Model Test of Heave Compensation System of Deep-ocean Mining

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ABSTRACT

In order to validate the simulation results and develop heave compensation control strategy, heave compensation model tests were performed. The model test installation included the mining ship motion simulator, the heave compensation system, the lifting pipe simulator, the buffer simulator and the water pool. The mining ship motion simulator was able to perform under the predetermined attitude path smoothly. The heave compensation system includes a heave compensated platform which is to compensate heave motion and a gimbaled platform which is to accommodate pitch and roll. Heave compensation tests of mining ship motion under harmonic wave and random wave were carried out. PID control is selected as the control strategy here. Tests under random wave show that the heave compensation effect is more than 60% and reach the requirement which is set to 50%. The model tests results indicate that this heave compensation system is effective and feasible.

KEY WORDS: Deep-ocean mining; heave compensation; model test; mining ship motion simulator; gimbal; PID control.

INTRODUCTION

At present, the pipeline lifting mining system is the most popular mining system. The nodules collected by the miner are lifted by the fluid rising force through the lifting pipeline to the mining ship. Under the sea wave, the lifting pipeline moves with the motion of mining ship, which causes large axial stress on lifting pipeline. To make mining operation secure, a heave compensation system is absolutely necessary. Since the 1960s, various studies and analysis have been carried out about heave compensation systems of pipelines in deep-ocean mining. In 1968, a heave compensation system between travelling block and hook used in oil drilling platform was proposed by VETCD Company, USA. It was composed of hydraulic cylinders, accumulator, locking device etc. The hydraulic cylinder displacement is larger than the heave amplitude of wave height and the load of hydraulic cylinders is nearly 600 tons. In 1976, a heave compensation device for marine use was proposed by William David Stevenson of Scotland Brown Brother Company (Stevenson, 1976). It included a passive load supporting system and an active force adjusting system. In the 1970s, Glomar Explore was built in USA. Minerals from 5400m seabed depth can be lifted to the mining ship by the pipeline lifting system and the max lifting load was 6800 tons (McNary, 1977). The outer gimbal ring was capable of accommodating pitch motion of ship and roll motion was eliminated by the inner gimbal ring. The heave compensation hydraulic cylinders were used to compensate the heave motion. In 1983, an ocean floor dredge system having pneumohydraulic means suitable for providing tripping and heave compensation modes, was proposed by James Blanchet of Deep-ocean Ventures Company Virginia America (Blanchet, 1983). The system can realize two functions: launching and retrieval, and heave compensation. In 1985, a heave compensation system suitable for a drilling pipe suspension system was proposed in the Netherlands (Lang, 1985). This is a passive system which and the stiffness was nonadjustable. In the 1990s, an actively compensating platform based on hybrid serial-parallel mechanism was proposed by Xiangzhou Zheng of Huazhong University of Science and Technology in China (Zheng, 2003). A 3D simulation was worked out successfully and the results show that kinematic feasibility for deep ocean mining is good. Light-load, media-load and heavy-load active heave compensation systems were proposed by Tibing Xiao of Guangdong University of technology in China. It was based on electro-hydraulic proportional control and intelligent control. The lab test results are good and show suitability of the heave compensation system for its purpose (Xiao, 2002, Xiao, 2004).

Here an active heave compensation system completed by electro-hydraulic proportional valve control is put forward. A model test installation is built in the lab because the heave compensation is too large to do the tests in field. The system includes a heave compensated platform which is to compensate heave motion and a gimbaled platform which is to accommodate pitch and roll. The schematic diagram of the model test installation is shown in Fig.1. It includes a mining ship motion simulator, a gimbal mount, a heave compensation electro-hydraulic system, the lifting system simulator, a pool and other auxiliary equipments.

Most of the heave compensation systems listed above are not used in the deep-ocean mining except the ones proposed by McNary, Zheng and Xiao. The differences are listed below:
1. The heave compensation in this paper is active compensation and the one proposed by McNary is passive;