Study Pressure Drop for Two-Phase Flow in a Large Diameter Tube

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Abstract

The aim of this study is to discover the deviation of two phase flow correlations. A comparsion was made between the expermital values of two-phase flow pressure drops data were obtained experimentally by Al-Jumaily (1999) by using air-water mixture in a horizontal tube of (132 mm) nominal diameter and a test section of (32 m) long at pressure and temperature close to atmospheric and those predicted by three correlations well-used in the literature, which show that the homogeneous model was the best.

Introduction

Knowing the pressure drop in a two-phase flow system is of primary interest to the designer in order to establish the pumping load and prescribe the longitudinal variation in pressure necessary to compute the final properties along a channel. The difficulty stems from the multi-dimensional variation in the mass of velocity distribution of the two-phase. [1]

The correlation developed by Lockhart and Martinelli was based on experimental two-phase pressure drop data taken in small diameter pipes at pressure up to (344.75 kpa.). Chenoweth and Martin [2] correlated these data as well as data of their own taken in pipes to (78mm) and pressure up to (689.5 kpa.). Both correlations were agreed reasonably to each other at low-pressure data, but at high pressure there was a deviation in some cases up to (25%). [3]

Duckler et al presented a critical comparison of the correlations of Baker bank off, Chenoweth and Martin, Lockhart-Martinelli, and Yagi prediction by these methods. The result of their study leads Duckler et al to propose a correlation for two-phase friction pressure drop based on similarity analysis by using data bank consisting of short tube laboratory and long tube oil field data in their work. More than (20,000) experimental measurements have been taken [4]. Beggs and Brill studied a wide range of conditions, and developed general correlations to predict, flow pattern, void fraction and pressure drop, through horizontal, vertical and inclined pipes. Baker Jardine and Associates (BJA) (1988), pressure drop have been developed over pipelines operating data at low liquid-gas rations [5].

The two-phase mixture in homogeneous model is considered as quasi-single phase flow using mean mixture property values. The mean deficiency of this model is that it does not allow for relative movement between the phases (slip) and hence should only be used for well-mixed flows. It might reasonably be expected that this model will be valid for bubble flow or spray flow under certain conditions-particularly at high pressure and high mass flow rates. The assumption upon which it is based are: [6]

(a) Equal gas (or vapor) and liquid velocity.
(b) Thermodynamic equlibrium between phases.
(c) The use of a suitably defined single-phase friction factor for two-phase flow.

Baroczy correlation is based on data for steam, water-air and mercury-nitrogen for a wide range, in this correlation the pressure parameter was made more general by defining it as the liquid to gas viscosity and density ratio [7].

Chisholm presented a correlation, which allowed for mass flow effects and dispensed with graphical procedures. He shows the equation for predicting gradients during two-phase flow [8].

P. Bhramara et al (2008) find drop pressure in designing the condinsate is as important of heat transfer coefficient. Modeling of two phase flow, particularly liquid – vapor flow under adiabatic conditions inside a horizontal tube using CFD analysis is difficult with the available two phase models in FLUENT Code Using Homogeneous model, average properties are obtained for each of the refrigerants that is considered as single phase pseudo fluid. The so obtained pressure drop data is compared with the separated flow models[9].

A. Carlson et al (2008) investigated Multiphase dynamics and its characteristics for two-phase gas-liquid flow by means of advanced numerical simulations such as FLUENT Code find good results comparision experimental with using FLUENT Code[10]..

M. N. Kashid (2005)studied two phase flow in capillary microreactor where well defined slug flow generation is a key activity in the development of methodology to study hydro-dynamics and mass transfer[11].

Domanski et al (2006) studied A new correlation for two-phase flow pressure drop in 180° return bends is proposed based on a total of 241 experimental data points for R-22 and R-410A. The data span smooth tubes with inner diameters (D) from 3.25 mm to 11.63 mm, bend radii (R) from 6.35 mm to 37.25 mm, and curvature ratios (2R/D) from 2.32 to 8.15. The correlation predicts all data with a mean deviation of 15.7 %, and 75 % of the data fall within ± 25 % error bands[12]

the aim of this work is:

1. To obtain the pressure drop results from the data of the pipeline of diameter (132mm) and test section of (32m) pressure drop correlations compared with the (3) correlations existing in the literature.
2. To develop a computer program to process the experimental data in the form of pressure drops and choose the fitted correlation in design pipe line.

Mathmatical model

The single phase friction factor (λ) can be expressed in the form

$$\lambda = k\,\mathrm{Re}^{-n}$$

The values of (k) and (n) were defined by [6] as (0.52) and (0.28) respectively. These quantities are necessary in some of the correlations considered

1. Homogeneous Flow Models[6]

$$\phi_{fo}^{2} = \left[x\frac{v_g}{v_f} + (1-x) \right] \left[\beta\frac{\mu_g}{\mu_f} + (1-\beta) \right]^{n}$$

2. Lockhart-Martinelli

Values of ϕ_f^2 to a base of (X) are presented by Martinelli as shown in table (1). Here the parameter (X) was defined by

$$X^{2} = \frac{\lambda_f (1-x)^{2} G^{2}}{2d\,\rho_f} * \frac{2d\,\rho_g}{\lambda_g x^{2} G^{2}}$$

$$\phi_{fo}^{2} = \phi_f^{2} (1-x)^{2-n}$$

3. Chenoweth-Martin[2]

Values of ϕ_{fo}^2 can be obtained from table (2) from known values of $(1-\beta)$ and a parameter Z where

$$Z = \frac{\rho_f}{\rho_g} \left[\frac{\mu_g}{\mu_f} \right]^{n}$$

Results and Discussion

The comparisons were mad by plotting predicated ϕ_{fo}^2 values against experimental ϕ_{fo}^2 values on Log-Log axis and the data distributed on the line inclined by angle of (45) degree , the plots are shown in figs. (1) to (3) respectively for the three correlations indicated previously. The data points are identified correspondingly to the values of Root Main Square (RMS) and Average Error (AVE) relating to the error between predication and experimental (based on experimental values) are shown on each figure. A computer program was written in order to carry out these comparisons. The relative measures of performance are measured statistically in terms of RMS errors and AVE errors of which the former are the more meaningful values in terms of accuracy of prediction. The average errors can often give good agreement due to the canceling of positive and negative prediction errors, but they do give an indication of general over-prediction or under-prediction.

The errors values indicated that none of the correlations tested had RMS less than (60 %) for data obtained from pipe diameter of (132 mm). there is also a variety of over-prediction and under-prediction suggesting the deficiencies in the correlations and not in the experimental data. The homogeneous model (65.7238%) gives best agreement with the experimental. It is worth noting that:

conclusions

1. None of the correlations gives overall prediction to RMS errors less than (60 %) over the data range.
2. Some of the correlations have very high RMS errors associated with predictions.
3. The best performance correlations tend to be under predicting the two-phase pressure gradient and the poor performance correlations that tend to be over predicted.
4. In general, the flow pattern has some effect on accuracy of prediction.

Table (1) Lockhart-Martinelli Parameter

	All mechanism		Turbulent Turbulent		Viscous Turbulent		Turbulent Viscous		Viscous Viscous	
X	1-α	α	ϕ_f	ϕ_g	ϕ_f	ϕ_g	ϕ_f	ϕ_g	ϕ_f	ϕ_g
0.01	-	-	128	1.28	120	1.20	112	1.12	105	1.05
0.02	-	-	68.4	1.37	64	1.28	58.0	1.16	53.5	1.07
0.04	-	-	38.5	1.54	34	1.36	31.0	1.24	28.0	1.12
0.07	0.04	0.96	24.4	1.71	20.7	1.45	19.3	1.35	17.0	1.19
0.1	0.05	0.95	18.5	1.85	15.2	1.52	14.5	1.45	12.4	1.24
0.2	0.09	0.91	11.2	2.23	8.90	1.78	8.79	1.74	7.00	1.40
0.4	0.14	0.86	7.05	2.83	5.62	2.25	5.50	2.20	4.25.20	1.70
0.7	0.19	0.81	5.04	3.53	4.07	2.85	4.07	2.85	02 308	2.16
1.0	0.23	0.77	4.20	4.20	3.48	3.48	3.48	3.48	2.61	2.16
2.0	0.31	0.69	3.10	6.20	2.62	5.25	2.62	5.24	2.06	4.12
4.0	0.40	0.60	2.38	9.50	2.05	8.20	2.15	8.60	1.76	7.00
7.0	0.48	0.52	1.96	13.7	1.73	12.1	1.83	12.8	1.60	11.2
10	0.53	0.47	1.75	17.5	1.59	15.9	1.66	16.6	1.50	15.0
20	0.66	0.34	1.48	29.5	1.40	28.0	1.44	28.8	1.36	27.3
40	0.76	0.24	1.29	51.5	1.25	50.0	1.25	50	1.25	50
70	0.84	0.16	1.17	82.0	1.17	82.0	1.17	82	1.17	82
100	0.90	0.10	1.11	111	1.11	111	1.11	111	1.11	111

Table (2)

Liquid Volume Fraction $(1-\beta)$	Z=50	Z=100	Z=200	Z=500	Z=1000
0	50	100	200	500	1000
0.00001	56.5	113	225	565	1125
0.00002	58.5	117	235	585	1175
0.00004	62.0	124	248	620	1230
0.00007	63.5	127	254	635	1200
0.0001	64.5	129	258	645	1150
0.0002	66.0	132	225	580	950
0.0004	67.5	129	249	470	680
0.0007	65.0	121	219	385	470
0.001	62.0	115	199	325	370
0.002	58.0	99	153	215	215
0.004	50.0	82	105	120	120
0.007	41.0	60	71.0	72.5	72.5
0.01	34.5	48	53.0	53.0	53.0
0.02	24.0	29.2	29.2	29.2	29.2
0.04	15.0	16.1	16.1	16.1	16.1
0.07	9.9	9.9	9.9	9.9	9.9
0.1	7.4	7.4	7.4	7.4	7.4
0.2	4.05	4.05	4.05	4.05	4.05
0.4	2.22	2.22	2.22	2.22	2.22
0.7	1.38	1.38	1.38	1.38	1.38
1.0	1.0	1.0	1.0	1.0	1.0

AVE =-23.781% RMS = 65.723% AVE = -5.88% RMS = 90.429%

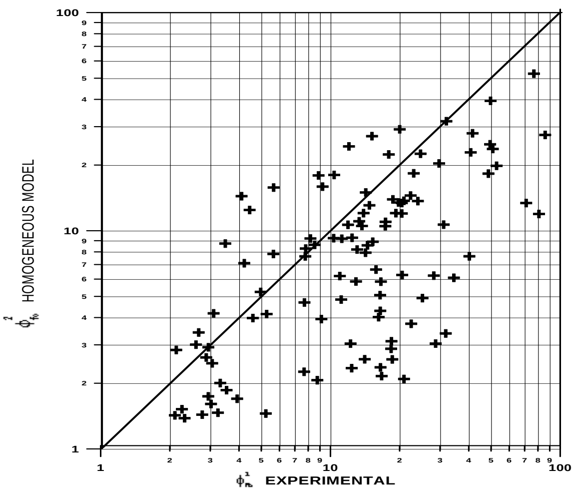

FIG. (1)
Comparison between experimental and homogeneous model

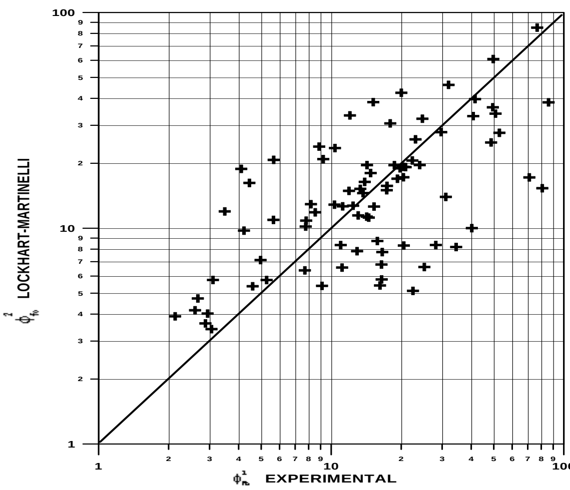

FIG. (2)
Comparison between experimental and Lockhart-Martinelli prediction

AVE = 10.0225%   RMS = 97.64%

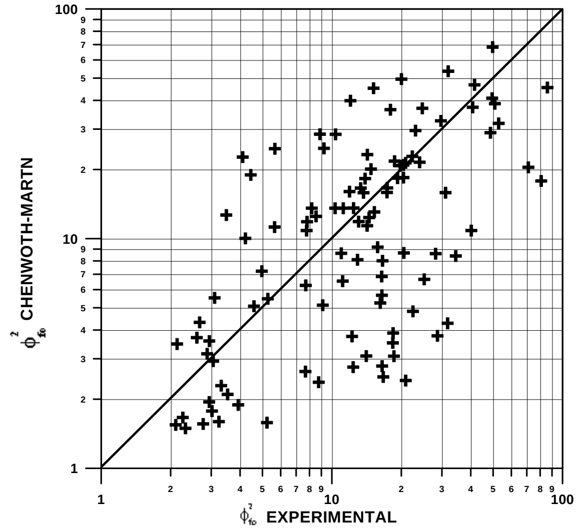

FIG. (3)

Comparison between experimental and Chenoweth-Martin prediction

Nomenclature

Symbol	Description	Dimension
B	Coefficient in Chisholm correlation	
D	Tube diameter	m
G	Mass velocity	kg/m^2s
P	Pressure	KN/m^2
Re	Reynolds number= $\frac{\rho.U.D}{\mu}$	
v	Specific volume= $\frac{1}{\rho}$	m^3/kg
x	Mass dryness fraction= $\frac{Q_g\rho_g}{Q_g\rho_g+Q_f\rho_f}$	
X	Martinelli parameter	
Z	Factor in Chenoweth-Martin correlation	

Greek

Symbol	Description	Dimension
β	Volume dryness fraction	
λ	Friction factor = 4f (Fanning factor)	
λ_1	Single phase friction factor	
λ_2, λ_T	Two phase friction factor.	
μ	Viscosity	kg/m.s
ρ	Density	kg/m^3
ϕ^2_{fo}	Ratio of two phase friction pressure drop to single phase friction pressure drop if total flow rate was liquid	

ϕ_f^2	Ratio of two phase friction pressure drop to single phase friction pressure drop if liquid fraction of flow rate flows alone	
ϕ_{go}^2	Ratio of two phase friction pressure drop to single phase friction pressure drop if total Flow rate was gas	
ϕ_g^2	Ratio of two phase friction pressure drop to single phase friction pressure drop if gas fraction of total flow rate flowed only	
$\frac{\Delta P}{\Delta Z}$	Fraction pressure gradient	N/m^3

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دراسة انخفاض الضغط للجريان ثنائي الطور في الانابيب ذات الاقطار الكبيرة

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الخلاصة

الهدف الرئيسي لهذه الدراسة هو اكتشاف الانحراف في العلاقات للجريان ثنائي الطور. المقارنة كانت بين معطيات القيم التجريبية لانخفاض الضغط المحصلة تجريبيا من الجميلي(1999) باستخدام خليط الهواء والماء في انبوب افقي بقطر داخلي (132) ملم ومقطع فحص بطول(32) م بضغط ودرجة حرارة تقترب من الظروف الجوية على طول المقطع هذه القيم المستحصلة للعلاقات الثلاثة استعملت بشكل جيد في البحوث السابقة. والتي بينت بان النموذج المتجانس كان الافضل.