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Deep seawater flow characteristics around the manganese nodule collecting device

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Abstract

Flow field characteristics with outflow discharge from a collecting device in deep seawater while gathering manganese nodules have been analyzed by CFD. Numerical model is used for the analysis with CFD program of FLUENT. It is assumed that the collecting device is 4.5 × 5.4 × 6.7 m with outflow speed = 1.75 m/s and the current speed = 0.1 m/s. Overall seawater flow field characteristics are largely influenced by the outflow discharge from the collecting device and manganese nodule particle behavior. The outflow discharge effect reaches to about few times of the collecting device in back. As simulation results, flow velocity and streamline distributions are compared including turbulence kinetic energy variation. This study will be useful for optimal design for manganese nodule collecting device system in deep sea.

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Keywords: Manganese nodule collecting device; Seawater flow; Computational Fluid Dynamics

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1. Introduction

Recently, many concerns of terrestrial mineral depletion have been seriously raised, and thus the interests in marine mineral resources which can replace is rapidly increasing. Among various marine mineral resources, manganese nodule is the typical mineral resource that is located in depth of 4000 ~ 6000 m on the seabed as a large quantity. Manganese nodule contains various rare metals such as manganese, nickel, copper, cobalt and etc. and it is very valuable. It is also known that manganese nodule is mainly in Clarion-Clipperton zone where is southeast of Hawaii (LRET Collegium 2012). Currently, Korea obtained the 75,000 km mining rights in the zone, which has more than few million tons of manganese nodules. Most collecting device systems are usually composed of manganese nodule collecting and the lifting parts. The collecting part is for gathering manganese nodules at seabed, and the lifting one is to draw up the manganese nodules on the surface of the sea. Continuous interaction of these parts is very important for efficient system operation in deep seabed with minimized malignant effects on the ecosystem.

A lot of researches and developments with the collecting device system in the sea depth of 4000 ~ 6000 m have been widely carried out. In Korea, presently developed collecting device is tested successfully on the seabed at about 1,400 m depth with experimental studies. As recent studies of the collecting device system, Taguchi robust design method of tracked vehicle for manganese nodule test miner in collecting operation considering deep-sea noise factors was applied by Cho et al. (2012). Choi et al. (2010) performed inshore tests with specific design concepts of deep sea manganese nodule miner system. Total dynamic analysis of deep-seabed integrated mining system is also carried out by Kim et al. (2010). Lee et al. (2013) investigated design optimization method of a hydraulic deep-sea manganese pick-up device using Coanda effect. Experimental tests of the underwater mining system with flexible riser were conducted by Deepak et al. (2001). Although many researches associated with the collecting device system have been actively carried out in various ways, there is not sufficient studies on seawater flow field around the collecting device in the deep sea. Especially it is necessary to investigate the characteristics of seawater flow field around the devices with manganese nodules behavior, since it seriously affects the ecosystem of the deep sea.

In this study, the seawater flow characteristics around the collecting device, including fluid velocity distribution and turbulent kinetic energy variation, are numerically analyzed by CFD. The simulated results from this study can be applicable to the prediction of the effects caused by the collecting device operation on the deep-sea ecosystem.

Nomenclature

D	Diameter (m)
L	length of collecting device (m)
u	velocity (m/s)
k	turbulent kinetic energy (m^2/s^2)
$\bar{k}$	cross-sectional averaged turbulent kinetic energy (m^2/s^2)
μ	viscosity (P·s)
ρ	density of seawater (kg/m^3)
x, y, z	coordinate axis (m)

Subscripts

cd	collecting device
mn	manganese nodule
i, j	general spatial indices
s	seawater