Deep-Ocean Mining: Technologies for Manganese Nodules and Crusts

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ABSTRACT

This paper reviews research, development and design aspects of recent technologies for deep-ocean mining systems to recover manganese nodules and cobalt-rich manganese crusts from the seafloor at an 800-6,000-m depth. It also discusses selective technological challenges. The manganese crust is characterized on the basis of preliminary data. Development of more sophisticated instruments and an extensive survey are required to determine its accurate distribution, abundance and physical characteristics. The technical challenges particularly in the fluid-structure interactions of the pipe systems and the miner track-keeping for production are yet to be defined. The United States has a greater geological emphasis, while Japan places a greater emphasis on engineering. In the last 15 years, few significantly new technologies appear to have evolved in the nodule mining system, system integration and integrated system control. However, subsystems have been designed and tested systematically in Japan. As the technologies of the past 30 years age, the mining systems and technologies need to be upgraded, with advancements in new sensors, control and data acquisition technologies.

INTRODUCTION

The deep seabed is one of the potentially most rewarding frontiers that challenge mankind in its quest for knowledge and material achievement. Manganese nodules (Fig. 1) and cobalt-rich crust (Fig. 2) are resources of current interest. They are deposited over and beneath the ocean floor at an 800-6,000-m depth.

Over the last 30 years, international consortia and government enterprises have invested in the exploration of deep-ocean hard minerals, manganese nodules in particular, and in the research and development of mining or production technology. Today some selective technologies for subsystems exist for recovering these minerals on a commercial scale. Publicly sponsored entities active recently in the '80s and '90s are from Japan, the Interocceanmetal (IOM) consortium, Finland, India, Korea and China. The U.S.-based industrial consortia were most active in R & D in the '70s. The first R & D, some with at-sea tests, has been conducted by 4 international consortia or groups composed of companies from the U.S., Canada, the United Kingdom, the Federal Republic of Germany, Belgium, the Netherlands, Italy, Japan and France. However, information about the technologies from these efforts has scarcely been made available in the public domain, and some technologies may have already become outdated.

As the 60th country ratified the Law of the Sea treaty in November 1993, it became effective as of 1994. Only Japan and India are currently active in their national deep-ocean mining program. Japan’s program started at country’s R & D work in 1981, but the at-sea test plan has been delayed for many years. An at-sea test of a subsystem may take place in 1997. Presently low-level exploration for nodule mining (but no noticeable mining-system research) is being conducted by IOM (Kotlinski, 1995), Korea (Kim, 1995) and China among others.

When R & D precipitated the first-generation manganese nodule mining technology, the pioneers were faced with a formidable task. Manganese nodules containing nickel, copper, cobalt and manganese (and possibly molybdenum, vanadium and titanium) are nodular objects of various sizes and shapes found on the deep-ocean floor at depths between 3,000 and 6,000 m. More recent commercial interest has centered on the cobalt-rich manganese crust near the equatorial zone in the North Pacific Ocean, but this requires development of more complex technologies.

Manganese nodule mining usually involves coordination or integration of 5 distinct systems of operations: (1) exploration survey, (2) nodule collection from the seafloor, (3) hoisting to the mining ship, (4) transportation to land, and (5) processing onshore or in the ocean. This paper restricts discussion to only technological aspects of the second, third and fourth stages. This paper is an updated technical version of Chung and Tsurusaki (1994) and Chung (1985).