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Three Dimensional Solid-liquid Flow Analysis for Design of Two-stage Lifting Pump

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ABSTRACT

Numerical analyses on the solid-liquid flow have been performed to design a lifting pump, which consists of two stages of impellers in series. Eulerian multi-phase model was applied using a CFD model. From the analyses, it was observed that backward flow occurred at the second stage of the lifting pump. No serious accumulation or plugging phenomena of solid particles did not occur in the first stage, but some accumulation area showed up at the second stage. It is suggested to reduce the numbers of the blade for the prevention of partial accumulation that can happen in the second stage impeller.

KEY WORDS: lifting pump, solid-liquid flow, CFD, Eulerian multi-phase

INTRODUCTION

The deep sea floor could be thought as the last treasury of mineral resources to be left for mankind. The advanced countries have already driven forward actively the development of deep sea mineral resources in preparation for the on-land mineral resource exhaustion since 1960's. Especially, the successful development of deep sea manganese nodules requires developing exploration, mining and transfer technologies simultaneously, among which mining technology includes collecting and lifting technologies of the manganese nodules (Chung, 1994). Lifting system is crucial to achieve the success of the deep-sea mining project, by which manganese nodules are conveyed from the seafloor to the mining ship. The conveying principle can be classified into the hydraulic pumping system and the air lift system according to the fluid dredging type, the continuous line buckets system of the mechanical type and the modular marine mining automation system (Yoon et al., 2003). Among the lifting methods, the hydraulic pump lifting system is situated between the buffer system and the lifting pipe that is connected to the mining ship. The lifting pump, one of the core parts in the hydraulic pump lifting system, need to be designed with multi-stages because it requires a high hydraulic head. In Japan, an 8-stage lifting pump was developed for its offshore experiment (Chung, 1994).

KIGAM had developed a few single-stage lifting pumps for on-shore lifting tests. But, the centrifugal type turned out not to be suited as lifting pump with required high capacity and head simultaneously. So, an axial-centrifugal mixed type pump has been designed by the help of a three dimensional CFD model and the experiences from the previous pumps. The newly designed pump is two-stage which guarantees high flow rate even with high loads. The diameter of inlet and outlet parts is the same as 100 mm.

In the study, the solid-liquid flow behavior analyses in a lifting pipe has been carried out to estimate efficiency of the designed multi-stage lifting pump and to investigate the efficiency of the design, using FLUENT, a commercial CFD model. In the analyses, the Eulerian model was applied using granular flow simulating water and nodules. Both conformal mesh and non-conformal mesh were used to describe the flow behavior area in the complex pump casing.

MODELING OF SOLID-LIQUID TWO-PHASE

Eulerian multi-phase modeling

In general, the modeling method of two-phase solid-liquid flow is categorized into two types. One is Eulerian-Eulerian(E-E) approach; the other is Eulerian-Lagrangian(E-L) approach. In the Lagrangian view-point, attention is focused on a specific piece of fluid or particles rather than a region of space, whereas the Eulerian viewpoint is fixed in space. In general, the two methods should be appropriately mixed and applied for simulation analysis of solid and liquid such as continuum-continuum (Eulerian-Eulerian) and Eulerian-Lagrangian numerical simulation (Patankar, 2002; Chiesa, et al., 2005).

In the two-fluid approach, the phases are treated as interpenetrating continua coexisting in the flow domain. Comparing the Eulerian multi-phase with the Lagrangian two-phase model, the former has the computational advantages with respect to computing time where the phases are widely dispersed and when the dispersed phase volume fraction is high (Patankar and Joseph, 2001). In the E-E approach, both the fluid phase and the solid phase are treated as a continuum. In this approach, the definition of the constitutive equations is the most significant issue to describe the solid phase as a continuum. On the other hand, in the E-L approach, while the fluid phase is described as a continuum using the equation of continuity and the equation of motion,