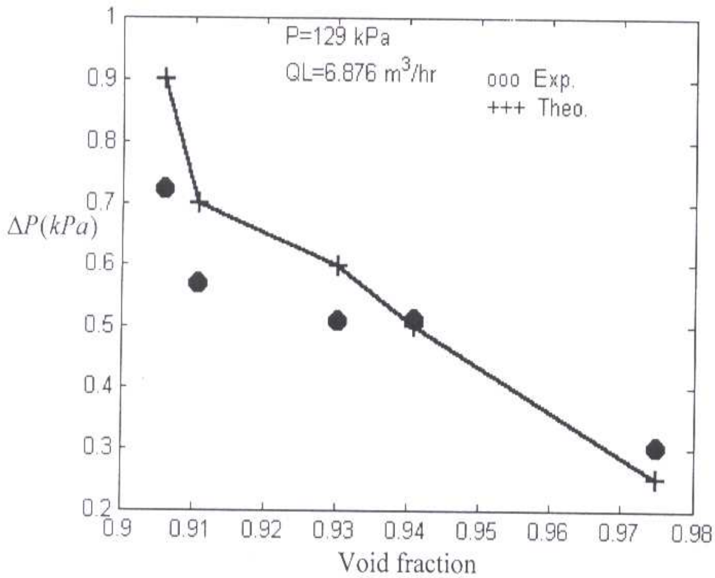

Fig.4.Variation of pressure drop with void fraction at constant liquid flow rate.

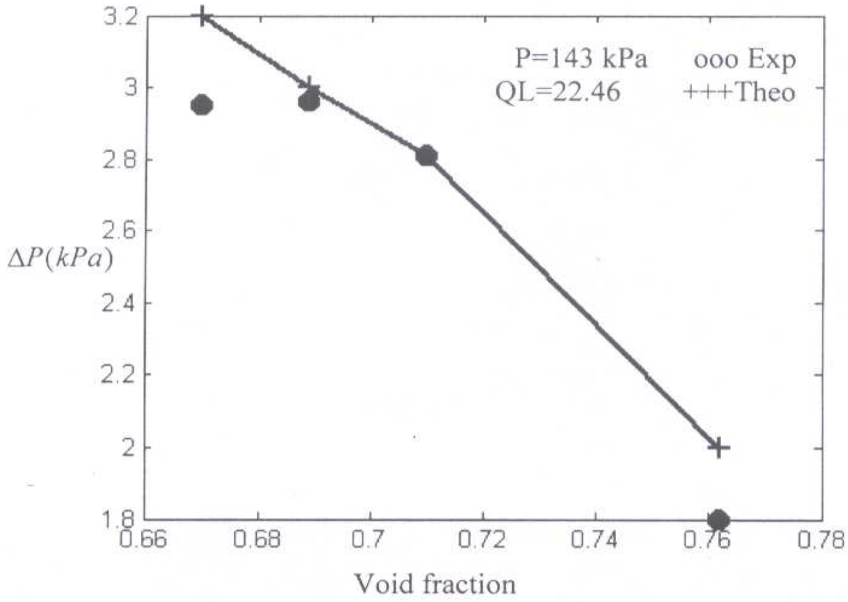

Fig.5.Variation of pressure drop with void fraction at constant liquid flow rate.

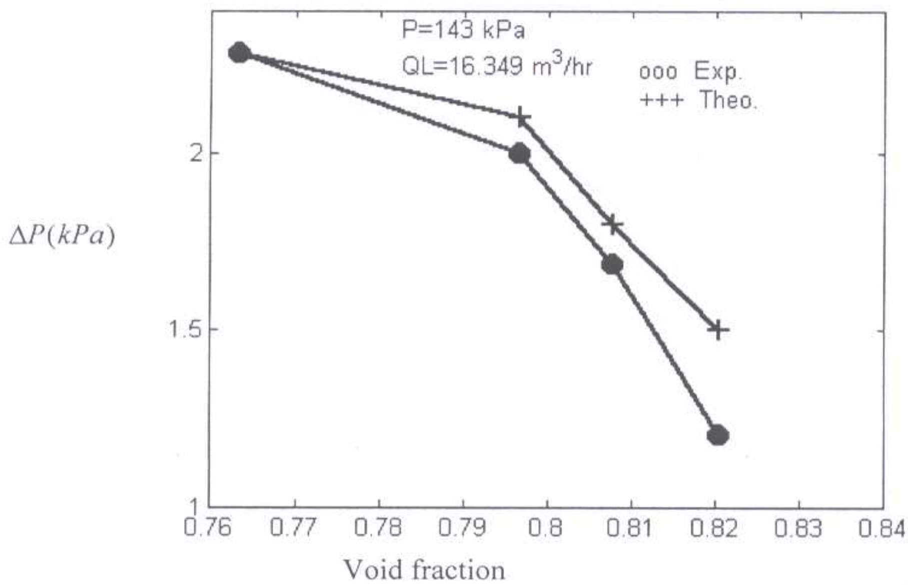

Fig.6.Variation of pressure drop with void fraction at constant liquid flow rate.

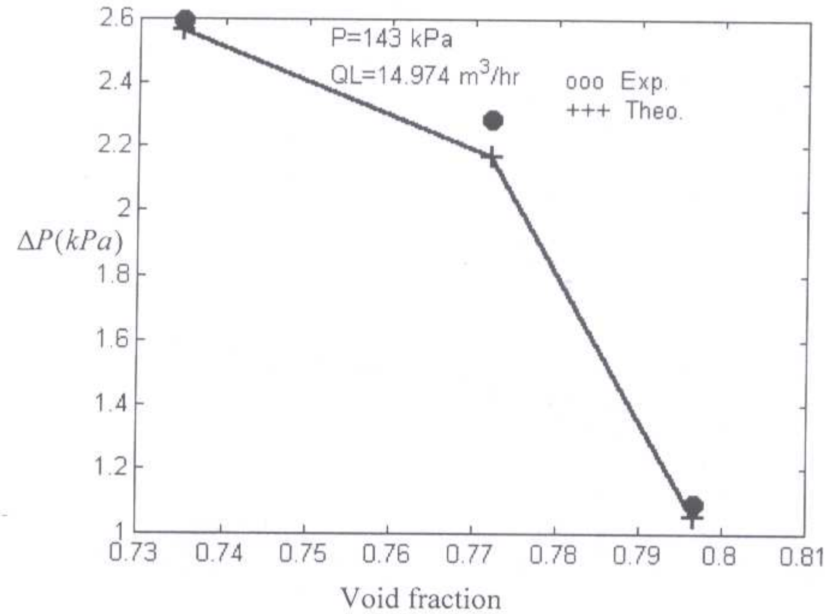

Fig.7.Variation of pressure drop with void fraction at constant liquid flow rate.

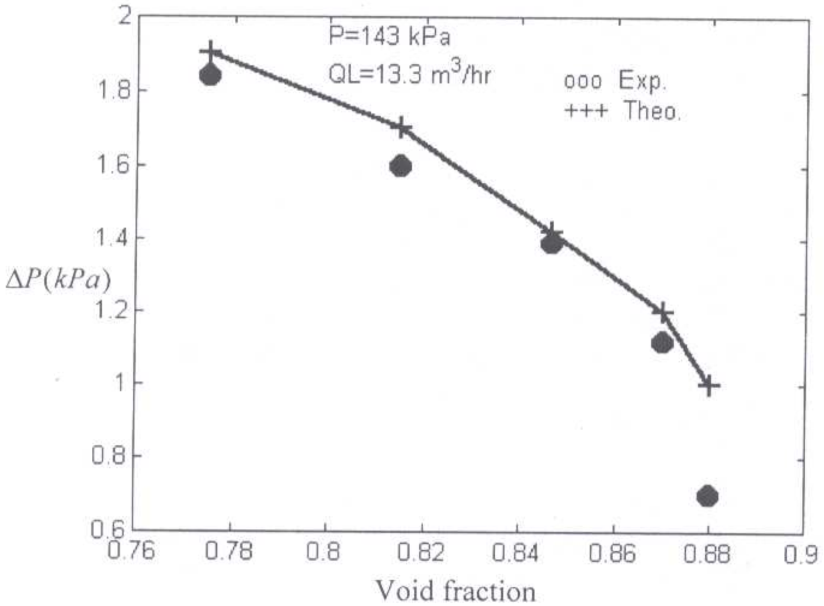

Fig.8.Variation of pressure drop with void fraction at constant liquid flow rate.

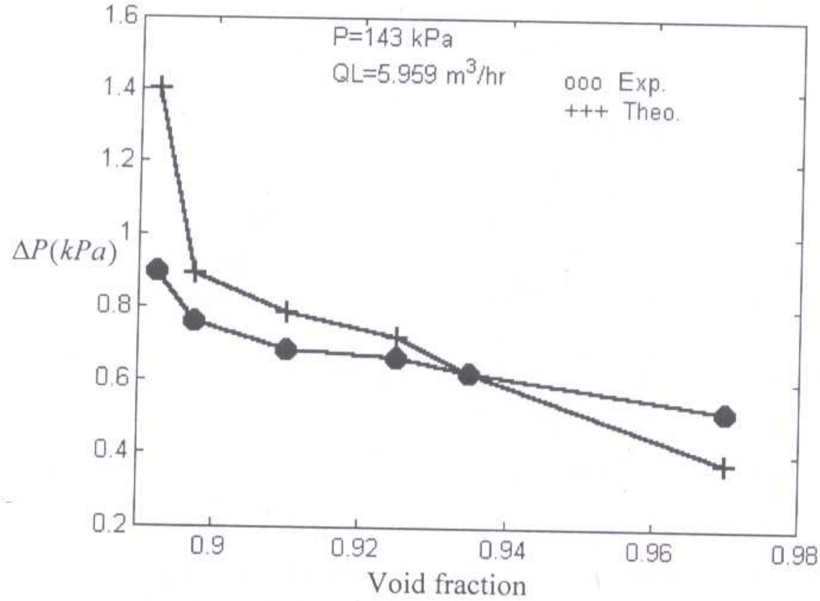

Fig.9.Variation of pressure drop with void fraction at constant liquid flow rate.

<u>Conclusions:</u>

An experimental and an analytical study on the pressure drop , void fraction in downward two-phase (Annular) air water flow was made leading to the following main conclusions :

1- **Three flow patterns was observed which is bubbly , slug and annular flow .**
2- **The transition between the different flow patterns occurs as observed gradually .**
3- **The transition between bubbly and slug flow occurs when the void fraction equal or more than 0.26 and 0.68 for transition from slug to annular flow .**
4- **The pressure drop in vertical pipe downward flow decrease with increase air flow rate at constant liquid flow rate .**
5- **A good agreements between the experimental results and an analytical calculation results through annular flow region .**

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Nomenclature

A	***Total cross-sectional area , m^2***
A_G	***Area accupied by gas-phase , m^2***
A_L	***Aerea accupied by liquid-phase , m^2***
C_L	***Constant in the liquid friction correlation***
D	***Pipe dimeter , m***
D_L	***Pipe dimeter accupied by liquid , m***
d	***Differentional***
emf	***Electromotive force , V***
f_L	***Liquid friction factor***
g	***Acceleration of gravity , m/s^2***
L^*	***Relative inductance , dimensionless***

P	*Pressure , Kpa*
DP/dz	*Pressure gradient i. e. Pressure difference Per unit length , N/m^3*
S	*Parameter over which the stress acts*
U	*Velocity in the z direction , m/s*
V_1	*Potential defference a cross output line , V*
V_2	*Potential defference a cross input line , V*
$(V_1)_m$	*Peak value of output emf*
$V_{p.p}$	*Input peak to peak amptitude voltage , V*
Z	*Coordinate in the downword direction , m*

<u>Greek symbols</u>

α	*Void fraction , dimensionless*
δ	*Liquid film thickness , m*
υ	*kinematic viscosity*
μ	*dynumic liquid viscosity*
ρ	*density , kg/m^3*
τ	*Shear stress ,*

Subscripts

G	*gas*
i	*liquid gas interface*
L	*Liquid*