IJNAOE
©SNAK, 2014

Int. J. Nav. Archit. Ocean Eng. (2014) 6:652~669
http://dx.doi.org/10.2478/IJNAOE-2013-0203
pISSN: 2092-6782, eISSN: 2092-6790

A study of the kinematic characteristic of a coupling device between the buffer system and the flexible pipe of a deep-seabed mining system

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ABSTRACT: *This paper concerns the kinematic characteristics of a coupling device in a deep-seabed mining system. This coupling device connects the buffer system and the flexible pipe. The motion of the buffer system, flexible pipe and mining robot are affected by the coupling device. So the coupling device should be considered as a major factor when this device is designed. Therefore, we find a stable kinematic device, and apply it to the design coupling device through this study. The kinematic characteristics of the coupling device are analyzed by multi-body dynamics simulation method, and finite element method. The dynamic analysis model was built in the commercial software DAFUL. The luid Structure Interaction (FSI) method is applied to build the deep-seabed environment. Hydrodynamic force and moment are applied in the dynamic model for the FSI method. The loads and deformation of flexible pipe are estimated for analysis results of the kinematic characteristics.*

KEY WORDS: Coupling device; Buffer; Deep-seabed mining system; Multi-body dynamic; Fluid Structure Interaction (FSI); Kinematic characteristic; Flexible pipe.

INTRODUCTION

Many concepts for the commercial production of deep-seabed manganese nodules have been studied from the 1970s (Brink and Chung, 1982; Chung, 1996; Herrouin et al., 1989; Amann et al., 1991; Liu and Yang, 1999; Hong and Kim, 1999; Deepak et al., 2001; Handschuh et al., 2001). The accumulate ground of the deep-seabed has a problem, in that the bearing capacity of the ground is not strong, because the accumulate ground is formed by fine particles with high moisture content. So it is impossible to carry manganese nodules in the collection system. Therefore, the validity of continuous mining by lifting pipe from ground to vessel is highly appreciated.

A continuous mining system is composed of mining vessel, lifting pipe, buffer system, transfer tube (flexible pipe), and self-propelled mining robot. The shape of the transfer tube between the buffer system and mining robot has a big impact on the driving efficiency of the mining robot. Also, the relative position between the buffer system and mining robot influences the efficiency of the mining robot. So, dynamic analysis of the integration of the mining system (mining vessel-lifting pipe-buffer

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system-flexible pipe-mining robot) is a very important technique in building a deep-sea mining system.

Currently, the lifting pipe and the flexible pipe are actively studied, according to the growth of offshore plant and the ocean floor industry. But studies on the buffer system are at an early stage. Just several functions to temporarily store nodules were mentioned by researchers (Chung, 2003; Kotlinski et al., 2008).

The coupling device of the buffer system is the main subject of this study. The buffer system is currently developing. This coupling device makes a big impact on the dynamic movement of a mining robot. And it is a very important mechanic device in a deep-seabed mining system. The specs of the coupling device are determined by various efficiency tests and changes of design. But the production and experiment of a buffer system is costly and time-consuming. So the design specs of this device must be found by simulation. In general, this design method is called the simulation-based design.

Dynamic analysis of mechanical systems using computers is rapidly performed through the growth of computing power. The method of simulation-based design is a useful technique in otherwise impossible cases, which is verified by using an experiment with a model as an integrated deep-seabed mining system. The simulation technique is an excellent means of understanding qualitative (or quantitative) optimization design, and can skip the process of test model production, which is costly and time-consuming.

The mining robot and vehicle model used in this study is an MBD model. This MBD model was developed by Kim (Kim et al., 2010). The integrated simulation model is developed by DAFUL (2012).

In this study, the used equations are the joint constraints, a beam elastic equation and a multi-body dynamic solution. The verifications of the joint constraints and the beam elastic equation are written in DAFUL verification manual (2012).

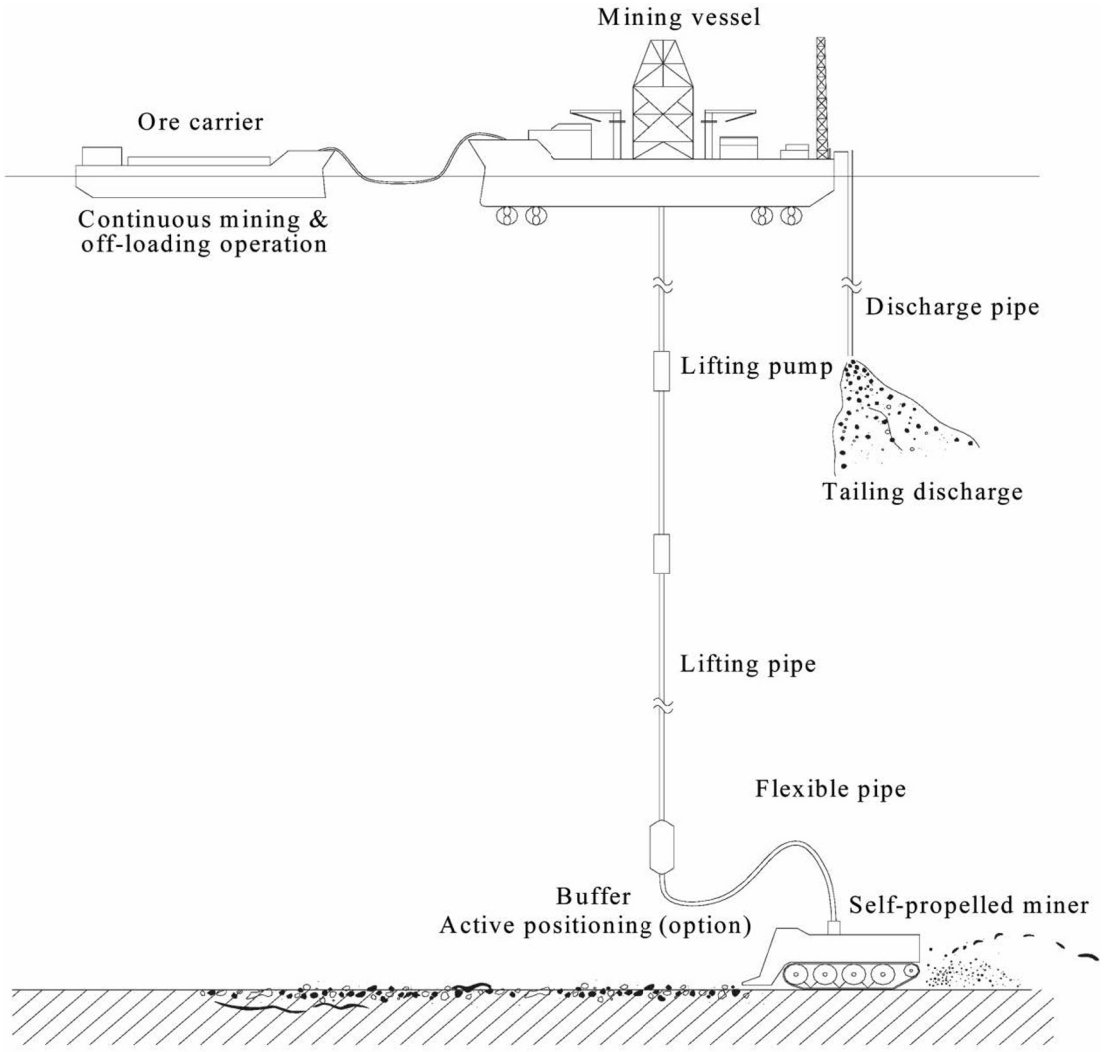

Fig. 1 Conceptual diagram of the deep-seabed mining system.