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Evaluating Two-Phase Flow Patterns in Airlift pumps Using Image Processing Technique

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Abstract **-** One of the most important criteria in determining the performance of airlift pumps is to determine the two-phase flow characteristics in the pump riser. These include the determining the average void fraction and both the slug velocity and frequency of the two-phase flow in the vertical pipe. In the current work, three image processing methods were examined to describe the two-phase hydrodynamic parameters as they relate to the pump performance. Experiments were carried out using Xanthan Gum-water solutions with varying XG concentrations between 0.05-0.25 wt% in a pump riser of 31.75 mm in diameter. High-speed camera with 3000 f/s capabilities was used to obtain the flow visualisation images for the two-phase flow distribution downstream of the pump injector. The preliminary results suggested that the image processing technique using background subtraction algorithm can be an effective approach in evaluating the flow structure and consequently can be used to determine void fraction and slug characteristics.

Keywords**:** Airlift Pump; Two-Phase Flow; Image Processing; Background Subtraction; Adaptive Thresholding; Void Fraction

1. Introduction

The void fraction is one of the most crucial parameters in determining the characteristics of a two-phase flow in airlift pumps [1-4]. Measuring the void fraction in two-phase flow has been discussed by several publications in the literature use varieties of psychical sensors and for different multiphase flow system, and for different fluid properties [4,5]. A method for experimentally evaluating the void fraction using flow visualisation is image processing of flow visualization images. Typical considerations were given to obtain a clear image in order to correctly differentiate between the gas and liquid phases specifically identify the liquid-gas interface. This includes the correction of light reflection that create undesirable shadows, especially at higher flow rates. The flow visualization images are processed using a developed image processing code created using MATLAB software to identify the gas-liquid interface which can be used to evaluate the bubble or slug volumes. Three image processing algorithms are examined in the present study. These include Region Growing Algorithm, Background Subtraction Algorithm and Adaptive Thresholding Algorithm.

2. Results and Discussion

2.1. Region Growing Algorithm

In this method, the image intensity image of discrete points that specify the various target flow field regions is segmented and considered as the inputs to the algorithm as explained by Mehnert and Jackway [6]. These discrete regions are expanded by the algorithm until all of the image pixels are assimilated [6]. Using this method, the desired slug is captured by manually choosing discrete point within the current frame's slug region. In order to more precisely identify the slug (target) region within the image, this technique separates each of the liquid and vapour interfaces. As a result, the background and foreground pixels are appropriately assigned, thus, the determined void fraction for each frame will be computed with good accuracy. Figure 1 below displays the flow chart for the algorithm used to determine the void fraction values. A sample result employing this method is shown in Figure 2.

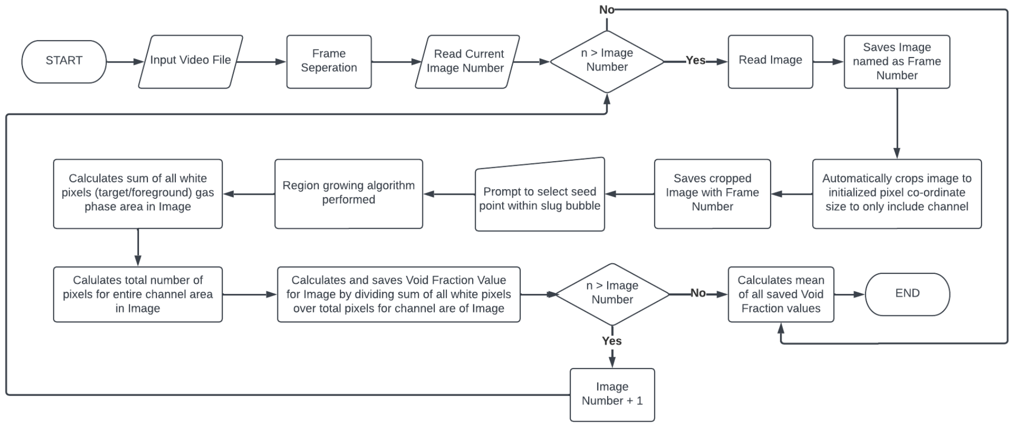


Fig. 1: Region Growing Algorithm Flow Chart

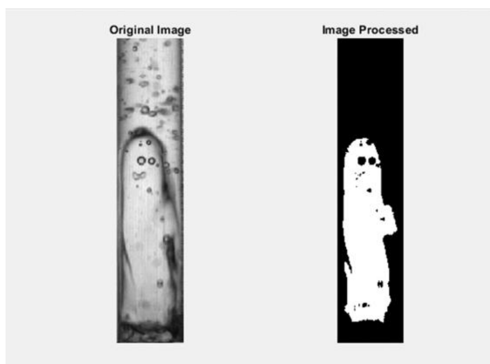
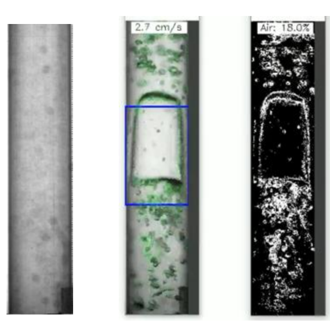


Fig. 2: Region Growing Algorithm MATLAB Displayed Results

2.2. Background Subtraction Algorithm

Background subtraction method is used to obtain for moving objects in sequence of images by taking the change between the background model generated and the required image frame [7]. To identify the change of the motion between two sequential frames, the absolute difference between the frames is examined [7]. A threshold value is then utilized to extract the targeted regions in successive frames. In this method, the background model is generated by averaging several frames then subtracting that from each successive frame, representing the flow channel when filled with liquid. Then, the gas and liquid phases can be easily identified as foreground and background respectively in the subtracted images. Figure 3 shows the background model and a sample image frame result of the background subtraction.

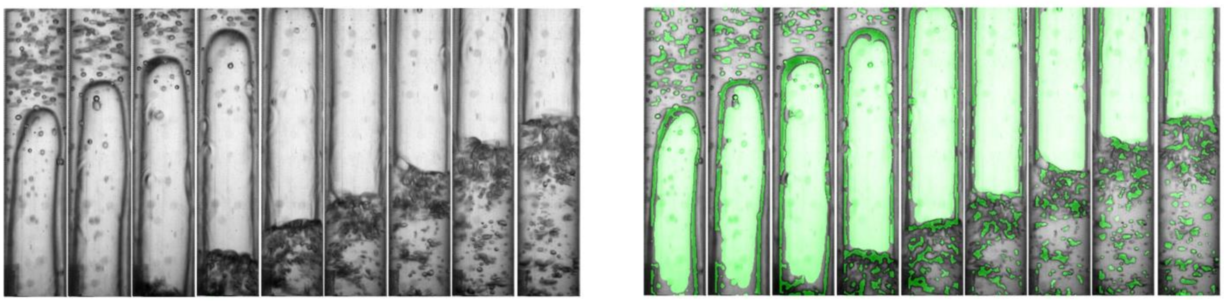


(a) (b) (c)

Fig. 3: Background subtraction: (a) Background model; image when the channel is full of liquid, (b) Image when there is bubble flow in the channel, and (c) Subtracted image with foreground mask, for 4.5LPM 0.05wt% XG.

2.3. Adaptive Thresholding Algorithm

In the third method, the adaptive thresholding algorithm is utilized to distinguish between the background and desired foreground image objects based on the differences in pixel intensities of each region [8, 9]. The threshold is based on the range of intensity values within a specific region, rather than a singular threshold value for the entire image [8],[9]. This makes it possible to identify an image with non-uniform illumination. When applied, this algorithm is able to divide the gas phase and liquid phase in the image by detecting all regions that are darker than the background. A sequence of frame results utilizing this method is shown in Figure 4.



(a) (b)

Fig. 4: (a) Sequence of Image and (b) Sequence of Image Results Using Adaptive Thresholding Algorithm, for 4.5LPM 0.05wt% XG.

The average void fraction values were determined using 2500 frames for all methods and the results are listed in Table 1. The results obtained using the three algorithms are compared to the void fraction measurements for the same flow conditions found in the literature [10]. The average void fraction value obtained using background subtraction found to agree very well with the measured value [10].

Table 1: Measured Void Fraction Values

Flow Rate [LPM]	Fluid Property Concentration	Region Growing Method Void Fraction [%]	Adaptive Thresholding Method Void Fraction [%]	Background Subtraction Method Void Fraction [%]	Research Correlated [10] Void Fraction [%]
4.5	**0.05 wt%**	12.6	15.8	18.3	≈ 21

3. Conclusion

Using image processing methods, the two-phase flow pattern and void fraction values in the airlift pump riser was obtained. Image processing technique found to be a promising approach for evaluating the void fraction. More work is currently under development to obtain both the slug velocity and slug length in order to accurately evaluate the hydrodynamic parameters of two-phase flow in airlift pumps.

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