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Use of Process Optimization and Cost Model for Metal Recovery from Manganese Nodules: The Role of Manganese Recovery

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ABSTRACT

Little attention has been paid during process development studies to possible changes in cost of metal production when a process plant is exposed to varying degrees of metal grades emanating from a sea nodules mining area. Study of these aspects requires process optimization. An approach for optimization of a process technology at a given throughput of nodules has been developed. This uses a robust multi-objective process optimization technique coupled with process simulation and indicative cost economics. A case study illustrates the approach; minimization of process chemical cost with simultaneous maximization of metal values produced is considered. The approach may easily be extended to include other objectives, including energy, for any process technology.

KEY WORDS: Hydrometallurgy; Ocean Nodule; Genetic Algorithms; Process Simulation; Cost Model; Multi-objective optimization.

INTRODUCTION

The multi-metal deep sea nodules as a resource has been compared to terrestrial nickel laterite ores which can be processed via pyrometallurgical or hydrometallurgical means. Although the process development strategies for sea nodules could be drawn from processing of similar terrestrial ores, the exploration, mining and transportation costs are greater than laterite ores. Thus, researchers who had embarked upon newer routes have been drawn into the manganese recovery option to work out a viable route for recovery of all metals. The manganese recovery option is not necessarily connected to the market situation; for recovery of three metals, stability of the manganese containing residue becomes an important consideration, specifically for environmental considerations. The polymetallic nodules resources can thus be compared to low grade manganese ores with higher investment risks where, additional income from copper and nickel recovery is expected to balance the extra costs for exploration, mining and transportation.

Current research efforts globally have realized the importance of manganese recovery, although, these have scarcely been directed towards flow sheet development and subsequent testing for commercial viability. The present thrust is more towards finding alternative reagents which could enhance performance of conventional reagents. Zhang et.al (2001) have described use of specific aromatic reductants in sulfuric acid medium for which laboratory scale studies were conducted leading to solubilization of all metals including manganese. Other potentially novel reagents for manganese nodules have been reviewed by Mukherjee et.al. (2004). Whereas these studies were directed at improving the performance of sulfuric acid leaching, the results cannot be analyzed from the point of view of flow sheet development and subsequent process design.

A major challenge in process design is to assess the viability of processing such a widely varying grade of an oceanic low grade manganese resource for recovery of manganese and other valuable metals. Any process scheme developed for multi metal recovery would need to be assessed from the angle of sensitivity of the proposed scheme to metal throughput and direct chemical costs incurred with input ore grade variation. As any developed process scheme would have certain constraints with regard to the operating variables, the proposed scheme could be optimal only for a certain range of input grades of the raw materials. Chemical composition of these nodules changes from location to location across the vast sea bed. Manganese, which is present as manganese dioxide, is the major metallic component, varying over a wide range of 17 % to 30 %. Other associated metals present in the nodule matrix are of lower proportions in comparison to manganese. The composition of medium grade sea nodules on average vary between Mn: 17 - 28%, Cu: 0.5 - 1.3%, Ni: 0.5 - 1.3% and Co: 0.1- 0.26%. Higher grade sea nodules, as is typically displayed for Pacific sea nodule, have the range of Mn: 24-30%, Cu: 0.8-1.4%, Ni: 0.8-1.4% and Co: 0.16%-0.26%.

The present paper brings into focus the methodology for choosing an appropriate ore grade range for a given process flow sheet. As any developed process scheme would have certain constraints with regard to the operating variables, the proposed scheme could be optimal only for a certain range of input grades of the raw materials. Use of a process optimization strategy would be a vital requirement for that. Pareto optimal solutions can be developed and appropriate decisions regarding the varying grades of raw material to be used for a given flow sheet can then be arrived at. Only use of different optimal solutions, however, may not permit choice of the input grade of nodules; indicative profitability for the different input grades for a given flow sheet under known recovery conditions would be useful to arrive at decisions with respect to ore grades. Thus, the present paper would be dealing additionally with the development of an indicative cost model.