Sensitivity of the Computational Domain Aspect Ratio for a Single Rising Bubble in a Hallimond Tube

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Abstract

This paper presents how a single rising bubble experiment in the Hallimond Tube can be predicted using computational fluid dynamics model. The study is emphasized on the effect of aspect ratio of cylinder domain to the pressure coefficient and axial velocity around the bubble. A rigid sphere with the radius of 0.00575 m using flow velocity of 0.25 m/s is considered in this study. Numerical and simulated data obtained by other researchers in the similar study were used to validate the simulation results from computational fluid dynamics model. It was observed that a change in width in aspect ratio, causing significant change in the value of simulation data. The highest percentage of difference was observed at the vicinity of ? = 85.26o which is 32.4

Index terms — aspect ratio; bubble; flotation; gridindependent test; hallimond tube.

1 Introduction

lotation is a process of particles capturing by bubbles based on the differences in the physicochemical properties of interfaces [1]. Flotation is widely used by mineral and chemical engineers for the separation and concentration of aqueous suspensions or solutions of a variety of minerals, precipitates, inorganic waste constituents, microorganisms and protein [2][3]. In most of the cases, flotation is used to selectively separate particles from other particles (unwanted).

Bubbles play significant role in flotation process. Therefore, understanding the dynamic characteristics of a rising bubble in water is crucial in flotation process. For this purpose, a laboratory scale flotation device is required. One of such device used for this purpose is Hallimond Tube (HT) as shown in Figure1. HT is a fairly well accepted method for testing of flotability since it allow researcher to control the mechanical and chemical variables easily [4][5].

Due to shedding of vortices [6], rising bubble experience shape deformation [7][8], helical and zig zag motion [8][9][10]. This will cause more complications to the study. Therefore, a small rigid sphere is considered in the present work to counter this problem. The computational fluid dynamics (CFD) model is re-create solely based on the HT characterization. Earlier, CFD model was used to study the motion of bubble [11], however the dynamics around a single bubble and effect of aspect ratio (AR) are not available in the literature.

Therefore, a CFD model is created to study the hydrodynamic of a rising bubble in HT. Furthermore, CFD model was implemented using Star-CCM+ V6.04® to determine the dynamics around a single bubble and to investigate the effect of aspect ratio (AR) to the single rising bubble inside HT.

2 II.

3 Model Description and Test Cases

On a single rising bubble in HT study, primary flow was solved. The fluid density was constant at 998.2 kg/m3 and viscosity was 0.001003 kg/m-s. Bubble rising velocity was 0.25 m/s based on the diameter of spherical solid which is 11.5 mm [12]. Since in this simulation a static spherical solid was used instead of rising bubble, therefore velocity of 0.25 m/s was used as water flow velocity in order to match the phenomena of bubble rising in Hallimond Tube. Location of spherical solid was kept fixed at (0, 0, 0). Figure 2 shows the schematic diagram of the computational domain. 1. Cell domain AR was used as the case study for this research. The geometries of the domain AR is shown in Figure 3. The AR was calculated on the basis of length from bubble centre to the outlet (L) over diameter of the domain (W). For the model equation, the Navier-Stokes continuous equation and momentum equations for primary flow in cylindrical coordinates were used [13]. The Navier-Stokes continuous equation in threedimensional is given by eq. 11 1 ( ) ( ) ( ) 0 rv v v r z t r r r z ? ? ? ? ? ? ? ? ? ? ? + + + = ? ? ? ? (1)

where, ? is fluid density, r is cylinder radius, vr, v?, and vz are fluid velocity in r-direction, ?-direction, and z-direction. The Navier-Stokes momentum balance equation in the r-direction is given by eq. 2 (2) where, µ is fluid kinematic viscosity, g is gravitational acceleration. The Navier-Stokes momentum balance equation in the -direction is given by eq. 3

The Navier-Stokes momentum balance quation in the z-direction is given by eq. 42 1 2 2 1 2 2 v z r r r r v v v v v ? z z z z ? v v r z t r r ? z v v p z z ? ?g z z z r ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? + + + ? ? ? ? ? ? ? ? = ? + + + + ?**(4)**

All the above-mentioned model equations were solved using Star CCM [14]. 1 2 2 1 1 2 2 2 2 2 r r v v v v v ? ? v v r z t r r ? z r v v v p r ? rv ?g ? ? ? ? ? ? ? ? + + + + ? ? ? ? ? ? ? ? ? ? ? = ? + + + + + ?**(3)**

III.

4 Results and Discussion

The surface angle ?, considered for this study is between 0° to 180°. Numerical simulation data [15] and( ) 2 2 2 1 1 2 2 2 2 2 v v v v v v ? ? r r r r ? v v r z t r r ? z r v v v p ? r r ? rv ?g r r r r r r ? r ? z r ? ? ? ? + + + ? ? ? ? ? ? ? ? ? ? ? = ? + + + ? + ?

simulation data [16] is used for mesh validation. This part of the research is carried out to improve confidence in the CFD prediction on the bubble surface. The results for case validation are shown in Figure 4. Figure 5 shows pressure coefficient, Cp around a bubble vs. the angular position of the bubble surface. Assuming the solution is in laminar flow regime under steady state conditions, three refined mesh size around the surface of the spherical solid are used as a part of grid independent test. Grid-independent test is a crucial process in determining the accuracy of the solution [17]. Grid independent solution is obtained for all the meshes. For this study the convergence criteria at is sufficient for all meshes, as beyond this there is no further change in Cp..

A test is performed to study the effect of AR of cylinder to the fluid characterization around the bubble. In this study, three different AR are considered in which the first dimension A1 is used in the case study validation. Radius of the spherical solid, solver parameters such as velocity, courant number, and water density are kept constant. The specification of AR is shown in Figure 3 and the description details are listed in Table 1. For this study, Cp versus ? co-relation is used to study the effect of AR on the fluid dynamics around the bubble surface.

Figure 5 shows the Cp comparison for flow around the bubble with different computational domain AR. Observing from A1 and A2 plot, it is evident that, length from bubble centre to the outlet (L) does not have a significant effect on the Cp behaviour. It is also observable that A1 and A2 plot does not show any significant difference starting from the stagnation point (? = 0o) until they reach the vicinity of (? = 110o), where Cp values of A2 start to divert from A1. It is observed that at this angular position, axial velocity, vz of A2 is higher than A1.

Comparing A3 plot with the A1 plot, it is observed that the effect of the diameter of the computational domain (W) is relatively significant. Starting from stagnation point, A3 and A1 is having high percentage of difference at 29.14%. The highest percentage of difference is observed Between A3 and A1 at the vicinity of (? = 85.26o) which is 32.4%. The result is in agreement with the Cp -vz co-relation.

5 IV.

6 Conclusion

For the effect of aspect ratio on the fluid characterization around the bubble, 210 divisions around the spherical solid periphery were required to attain grid independent solution. Using a finer mesh offered closer agreement between simulated and numerical results. However, in this study it was observed that using finer mesh causing instability in a solution. In the aspect ratio case study, it was observed that a change in width in aspect ratio, causing significant change in the value of simulation data. The highest percentage of difference is observed at the vicinity of (? = 85.26o) which is 32.4%. The result is in agreement with the Cp -vz co-relation.

V. [1]

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Figure 1: Figure 1 :

2

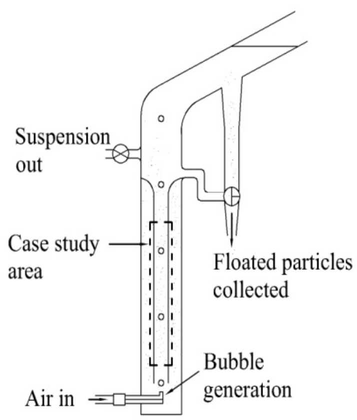

Figure 2: Figure 2 :

3

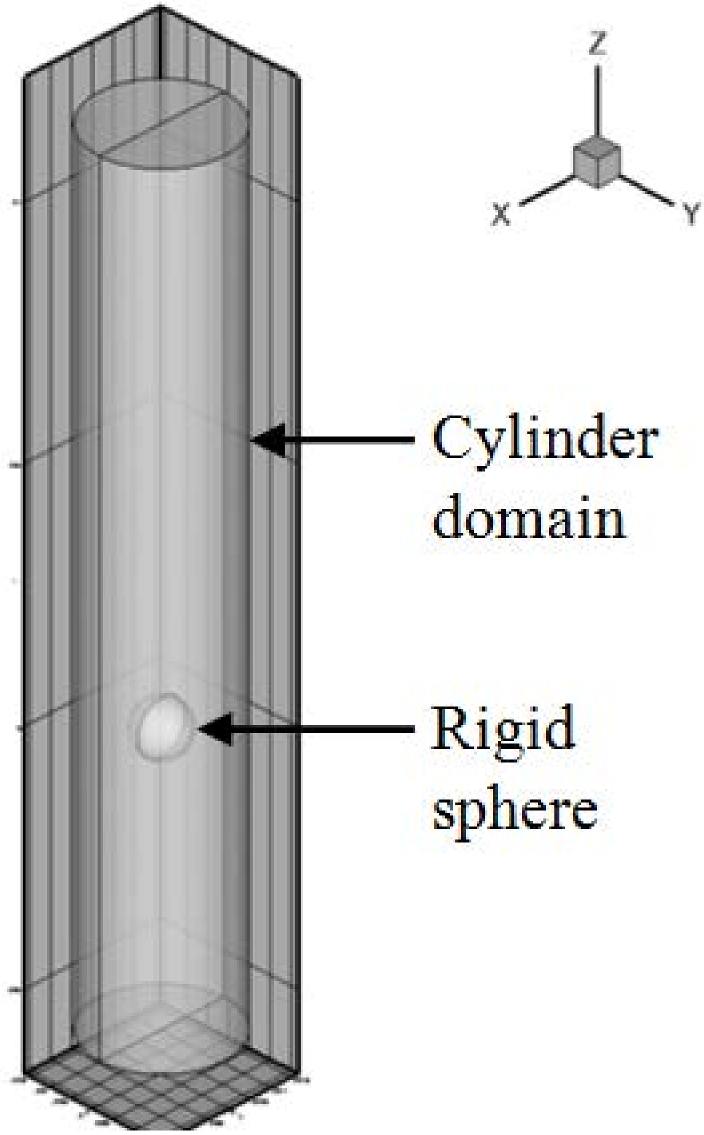

Figure 3: Figure 3 :

4

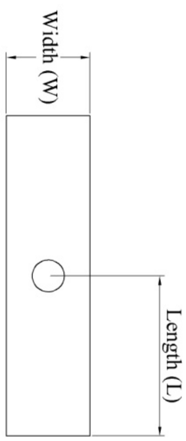

Figure 4: Figure 4 :

5

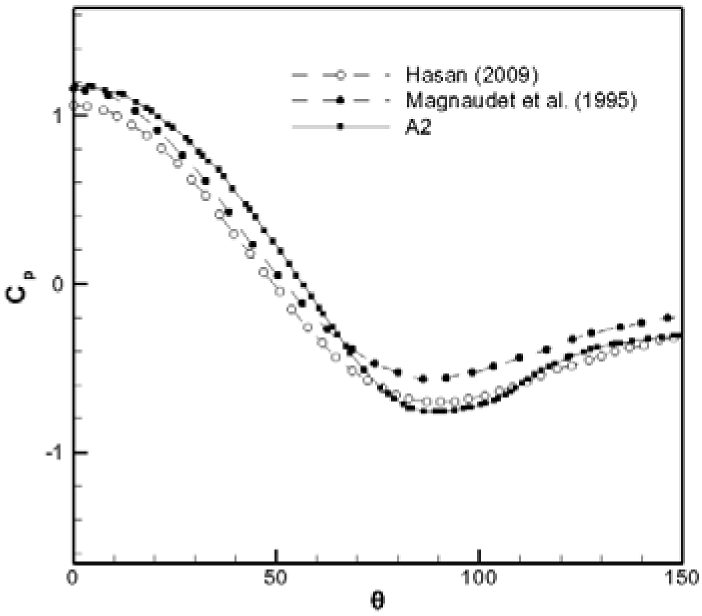

Figure 5: Figure 5 :

1

Aspect Ratio	Test 1 (A1)	Test 2 (A2)	Test 3 (A3)
Width / Length	0.02875 / 0.0575	0.02875 / 0.115	0.046 / 0.0575

[Note: Descriptions of test cases are listed in Table]

Figure 6: Table 1 :

.1 Acknowledgements

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