International Journal of Engineering Applied Sciences and Technology, 2018
Vol. 3, Issue 5, ISSN No. 2455-2143, Pages 38-45
Published Online September 2018 in IJEAST (http://www.ijeast.com)

EFFECT OF MAGNETIC FIELD ON PRESSURE DROP USING TWO-PHASE FLOW IN SMALL DIAMETER TUBES AT HORIZONTAL ORIENTATION

N. J. Sisodiya
Mechanical Engineering Department,
Maharashtra Institute of Technology, Aurangabad,
(Maharashtra), India

A.T.Autee
Mechanical Engineering Department
Maharashtra Institute of Technology, Aurangabad,
(Maharashtra), India

S. B. Charthankar
Mechanical Engineering Department,
Maharashtra Institute of Technology, Aurangabad,
(Maharashtra), India

B. G. Toksha
Mechanical Engineering Department,
Maharashtra Institute of Technology, Aurangabad,
(Maharashtra), India

Abstract: The influence of a transverse magnetic field on the pressure drop of an electrically conducting two-phase fluid flow and nanofluid is studied experimentally. The effect on pressure drop was examined with different volume concentrations and constant applied magnetic field. Test sections are made of transparent acrylic tubes having different internal diameters ranging from 8.0-12.0 mm. Experimental results of two-phase pressure drop in small diameter tubes are presented in this work. Increasing the flow rates and applying constant magnetic field of nanoparticles (Fe_3O_4) increases the two phase pressure drop for both the cases. One of the objectives of this work is to investigate the role of nanoparticles which may cause particle migration and disturbance of the boundary layer by utilizing magnetic field and its effect on two phase pressure drop. The comparative study of two-phase pressure drop using available correlations from open literature shows inadequate results.

Keywords: **Nanofluid, Two-phase flow, Magnetic field, Pressure drop**

I. INTRODUCTION

In recent years, the study of nanofluid has become necessary in natural philosophy and fluid engineering due to their increased thermal properties over the base fluids. Advancements within the synthesis of nanoparticles and their applications in numerous fields are topic of nice analysis [1]. The world of nanofluids is additionally explored for their campaigning in mechanical advancements [2-4]. Application and technological development of nanomaterials are growing rapidly in industrial and educational fields, but all of the studies mistreatment this idea faces some irregular issues together with sedimentation, erosion of the parts by abrasive action, obstructive in little passages and increase within the pressure drop of the flow due to massive size of particles [5].

Numerous studies have mentioned regarding the thermal properties, convective and boiling heat transfer coefficient of the nanofluids, but there are a few studies that take into thought the increased quantity of nanofluid pressure drop besides their heat transfer analysis. The application of single and multi phase flow has been often determined in several numerous fields of science and engineering. It is necessary to predict design parameters like friction factor, pressure drop, bubble size, void fraction so as to see in operating conditions and also the size of apparatus required for specific application. Kawahara et al. [6] worked on two-phase flow pattern, void fraction and pressure drop by a microchannel having 100 μm diameter circular tubes. Single-phase friction issue and two-phase friction multiplier factor information were obtained from the pressure drop analysis. Similar worked is carried by M. Venkatesan [7] on two-phase pressure drop by narrow tubes within which the result of tube diameter on two-phase friction pressure drop was investigated in circular tubes with inner diameters of 0.6, 1.2, 2.6 and 3.4 mm using air and water. Aritra sur and Dong Liu [8] conducted experiments for adiabatic air-water two-phase flow in circular micro channels. The effect of channel size and superficial phasic velocity on the two-phase flow pattern and pressure drop of air-water mixture in circular micro channels with inner diameters of a 100, 180 and 324 µm. Two-phase flow patterns were visualized using high-speed photographic technique. Autee et al. [9] studied adiabatic two-phase pressure drop for the take a look at section manufactured from diameter vary between 3 to 8 mm. The investigation is allotted inside the vary of mass flux of water 16.58 -3050 kg/m2s, mass flux of air 8.25-204.10 kg/m2s and total mass flux 99.93-3184.69 kg/m2s. Some of the prevailing correlations of macro and mini channels area unit compared with experimental information and developed new correlation for two-phase pressure drop.

To development into the research work on two-phase flow within the place of water different kinds of nanofluid area unit employed in the research and allotted study on the pressure drop recently from few years. K.B. Rana et al. [10] studied on the result of pressure drop by using ZnO-water nanofluids through the horizontal annulus. Experiments were performed in single phase and boiling flow of nanofluids underneath flow with totally different low particle concentrations (≤0.01 vol. %). The result shows that pressure drop of the water and nanofluids will increase with a rise within the rate of flow. Further investigation by H. Almohammadi et al. [11] the convective heat transfer and pressure drop of Al_2O_3/water nanofluid in streamline flow regime within a circular tube with 0.5% and 1% volume concentrations with 15 nm diameter nanoparticles as operating fluid. The result of various volume concentrations on convective heat transfer constant and friction factor was studied. Sandeep Kumar et al. [12] studied the result of CuO-distilled water based nanofluids on heat transfer and pressure drop characteristics of nanofluid flowing during a horizontal circular pipe under constant heat flux condition. Similarly Hamad et al. [13] carried investigation of pressure drops in horizontal pipes with different diameters. The result of the volumetric quality and mixture velocity on pressure drop of gas-liquid flow in horizontal pipes of various diameters is investigated by experimentation and numerically. The friction pressure drop increased with the increasing of gas rate of flow for constant water flow. S. Giri [14] conducted study on two-phase flow pressure drop by small diameter bends and study on a number of the out there two-phase pressure drop correlations that reveals that the expected values of pressure drops might dissent by massive. The pertinence of those correlations to the small diameter tubes of 4.0—8.0 mm and totally different bend angles of the vary 90^0- 180^0 aren't totally established.

A number of researchers have evaluated the influence of external magnetic field on the nanofluid to review the result of magnetic field on heat transfer and pressure drop. Li and Xuan [15] by experimentation investigated the convective heat transfer of ferrofluid flowing past a heated fine wire within the presence and absence of an outwardly applied magnetic field. They determined increment in heat transfer between the magnetic fluid and also the heated wire. L. Syam Sundar et al. [16] conducted experimental investigation of forced convection heat transfer and friction considers a tube with Fe_3O_4 magnetic nanofluid. The improvement of friction issue determined during a plain tube with 0.6% volume concentration of Fe_3O_4 nanofluid in comparison to water is 1.09 times and 1.10 times for Reynolds number of 3000 and 22, 000 severally. Experimental investigation of result of magnetic field on convective heat transfer and pressure drop on nanofluid flowing within spirally twisted tubes was carried by Naphon et al. [17]. The obtained results area unit compared without magnetic field under same condition that shows that the magnetic field result will increase the Nusselt number. Hatami et al. [18] study the effect of magnetic field on nanofluids heat transfer through a uniformly heated horizontal tube. In their study, the results of field of force on forced convection heat transfer of Fe_3O_4–water nanofluid with streamline flow regime during a horizontal pipe under constant heat flux conditions were studied. They determined that Fe_3O_4 nanoparticles suspended in water increase stratified convective heat transfer within the flow regime and for the improvement in determined in are by increasing volume fraction of nanoparticles. Similarly Karamallah et al. [19] investigated the result of magnetic field with nanofluid on heat transfer during a horizontal pipe and conducted study of heat transfer and fluid flow of distilled water or metal oxide nanofluid Fe_3O_4 distilled water at concentrations of (0.3, 0.6, 0.9 %) by volume during a horizontal pipe with constant magnetic field. Ajay Katiyar et al. [20] investigated on magnetic field induced augmented thermal conduction phenomenon in magneto nano colloids within which magnetic field induced drastically increased thermal conductivity of the magneto-nanocolloids involving magnetic compound nanoparticles, Fe_2O_3, Fe_3O_4, Nickel oxide (NiO), Cobalt oxide (Co_3O_4), spread in several base fluids (heat transfer oil, kerosene, and ethylene glycol) are reportable.

The friction pressure drop is often determined by totally different models and correlations for macro channels. The homogeneous correlation that makes the analysis of two-phase easier. The Friedel [21] and Chisholm [22] correlation for two-phase pressure drop was specially developed for separated macro channels. In Lockhart model [23] the Martinelli parameter X, is that the combination of the inertia and viscous forces of each phases.

The motive of this paper is to review the result of magnetic field on two-phase flow pressure drop at fluid flowing through horizontal orientation. Incorporation of nanofluid in place of water as fluid mixed with compressed air and flowing two-phase flow through horizontal tubes and evaluating result of magnetic field on two-phase flow is reportable during this work.

International Journal of Engineering Applied Sciences and Technology, 2018
Vol. 3, Issue 5, ISSN No. 2455-2143, Pages 38-45
Published Online September 2018 in IJEAST (http://www.ijeast.com)

II. SYNTHESIS OF NANOFLUID

The synthesis of Nanofluids is allotted by two step methodology. Firstly nano-sized magnetic Fe_3O_4 particles were synthesized then the next dispersion and stabilization of nanoparticles into the primarily based fluid like distilled water is done. The Fe_3O_4 nanoparticle has been synthesized by auto combustion technique. A combination of Ferrous Nitrate and fuel used is Citric acid, are used as precursors in applicable stoicheometric ratios. The elaborate synthesis methodology used within the present work is mentioned by Toksha et al. [24].

For getting ready of Fe_3O_4 nanofluid the nanoparticles ready are to be mixed within the primarily based fluid used as water. The proportion of nanofluid area unit calculated by volume concentration is given by,

% volume concentration =

$$\frac{\text{volume of nanopartical}}{\text{volume of nanopartical} + \text{volume of water}} * 100$$

$$\phi = \frac{(m/\rho)_{nanopartial}}{(m/\rho)_{nanopartial} + (m/\rho)_{water}} * 100 \qquad (1)$$

Based on above equation nanofluid of various volume concentration like 0.02 and 0.04 are prepared. The prepared nanoparticles are to be mixed in equal proportion with water within the beaker then mixture is stirred with rotating stirrer at 500 rpm for the amount of 1 hour. Due to used of same methodology totally different concentration of nanofluid are prepared. The density of nanofluid is calculated by the following equation:

$$\rho_{nf} = (1-\phi)\rho_{bf} + \phi\rho_{p} \qquad (2)$$

III. EXPERIMENTAL SET UP

A schematic diagram of the experimental set-up is shown in Figure 1. The test facility was designed and developed for many future investigations to review two-phase pressure drop in macro-channels. It includes a test section, pump, compressor, electromagnets, rota meters, mixing chamber, control valves, differential pressure transducer device and data Acquisition System.

Water from the tank is pumped-up to the test section by pump. The water rate of flow and air rate of flow is regulated with the assistance of control valve and bypass valve. Air and water mixed within the mixing chamber and passes through the test section. Air-water mixture commencing from the test-section is collected within the water tank. Within the tank air gets separated and therefore the water is recirculated.

Three totally different diameters test sections were used throughout experimentation. This square measure created of transparent acrylic material with circular cross section, with a complete length 500 mm and internal diameters of 8.0, 11.0, and 12.0 mm. The full length of test section is split into the three segments: 1. Entrance phase of 50 mm length used for stabilization of flow after mixing chamber 2. Measure phase of 300 mm length was used for measurement of pressure drop 3. Outlet phase of 50 mm length to avoid the back pressure impact on the measurement of pressure drop.

The pressure drop of the air-water mixture is measured by a differential pressure transducer device of range 0-1 bar. Pressure transducer device of range 0-2.5 bar is employed for measurement of the water static pressure. The smallest amount count of each differential transducer is 0.001bar. The subsequent flow parameters were measured: flow rates of air and water, pressure drop and temperature recorded by a data acquisition system within the test section. Two rota meters were used to measure the mass rate of flow. One was used for water flow line having a range 3-30 LPM whereas the opposite was utilized in the air line having a range 10-100 LPM. A pressure gauge was situated simply before the inlet to mixing chamber (range of 0-150 lb/in²). This is often wont to live the static pressure of air for calculation of density.

For comparison the pressure drop of two phase water, nanofluid is employed. The results of magnetic field on two-phase flow are evaluated. For producing magnetic field two constant electromagnets are used. Having 100 mm length and 20 mm outer diameter made from GI pipes. A little insulated copper wire was wounded on the GI pipe. There are 200 numbers of turns of copper wire on the pipe. DC Power provide for 12 V electrical devices passing through copper wire and manufacturing up to 400 Gauss constant magnetic field.

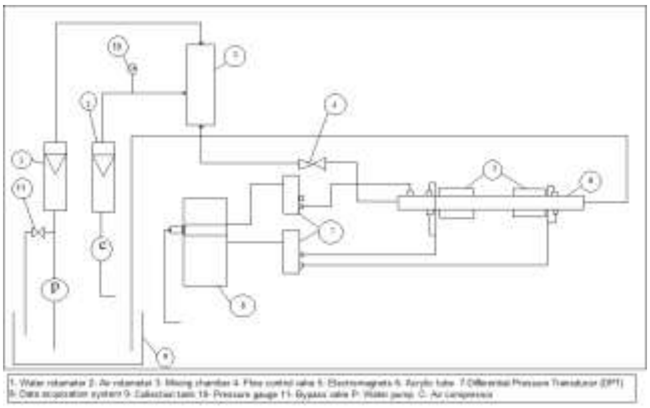


Fig 1. Schematic diagram of Experimental set up

IV. RESULT AND DISCUSSION

A. Experimental Validation

Single-phase pressure drop tests were conducted to validate experimental set-up and instrumentation. Experiments were conducted with 8.0 mm internal diameter and 400 mm length test section. Water was used as operating fluid. The experimental pressure drop for water flow was recorded. Figure 2. Shows the comparison of the experimental friction factor f with Blasius correlation predicted values. It is observed that experimental values are in smart agreement with Blasius correlation (f=0.079/Re^0.25) prediction. The error related to the pressure drop measurements proves to be quite affordable ±10%. The pressure drop information for various water flow rates is recorded and this can be used to calculate the friction factor by applying Darcy equation for smooth pipe as:

$$f_{\exp} = \frac{\Delta PD}{2L\rho v^2} \quad (3)$$

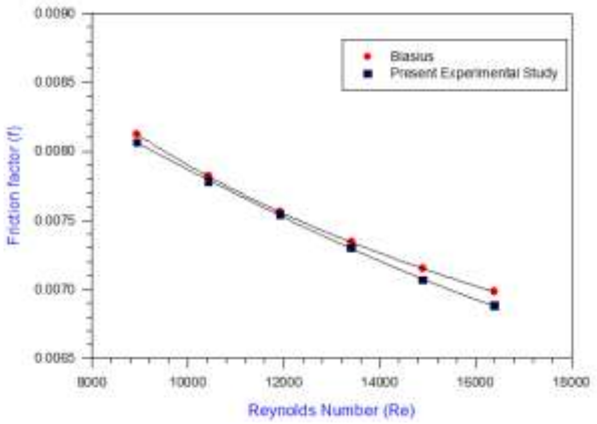


Fig 2. Comparison of experimental single-phase friction factor with Blasius correlation

B. Two phase pressure drop

The friction pressure drop by present study was investigated with constant water flow method of two-phase generation. During this methodology, air is injected variably whereas the water flow rate was taken constant; hence that will increase the entire mass rate of flow of mixture. Two-phase air-water mixture is to be flow through horizontal tube. The pressure drop is measured at totally different flow rates. Following correlations are used for analysis of information from experimental results. The generated information is statistically analysed to evaluated air and water mixture, air-nanofluid mixture at totally different concentrations and additionally within the presence of magnetic field for that air-nanofluid mixture. The concentrations of nanofluid used area unit 0.02 and 0.04 for Fe3O4 nanofluid. The constant field of force of 400 gauss are supplied around the tube.

Figure 3.present the comparison of friction pressure drop calculated by the evaluated correlations with the experimental data. The abscissa denotes experimental pressure drop, whereas the ordinate will the predicted one. The error band of ±50% is shown by solid lines in these figures. The measured pressure drop for constant water rate of flow is presented in Fig.3 relative to tube of 0.008m, 0.011m and 0.012 m ID respectively.

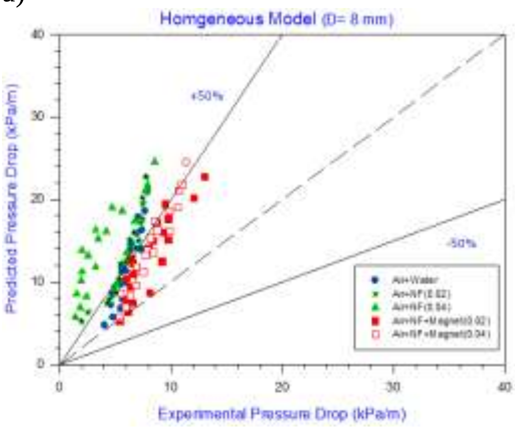
Figure 3.a-c shows the comparison of experimental friction pressure drop data with the predictions of the Homogeneous flow model. Two-phase flow solid consistence is calculated using McAdams et al. correlation. This correlation over predicts for 8.0 mm diameter tube friction pressure drop data. Only 20% data points area unit inside the ±50% error band for air-water mixture. The data points for nanofluid are a lot of over predicts for each concentrations 100% severally. The Friction pressure drop data points of 11.0 mm are inside ±50% error band and for 12.0 mm diameter tube shortly under predicts 20% within the existence of magnetic field.

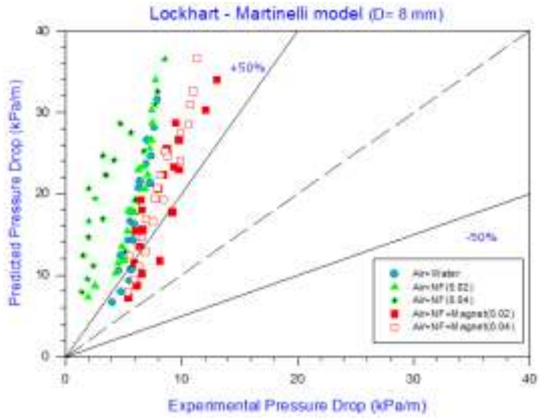
Figure 3.d-f shows the comparison of experimental friction pressure drop data with the Lockhart-Martinelli [23]. The prediction is clearly not satisfactory for 8.0 mm diameter tube employed in this study. Total numbers of information purpose inside the ± 50% error band are 15% for 0.02 concentration nanofluids in presence of magnetic field. From Figure.3 g-i the comparison between Friedel [21] correlations they predict data points aren't indicating satisfactory agreement due to some uncertainties present in experimental work. The Friedel correlation doesn't predict data, most of data are over predict from ± 50% error band. So it can be over that the Friedel correlation is far a lot of appropriate for air-water mixture than nanofluid. Figure 3.j-l shows Chisholm [22] correlation within which data points for 8.0 mm diameter tubes at each concentrations of nanofluid is over predicted to ± 50% error band.

From overall study of experimental result it shows that the rise in rate of flow of two-phase flow result in increase in pressure drop. There are also mean absolute error can turn out due to presence of some uncertainties like density of fluid, viscosity, surface tension, test section dimensions, etc. This study additionally shows as compare to air-water mixture, once nanofluid is employed the pressure drop are going to be slightly decreases and additionally will increase once the concentration of fluid will increase. The diameter of tube also results in whenever the scale of the tube decreases will result in increase within the pressure drop. Finally due to use of magnetic field as compare to air-nanofluid mixture the pressure drop are going to be increase slightly.

International Journal of Engineering Applied Sciences and Technology, 2018
Vol. 3, Issue 5, ISSN No. 2455-2143, Pages 38-45
Published Online September 2018 in IJEAST (http://www.ijeast.com)

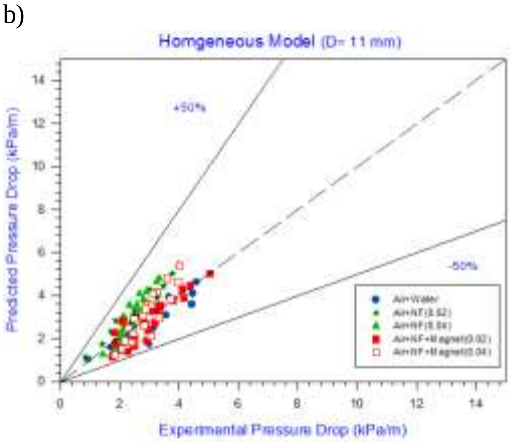
a)

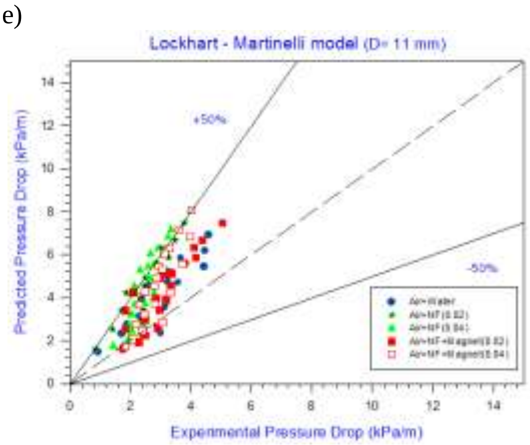




b)

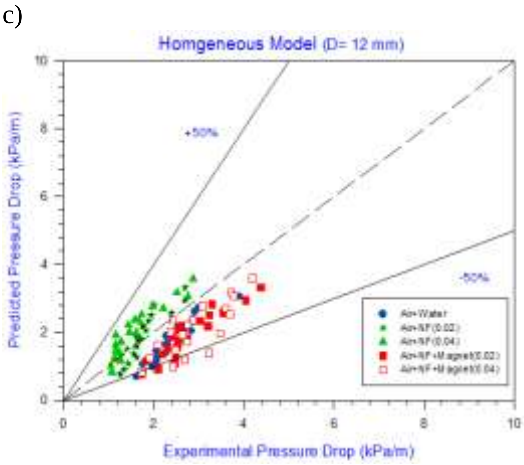
e)

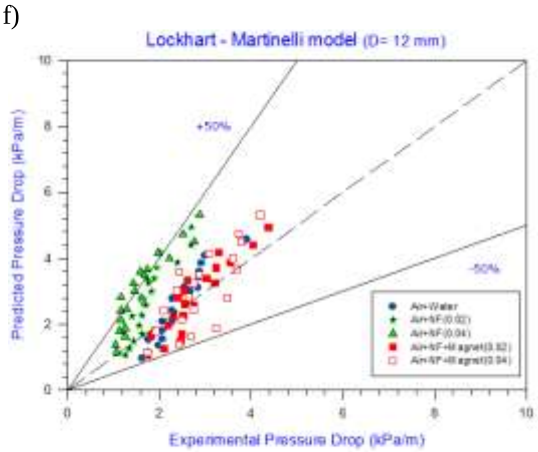




c)

f)





g)

d)

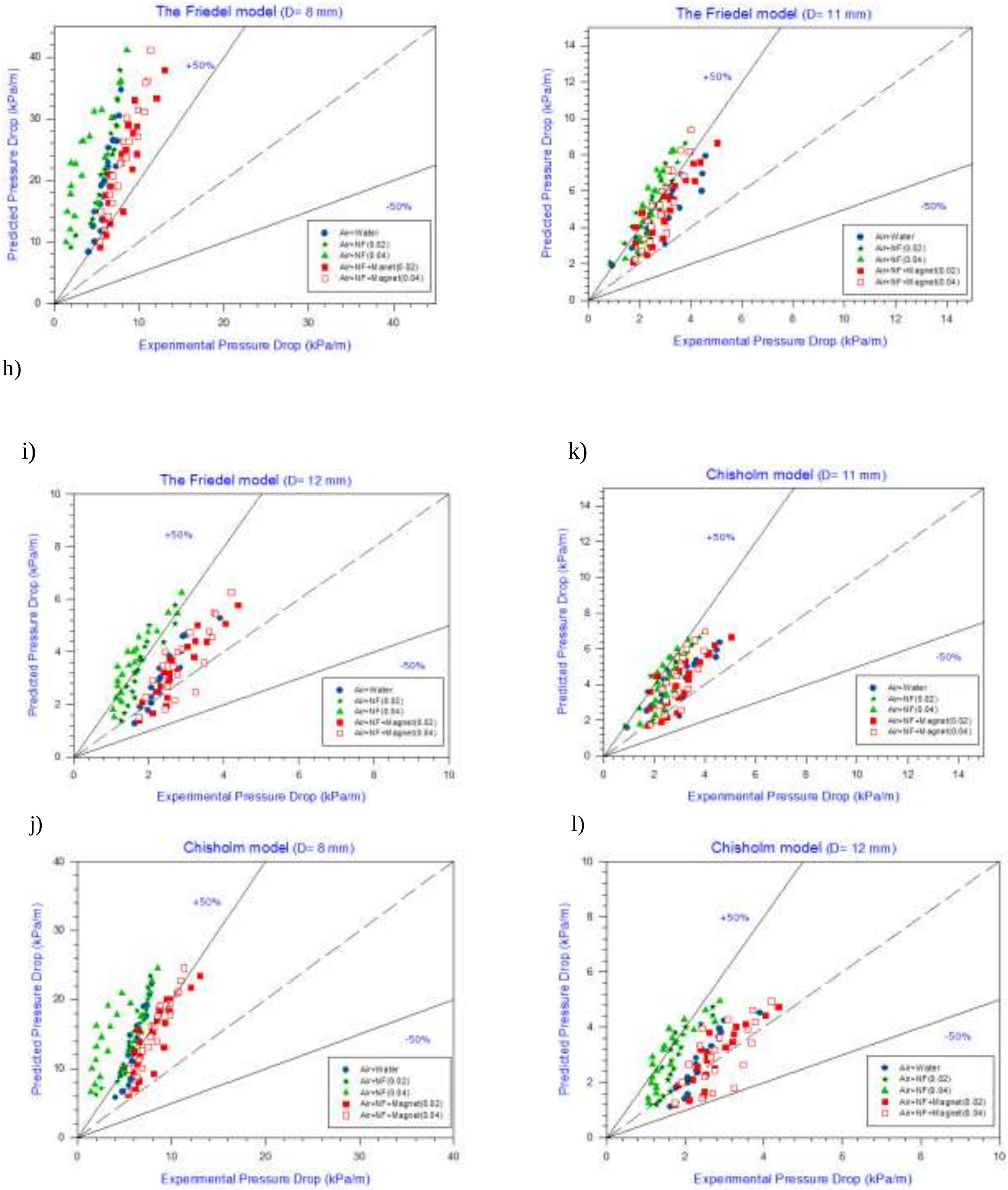


Fig.3 Comparison of various existing correlations with experimental data

V. CONCLUSIONS

The effect of constant water two-phase flow provide adequate results on pressure drop of air-water flow in horizontal macro channel tubes with totally different ID are investigated each by experimentation. There are 4 numbers of existing correlations studied and compare with experimental data points. Also predicted results for using nanofluid (Fe3O4) as two-phase friction pressure drop and compare the result with present of constant magnetic field.

1. Single phase water flow tests were performed for experimental validation and results confirmed the suitableness of the test facility which may use for two-phase flow investigation.

2. The friction pressure drop increased with increasing rate of flow and additionally with decreases of tube internal diameter.
3. Effect of nanoparticles used at totally different concentration ends up in decrease of pressure drop up to 19.34% as compare to water. The result of constant magnetic field equipped through nanofluid also results in increase in friction pressure drop up to 14.75% as compare to water, because of frictional behaviour occurs in nanoparticles.
4. The measured two-phase experimental pressure drop data was compared with some of the available two-phase pressure drop correlations applicable for the particular type of different diameter tube. It has been found that these correlations have poor predictive capability for 8 mm diameter tube from present range of experimental data.

VI. REFERENCES

[1] B.G. Toksha, S.E. Shirsath, S.M. Patange, et al, Structural investigations and magnetic properties of cobalt ferrite solution nanoparticles ready by sol–gel auto combustion methodology , *Solid State Communications*, 2008, 147 (11-12), 479-483.

[2] S.A.Angayarkanni, John Philip, Review on thermal properties of nanofluids: Recent developments, *Renewable and property Energy Reviews*, 2015, Volume 43, Pages 164-177.

[3] Emad Sadeghinezhada, Mohammad Mehralib, R.Saidurc, et al, A comprehensive review on graphene nanofluids: Recent analysis, development and applications, *Energy Conversion and Management*, 2016, Volume 111, Pages 466-487.

[4] Veeresh Fuskele, R.M.Sarviya, Recent developments in Nanoparticles Synthesis, Preparation and Stability of Nanofluids, *Materials Today: Proceedings*, 2017, Volume 4, Issue 2, Pages 4049-4060.

[5] Stephen U. S. Choi and J. A. Eastman, Enhancing Thermal conduction of Fluids With Nanoparticles, *ASME International engineering science Congress & Exposition*, November 12-17, 1995.

[6] Kawahara, P.M.-Y. Chung, M. Kawaji, Investigation of two-phase flow pattern, void fraction and pressure drop in a microchannel, *International Journal of Multiphase Flow*, 2002, pp.1411–1435.

[7] M. Venkatesan , Sarit K. Das , A.R. Balakrishnan, Effect of diameter on two phase pressure drop in narrow tubes, *Experimental Thermal and Fluid Science*, 2011, pp. 531 -541.

[8] Aritra sur, Dong Liu, Adiabatic air-water two-phase flow in circular micro channels, *International Journal of Thermal Sciences*, 2011, pp. 18-34.

[9] Arun Autee, S.Srinivasa Rao, Ravikumar Puli, et al, Experimental Study on Two-Phase Pressure Drop of Air-Water in small Diameter Tubes at Horizontal Orientation, *Thermal Science*, Online-First Issue 00, 2012.

[10] K.B. Rana, A.K. Rajvanshi, G.D. Agrawal, et al, Experimental Pressure Drop Study with Nanofluids, *Journal of Materials Science & Surface Engineering*, 2013, Vol. 1, pp 8-10.

[11] H. Almohammadi, Sh. Nasiri Vatan, E. Esmaeilzadeh, et al, experimental investigation of convective heat transfer and pressure drop of Al2O3/water nanofluid in streamline flow regime within a circular tube, *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering*, 2012, Vol:6, No:8, pp. 1750-1755.

[12] Sandeep Kumar, Gurpreet Singh Sokhal and Jaspreet Singh, result of CuO-distilled water primarily based nanofluids on heat transfer characteristics and pressure drop characteristics, *Int. Journal of Engineering analysis and Applications*, 2014, pp. 28-37.

[13] F.A. Hamad, F. Faraji, C.G.S. Santim, et al, Investigation of pressure drops in horizontal pipes with totally different diameters, *International Journal of Multiphase Flow*, 2016, pp. 120–129.

[14] Giri S.V and Autee A.T, Experimental study on two-phase flow pressure come by small diameter bends, *Preservatives in Science*, 2016, 8, pp. 621—625.

[15] Qiang Li, Yimin Xuan, Experimental investigation on heat transfer characteristics of magnetic fluid flow around a fine wire under the influence of associate external flux, *Experimental Thermal and Fluid Science*, 2008, pp. 591–596.

[16] L. Syam Sundar, M.T. Naik, K.V. Sharma, et al, Experimental investigation of forced convection heat transfer and friction factor in a tube with Fe3O4 magnetic nanofluid, *Experimental Thermal and Fluid Science*, 2011, pp. 65–71.

[17] P. Naphon, S. Wiriyasart, T. Arisariyawong, et al, Magnetic field effect on the nanofluids convective heat transfer and pressure drop in the spirally coiled tubes, *International Journal of Heat and Mass Transfer*, 2016, pp. 739–745.

[18] N. Hatami, A. Kazemnejad Banari, A. Malekzadeh, et al, The effect of magnetic field on nanofluids heat transfer through a uniformly heated horizontal tube, *Physics Letters*, 2016, pp.1-6.

[19] Abdulhassan A. Karamallah, Laith Jaafer habeeb, Ali Habeeb inquirer, the result of flux with nanofluid on heat transfer in a horizontal pipe, *Al-Khwarizmi Engineering Journal*, 2016, volume 12, pp. 99- 109.

[20] Ajay Katiyar, Purbarun Dhar, Tandra Nandi, et al, Magnetic field induced augmented thermal conduction phenomenon in magneto nanocolloids, *School of Mechanical, Materials and Energy Engineering (SMMEE)*, 2013, pp. 1-28.

[21] Friedel, L., "Improved friction pressure drop correlations for horizontal and vertical two-phase flow", *European two-phase flow Group meeting*, Ispra, 1979.

[22] Chisholm, D., "Pressure gradients due to friction during the flow of evaporating tow-phase mixtures in smooth tubes and channels", *International Journal Heat Mass Transfer*, 1972, Vol.16, pp.347-358.

[23] R.W.Lockhart, T.C.Martinelli, "proposed correlation of data for equal two-phase, two-component flow in pipes", *Chem. Eng. Prog*, 1949, vol. 45, pp. 39-48.

[24] B.G .Toksha, S.E. Shirsath, M.L.Mane, Auto combustion High-Temperature Synthesis, Structural, and Magnetic Properties of CoCr x Fe2– x O4 (0≤ x≤ 1.0), *The Journal of chemistry*, 2011, C 115 (43), 20905-20912