

Life-Cycle Cost Evaluation of Corrosion Mitigation Strategies in the Mining Industry

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ABSTRACT

Corrosion-related challenges are usually addressed during the detailed engineering phase to meet the specified service life of the asset, but a comprehensive strategy to lower corrosion costs is rarely implemented. A life-cycle cost (LCC) analysis is often used to optimize the design and consider direct and indirect costs. The approach allows to quantify the capital and operating costs and costs associated with the failure of assets and potential implications associated with safety and environmental damage. The present paper explores the cost of corrosion in the mining industry and attempts to identify pathways for design optimization. The current work examines the corrosion costs associated with the lithium processing industry using an LCC analysis. The direct cost of corrosion was determined by quantifying the cost of all corrosion-related activities and design, and the indirect cost of corrosion was estimated through industry-accepted models. The effectiveness of corrosion mitigation strategies was evaluated by examining the sum of present value of money. Net present value of money over the design life of the investment and/or the shortest payback period, and/or the highest return on investment (ROI) were briefly discussed as the alternative approaches for identifying the most economic corrosion control system.

Keywords: Corrosion Mitigation, Cost of Corrosion, Life Cycle Cost, Materials of Construction

INTRODUCTION

An economic evaluation of a project plays a significant role in determining its feasibility. Corrosion is intrinsic to the operation of metallic assets, and the costs dedicated to its prevention and/or its consequences are unavoidable. Different corrosion strategies could be developed to address the project's needs while complying with relevant codes and standards. These various corrosion control strategies are characterized by inherently different capital expenditures (CAPEX) and operating expenses (OPEX). Careful analysis of the cost projections for each of the considered corrosion mitigation strategies is needed for project optimization and improvement of return on investment.

The accuracy of the optimization analysis relies on a deep understanding of the governing corrosion mechanisms and the experience of the corrosion engineer in knowing the various corrosion mitigating products on the market. An overly optimistic corrosion mitigation plan will likely have a lower overall cost but may carry a risk of premature failure. Conversely, an overly conservative plan may use a high costing corrosion mitigation strategy that is not justified for the particular application.

Corrosion costs can be calculated in several ways. One of the earliest scientific efforts to estimate corrosion costs was made by Uhlig [1,2], who defined the cost of corrosion as the total expenditure by manufacturing industries and corrosion-protection measures. The Uhlig method underestimated the cost of corrosion. In a direct-indirect cost model [3], the corrosion cost is estimated as the sum of the recognizable direct cost of corrosion control expenditures (the costs that are directly incurred by the owner, including any planned repair or replacement) and the indirect or consequential costs of corrosion (the cost that results from unexpected corrosion incidents).

The life-cycle cost (LCC) method approximates the present value of all relevant costs of corrosion mitigation and alternative corrosion protection systems, including direct and indirect costs, over a specific timeframe [4]. An LCC analysis identifies the corrosion mitigation system with the lowest associated total cost of corrosion. This method is used to determine whether a higher upfront investment is economically justified by reductions in future costs when compared to an alternative system with lower upfront costs but higher operating costs.

Although applying LCC analysis in selecting corrosion control strategies has increased over the past decade, its widespread adoption as a design practice has not occurred yet. The present work demonstrates an application of life cycle cost analysis in evaluating three alternative corrosion mitigation system designs that satisfy the service life of a leach liquor tank system within a lithium processing plant. The aim of this work is to increase awareness about the existing opportunities in the mining industry to reduce corrosion costs and optimize operations during the detailed engineering phase.

LITHIUM HYDROXIDE CASE STUDY

As society searches for cleaner energy sources to drive down carbon emissions, the requirement for battery-grade lithium hydroxide (LiOH) is projected to increase over the next decade. LiOH production plants are comprised of several processing circuits, each operating under different process conditions. The various equipment in each circuit has different requirements for mechanical properties and corrosion resistance characteristics. Although the selected case study focuses on a specific leaching operation, the approach used to evaluate the corrosion cost is considered to be applicable to a much broader set of chemical processing steps. Table 1 highlights the process parameters associated with a leach liquor produced in the leaching phase of the LiOH production.

Table 1: Operating Conditions for the Leach Liquor Storage Tank and the Leach Liquor Agitator. Some of the process parameters have been omitted as per client confidentiality agreements.

Fluid Contents Description	Values
pH	4.8
Fluid TDS (g/L)	81.6546
Solids Content (wt.%)	0.7339
Cl ⁻ Content (g/L)	1.4
SO ₄ ²⁻ Content (g/L)	75
Design fluid temperature (°C)	52
Internal design pressure (kPa(g))	0
Minimum external design pressure (kPa)	0.25

The operating temperature, the pH and the chloride concentration of the solution in the storage tank were specified to be 52 °C, 4.8, and 1400 ppm. The solid content of the leach liquor is 0.7%, and the storage tank and agitator will be subjected to a fluid velocity greater than 0.9 m/s. Thus, in addition to corrosion control, protecting the assets from erosion-corrosion is a key consideration in corrosion mitigation strategy planning.

A general approach to identify the most economic corrosion mitigation plan for the storage tank and agitator is shown in Figure 1. A detailed view of these steps is given in the following sections. This techno-economic approach would result in an optimized corrosion mitigation strategy throughout the design life of the asset.

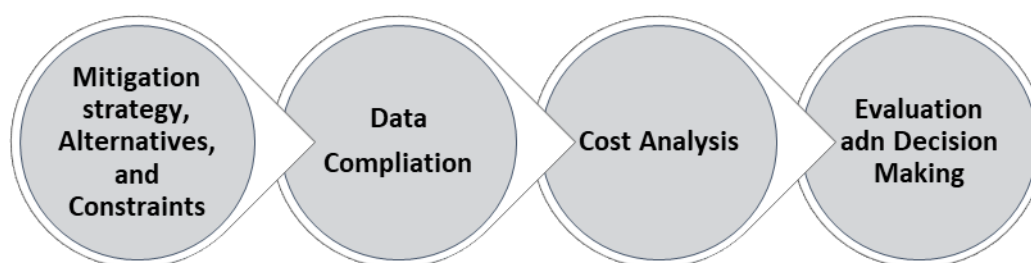


Figure 1: Identifying the most economic corrosion control option.

Mitigation Strategy, Alternatives and Constraints

Material selection to determine the materials of construction for the plant considers the trade-off between upfront capital cost and ongoing operating cost for maintenance. Appropriate material selection is considered to set the foundation for the development of a corrosion mitigation strategy. Material selection considerations should be addressed through each phase of the design process, from the pre-feasibility study to detailed engineering. In each phase, the validity of the selected material should be evaluated to account for any changes in the process that may occur during the design phase.

It is important to note that the material selection study should account not only for corrosion considerations but also address mechanical performance, constructability, and any other factor that needs to be considered by the design. In the present study, the materials that are analyzed were selected on the basis of price, technical merit and availability. Industry best practices, published reports, scientific textbooks, and manufacturer specification data were utilized to establish the expected service life.