Penerbit Akademia Baru

Journal of Advanced Review on Scientific Research
ISSN (online): 2289-7887 | Vol. 15, No.1. Pages 15-20, 2015

Study of Fluid Flow in Pipe using Image Visualization: A Review

Y. Mohd Yunos

Department of Thermofluid, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.
yushazaziah2@live.utm.my

Abstract – *A summary of research on image visualization in fluid flow is presented. The review addresses the topics of method in image processing, the application of particle image velocimetry and different sensor source of tomography. One of the greatest challenges in image visualization research is the improvement of flow measurement for multiphase flow. As there a lot of prediction in studying multiphase flow, the selection of image visualization method has to be chosen carefully. The important part is the method to process the image which consists of parameters to be studied. The improvement in image visualization method is important to further applied to other area of process.* ***Copyright © 2015 Penerbit Akademia Baru - All rights reserved.***

Keywords: Image visualization, Image processing, Velocimetry, Tomography

1.0 INTRODUCTION

A work by Osborne Reynolds in 1883 shown the laminar-turbulent behavior in circular pipe was done by hand sketches rather than photography film. A century later, using the same experimental rig, Johansen and Lowe captured a series of image sequence that shown a change of flow in laminar to turbulent [1]. In the history of fluid study, this image series has risen as one of the major contribution in this area. Image visualization is essential for a wide range of technologies such as of machine vision, control system, telecommunication, medical and military [2]. The development in image visualization has help researchers to accurately model the fluid flow compare to the use of empirical correlation which is limited by the availability of high quality experimental data [3]. It is important to help researcher to understand the flow characteristic, to measure the flow rate and to see the change of phase of fluid flow in channel. There are various technique and method used to visualize the fluid flow based on the different purpose of study.

A long time ago, Sakakibara et al. [4] used laser induced fluorescence to measure the concentration in turbulent flow consists of chemical reaction. Another method to enhance the image capturing method is shown by Uchimura et al. [5] used a real time neutron radiography (RTNR) together with image processing to capture the two phase flow of gas-liquid metal interface. This study can be applied in the metal test section. Ito et al. [6] used ultrasonic array sensor to study the velocity profiles and bubble distribution in a vertical air-water bubbly flow. They cited that the ultrasonic array sensor gave higher accuracy in bubble flow measurement. However, it has less temporal resolution compare to other high speed measurement method. A new method claimed by Da Silva et al. [7] that applied wire mesh sensor based on electrical capacitance is used to get the flow structure information of gas void fraction in two

phase gas-oil flow. Further, Ahmed [1] applied the electrical capacitance method along the image obtained from image processing to measure the elongated bubble length in air -slug flow.

As each flow measurement technique used is incomparable in approach, it is believe that no review work has been done before to discuss the study of image visualization in fluid flow. This paper is aim to discuss on three major methods in image visualization which are image processing, particle image velocimetry and tomography method as it gave significant contribution on the fluid flow study recently.

2.0 FLOW MEASUREMENT

Flow measurement parameters include velocity measurement, flow rate measurement, bubble characteristic, film thickness and flow pattern. Recent development in two phase flow has required an improved method that can measure the instantaneous parameter of fluid and solid flow. Local measurement method such as image visualization is not directly in contact with the flow thus it will not interfere the process.

2.1 Image processing

Image processing technique is a conventional image visualization by using a camera and image processing software or algorithm to extract the subject of study from the image. The simplest form of image processing method is shown by Zhang and Ishii [8]. They applied a pixel counting to measure the droplet size in two phase high velocity gas-droplet flow. Then, a better image processing method in object sizing is by edge detection process as shown in work by Dinh & Choi [2]. They determine the size and parameter of bubble in two phase air-water flow. The determination of bubble size is also used in calculating the velocity profile in fluid flow as shown by Zawada et al. [9]. In their work, they measured the bubble formation by hydrogen streak. The image has to be converted to text and graphical file to read the statistical data. After more than 10 years, do Amaral et al. [10] calculate the velocity profile by using watershed segmentation, top-hat filtering and H-transform to determine the bubble shape.

Lu et al. [11] calculate the droplet volume at the outlet of micro pipe to determine the volume flowrate by using the connected labelling algorithm. The droplet shape is then refined by using a Laplace Young equation based fitting. Other than to determine the size of object, image processing in fluid flow is successfully in identified the flow pattern. Flow pattern is important particularly in two phase flow and to determine the transition between laminar and turbulent flow. A flow pattern in air-water flow is studied by Ozbayoglu and Yuksel [12] and Hanafizadeh et al. [13]. The first used boundary and pixel intensity method to differentiate between air and water region meanwhile the former used an image morphological process on gray scale image to enhance the bubble parameter. Recent work by Riaño et al. [14] used image processing to measure the film thickness dispersed oil in water mixture on the wall of horizontal pipe.

2.2 Particle image velocimetry

Particle image velocimetry is a technique used to measure the flow characteristics by determining the particles displacement in a flow. In PIV, the particles is used as a seeding to trace the fluid motion. Conventionally, image during PIV is captured on photographic film and each spatial correlation in the whole pixel of the negative film is studied. Even though this method is accurate but it is tedious and took a long time. Westerweel et al. [15] proposed the digital PIV to study the turbulent flow of water in pipe. They concluded that the digital PIV is comparable to the conventional PIV in a study of turbulent flow which required a big scale image. Hassan et al. [3] took the advantage of PIV as an instantaneous measurement of velocity profile to measure the velocity of bubble flow in two phase air-mineral oil flow and proposed this study in evaluate the future multiphase flow. Kumara et al. [16] compared the used of PIV and Laser Doppler anemometer to study oil-water two phase flow in horizontal pipe. They found out that both method are comparable in terms of velocity profile and turbulent flow but due to

Journal of Advanced Review on Scientific Research
ISSN (online): 2289-7887 | Vol. 15, No.1. Pages 15-20, 2015

PIV is more sensitive in optical disturbance, it gave low quality result in the region between oil-water interface. Another study by Zhou et al. [17] examined the turbulent flow in liquid phase. The bubble is used as a seeding to visualize the two phase flow. They listed several limitation of PIV in two phase flow which include the distortion of laser beam due to reflection and refraction of light to the bubble. They suggested a further improvement in image processing algorithm due to noise created. Table 1 listed the study in PIV method as discussed.

Table 1: Selected PIV study

Author	Parameter	Fluid	Experiment (Camera, light source, seed particle)
Westerweel et al., [15]	turbulent flow	Water	CCD 1000 x 1016 Argon ion laser Small particle optimise 30μm
Hassan et al., [3]	Velocity measurement	Heavy mineral water	Vidicon tube camera Ni:YAG laser Air bubble seeding
Pan et al., [18]	Velocity measurement	Mineral oil	CCD 795 x 596 Illuminated by diffused back lighting Polystyrene particle 5.47mm and 3.10mm
Kumara et al., [16]	Velocity measurement and turbulent flow	Oil-water mixture	CCD 1260 x 1024 Nd:YAG laser Polyamide particle 20μm
Knisely et al., [19]	Transition to turbulent	Water	High speed video camera He-Ne laser Several types of tracer: Liquid yogurt, Aluminium powder, methyl blue

2.3 Tomography

Tomography is the image visualization technique that construct 2D cross sectional image which known as tomogram. The image is acquired from the measurement signal of sensors at the periphery of an object such as vessel and pipeline [20]. There are several types of tomography which depends on different types of sensor. The selection of sensor depends on the characteristic of multiphase flow, spatial and temporal resolution of image, cost, dimension and risk hazard towards the personnel handling the equipment [21].

Jeanmeure et al. [22] used electrical capacitance tomography to examine the two phase flow pattern of gas-liquid mixture in horizontal pipe. The sensor signal is from capacitance value between 4 pairs of electrode installed on the circumferential pipe diameter. This direct approach successfully determine

the annular and stratified flow pattern of the flow. Giguère at al. [23] applied electrical resistance tomography which used the value of voltage difference between pair of electrodes. The thicker composition of solid slurry can be measured using resistance tomography and further classified the homogenous and heterogeneous flow pattern of the liquid-solid flow. Meanwhile, Maad and Johansen [24] experimentally studied the flow regime of gas-liquid flow using high speed gamma ray tomography which used a multiple fan beam collimate radioisotope source. They recommended a further study on scatter radiation which contributed to the performance decreasing of the tomography method. Another type of tomography is by using ultrasonic sensor as been discussed by Rahiman et al. [25]. In this tomography method, the propagation time of ultrasonic wave is measured as it go through the water and oil composition. Different time is taken for different types of fluid. They suggested this method can be applied to other industries such as food and raw material processing.

3.0 CONCLUSION

In this paper, a review has been performed on different application and parameter for image visualization flow measurement. The discussion has been carried out on of image processing, velocimetry and tomography method. The need in image quality with the advance of sensor design, electronic measurement, computing hardware and image processing algorithm is part of the improvement in future work. As the reconstructed images improved, the potential application of image visualization technique can be apply to a more various application and industry.

REFERENCES

[1] W.H. Ahmed, Experimental investigation of air-oil slug flow using capacitance probes, hot-film anemometer, and image processing, International Journal of Multiphase Flow 37(8) (2011) 876-887.

[2] T. B. Dinh, T. S. Choi, Application of Image Processing Techniquf, S in Air/Water Two Phase Flow. Mechanics Research Communication 26(4) (1999) 463-468.

[3] Y. A. Hassan, T. K. Blanchat, C. H. Seeley, R. E. Canaan, Simultaneous velocity measurements of both components of a two-phase flow using particle image velocimetry, International Journal of Multiphase Flow 18(3) (1992) 371-395.

[4] J. Sakakibara, K. Hishida, M. Maeda, Measurements of thermally stratified pipe flow using image-processing techniques, Experiments in Fluids 16(2) (1993) 82-96.

[5] K. Uchimura, G. D. Harvel, T. Matsumoto, J. S. Chang, An image processing approach for two-phase interfaces visualized by a real time neutron radiography technique, Flow Measurement and Instrumentation 9(4) (1998) 203-210.

[6] D. Ito, H. Kikura, M. Aritomi, M. Mori, Application of an Ultrasonic array sensor to air-water bubbly flow measurement, Journal of Physics: Conference Series, 147 (2009) 012005.

[7] M. J. Da Silva, S. Thiele, L. Abdulkareem, B. J. Azzopardi, U. Hampel, High-resolution gas-oil two-phase flow visualization with a capacitance wire-mesh sensor, Flow Measurement and Instrumentation 21(3) (2010) 191-197.

[8] G. J. Zhang, M. Ishii, Isokinetic Sampling Probe and Image Processing System for Droplet Size Measurement in Two-Phase Flow, International Journal of Heat and Mass Transfer 38(11) (1995) 2019-2027.

[9] A. C. Zawada, J. Jarnick, J. Jankowski, J. Plutecki, Computer Aided Measurement of Velocity Fields in Liquid Flows, Image Processing and Its Applications 443 (1997) 15-17.

[10] C. E. F. do Amaral, R. F. Alves, M. J. da Silva, L. V. R. Arruda, L. Dorini, R. E. M. Morales, D. R. Pipa, Image processing techniques for high-speed videometry in horizontal two-phase slug flows, Flow Measurement and Instrumentation 33 (2013) 257-264.

[11] Lu, Jian-Gang, Liu, Yu-Cong, Ye, Xin-Xin, Shi, Ying-Zhi, Gao, Hua, Y. Jiang, Image based micro flow measurement technology, Information Technology Journal 12(19) (2013) 4901-4905.

[12] A. M. Ozbayoglu, H. E. Yuksel, Estimation of Multiphase Flow Properties using Computational Intelligence Models, Procedia Computer Science 6 (2011) 493-498.

[13] P. Hanafizadeh, M. H. Saidi, A. N. Gheimasi, S. Ghanbarzadeh, Experimental investigation of air–water, two-phase flow regimes in vertical mini pipe, Scientia Iranica, 18(4) (2011) 923-929.

[14] B. A. Riaño, I. H. Rodriguez, A. C. Bannwart, O. M. H. Rodriguez, Film thickness measurement in oil–water pipe flow using image processing technique, Experimental Thermal and Fluid Science, 68 (2015) 330-338.

[15] J. Westerweel, A. A. Draad, J. G. T. van der Hoeven, J. van Oord, Measurement of fully-developed turbulent pipe flow with digital particle image velocimetry, Experiments in Fluids 20 (1996) 165-177.

[16] W. A. S. Kumara, G. Elseth, B. M. Halvorsen, M. C. Melaaen, Comparison of Particle Image Velocimetry and Laser Doppler Anemometry measurement methods applied to the oil-water flow in horizontal pipe, Flow Measurement and Instrumentation 21(2) (2010 105-117.

[17] X. Zhou, B. Doup, X. Sun, Measurements of liquid-phase turbulence in gas–liquid two-phase flows using particle image velocimetry, Measurement Science and Technology 24(12) (2013) 125303.

[18] X. Pan, R. Luo, X. Yang, H. Yang, Three-dimensional particle image tracking for dilute particle – liquid flows, Measurement Science and Technology 13 (2002) 1206-1216.

[19] C. W. Knisely, K. Nishihara, M. Iguchi, Critical Reynolds Number in Constant-Acceleration Pipe Flow From an Initial Steady Laminar State, Journal of Fluids Engineering 132(9) (2010) 091202.

[20] N.M.N. Ayob, S. Yaacob, Z. Zakaria, M. H. F. Rahiman, R. A. Rahim, Simulation on using cross-correlation technique for two-phase liquid/gas flow measurement for Ultrasonic Transmission Tomography, 6th International Colloquium on Signal Processing & Its Applications (2010) 1-5.

[21] J. F. Borowsky, T. Wei, Two-phase interactions through turbulent events as described by fluid-particle correlations. Chemical Engineering Science 66(2) (2011) 128-134.

[22] L. F. Jeanmeure, T. Dyakowski, W. B. Zimmerman, W. Clark, Direct flow-pattern identification using electrical capacitance tomography, Experimental Thermal and Fluid Science 26(6-7) (2002) 763-773.

[23] R. Giguère, L. Fradette, D. Mignon, P. A. Tanguy, Characterization of slurry flow regime transitions by ERT. Chemical Engineering Research and Design 86(9) (2008) 989-996.

Journal of Advanced Review on Scientific Research
ISSN (online): 2289-7887 | Vol. 15, No.1. Pages 15-20, 2015

[24] R. Maad, G. A. Johansen, Experimental analysis of high-speed gamma-ray tomography performance, Measurement Science and Technology 19(8) (2008) 085502.

[25] H. F. M. Rahiman, Z. Zakaria, R. Abdul Rahim, W. Nyap Ng, Ultrasonic tomography imaging simulation of two phase homogeneous flow, Sensor Review 29(3) (2009) 266-276.