Proceedings of The Eighth (2009) ISOPE Ocean Mining Symposium
Chennai, India, September 20-24, 2009
Copyright © 2009 by The International Society of Offshore and Polar Engineers (ISOPE)
ISBN 978-1-880653-75-3; ISSN 1946-0066

Fluid-solid Coupled Dynamical Analysis of Deep-ocean Mining System

Qiuhua Rao, Zhi Wang
School of Civil Engineering and Architecture, Central South University
Changsha, Hunan, China

*Shaojun Liu**
College of Mechanical and Electronic Engineering, Central South University
Changsha, Hunan, China

Min Fang
School of Civil Engineering and Architecture, Central South University
Changsha, Hunan, China

ABSTRACT

Fluid-solid coupled dynamical response of a 1000m deep-ocean mining system is studied based on nonlinear finite element method with fluid-solid coupling model using. Finite element software MSC.MARC 2005 is adopted to calculate displacements, support constrained forces and stresses of the mining system. Effects of the towing velocity of the mining ship and the mining machine, wave period and nodule mass stored in the buffer on dynamic responses of the mining system are analyzed in order to provide scientific basis for optimal design of the deep-ocean mining system. Research results show that for safety and efficiency of the mining operation, the velocity of the mining machine and the nodule mass should be limited within appropriate ranges (about 0.3-0.5m/s and 2000-4000kg) and the countercurrent mining operation should be avoided in the case of smaller wave period.

KEY WORDS: Fluid-solid coupling effect; dynamic analysis; integrated motion; finite element method; deep-ocean mining system.

* Corresponding author

INTRODUCTION

With the rapid development of science technology and the gradual exhaustion of land resources, governments in different countries are becoming more aware that exploitation of ocean resource will be main strategic tasks of countries in 21st century and very importance for national interests of global ocean. Deep-ocean mining technology has aroused increasing attentions of researchers in the world. Usually, a test system of deep-ocean mining for polymetallic nodule consists of mining machine, flexible hose, buffer, rigid pipe and mining ship. Current research on the deep-ocean mining system is mainly focused on static and dynamic analyses of the rigid pipe or flexible hose independently. Although geometrical nonlinear static and dynamic responses of the rigid pipe with free-hanging bottom end were studied by finite element method (Chung,1978; Chung and Felippa,1981; Chung,1981; Chung and Whitney,1981,1993) and results showed that large transversal and axial vibrations of the rigid pipe leading to difficulty in control of the mining system could be greatly decreased by damping system (Cheng and Chung,1995, 1997), towing effect of the flexible hose on the rigid pipe and coupling effect of inner fluid on the rigid pipe were not taken into account. In additions, static and dynamic responses of the flexible hose were analyzed by finite element method or boundary element method (Giese, 1989; Jian, 2001; Liu, 2001; Cui, 1999; Guo, 2000), where the actions of inner and outer fluids were simplified as additional mass matrix and fixed forces applied to the solid without any consideration of fluid-solid coupling effect and towing effect of the rigid pipe on the flexible hose. Since each part of the mining system (including the mining machine, flexible hose, rigid pipe and mining ship) has complicated dynamical response caused by the coupling action of wave, current and high water pressure, it must be in coordinated following motion for the mining operation in order to avoid any blockage of the manganese nodule transportation and tensile failure of the pipeline system. Research on the integrated motion of the whole mining system is of great significance to the safety and efficiency of the mining operation. Unfortunately, only a very few literatures (Brink and Chung, 1981; Cheng and Chung, 1995; Wang, 2004, 2005; Li, 2006) are concerned with the integrated motion of the whole mining system, in which the dynamic characteristics of each part are investigated under different operation modes, regardless of the effect of inner fluid on the mining system.

Fluid-solid coupled dynamical response of a 1000m deep-ocean mining system is studied based on nonlinear finite element method with fluid-solid coupling model in this paper. Effects of towing velocity of the mining ship and the mining machine, wave period and nodule mass stored in the buffer on dynamic responses of the whole mining system are analyzed in order to provide scientific basis for optimal design of the deep-ocean mining system.

CALCULATION MODEL

Force analysis

A test system of 1000m deep-ocean mining in China is shown in Fig. 1, where the mining machine located on sea floor is joined by a space