Modeling Bubble Dynamics Under Magnetic Fields

Colin Waldie and Hadi Mohammadigoushki
FAMU-FSU College of Engineering, Department of Chemical and Biomedical Engineering

FAMU-FSU College of Engineering

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Motivation and Background

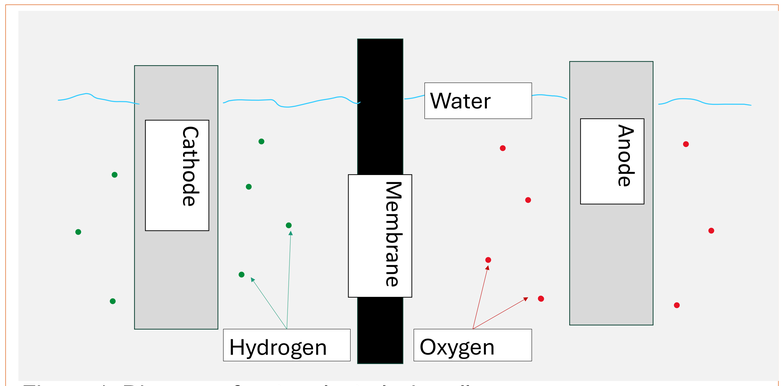

Figure 1: Diagram of water electrolysis cell

- Water electrolysis can be used for oxygen production in space but is limited by the lack of buoyancy to remove bubbles from electrode surfaces
- Induced magnetic fields are a potential solution to controlling bubble dynamics in two-phase flow systems in microgravity

Objective

- The goal of this study is to investigate the modeling and effects of a magnetic field on a bubble in a two-phase flow system

Methods and Materials

Experimental Structure

- Air bubbles were injected with an inner diameter 0.0012” PTFE needle at 0.1 mL/min into an 80wt% corn syrup and water solution
- Air bubble rise compared with and without magnet field present using Pasco EM-8618 Variable Gap Magnet
- Magnet gap set to 5mm when in use to maximize magnetic field
- Infinity 8 Analyze high speed camera used for trajectory collection

Numerical Simulation

- One-Dimensional model developed using analytically derived equation of motion and Sigmoidal fit curve magnetic field
- Two-Dimensional model developed in COMSOL utilizing Phase Field Multiphysics interface
- Model trajectory results compared to published results from Wakayama [1]

Resources

1] - N. I. Wakayama, “Magnetic buoyancy force acting on bubbles in nonconducting and diamagnetic fluids under microgravity,” *J Appl Phys*, vol. 81, no. 7, pp. 2980–2984, Apr. 1997, doi: 10.1063/1.364330.

Results and Discussion

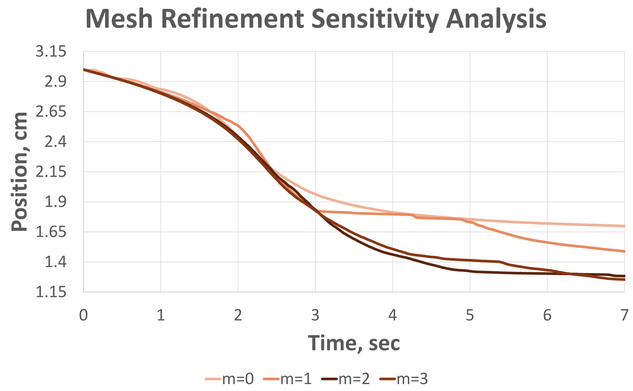

Figure 2: Plot detailing results from Sensitivity Analysis of Mesh clarity in which the mesh was refined to varying degrees to determine optimal settings

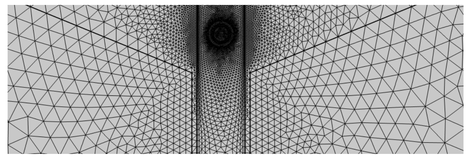

Figure 3: COMSOL Simulation Mesh at refinement m=0

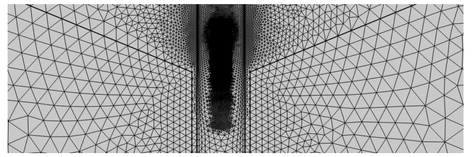

Figure 4: COMSOL Simulation Mesh at refinement m=2

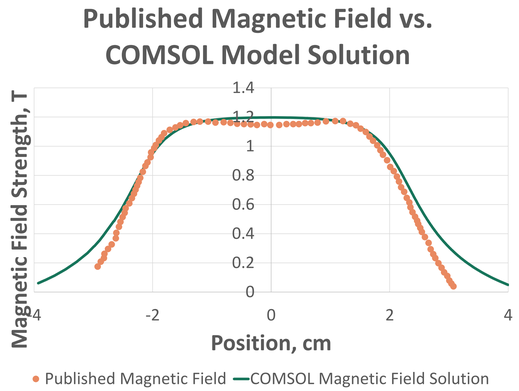

Figure 5: Plot comparing magnetic field curve from Wakayama [1] with solution from COMSOL Magnetic Fields physics

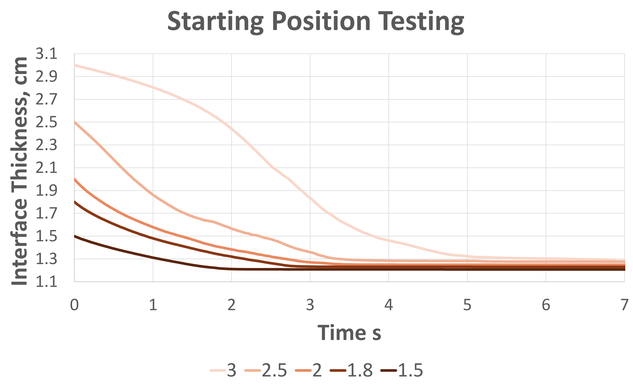

Figure 6: Plot shows trajectories from different starting positions with constant bubble size, resulting in the same settling point

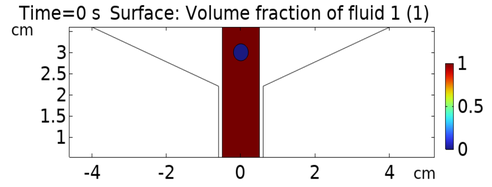

Figure 7: Volume Fraction plot at beginning of simulation, gas bubble = 0

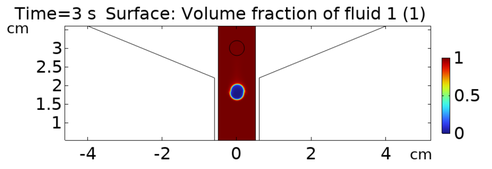

Figure 8: Volume Fraction plot 3 seconds into simulation, gas bubble = 0,

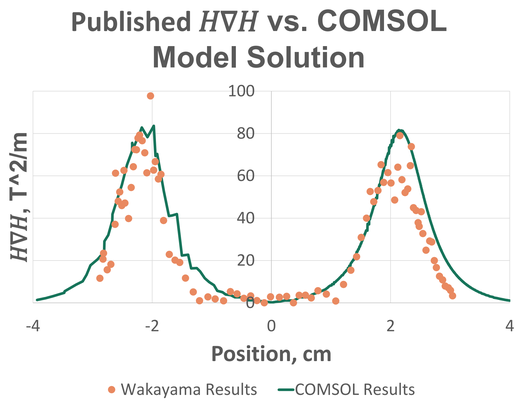

Figure 9: Plot comparing $H\nabla H$ from Wakayama and the COMSOL model solution

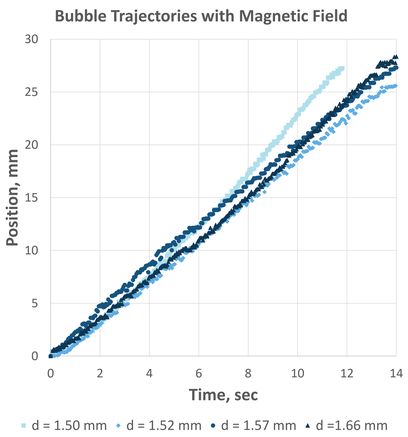

Figure 10: Experimentally Collected bubble rise trajectories with varying diameters and a magnetic field present

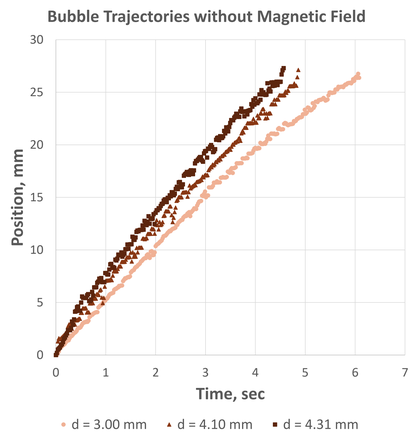

Figure 11: Experimentally Collected bubble rise trajectories with varying diameters and no magnetic field

Figure 12: Experimental set up including, from top to bottom, Infinity 8 Analyze Camera, Pasco Variable Gap Magnet, 80wt% Corn syrup solution, and WPI syringe pump

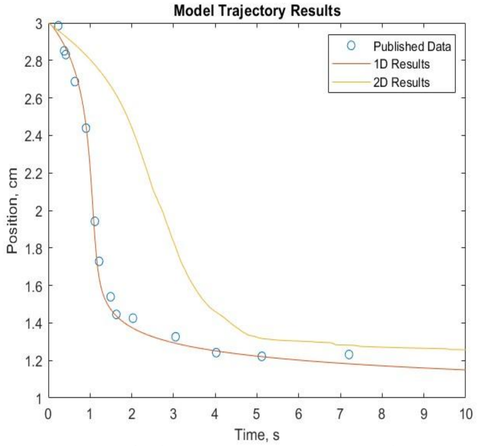

Figure 13: Comparison of Wakayama trajectory starting at 3 cm with trajectory predictions from both the 1D and 2D models