Design, startup and operation of the new digestion facility at the Ma'aden Alumina Refinery

Brady Haneman[1] and Brandon Lindsay Rae[2]
1. Director Light Metals (B&A), Hatch Associates Ltd, Australia
2. Technical Manager, Ma'aden Alumina Refinery, Saudi Arabia
Corresponding author: bhaneman@hatch.com.au

Abstract

The sustainable operation of a new high temperature alumina refinery in an emerging mineral processing region with a hot climate provides many unique challenges. Avoidance of operational complexities and reducing the labour intensity more typically associated with these high temperature process plants required a bespoke approach to the refinery flowsheet development and design. The Az Zabirah deposit is a high boehmitic grade bauxite. In assessing the optimal flowsheet, options ranging from a full tubular digest to conventional dual (or split) stream flowsheets and hybrid versions incorporating direct injection heaters were reviewed. Whilst energy efficiency, capital and operational costs were key flowsheet assessment parameters, considerations for maintainability were paramount. As such, the digestion facility for the Ma'aden Alumina Refinery utilizes a new hybrid tube digestion design developed specifically to process the Az-Zabirah bauxite at Ras Al Khair. The refinery incorporates two digestion units that encompass both aspects of tubular digestion technology and more conventional digesters to achieve its nameplate 1.8 Mtpa smelter grade alumina. This paper reviews the unique design and operating solutions developed as well as the operating experiences and plant performance since startup of the Ma'aden refinery in December 2014.

Keywords: Digestion; high temperature.

1. Introduction

The Ma'aden alumina refinery located at Ras Al Khair in Saudi Arabia, is part of a fully integrated aluminium facility and once fully operational, will be the lowest cost aluminium complex in the world. The greenfield refinery has a nameplate capacity of 1.8 Mtpa smelter grade alumina and commenced operation in December 2014. The refinery processes a boehmitic and gibbsitic bauxite from the Az Zabirah deposit. As a result, a high temperature digestion process is employed to extract the alumina.

For a greenfield high temperature refinery operating in an emerging mineral processing region of Saudi Arabia, a strategic flowsheet objective to guarantee sustainable continuous operation was the avoidance of operational complexity and a minimization of labour intensity required to sustain equipment performance and reliability.

During the early phases of the project development, several high temperature digestion processing options were integrated into the refinery flowsheet and examined. Each flowsheet was assessed to provide the optimal balance between energy recovery, capital cost, operating cost, operability and of paramount importance, maintainability. Flowsheet alternatives incorporated a review of high temperature tubular digestion (with jacketed pipe heating), split stream digestion with the liquor heated separately to the bauxite slurry and various hybrid options utilizing both tubular digestion and traditional autoclaves with and without direct injection heaters.

The selected digestion option is a hybrid tube digestion flowsheet utilizing high pressure positive displacement slurry pumps, jacketed pipe slurry heating for the recuperative circuit and traditional autoclaves (or digesters). The gibbsitic alumina is extracted through the jacketed pipe heaters and the boehmitic alumina extraction occurs in the digesters. Pre-desilication is employed to extend recuperative heat transfer life.

2. Flowsheet overview

Figure 1 below represents a simplified flow schematic for the “hybrid” digestion facility. Multiple trains of single stream jacketed pipe heaters fed by positive displacement triplex piston diaphragm pumps are used to digest the gibbsitic alumina. The slurry is further preheated up to a controlled recuperative temperature limit of ~ 200 °C. This limit is selected so as to avoid titanate scale formation through the heater tubes.

In limiting the recuperative temperature to this target, the aim is to avoid the requirement for on-going and labour intensive mechanical cleaning of the elevated temperature heater tubes with high pressure water jet blasting (or other means). Pre-desilication is incorporated into the slurry feed circuit using direct contact heaters. The targeted cleaning requirements for the digestion heater tubes is an estimated 9-10 week rotational cycle for acid cleaning to remove sodalite scale only.

After discharging from the jacketed pipe heaters, the slurry is then heated to 270 °C in digesters. The digesters are sized to provide sufficient residence time for the boehmite extraction. Direct steam injection is used to attain the requisite temperature for the reaction. The slurry is then flash cooled through the flash vessel train to atmospheric boiling point prior to being pumped to the clarification circuit.

As a result of the recuperative limit of ~ 200 °C there is more energy available to be liberated from the vessel train than can be practically absorbed in the slurry heating circuit. Export steam from the flash tanks is therefore used as the low pressure live steam supply for the evaporation circuit live steam heaters supplying all low pressure steam demand. Additional low pressure and temperature steam from the flash tanks is used as export steam to both the pre-desilication direct contact heaters and the mill liquor heater.

To further reduce the energy usage for the refinery, additional energy recovery optimization features were incorporated into the process design. These include export of both, digestion condensate and evaporation “live steam” heater condensate (from the flash tank export vapour), back to the boiler-plant. Mid pressure and temperature condensate from the digestion unit is exported via plate heaters in the boiler-plant to exchange heat with the boiler feedwater. The subcooled mid pressure digestion condensate is then mixed with low temperature digestion process condensate as the initial pre-heating stage of the boiler feedwater.

6. Conclusions

This paper outlines the strategic elements of the flowsheet development and digestion facility design incorporated into the new Ma'aden alumina refinery in Saudi Arabia. The flowsheet and detailed design sought a critical balance between refinery energy targets, operational flexibility and equipment maintenance activities, to provide a facility unburdened by many of the more typical labour intensive commitments found in other high temperature alumina refineries.

The digestion facility employs sufficient equipment sparing to provide near continuous facility operation and additional process control features to maintain optimal process performance.

7. Acknowledgement

The input and support from Ma'aden and Alcoa in the flowsheet development and project execution is kindly acknowledged.

8. References

1. Haneman, B., Wang, A. Optimising Digestion Flash Tank Design for the Alumina Industry, Alumina Quality Workshop, 2010.