

Numerical Prediction of a lifting pump for deep-sea mining

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ABSTRACT

The performance of a lifting pump is numerically predicted using commercial code. This four-stage lifting pump is designed for deep-sea mining. Pressure distribution, head chart, and streamlines are calculated in this paper. The number of blades of impeller in one-stage is 5 and the number of guide vanes is 6. Solid-liquid flow in a pump is analyzed and compared with the result of clean water.

KEY WORDS: lifting pump; solid-liquid flow; pressure distribution; manganese nodules

INTRODUCTION

Since 1960's the advanced countries have tried to develop deep sea mineral resources in preparation for the on-land mineral resource exhaustion. 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 (Yoon et al., 2005). 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. This designed pump was two-stage which guarantees high flow rate even with high loads (Park et al., 2007)

In the study, the solid-liquid flow in the four-stage lifting pump working at the depth of 1000m is analyzed by using CFX, a commercial CFD code.

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, the solid phase is described using the equation of motion of particle. Since the motion of each particle is calculated, it is difficult to apply the E-L approach to large scale systems (Okayama et al., 2006).

Basic equations

For the Eulerian modeling of solid-liquid mixture, the CFD model is based on the following: A single pressure is shared by all phases. Momentum and continuity equations are solved for each phase. Also