Studies on Polymetallic Nodule Processing in DORD

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ABSTRACT

Polymetallic nodules include useful metals such as cobalt, nickel, copper, and manganese, and are expected to be economic deep-sea mineral resources in the future. The Metal Mining Agency of Japan (the Japan Organization for Metals and Energy Security at present) has performed studies on the recovery rate of cobalt, nickel, copper, and iron from nodules and selected the smelting and chlorine leaching (SCL) process, which is a combination of pyrometallurgical and hydrometallurgical treatments. Meanwhile, Deep Ocean Resources Development Co., Ltd. has been investigating the SCL process to improve its process flow and reduce the capital expenditure/operating expenditure. The slow cooling of the matte from the nodules is suggested to be effective in phase separation and may reduce the load on the hydrometallurgical treatment.

KEY WORDS: Polymetallic nodules; Clarion Clipperton Zone; Processing; Smelting.

INTRODUCTION

Polymetallic nodules (nodules hereafter) occur on the seafloor at water depths between 4,000 and 6,000 m in the world's oceans (e.g., Kuhn et al., 2017). They are especially distributed widely on the seafloor of the Clarion–Clipperton Fracture Zone in the Central Pacific. These nodules contain useful metals such as Co, Ni, Cu, and Mn, which are expected to bring great economic interests. Thus, the growing expectations for deep-sea mining have led to environmental impact assessments and collection and lifting tests by contractors and the development of exploitation regulations by the International Seabed Authority (ISA).

Although the results of economic evaluations are important determinants in the decision to move from exploration to exploitation of these resources, the enormous processing costs are particularly a key issue. For example, according to Abramowski et al. (2021), for the cases with a production of 4.5 million dry tons per year, which include investments in a combination of mining and processing, the project results were negative regardless of the technology chosen. This resulted from both high plant construction costs and operating costs. Meanwhile, Van Nijen et al. (2018) reported that 59.6% of capital expenditure (CAPEX) was construction costs of onshore processing plants in the annual production of 3 million dry tons. Therefore, the reduction in processing costs is expected to contribute significantly to the economics of nodule development.

The deep sea nodule processing has studied for many years. American consortia mainly proposed several processes to recover metals from polymetallic nodules in the 1970s (e.g., Agarwal et al., 1976). They were: The Kennecott Corporation, Deep Sea Ventures, The Metallurgie Hoboken-Overpelt, and The International Nickel Company (INCO). These studies have resulted in the ability to recovery of Cu, Ni, and Co or Cu, Ni, Co, and Mn. China research institute also proposed nodule processing method in the 2000s (e.g., Jiang et al., 2005).

The processing technology for nodules in Japan was studied by the Metal Mining Agency of Japan (the Japan Organization for Metals and Energy Security at present), and the smelting and chlorine leaching (SCL) process was finally selected (Kojima, 1997). Subsequently, Deep Ocean Resources Development Co., Ltd. (DORD), which has an exploration contract with ISA for the nodules, is attempting to improve the SCL process (Haiiki et al., 2014). The SCL process consists of pyrometallurgical and hydrometallurgical treatments. By reducing and sulfuring the nodules, manganese and iron are separated into slag, and nickel, cobalt, and copper are recovered as matte. Finally, electrolytic cobalt, nickel, and copper are recovered from the matte by chlorine leaching, solvent extraction and electrowinning processes. The SCL process has the following advantages: (1) the volume of slag is relatively small and chemically stable; (2) chlorine gas can be used repeatedly and is economical. Each process is being reviewed to reduce processing costs, especially in recent years, to add a slow cooling process and mineral processing of the matte.