

Interaction of Fluid-solid Coupled Flexible Hose and Mining Machine in Deep-ocean Mining System

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ABSTRACT

Interaction of fluid-solid coupled flexible hose and mining machine in a 1000m deep-ocean mining system is studied based on nonlinear finite element method with fluid-solid coupling model. Effect of the walking paths (e.g. line, circle and square) and walking velocities of the mining machine on the space configuration, support restrained force and maximum tensile stress of the flexible hose is investigated in order to provide guidance for the deep-ocean mining operation. Results show that the line walking of the mining machine is better for small lateral displacement, maximum tensile stress and support constrained force of the flexible hose than the circle and square walking. The walking velocities of the mining machine should be limited to an appropriate range (about 0.2-0.4m/s when the lifted speed of inner fluid is 4m/s) for the safety and efficiency of the mining operation.

KEY WORDS: Fluid-solid coupling effect; walking path; walking velocity; finite element method; mining machine; flexible hose.

INTRODUCTION

Popular deep-ocean mining system is usually composed of mining ship, rigid pipe, buffer, flexible hose and mining machine. Whether the mining machine can walk freely and stably or not has great effect on success of the deep-ocean mining operation. On the one hand, walking performance of the mining machine is strongly influenced by the flexible hose, which is subjected to itself gravity, buoyancy of seawater, buoyancy of buoy, and action of current, wave and inner fluid. On the other hand, the walking path and velocity of the mining machine greatly affect the dynamic characteristics of the flexible hose, which is directly related to safety of the flexible hose and efficiency of the mining operation. It is of importance and significance to study the interaction of fluid-solid coupled flexible hose and mining machine in order to provide guidance for the deep-ocean mining operation.

Currently, the flexible hose of high nonlinearity is mainly studied by finite element method (Owen, 1986; Vogel, 1987), finite difference method (Brown, 1989; Chatjigeorgiou, 1998) and lump mass method (Nakajima, 1982; Ghadimi, 1987). Initial space configuration of the flexible hose during the walking of the mining machine from its limited position to the buffer was analyzed by nonlinear finite element method, where the influence of outer fluid rather than inner fluid on the flexible hose was taken into account (Guo, 2000). Space beam element with update Lagrangian method was used to calculate stresses, displacements and space configurations of the flexible hose when the mining machine walks on different paths at a uniform speed (Cui, 1999; Liu, 2001) and acceleration (Jian, 2001). But the effect of inner fluid on the flexible hose was not considered. Dynamic responses of the flexible hose under the uniform circle motion of the mining machine were investigated experimentally and numerically, regardless of impulsive force of the inner fluid exerted on the flexible hose (Freitag, 1993).

Interaction of fluid-solid coupled flexible hose and mining machine in a 1000m deep-ocean mining system is studied based on nonlinear finite element method with fluid-solid coupling model. Effect of the walking paths (e.g. line, circle and square) and walking velocities of the mining machine on the space configuration, support restrained force and maximum tensile stress of the flexible hose is investigated in order to provide guidance for the deep-ocean mining operation.

CALCULATION MODEL

Fig.1 shows a deep-ocean mining system of 1000m, where the mining machine is located at the sea floor and the flexible hose is connected by space hinges to the mining machine and the buffer. The relative height of the buffer and the mining machine is 150m (Liu, 2005). In order to reduce the effect of the flexible hose on motion of the mining machine and improve the space configuration of the flexible hose for inner nodule-fluid transportation, buoy is usually added in the range of half