Modern Efficient Alumina Refinery Digestion Design

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Abstract

Safety, operability, high availability and stability, optimum alumina recovery, capital efficiency and energy efficiency are key features in any alumina refinery digestion design. Digestion is a critical part of the Bayer process and must be designed to consider current and future production rate plans.

Worley was challenged by the owner of a partially constructed but stalled alumina plant expansion to redesign the digestion plant and deliver an improved refinery-wide design that would set industry benchmark performance and product quality metrics with significantly improved safety, availability, operability and maintainability, energy efficiency, and capital efficiency. The improved Digestion design includes a modified flash vessel bottom feed arrangement with specifically designed internals, targeted changes in valve, equipment, and pressure relief arrangements, as well as redesign of slurry heaters to reduce erosion and blockages.

The result of the design changes will increase heat recovery and provide a 40 % increase in throughput compared to the original design, as well as a step change in availability, reliability, stability, and safety. The improved heat recovery will contribute to reduction in overall energy consumption and carbon emission in the refinery.

Keywords: Waste heat minimisation, Availability and operability, Digestion throughput, Safety, Flash vessel internals.

1. Introduction

The Bayer process, used worldwide predominantly for production of smelter grade alumina from bauxite, is a hydrometallurgical process. In simple terms bauxite is leached with a caustic soda solution at elevated pressure and temperature to dissolve alumina. The dissolved alumina in the pregnant liquor is then separated from the insoluble residue before being precipitated in a granular form suitable for smelting to aluminium.

The digestion process is a critical section to the design and performance of the Bayer plant in both production (extraction of alumina) and energy consumption (nearly one third of the overall energy consumptions). Several important publications are available in the literature regarding fluid-dynamic aspects, optimization, safety relief and energy improvement in flash processes. See Fort [1–4], Thomas [5], Henrickson [6] and Furlong et al. [7] for more details.

Any loss of flow or yield in digestion causes a production loss. Any new refinery design is expected to have very high energy efficiency to reduce energy costs and minimise carbon emissions, high volumetric throughput, maximum equipment availability, and the highest level of safety possible to maximise the production rate.

Due to the high process scaling rates occurring in Bayer plants, regular descaling is critical to ensure the performance of all heat transfer equipment is as close to design values as possible. To allow this cleaning with no loss of production, spare equipment must be installed. The challenge then becomes how to provide the required spare equipment with low overall capital cost to maximise investment return. In alumina industry, it is sometimes required to modify an existing design for a particular Bayer plant to meet updated owner's requirements for production rate, performance, safety and / or capital cost etc.

In the case study presented in this paper, a digestion design was previously completed with three digestion lines with a targeted production rate of 1 Mtpa (million tonnes per annum) in each production line.

Some equipment had already been procured and installed in a partially constructed plant. The project was then put on hold for several years. Subsequently, the owner wished to revitalise the project with a new requirement to provide an overall production of 2.8 Mtpa utilising two of the three digestion units, corresponding to a 40 % increase in production per unit, whilst re-using existing procured / installed vessels were possible.

A parallel goal of the project was to maximise energy efficiency with the minimum specific energy consumption in digestion, which is an important step to minimise with the aim of eliminating carbon emissions in the refinery.

Worley was awarded the contract to modify the design of the existing equipment. This presents additional challenges in development of analytical tools:

- To study the performance and limitation of the existing design and equipment;
- To improve the existing design and equipment and increase the throughput, availability, and stability.

This project has proven itself to be challenging and innovative. The purpose of this paper is to present this excellent case study to the alumina industry.

2. Brief Description of the Original Design

The digestion technology used is a single stream low temperature process at 145 °C with 55 minutes residence time in eight digestors. The slurry heating is achieved via three stages of shell and tube recuperative heating by flash steam from three stages of flash tanks. The slurry is finally heated up to 145 °C by the fourth stage of shell and tube heating using live steam.

Construction of two digestion units was reasonably advanced whilst the third unit was barely started. The aim of this project is to increase the digestion flow by ~ 40 % while maximising the installed equipment in the two trains with minimal modifications.

To increase the digestion flow by ~ 40 %, the existing shell and tube heating design does not have sufficient capacity nor the required pressure rating. The project therefore, decided to apply a revised shell and tube heat exchanger design to accomplish the heating duties.

Other limitations for the flow increase by the original expansion design are:

- Relief and blow-off system:
    - The original design in relief system does not meet the environmental standard of the modern alumina refinery. For example, only a small local relief pot was provided for direct relief to atmosphere.

maximises energy efficiency through recovery of vapor from the blow off tank keeping carbon footprint low.

The future design in Digestion must also focus on decarbonisation of the energy supply and how this is integrated into the Digestion and rest of the refinery. Waste heat from the refinery can be electrified and supplied to Digestion as steam to further reduce carbon emissions. The Digestion design enables efficient means of electrification by requiring a low steam pressure as per the paper by Furlong et al. [7]. Flash vessels may potentially be removed altogether if downstream processing such as decantation and filtration are done at 145 °C.

Worley has also demonstrated that preconceived barriers to upgrading legacy flash vessel technology in older refineries to modern standards need not be as pervasive as expected.

Modern digestion design is likely to continually evolve for improved energy efficiency, safety, and operability in line with mega-trends of decarbonisation, sustainability and digitisation (predictive maintenance and process optimisation), in which Worley is taking an active role.

6. References

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