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A novel low grade heat driven process to re-concentrate process liquor in alumina refineries

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ABSTRACT

Evaporation is an essential process in alumina refineries both to produce water for such applications as residue washing processes, and re-concentrating process liquor back to the main process circuit for further digestion. This article reports on the application of a re-concentration process driven by low grade heat. It couples flash and falling film evaporation, fed by a low-grade heat source, to recover heat and concentrate process liquor. Process condensate is the stream used for this evaluation. The condenser of the re-concentration process is cooled barometrically by water from the recovery lake. The freshwater generated is either discharged or sent to the freshwater lake so as to manage the water balance of a refinery. For 200 m^3/h process condensate simulated at two fixed temperatures of 75 °C and 85 °C, the process generates up to 36% more re-concentrated process liquor, and about 10% less specific capital cost compared to the conventional multi effect falling film evaporation system.

1. Introduction

The evaporation process is one of the key parts of an alumina refinery. It consumes a large amount of thermal energy. It controls the water balance of the plant, and provides liquor for digestion and fresh water for washing and impurity removal. Evaporation is typically run by low pressure steam and is one of the more energy intensive sections in an alumina refinery plant (Liu et al., 2006). Improvements in evaporation therefore reduce steam consumption, which saves the fuel and reduces greenhouse gas emissions.

Evaporator has to suit process liquor which is viscous and prone to scaling. Tube falling film and flash evaporators can be used. A plate falling film evaporator is used by Aluminum Company of Shanxi and Guizhou Alumina (Chen, 2006; Jiang, 2004) to improve the evaporation efficiency in evaporation of low concentration feed streams. A state-of-the-art pilot plant consisting of two serially connected Alfa Laval's single-effect rising film plate evaporator/condenser modules (Christ et al., 2015) is being tested in Worsley Alumina Refinery Plant to study potential scaling issues when it is coupled to different process streams (Fig. 1).

Evaporation and flashing configurations are shown in Figs. 2 and 3. Independent of evaporator type, a multi effect evaporation (MEE) process is the preferred choice to reduce energy consumption. In the falling film technique, the feed liquor enters the evaporator from the top, which is specially designed to distribute the feed into the tubes. Gravity pulls the film down along the inner walls of the heater tubes, so that the fast moving and thinning film gives rise to a high heat transfer coefficient (Glover, 2004). At the bottom of the heat exchanger, the feed stream is re-concentrated. The outgoing vapour from the first effect can be the heat source of the second effect, and this trend continues through to the last condenser.

Alternatively, a combination of heat exchangers and flash vessels known as multi stage flash (MSF) can be used (Fig. 3). In this system, the feed liquor is preheated in a series of heat exchangers (preheaters) and is then introduced to a battery of flash vessels. The flash vapours from the vessels are condensed in the preheaters, and the highly concentrated feed from the last outlet is the final product of the evaporation unit. The first heat exchanger in this system uses the available live steam as the heat source.

This article introduces a novel process (Rahimi et al., 2014a, 2014b; Rahimi et al., 2015a; Rahimi et al., 2015b) that can be coupled with waste heat sources in an alumina refinery plant to reduce the steam consumption of the evaporation unit. This reduces fuel consumption, greenhouse gas emissions and production cost (Rahimi et al., 2015c). It should be clarified that the novelty herein lies with the process design instead of the process units themselves, the latter are simply standard technologies. The fact that standard process units are used augurs

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Fig. 1. The two serially connected Alfa Laval's single-effect rising film plate evaporators modules (JWP-16-C Series) (Christ et al., 2015).

well for scale-up adoption in refineries. For illustration purpose, we elect to focus on one available waste heat stream that comes out from an evaporation unit of Worsley Alumina Refinery Plant. This stream is the outlet process condensate stream of the main evaporation unit (Fig. 3, MSF Process). The technique can potentially harvest all available sensible waste streams to run an auxiliary evaporation unit so as to reduce the load of the main evaporation unit (Rahimi et al., 2015c).

Rahimi et al. (2014a, 2014b, 2015a, 2015b) developed a process that can be coupled with low grade waste sensible heat streams to boost freshwater production as compared to the conventional MEE process. Fig. 4 shows the flash boosted MEE (FB-MEE) process when it is coupled with the outlet process condensate of the evaporation unit (Rahimi et al., 2015c). The available temperature is around 85 °C. The simulation has also been done for 75 °C.

As shown in Fig. 4, the process condensate (inlet sensible heat source) is first used to power the primary MEE section, and then to heat the feed stream which supplies the flash vessels. Each vessel produces flash vapour which is directed to an appropriate primary MEE effect according to the relevant pressure differences, thereby supplying more heat and increasing the amount of feed which can be evaporated across the MEE effect. The result of this vapour injection scheme is an increase in freshwater production and re-concentrate flow across the primary MEE effects. The number of falling film evaporation effects can be set based on the available temperature difference between the heat source and the cooling water temperature and the relevant boundary conditions (Rahimi et al., 2014b; Wang et al., 2011).

2. Numerical analysis and validation

A simulation model has been developed to quantify the efficiency of the flash boosted MEE system (Rahimi et al., 2014b, 2015c). The

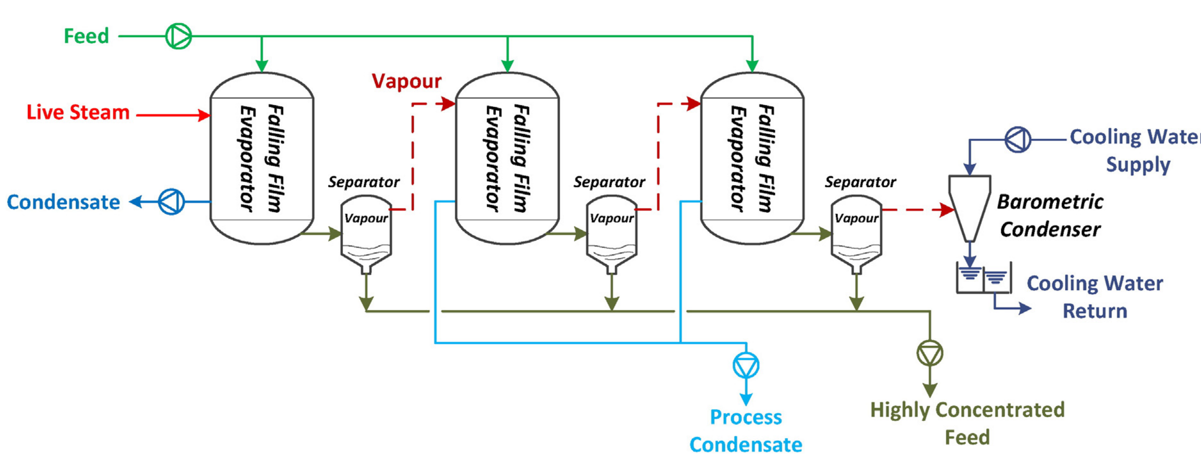

Fig. 2. Schematic design of a multi effect evaporation (MEE) unit in alumina refineries.