International Journal of Offshore and Polar Engineering
Vol. 10, No. 3, September 2000 (ISSN 1053-5381)

Smart Seafloor Mining Vehicle: Simulation with Successive Learning Track-Keeping Control

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ABSTRACT

A large self-propelled seafloor miner or vehicle was tested in the '70s on the seafloor at a depth of 3,000 to 5,000 m. It was a subsystem of the integrated ship-pipe-buffer-link-miner production system of manganese nodules from the seafloor at that depth. In tracking the set points of the target track, turning and varying its speed, the miner maneuver must overcome uncertainties in many unknown operational parameters, in addition to the positioning uncertainty of a long pipe. It requires a *smart* miner. A basic control algorithm, the *successive learning track-keeping control* (SLTC) algorithm, was proposed to correctly track-keep the prescribed target track of set points or miner path. Successful learning and overcoming of the uncertainties in soil friction and hydrodynamic drag by the SLTC algorithm are demonstrated with the simulation of a miner following a zigzag target track on the flat seafloor. In controlling the miner with the initial off-track disturbance, it takes the first 3 to 5 tracks of the learning process to move the miner to the zigzag tracks.

INTRODUCTION

Self-propelled seafloor miners or vehicles have recently been adopted by many countries to develop their respective production systems for the manganese nodules from the deep-ocean floor (Chung, 1996). A deep-ocean mining system is an integration of a seafloor miner system, miner-to-buffer link system, lift pipe/buffer system, ship system and ocean transportation system, as shown as part of the integrated production system (IPS) in Fig. 1a (Brink and Chung, 1980, 1982).

The miner is designed to maneuver on the seafloor with an intelligent control system, and track-keep the prescribed target track. Such a miner can be a subsystem of the total integrated (ship-pipe-buffer-link-miner production) system, TIS (Fig. 1b) (Park, Min and Chung, 1997) and several orders of magnitude larger than the existing ROV or AUV. A miner of such a size was previously tested at ocean depths in the range of 5,000 m with the *Hughes Glomar Explorer* in the '70s. Pipe/buffer and ship can be dynamic-positioned to follow the moving miner during the mining operation (Chung and Tsurusaki, 1994).

The maximum seafloor coverage or sweep by the miner increases the manganese-nodule recovery rate for given collector efficiency. Precise miner track-keeping ability is the focus of the entire deep-ocean system (Brink and Chung, 1980, 1982). To achieve high sweep efficiency, a seafloor miner must be controlled for efficient, correct track-keeping, and the development of such a smart miner requires an intelligent control system (Chung and Olagnon, 1996).

Key tasks in the design of the miner controller are to direct the miner to follow the prescribed mining track of set points and set speeds as precisely as it can, and to coordinate the nodule collector speed. The collector speed is a direct function of mineral

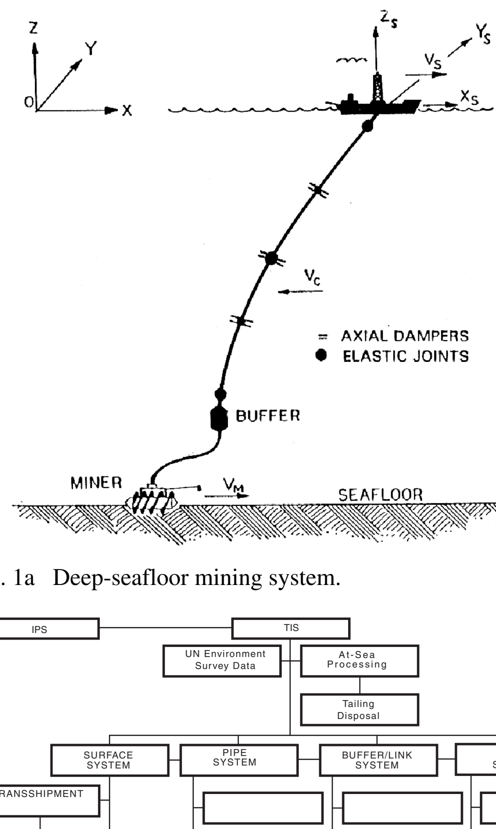

Fig. 1a Deep-seafloor mining system.

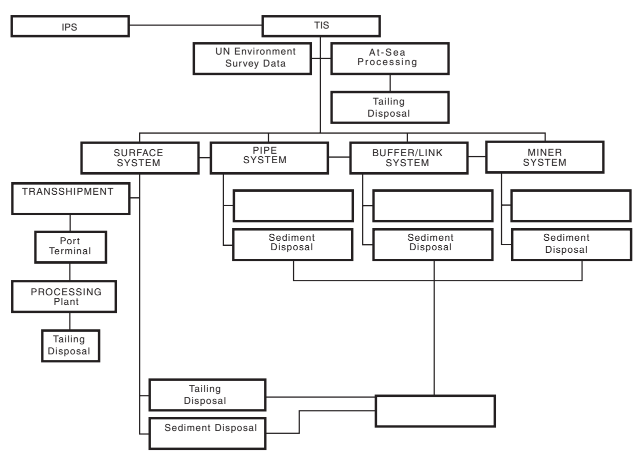

Fig. 1b Block diagram of total integrated system (TIS) of integrating systems of production, ship and ocean transshipment/transportation (Park, Min and Chung, 1997)

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Received March 28, 1999; revised manuscript received by the editors August 6, 1999. The original version (prior to the final revised manuscript) was presented at the Ninth International Offshore and Polar Engineering Conference (ISOPE-99), Brest, France, May 30-June 4, 1999.
KEY WORDS: Learning control, algorithm, track-keeping, seafloor vehicles, smart miner, deep-ocean mining.