Study Effect of Bubble Size on Drag Reduction

Sajida Lafta Ghashim

***Abstract*— Studied experimentally the effect of air bubbles injection on drag reduction for water flow in a vertical pipe. Test section made from transparent pipe with internal diameter of (0.025 m) and length (2m). Air bubbles injection in a vertical pipe from bottom by two methods nozzle and porous ring. The experiments were conducted using range of Reynolds number (13321.68 - 22202.79) and air flow rate (0.5, 1 and 1.5 L/min) . The results showed that small air bubbles injection in the pipe reduced the pressure gradient more than that large bubbles produced by nozzle. Also, it was concluded that, bubbles injection by porous ring tended to collect near the wall along the pipe .Furthermore, drag reduction reached to its maximum value at (28%) at a maximum value of void fraction (11%) and minimum value of Reynolds number (13321.68) by porous ring method .**

***Keywords*—two phase flow, bubbles, turbulent flow, drag reduction.**

I. Introduction

The technique of bubble injection into turbulent flow is one of the best methods of viscous drag reduction. The effect of bubbles is investigated through many researches.

[1]. Investigated experimentally air bubbles injection on water flow in a vertical tube. Bubbles injection was ensured using two type of injection: nozzle and porous sinter. Experiments had been carried out with the following conditions, superficial velocities (0.01 to 0.2 m/s) and (0.02 to 0.87 m/s) were used for water and air respectively. The main scope of the work was to clarify the effect of air bubbles by two method injection on: pattern of flow by high- speed video camera, pressure drop along the test section and local void fraction distributed. The results illustrated the flow pattern by nozzle method changed from bubbly flow to churn flow while by porous sinter bubbly flow and bubbles moves upward with no significant fluctuation was observed. Also, results showed differential pressure decrease with increased air injection rates. Effect of air bubbles injection on pressure differential and distributed of gas phase on lower part of the test section showed more sensible values than the upper part of the test section.

[2] Presented experimentally micro-bubbles effect on skin friction reduction for water circulating in tunnel. The direction of micro-bubbles with the main flow along test section in tunnel enabled measurements skin friction reduction. Skin friction sensor was used to measure skin friction reduction. Superficial water velocity (5 to 100) m/s, air bubbles radius (2µm) ,void fraction (5.3%) and Reynolds number of ($7.8x10^6$) were used in the experiments. Suction tube was put in the test section to measure local void ratio. The results showed a reduction in skin friction up to (30%) at velocity V=7 m/sec).

S. L. Ghashim, Department of Mechanical Enginnering University of Baghdad , Iraq

[3] **S**tudied experimentally air water two phase flow in a vertical pipe . The diameter of pipe was (72 mm) and the height (18 m). Air bubbles injection by three methods. Flow pattern bubbly and slug flow also investigated. The results showed a good agreement with the theoretical models used transition from bubbly flow to slug flow.

[4] Investigated experimentally the effect of micro bubbles generating by water electrolysis on friction drag reduction for turbulent flow in vertical channel . The Reynolds number of (4800), diameter of micro-bubble (30 –200) µm ,velocity of water 1m/s ,inlet water temperature (15°C) ,dimension of electrodes (45x 5x 5) mm, and current values (0.02, 0.2, 0.4, 0.6, 0.8, 1.0, and 1.2) Am were used in the experiments. Particle tracking velocimetry used to measure velocity fields. The results suggested that the drag of friction reduction was (30%) compared to single phase at low void fractions ($\alpha \approx 3x10^{-4}$), effective drag reduction at distance downstream from array of electrode. High speed video camera used to visualize flow patterns.

[5] Illustrated experimentally air-water two-phase flow on drag reduction in upward flow in a vertical pipe. Liquid Reynolds number was varied from (15000 to 30000), void fraction was varied from (0 to 9%) and bubble diameter of (300 µm) was used in the experiments. The results showed that the effect of void fraction on drag reduction for low Reynolds numbers was greater than for high Reynolds numbers. Furthermore, drop reduction reached to its maximum value of (35%) at a maximum volume fraction value of (9%) and minimum Reynolds number value of (15000) .At, very low volume fraction of (0.6%), drag reduction of (13%) was observed in Reynolds number (15000).

[6] Studied experimentally air–water bubbly flow in vertical helical coils. Two helical coils with different curvature ratio of (0.06 and 0.095) had been investigated. The liquid Reynolds number was varied from (8000 to 50000), void fraction was varied from (0–0.09) and bubble diameter of (270 µm) was based in the experiments. Camera with high shutter speed was used to describe the flow regime. It was concluded that, the drag reduction increased with increasing void fraction. Also, when curvature ratio of helical coils increased, drag reduction was decreased. The rate of maximum reduction of pressure drop reached up to (25%) in low Reynolds numbers.

[7] **S**tudied numerically water- air bubbles in a horizontal pipe. Fluent program used method of VOF to solve the continuity and momentum equations in two directions (radial and axial). The water velocity was (1m/s), range of air velocity (0.55 to 2.25) m/s, inlet temperature of both the fluids was (300 K) and heat flux of (159.15 KW/m^2) was applied on the channel wall. The results showed that the average Nusselt number was high at the velocity of (1.45 m/s) which indicated an enhanced in heat transfer rate. It can also be noted that above velocity of (1.45 m/s), there was no significant enhancement in the Nusselt number (or heat transfer rate). Thus the velocity of (1.45 m/s) can be considered as an optimum velocity for the multi-phase flow.

[8] **I**llustrated experimentally geometric effects on air–water downward bubbly flow in a vertical and horizontal pipes connected with 90° glass elbows. Test sections made from acrylic pipes with 50.8 mm inner diameter and with length of 3.35 and 9.45 for vertical and horizontal pipes . The experiments were conducted using three types of inlets configurations. Air bubbles injected by using two sintered spargers with diameter of 2-3mm .

[9] Studied experimentally water flow in a vertical pipe with injected air bubbles through small diameter of nozzle. Different types and sizes of nozzle have been used in the work (1.25, 1.75, 2.25, 3.00 and 3.50). Pressure in tank of water 0 - 10 bar , Pump inlet pressure 0 - 7 bar , water flow rate 0 - 100 L/h and air velocity 0.4 - 60 m/s. The results represented by void fraction flow regime , and orientation.

In this paper, investigated experimentally influence of bubble diameter on pressure drop loss and drag reduction in a vertical pipe for range of Reynolds number (13321.68-22202.79).

II. DESCRIPTION OF EXPERIMENTAL APPARATUS

The experimental works are performed to study air - water in a vertical pipe as shown in Fig. 1. The rig design consists of test section is a transparent pipe made from acrylic with diameter of (D=0.025 m) and length (L=2 m) as shown in Fig.2 . Two Borden gauge with range (0 – 1 bar) was used to measure pressure in the inlet and the outlet of the pipe. The pressure gauge is calibrated as shown in Fig.3 .Water Flow meters of (0-20 L/min) range is calibrated by plotting its reading against the measured flow rates by accumulating water in rectangular tank (30 L) volume and dividing this reading on the filling elapsed time as shown in Fig. 4. Air flow meter is used in air bubbles generation circuit of range (0-5 L/min) .Air bubbles injection in test section by two methods as shown in Fig. 5 . Nozzle method consist of pipe made from copper with diameter of (d=0.8 mm) and porous ring also made from copper with diameter of (d=10 mm) . Compressor is used to provide air bubbles and air flow meter with valve also used in the circuit. Water pump was used to pump water in the test section at different values of flow rate . Tank supply liquid water is open from the top and equip with orifices. The tank orifices were connected to the water line, to the pump suction line, and to the drain **.** Centrifugal water pump has maximum head of 35 m and maximum discharge of 45 L/min is used to pumping water. Polyvinyl chloride Pipe with diameter of (0.0125 m) and valves were used to connected parts of rig.

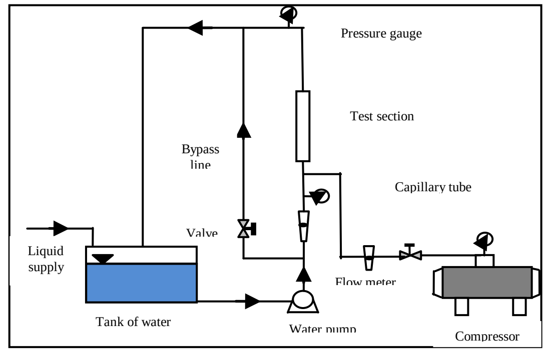


Fig. 1. Rig design of the physical problem.

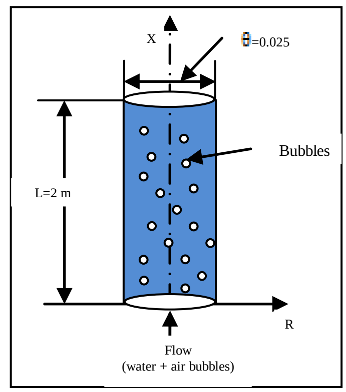


Fig. 2. Test section.

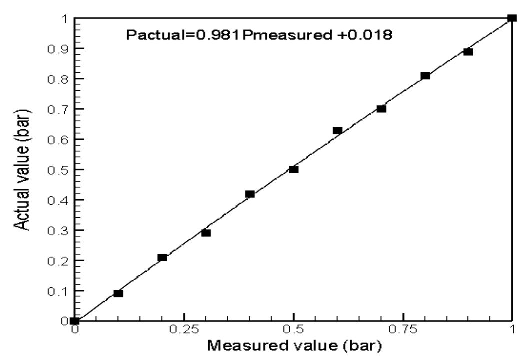


Fig. 3. Measured pressure calibration result versus actual value.

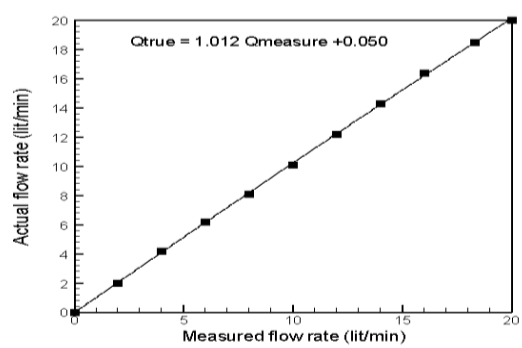


Fig. 4.:Calibration water Flow meter at water inlet temperature 32°C.

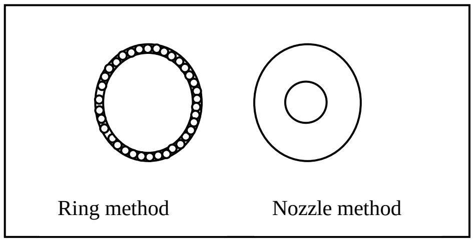


Fig. 5.Methods of injection bubbles.

III. EQUATIONS

The average velocity of fluid could be determined as follows:

$$u=Q/A \quad (1)$$

The equation of Reynolds defined as:

$$\mathrm{Re} = \rho u D_i / \mu \quad (2)$$

The friction factor represented by the following equation [6]:

$$f = \Delta P D_i / 2L\rho u^2 \quad (3)$$

The ratio of drag reduction calculated as [5];

$$DR(\%) = 1 - \left(\Delta P_{twophaseflow} / \Delta P_{\sin glephaseflow}\right) \quad (4)$$

Void fraction in two phase flow defined as [5]:

$$\alpha = \theta_{air} / \left(\theta_{water} + \theta_{air}\right) \quad (5)$$

IV. RESULTS AND DISCUSSIONS

The present work discussed the effects of bubbles injection in a vertical pipe. Two method of injections were used at different water and air bubbles flow rates as shown in Table .1.

TABLE I: VALUES OF VOID FRACTION

Q_{water} (L/min)	Q_{air} (L/min)	α
12	0.04	0.5
	0.076	1
	0.11	1.5
14	0.034	0.5
	0.066	1
	0.096	1.5
16	0.0303	0.5
	0.058	1
	0.085	1.5
18	0.027	0.5
	0.052	1
	0.076	1.5
20	0.024	0.5
	0.0476	1
	0.04	0.5

Fig. 6 shows the friction coefficient for the pure water in comparison with the Blasius equation. It can be observed that the experimental results have suitable agreement with the Blasuis equation.

The friction coefficient of single and two-phase flow versus Reynolds number as shown in Fig.7. The results seen, when bubbles are injected by nozzle method (large bubbles) tend to cluster at the center of pipe whereas , bubbles are injected by porous ring method (small bubbles) accumulate near the internal surface of pipe. Also, the small bubbles have a great effect on the reduce friction coefficient rather than large bubbles . This effect is increased with increased value of void fraction.

Fig.8 indicates the amount of drag reduction versus Reynolds for two methods injection with different values of void fraction. As it can be observed, the size of bubble more effective parameter on the value of drag reduction .The drag reduction ratio increased with an increased void fraction and the maximum drag reduction reach to 28% by porous ring method and occurs at low Reynolds numbers (13321.68**)** with void fraction (11.1%)

Fig. 9 indicates the amount of drag reduction for two sizes of bubbles and with different void fraction ratios.

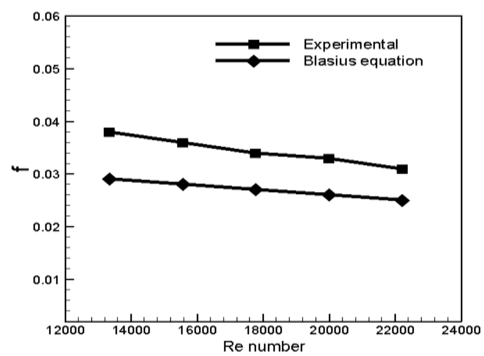
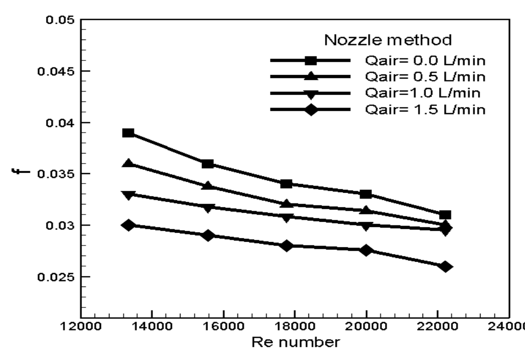
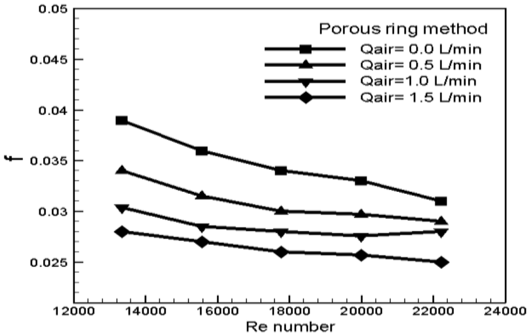


Fig. 6. Comparison between friction factor obtained from experimental results and Blasius equation verse Reynolds number .

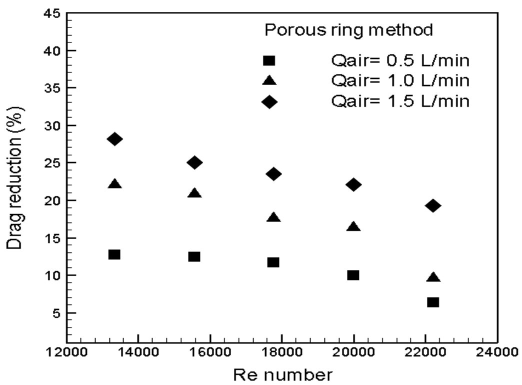


(a)

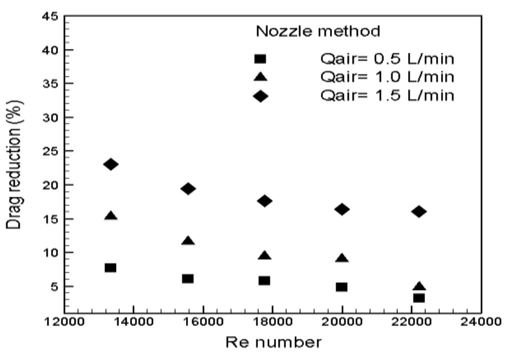


(b)

Fig.7. Friction factor obtained from experimental results verse Reynolds number at different values of air bubbles : (a) Nozzle method (b) Porous ring method.



(a)



(b)

Fig.8. Drag reduction verse Reynolds number at different values of air bubbles: (a) Nozzle method (b) Porous ring method

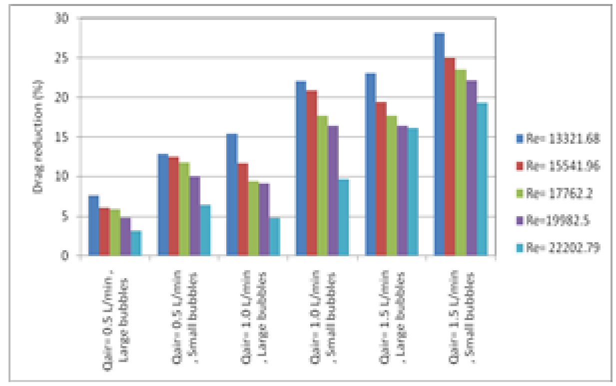


Fig.9. Ratio of Drag reduction at different values of air bubbles by two methods of injection.

V. CONCLUSION

1. Air bubbles injection causes decrease in friction coefficient with increases in Reynolds number.
2. The high rate of bubbles injection had more effect on drag reduction ratio.
3. A reduction in pressure drop along test section by injection bubbles increases with increasing the ratio of void fraction.
4. The diameter of bubbles have a great effect on the drag reduction ratio.
5. pressure drop reduced by small bubbles large than large bubbles.

VI. NOMENCALSURE

Latin symbol

A Area of cross section, m^2
D_i Tube inner diameter, m
f friction factor
L Length of pipe, m
P Pressure , Pa
Q Flow rate, L/min
Q_{air} Air bubbles flow rate, L/min
Q_{water} Water flow rate , L/min
Q_{total} Total bubble flow rate, L/min
Re Reynolds Number
u Inlet velocity, m/s

Greek Symbols

α Void fraction
ρ Density , kg/m^3
μ viscosity, kg/m.s

REFERENCES

[1] Ohnuki, A. and Akimoto, H., "An experimental study on developing air-water two-phase flow along a large vertical pipe: effect of air injection method", International Journal of Multiphase Flow , vol.22 , PP. 1143–1154, 1996.
[2] Kodama, Y., Kakugawa, A., Takahashi, T., and Kawashima, H., " Experimental study on microbubbles and their applicability to ships for skin friction reduction", International Journal of Heat and Fluid Flow, vol, 21,PP. 582-588, 2000.
[3] S. Guet , G. Ooms, R.V.A. Oliemans, "Influence of bubble size on the transition from low-Re bubbly flow to slug flow in a vertical pipe ", Journal of Experimental Thermal and Fluid Science, vol. 26 ,PP. 635–641, 2002.

[4] Hara,K., Suzuki , T., and Yamamoto,F., " Image analysis applied to study on frictional-drag reduction by electrolytic microbubbles in a turbulent channel flow", Journal of Experiments in Fluids , vol. 50, PP. 715–727, 2011.

[5] Nouri , N. M. , Yekani Motlagh, S., Navidbakhsh, M., Dalilhaghi, M., and Moltani , A.A., "Bubble effect on pressure drop reduction in upward pipe flow", Journal of Experimental Thermal and Fluid Science , vol. 44, PP. 592–598, 2013 .

[6] Saffari, H., Moosavi ,R., Gholami, E., and Nouri ,N.M., " The effect of bubble on pressure drop reduction in helical coil", Journal of Experimental Thermal and Fluid Science ,vol. 51 , PP. 251–256, 2013 .

[7] Srusti, T., Anand S. N, Narasimham, G. S. V. L., and Srikrishna, P. , "Numerical investigation of enhancement of heat transfer by two phase flow in mini channels", International Journal of Advanced Technology in Engineering and Science , vol. 2, PP.306- 313 , 2014.

[8] *S. Qiao, D. Mena & S. Kim," Inlet effects on vertical-downward air-water two-phase flow", Journal of Nuclear Engineering and Design, vol.312 , PP. 375-388, 2017.*

[9] Nicolò Falconea, Andrea Bersanoa, Cristina Bertania, Mario De Salvea, Bruno Panellaa , " Characterization of water-air dispersed two phase flow, Journal of Energy Procedia , vol.126, PP. 66- 73, 2017.

Dr. Sajida Lafta Ghashim

Specialization: Thermo& fluids
Work Address: Baghdad University, Department of Mechanical Engineering
E-mail: Sajda_lafta@yahoo.com

Academic qualifications:
1. Ph.D in Mechanical Engineering, University of Baghdad, Iraq, 2016.
3. M.Sc in Mechanical Engineering, University of Baghdad, Iraq, 2007.
4. B.Sc in Mechanical Engineering, University of Baghdad, Iraq, 2003.

Scientific Research Points:
Conduction Heat Transfer, , Forced, Free & Combined Convection Heat Transfer,Two phase flow.

Publications:
(5) Papers locally in Engineering Journal and Iraqi Journal of Chemical and Petroleum Engineering/ University of Baghdad, (1) Paper International.