

Chapter 16

Wavy Motion of Viscous Bubbly Liquid in Tubes of Orthotropic Material

Rafael Yusif Amenzadeh
Baku State University, Azerbaijan

Akperli Reyhan Sayyad
Baku State University, Azerbaijan

Faig Bakhman Ogli Naghiyev
Baku State University, Azerbaijan

ABSTRACT

This article investigates the pulsating flow of a compressible two-phase bubble of viscous fluid contained in an elastic orthotropic direct axis tube. In this work, one-dimensional linear equations have been used. It is assumed that the tube is rigidly attached to the certain environment. In the case of finite length the pressure is applied at the end of its faces. In the limited process, relations obtained for a very long tube. Such a description, in a sense generalizes and strengthens the work of this type. In the numerical experiment a semi-infinite tube with flowing water containing small amount of air bubbles is considered. The influence of volume fraction of bubbles on wave characteristics is determined.

INTRODUCTION

The problem of wave propagation in deformable shells with flowing fluid in their cavities is quite popular. When considering the problems of this kind it should be encouraged to consider the equations of motion cover, considering the effect of moving the liquid in it. It is assumed that one –

dimensional approximation is applicable when the tube length is much greater than its radius. Such approximation describes the basic properties of the “cover-fluid”. To date, the aggregate of such problems is well developed area of fluid dynamics (Lightfoot, 1977; Pedley, 1983). However, the mechanism of the phenomena associated with simultaneous consideration of two-phase fluid in

DOI: 10.4018/978-1-4666-4010-8.ch016

the compartment considering its compressibility, viscosity and orthotropy of the material tube, is not well understood. The interest in problems of wave dynamics of bubbly liquids flowing in deformable tubes is due to the importance of application of research results to problems in calculating the hydraulic systems in aircrafts, oil and gas industry, chemical technology, thermodynamics (Skalak, 1956; Suo & Wylie, 1990). Fluid-structure interaction (FSI) problems arise in industrial piping systems, underwater explosions and turbomachinery (Cole, 1948; Wylie & Streeter, 1993; Brennen, 1994). These flows often involve gas (or vapour) bubbles that alter the dynamics of the fluid dramatically (Brennen, 1995, 2005). Dynamic loading of fluid-filled, deformable tubes have been extensively studied as an FSI model problem (Tijsseling, 1996; Ghidaoui et al., 2005). Liquid-filled tubes were first studied by (Korteweg, 1878) and (Joukowsky, 1898), who introduced a linear wave speed that accounts for the compressibility of both the liquid and the structure. The Korteweg–Joukowsky wave speed is also known as the Moens–Korteweg wave speed in a biomedical context concerning pressure pulses through blood vessels (Pedley, 1980). The wave speed in the case of bubbly liquids was later validated by Kobori, Yokoyama, and Miyashiro (1955). For cases without FSI, shock problems in bubbly liquids have also been considered by many researchers. The shock theory has been validated by experiments (Campbell & Pitcher, 1958; Noordzij & van Wijngaarden, 1974; Beylich & Gülhan, 1990; Kameda & Matsumoto, 1996; Kameda et al., 1998). In these experiments, bubbly mixtures were created in a tube, but the shock pressure was small enough to minimize the FSI effect. The detailed shock structure was also confirmed by computations (Kuznetsov et al., 1978; Nigmatulin, Khabeev, & Hai, 1988; Watanabe & Prosperetti, 1994; Kameda & Matsumoto, 1996; Kameda et al., 1998; Delale, Nas, & Tryggvason, 2005; Delale & Tryggvason, 2008). However, to the authors' knowledge, a (nonlinear) shock theory that includes both structural compressibility and

bubbles has not been presented so far (Smereka, 2002; Yates, & Satterfield, 1991; Zhang & Prosperetti, 1994).

METHOD

Basic Relations of the Problem

Closed system of equations consists of hydro equations of fluid motion and tubes, as well as the equations components' velocity continuity on the border of the interface of the liquid and tube.

Mathematical Model of the Fluid

Biphasic mediums consisting of a mixture of liquid with tiny bubbles of gas are very important example of the relaxing environment. Experimental and theoretical studies have shown that when solving the problem of transporting of the two-phase liquid-gas flows, it should be kept in mind that such environments are different from other two-phase media. The difference is that the heat of the carrier phase is much higher than the heat capacity of the dispersed phase due to the prevailing mass content of the carrier phase in the volume unit. Therefore, the liquid can be regarded as a thermostat with constant temperature (Nigmatulin, 1987). Methods of continuum mechanics have been used in the basis of the theory used to describe the flows of bubbly mixtures (Nigmatulin, 1987). We establish the following hypotheses and assumptions that greatly simplify the formulation and solution of the problem, without altering the essence of the phenomenon:

- Bubbles are present in the form of spherical inclusions of the same radius r_0 in every elementary macro-volume. Furthermore, the volume of concentration of bubbles α_{20} is low (a mixture of mono-disperse) and the value r_0 is much smaller than the characteristic size of the problem.

8 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage:
www.igi-global.com/chapter/wavy-motion-viscous-bubbly-liquid/77080

Related Content

Computational Techniques in Binding Affinity Prediction of Drugs

Kshatresh Dutta Dubey and Rajendra Prasad Ojha (2012). *Advanced Methods and Applications in Chemoinformatics: Research Progress and New Applications* (pp. 333-347).

www.irma-international.org/chapter/computational-techniques-binding-affinity-prediction/56462

Brain-like Processing and Classification of Chemical Data: An Approach Inspired by the Sense of Smell

Michael Schmuker and Gisbert Schneider (2011). *Chemoinformatics and Advanced Machine Learning Perspectives: Complex Computational Methods and Collaborative Techniques* (pp. 289-303).

www.irma-international.org/chapter/brain-like-processing-classification-chemical/45476

Chemoinformatics on Metabolic Pathways: Attaching Biochemical Information on Putative Enzymatic Reactions

Masahiro Hattori and Masaaki Kotera (2011). *Chemoinformatics and Advanced Machine Learning Perspectives: Complex Computational Methods and Collaborative Techniques* (pp. 318-339).

www.irma-international.org/chapter/chemoinformatics-metabolic-pathways/45478

Symbolic Equation for the Instantaneous Amount of Substance in Linear Compartmental Systems: Software Furnishing the Coefficients Involved in it

J.M. Villalba, R. Varón, E. Arribas, R. Diaz-Sierra, F. Garcia-Sevilla, F. Garcia-Molina, M. Garcia-Moreno and M. J. Garcia-Meseguer (2012). *Advanced Methods and Applications in Chemoinformatics: Research Progress and New Applications* (pp. 348-379).

www.irma-international.org/chapter/symbolic-equation-instantaneous-amount-substance/56463

An Epistemological Analysis of QSPR/QSAR Models

Jordi Vallverdú (2012). *Advanced Methods and Applications in Chemoinformatics: Research Progress and New Applications* (pp. 318-332).

www.irma-international.org/chapter/epistemological-analysis-qspr-qsar-models/56461