Improvement of Spent Liquor Evaporation at RUSAL Krasnoturyinsk

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Abstract

The spent liquor evaporation unit at RUSAL Krasnoturyinsk uses four-effect counterflow - straight-flow evaporation trains equipped with natural circulation and rising film evaporators. These evaporating trains have a number of significant drawbacks due to the fact that boiling of liquor takes place in heater tubes which causes high abrasive and erosion wear on the tubes and consequently a decrease in service life. In the course of operation, sodium carbonate and aluminosilicate scale builds up in the heater tubes. It should be noted that superheated steam is supplied to the evaporators from turbine pressure steam (TPS). These drawbacks lead to decrease in capacity utilization and production rate of the evaporation train, increase in steam consumption, as well as reducing the service life of heat exchanging tubes. The paper presents technical, structural and process solutions to improve technical and economic efficiency of evaporators.

Keywords: evaporation, efficient heat exchangers, reduction in steam consumption.

1. Introduction

In alumina production used as raw material for aluminum smelting; evaporation process is of great importance. Aluminate (so-called spent) liquors resulting from precipitation of aluminum hydroxide from alkaline aluminate liquors formed in the process of bauxites digestion with caustic soda undergo evaporation. In the course of evaporation, water fed into the process for dilution of autoclave slurry to improve red mud separation is removed from spent liquors; caustic soda contained in liquors is concentrated and crystal sodium carbonate is extracted. The formed solid phase is separated from liquor on filters and fed to alumina production by sintering. Filtered strong evaporated liquor is fed to bauxite grinding [1.2]. At domestic alumina refineries processing bauxites by Bayer process, one of the major components in alumina cost is the cost of thermal energy [3]. Hence, an important objective is to minimise energy consumption during the evaporation process and to improve operation efficiency [3].

In alumina production of RUSAL Krasnoturyinsk, the evaporation process includes four-effect counterflow - straight-flow evaporation trains comprising natural circulation and rising film evaporators [4]. The practice of operation of these multi-effect evaporators has shown that these evaporators have a number of essential design faults caused by boiling of liquor in heater tubes. In the course of operation soda and aluminosilicate scale intensively grows in the heater tubes. Besides, scaling of heater tubes with salt reduces heat exchange intensity that leads to considerable decline in production of the evaporator train. Boiling of liquor in tubes of evaporators causes enhanced abrasive and erosive wear of heating tubes, service life of tubes achieves about 1.5 - 2 years, then they need to be replaced which requires significant labor costs [5].

Process flowsheet has also a significant impact on operational and power data of evaporators. Evaporators used for concentration of spent liquors comprise some countercurrent elements. It is caused by a reverse nature of solubility of sodium hydroaluminosilicates [6].

Besides, a system of liquor heating has a significant impact on power consumption and capacity of evaporators. Shell and tube type heaters are an integral part of the evaporation train and are inclined to intensive scaling with aluminosilicates. Some modification were carried out in the past on the multiple-pass heaters of liquor to one-pass heaters. It reduced somewhat blockages with scale, but led to manifold decrease in intensity of heat exchange and deterioration of evaporator train performance in general. Therefore, an important objective is to improve heaters design to provide longer life and intensive operation [7].

In alumina production at RUSAL Krasnoturyinsk steam is fed to evaporators from TPS at pressure of 0.5 - 0.6 MPa (5 - 6 kgf/cm^2) and temperature 230 - 260 °C, obtained as a result of reduction of high pressure steam selected from turbines.

Thus, superheated steam is fed to heating chambers of evaporators. As a result, intensity of heat transfer from steam to the wall of heat-exchanging tubes leads to decrease in productivity of the train as a whole. Besides, heating of evaporators with superheated steam leads to increase in thermal stresses in heating chambers decreasing service life of heat-exchanging tubes. They fail and should be replaced

Therefore, to avoid the specified negative effects it is necessary to cool steam to the temperature close to saturation before feeding to a heating chamber. It allows to reduce to some extent specific consumption of steam for evaporation and raise evaporator capacity and, most important, to increase by 1.5 - 2 times service life of heat-exchanging tubes of evaporators fed with cooled steam [8].

The above shortcomings in operation of the existing evaporators at RUSAL Krasnoturyinsk lead to significant increase in cost of evaporation of spent liquors. Aiming to eliminate these shortcomings, work was carried out to determine conditions for application of equipment for heating of liquor and cooling of steam. Optimum designs were chosen of liquor heater for evaporators and cooler of steam directed to the evaporator, comparison was made of the proposed designs with the existing ones on the basis of hydraulic simulation, scale growth in tubes was assessed.

2. Design Description of the Existing Heaters

A one-pass shell and tube heater with tubes of 6 m long and diameter of shell 1.2 m is installed in the evaporator. The number of tubes in this device is 192, and heat-exchanging surface area (by average diameter of tubes) is 193.5 m^2. There are also heaters with tubes 5 m long in the evaporation area. The number of tubes is 254 and 236, and the area of heat-exchanging surface (by average diameter of tubes) is respectively 213 and 198 m^2.

Originally, the evaporators were equipped with four-effect heat exchangers. However, the heaters scaled excessively . As a result, hydraulic resistance increased so that transfer pumps failed to pump liquor via heaters to evaporators. Therefore, heaters were shut off, liquor bypassed the heaters, and evaporators operated without them.

Coefficient of a heat transfer of such heaters, makes 250 – 600 W/(m^2×K), depending on heating steam pressure.

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