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Analysis of magnetohydrodynamics peristaltic transport of hydrogen bubble in water

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ABSTRACT

This paper established the theoretical and analytical analysis of a unidirectional laminar bubbly two-phase flow in a symmetric channel with flexible wall. The two-phase model uses water as base fluid with hydrogen bubble suspended in it. Rayleigh-Plesset equation in term of volume fraction is used to model void produce due to presence of hydrogen. The flow is driven by symmetric peristaltic movement of the wall. A uniform magnetic field in the transverse direction to peristaltic motion is applied. Homotopy perturbation Method (HPM) is utilized to formulate the series solution, after simplifying the differential governing equations under the influence of long wave length and low Reynolds number. The volume of the void and radius of the bubble is analyzed graphically. The consequence demonstrates that the void fraction bubbles rapidly approaches to unity, which is due to quasi-statically unstable. Due to Lorentz force fluid velocity suppresses by increasing the transverse magnetic field while reverse performance is noted for Weber number and power law index.

Introduction

Bubbly flow is determined as a two-phase flow in which micron sized bubbles are scattered or suspended as discrete substances in a liquid continuum. Classical topographies of this flow are moving and deformable interfaces of bubbles in time and space domains and complex connections between the interfaces, and among the bubbles and flow of liquid. Two-Phase or Multiphase flows and heat transport comprehend a large scale of industrial and engineering applications like thermo-siphons for micro-heat-pipe systems, cooling of electronic components, oil industry and biotechnology, materials processing, chemical plants, evaporators, evaporators and fluidized bed combustors. In literature vertical bubbly flows have gained much attention as compared to horizontal bubbly flows, however the orientation of this type of flow is of equal importance in industrial applications such as hydro transport, a significant technology in bitumen extraction. Ishii [1] was the first who deliberated the two-phase flow modelling, in which he solved it numerically for local time average equations. Antal et al. [2] analyzed fully developed laminar bubbly flow in a vertical pipe by a finite element method. They presented a new model for the wall lubrication force preventing the bubbles from touching the wall. Bertodano et al. [3] numerically predicted the fully developed phase distribution in vertical ducts (a pipe and a triangular duct) using the PHOENICS code & Rosten and Spalding [4]. Anglart et al. [5] performed a CFD to forecast the boiling bubbly flow in geometries like BWR fuel bundles. Xu et al. [6] examined two-phase flow experimentally in rectangular channel with small gap. They concluded that that the transition from one region

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of to another occurs at lower gas flow rates when channel gap is decreases. They established a new principle to forecast transition from annular flow, as well. Nakoryakov et al. [7] executed the study of liquid-gas flow in vertical pipe with small diameter and found robust tendency for the bubbles to gather nearby a vertical pipe wall for concurrent up flow. Mishima et al. [8] demonstrated two-phase flow experiments, void fraction, pressure drop, bubbly velocity, occurring in micro and mini channels along with small gap and a huge aspect ratio.

Peng and Wang et al. [9], Peng et al. [10], Peng and Peterson et al. [11] discussed the flow and heat transport in a channel with water is considered as a base fluid. They calculated both heat transfer coefficients and single-phase pressure, and establish that both were relatively different from conventional correlation. They also considered subcooled boiling heat transport in a channel. Wilmarth and Ishii [12] considered two-phase flow of water and air along with adiabatic concurrent via thin channels having widths of 1 and 2 mm. Fujita et al. [13] premeditated adiabatic two-phase flow in five rectangular mini or micro channels of depth 0.2–2.0 mm and width 10 mm. Olesen et al. [14] used novel numerical approach to study two-phase flow gas-liquid in a circular-planar, interdigitated flow field. They observed that maldistribution of the liquid phase is harmfully affected under the influence of gas phase. Ghadi et al. [15] developed a mathematical model to discuss the impact of dual gas injection system on distribution process and energy consumption in the Midrex shaft furnace. They concluded that Energy consumption decreases by applying twin gas injection system. Liu et al. [16] have analyzed the periodical bubble growth and detachment within the current density range of 15.9–57.3. Their analysis showed that a pair of lower pressure regions was formed as the rotating flow of fluid around the bubble driven by the Lorentz force. Koza et al. [17] examined the detailed analysis of magnetic field on the hydrogen evolution reaction during water electrolysis by utilizing the standard electrochemical procedure combined with direct microscopic interpretations and numerical simulations. Ellahi et al. [18] explored the peristaltic flow of couple stress fluid in a non-uniform rectangular duct with compliant walls. Recebli et al. [19] discussed hydrodynamic immiscible flow in a pipe analytically by applying differential transform method. Flow case are considered for two different flow patterns, one is for low electrically conductive fluid inner core and higher one for outer flow regional pattern and the second one is high electrically conductive fluid inner core and lower one is outer regional flow case in a vertical circular pipe. Ellahi et al. [20] examined theoretically the peristaltic flow of Jeffrey fluid in a non-uniform rectangular duct under the effects of Hall and ion slip. Selimli et al. [21] investigated the combined impact of applied magnetic and electrical field on the hydrodynamic incompressible magnetoviscous flow of liquid lithium in an enclosure with thermophysical properties. Khan et al. [22] studied peristaltic flow of Pseudoplasticity fluid with variable viscosity in an asymmetric channel is examined. The bionic effects by means of MHD are also considered. Recently some of the studied investigated by researcher about magnetic field can be found in Ref. [23–31].

The present work is to scrutinize peristaltic propulsion of laminar bubbly two-phase flow of small hydrogen bubbles in water. The flow is not studied and has fantastic applications. A fascinating understanding is developing of phase distribution of two-phase flow in the presence of magnetic field in transverse direction. Motivation of the modeled bio-fluid problem its applications observed in living body. The muscular contraction and expansion propel the said fluid through the channel. The resulting set of coupled nonlinear equations of bubbly flow are solved analytically obtained series solutions with the help of homotopy perturbation method.

Geometry of the problem

The geometry of the problem is displayed in Fig. 1. The mathematical formulation of the traveling sinusoidal wave is given as.

$$Z = H(X,t) = \begin{cases} a(1-\eta(X,t)), \mathit{if}\ t < X < t+1 \\ a(1-\phi), \mathit{otherwise} \end{cases}. \tag{1}$$

where $\eta(x,t) = \phi \mathrm{Sin}\left(\frac{2\pi}{\lambda}(X-ct)\right), \phi = \frac{b}{a}$ (amplitude ratio) and $0 \le \phi \le 1$.

Flow equation of flexible wall is represented as [18].

$$\tilde{L}(\eta) = p - p_0. \tag{2}$$

$\tilde{L}$ is an operator for stretched membrane which is taken as

$$\tilde{L} = \tilde{K}\frac{\partial}{\partial x} + \tilde{m}\frac{\partial^2}{\partial t^2} + \tilde{D}\frac{\partial}{\partial t} + \tilde{B}\frac{\partial^4}{\partial x^4} - \tilde{T}\frac{\partial^2}{\partial x^2}. \tag{3}$$

In the view of above equation $\tilde{K}$, $\tilde{m}$, $\tilde{B}$, $\tilde{D}$, and $\tilde{T}$ are the spring stiffness, mass per unit area, the flexural rigidity of the plate, the coefficient of the viscous damping membrane, the elastic tension is the membrane. The pressure from outside the wall owing to tension in muscle is p_0, which is taken as zero here. The relation is used in stress with x-momentum equation of liquid matrix.

Bubble-water two phase modelling

Numerous industries utilized the phase distribution for the two-phase flow of gas and liquid. We can find extensive

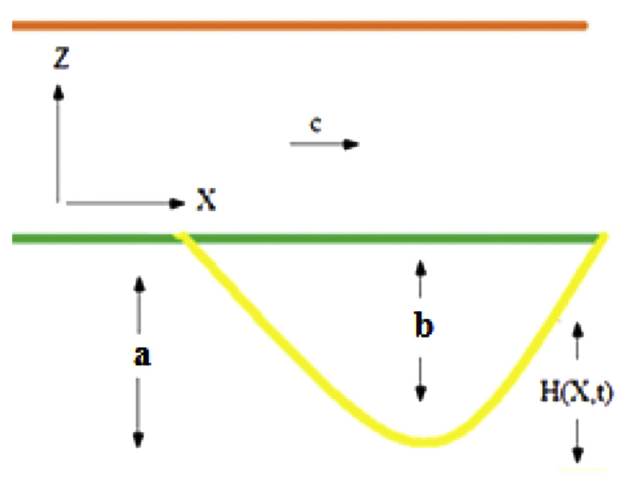

Fig. 1 – Geometry of the problem.

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