Experimental and Numerical Study of Free Surface Flow Impact on a Vertical Cylinder

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論文題目：Experimental and Numerical Study of Free Surface Flow Impact on a Vertical Cylinder
（鉛直柱体への自由表面衝撃問題に関する実験的及び数値的研究）

区　　分：　甲

論　文　内　容　の　要　旨

In coastal and ocean engineering research, violent wave-structure interaction is one of the important problems. This problem generally involves free surface flow impact phenomena associated with a very fast impulsive force followed by a relatively smooth variation. Several numerical simulation methods have been proposed for prediction of such impact force in the past decades. Experimental studies have been carried out in order to find the insights on the occurrences and the features of the wave impact events and to provide benchmark database for validation of numerical simulations. To develop more efficient numerical methods and to obtain more reliable experimental data are still attracting great attention from the researchers.

In this study, the free surface flow impact phenomena have been studied in two phases. First, a new and non-conventional numerical approach, the lattice Boltzmann method (LBM) is applied to solve three-dimensional free surface flows impacting on structures with complex geometry. Important numerical features are investigated and feasibility and efficiency of the LBM for such free surface impact problem are discussed. Second, a physical experiment is conducted on dam-break flows. The present experiment focusses on the problems including the effect of the gate removing, three-dimensionality of the free surface flow, and impact pressure measurement, which are important for the purpose of validation of numerical methods. In the experiment, a square and a circular vertical cylinder are placed in front of the dam to study the free surface flows impacting on a structure with complicated geometry. Many improvements on the existing experimental setup have been made. The experimental measurements have been analyzed and their reliability has been discussed. Comparison between the experiment and LBM simulation has been made and the performance of LBM for such free surface flow impact problem has been discussed.

The thesis consists of the following contents.

In chapter 1, background and motivation of the present research are outlined. The wave impact phenomenon is briefly described with a review of the related works in the past. The researches on dam-break experiment during the past decades are also reviewed. It is found that the emphasis of the past researches has been given to the dam-break flows. For the lattice Boltzmann method, an extensive review has been carried out. Some well documented LBM

models that can be used for free surface flow simulations are described, such as Shan-Chen model, Rothmann-Keller model, free energy model, and single phase model, etc..

In chapter 2, mathematical formulation for LBM and the LBM for free surface flows are introduced. Two types of collision model, the single-relaxation time (SRT) model and the multi-relaxation time (MRT) model, are presented. Implementation of initial and boundary conditions and body force modeling are described.

Chapter 3 is about the newly performed dam-break experiment. The experimental setup, tank geometries and data acquisition method are described in detail. The gate system has been largely improved. The new gate design, the improved gate release system, and the result of repeatability test are presented. Two vertical cylinders with circular and square cross-section are used in the experiment. The measurement results for free surface profile, wave propagation speed, deformation of free surface profile, and impact pressures, are obtained and analyzed. A high-quality database is established that can be easily used for validation of numerical simulations.

Chapter 4 is for presentation of the numerical simulations by the free surface LBM. Numerical simulation is carried out on the case of dam-break experiment. The numerical results are compared with the correspondent experimental measurements. This is the first attempt to simulate free surface flows impacting on vertical cylinders by using LBM. Discussions on the performance of the free surface LBM are made.

Finally, conclusions are provided in chapter 5.