博士（工　学）　Warjito

学 位 論 文 題 名

Bubbles Undergoing a Sudden Change in Pressure

（急な圧力変化を受ける気泡）

学位論文内容の要旨

Bubbly flow undergoing a sudden change in pressure was studied experimentally to find a cause of noise emanating from component of piping system. This study is motivated by facts that in practical situations, water flow frequently contains bubbles due to such phenomena such as splashing, plunging of a water-jet, breaking of the crest of waves, and exsolution of air in water. When bubbles in such flow are subjected to sudden change in pressure at the components of a piping system, the characteristics of bubbles are changed. The bubble will deforms and oscillates. Depending on the degree of pressure difference, bubbles may break up near the components. Oscillation of bubble and a sudden change in volume of a bubble due to breakup is thought to be a cause of sound emanation due to bubbly flows.

There are studies related to the relationship of pressure change and bubble dynamic in liquid flow. Those studies mostly deal with a bubble that sustained moderate pressure gradient as can be found in venturi flows. Some characteristics of the flow: void distribution, bubble trajectory and pressure drop have been made clear. However, many physically interesting and important phenomena remain yet, and these are not explained well

It is clear that the pressure change effects bubbly flow very much. Pressure change causes bubbles distort and may break up. However the relationships between the pressure change and possibility of breakup and sound generated by the breakup remains unclear. In real situations, bubbles in water flow have different sizes and not all of the bubbles broke up when sustain a pressure gradient even though the pressure gradient was very steep as observed in our experiment. There are many parameters determining the breakup of a bubble and a particular condition for determining the occurrence of breakup is believed to exist. Understanding of those parameters will give possibilities for us to predict the occurrence of breakup and control the noise generated by the breakup of bubble.

The main objectives of this study are to reveal the phenomena of bubble undergoing a sudden change in pressure and to investigate the characteristic of noise generated by bubble and bubbly flow.

A water loop consists of a bubble generator, test section and tank was used in this study. An orifice positioned in the middle of test section was employed for producing a localized steep pressure different. Various pressure different were obtained by changing the water flow rate.

The bubbles behavior when sustain a pressure change was studied by flow visualization and image processing. The variation of bubble size spectrums across the orifice was observed. Some bubbles breakup when pass through the orifice, so we notice that the average bubble size in downstream orifice smaller than that in upstream orifice. It was found that the number of small bubbles in the downstream region of the orifice increased with increase in the pressure different.

The effects of a sudden pressure change and initial size of bubble on the breakup of a single bubble were investigated. We discussed processes, fraction and location of breakup by using initial bubble size and pressure difference as parameters. A non-dimensional pressure gradient p^* which compose of the initial bubble size and the pressure gradient was introduced. It was found that the breakup process of a single bubble could be explained by means of p^*.

To investigate the breakup mechanism, we observed behavior of a single bubble near the orifice. We used a still camera to get clear pictures of a single bubble. It is found that a steep pressure difference causes a micro jet protruding in the downstream direction in the bubble. The development of micro jet is affected by pressure different.

Oscillation and breakup of bubble generate noises. Measurement by a condenser microphone indicate that the sound pressure level of noise generated by a bubbly flow was proportional to the pressure difference. An empirical formula for estimating noise level is proposed. Investigation on the frequency spectrum show that bubbly flows generate noise with low frequencies, much lower than the natural frequency of constituent bubbles. The frequency is airflow rate dependence. The breakup of single bubble generate a damped sinusoidal sound at high frequency.

学位論文審査の要旨

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学位論文題名

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配管系から生じる音の多くはキャビテーションが原因と考えられている．しかし，気液混相流を扱う冷暖房機において顕在化したように，必ずしもキャビテーションが発生しない部位からも音が発生することがわかってきた．ファンの空力音が静粛化されるにともない，従来目立たなかった水流音が騒音問題としてクローズアップされてきている．これまで，気泡流による音を扱った研究は少なく，この音の発生および特性および低減化に関する知見は皆無といってよい．

本論文では，急な圧力降下をうける気泡流によって発生する音に関する実験的研究を行い，配管系において圧力変化を生じる部分から発生する流体騒音の発生機構を明らかにしている．水流に注入された気泡がオリフィスなどのような絞り部を通過するとき，局所的な急激な圧力変化が原因で気泡は変形し，場合によっては気泡が分裂する．気泡が分裂したとき音を発生する．音が発生するときにおける，圧力降下と気泡流による音との関係，音の発生原因である気泡の変形・分裂機構などについて詳細に調べたものである．

本論文では以下のような結論を得ている．

（1）単独気泡がオリフィスを通過して分裂するとき，分裂直前において気泡内にマイクロジェットが発生する．これが気泡を分裂させ音を発生する．オリフィスを通過する気泡がどの程度の割合で分裂するかという確率を，本論文で定義された無次元圧力勾配により見積もることができることを示した．

（2）オリフィスを通過する気泡流によって発生する音の音圧レベルを圧力降下量の関数として推定する実験式を提案した．これは低騒音管路系の設計指針を与える上で重要である．

以上のように，本論文は気泡流による音の発生を扱った点で極めて独創的であり，その研究成果は工学および工業，騒音問題に貢献するところ大なるものがある。よって著者は北海道大学博士（工学）の学位を授与される資格あるものと認める。