Optimization of Alumina Precipitation Circuit Arrangement using Simple Modelling Tool

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Abstract

Some fifty years ago, most alumina plants had precipitation circuit operating in batch. For reasons of efficiency and productivity these were converted to what has been called since then Continuous circuit. From that point on all new refineries were built in such a way, somewhat forgetting that despite its negative aspects (operation complexity, manpower, etc), the precipitation rate is always at its highest during batch operation. The tendency to build bigger tanks to save on capital costs and also installing some of tanks in parallel, is moving away from optimum which is a large number of small cascading tanks (quasi plug flow or batch operation). Of course, the losses from this optimum are at least partly offset by the gains in operation simplicity. For some refinery, parallel tanks are a way to reduce slurry bypass for instance. This paper shows how simple mathematical tool can be used to quantify the deviation from optimum and for conceptual stage find the optimum arrangement of tanks and their sizes depending of the classification strategy and cooling capacity.

Keywords: Optimization, Alumina, Production, Precipitation, Modeling.

1. Introduction

The Alumina industry is now well into its century of history and improvements to every aspect of the process are too many to count. In the early years of alumina industry, the possibility of pneumatic or electric control were only used in area where it was needed, like high temperature and pressure. The precipitation area was run in a much simpler way using batch tanks. Changes happened gradually facilitated as technology allowed to reduce cost and increase productivity: either simplification of the process or reduction in manpower requirements. The major change in the precipitation area from batch operation to continuous operation achieved both.

From that point in time, mid-seventies, all new plants were built with a continuous precipitation circuit with tanks progressively bigger as technology allowed [1]. The justification for bigger tank is a significant reduction in capital cost and allowing longer precipitation time, hence higher productivity. But bigger tanks caused problems of civil and mechanical engineering, that needed to be addressed in the same time as the requirement to maintain an adequate slurry suspension in the precipitators. Scaling in the tank became an issue at high supersaturation at the front of the circuit, and many configurations were designed over the years to solve all of the issues [2]. But in the same time as resolving these some precipitation efficiency got lost. This paper describe how it might have happened.

2. Aspect of the Precipitation Circuit that can be Optimized

In order to optimize the precipitation circuit, it is important to understand what drive the precipitation rate of the reaction. As it has been documented in many articles [3], the reaction depends mostly on supersaturation (second order) temperature and seed surface. The latter being a factor that is much harder to try to influence.

By far the strongest factor is the supersaturation which means that basically as the solution is depleted progressively in alumina, the reaction slows down until the solution reaches the solubility. But in industrial practice this never happens as it would take too long a residence time; which would not be economical.

Temperature is also a strong driver and has two antagonist/contrary effects, one on the reaction rate (higher temperature is faster) and the other via the supersaturation (higher temperature lower supersaturation). This means that for a given aluminate concentration there is an optimum temperature.

Another factor that is often overlooked is the reactor type, batch or continuous, as this choice is normally part of the design/history of the plant. Basically, the reaction is always faster in batch mode as it has the highest supersaturation all the time as the reaction proceed. Continuous reactor can approach this rate if they are close to Plug Flow. This can be achieved using a multitude of very small reactors.

The reason behind this is that the reaction rate is averaged for the whole residence time in a continuous reactor and this concentration reached at steady state is lower than what would be achieved for the same time in batch mode, and the difference is also more important for a reaction of the second order. This has been well documented in reactor technology [4] and is illustrated in figure 1, where a succession of two reactors of 4000 m^3 is compared to one big tank of 8000 m^3 and the corresponding reaction time in a batch reactor 3.5 hr. The highest A/C ratio (lowest productivity) is achieved with the single tank at 0.557. The ratio after the second small reactor is significantly lower at ~0.537 and the batch reactor is by far the lowest at 0.503. However, one can already see that this difference is getting smaller for the 3rd small tank.

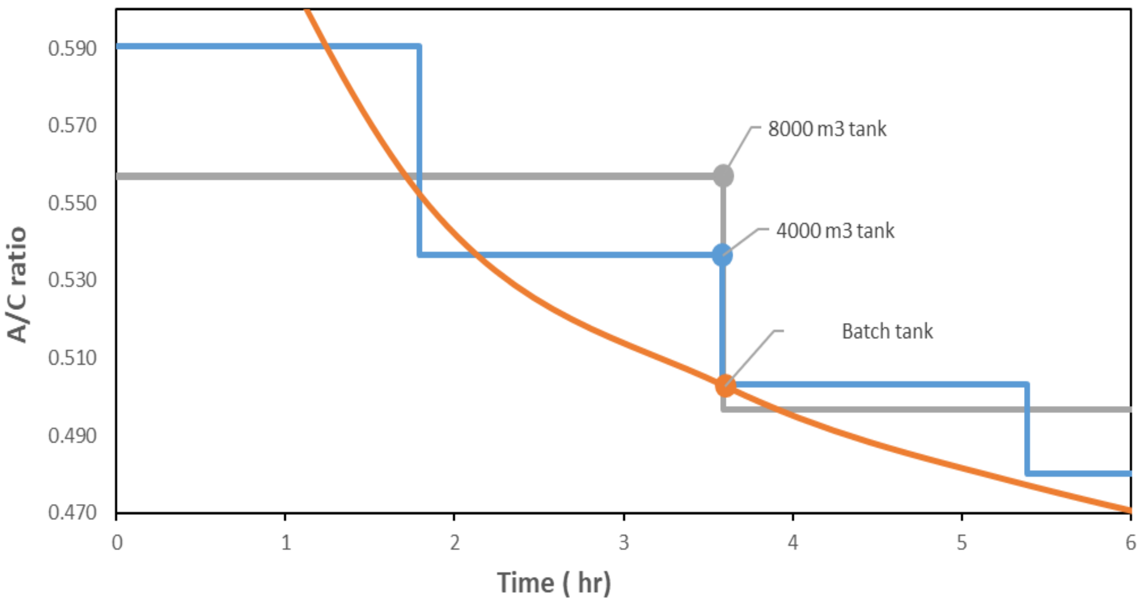

Figure 1. Comparison of ratio changes with time with different tank sizes.

The next graph, figure 2, is done for a succession of small tanks of 4000 m^3 to illustrate this latest point. Hence, the difference between the line and the series of tank is becoming smaller and smaller towards the end of the series. Which means that for a longer residence time, or a liquor with less impurities, the difference between the two modes becomes less significant, but still exists.

Like for the other factors studied, the difference starts large but gets much smaller before the end of the circuit. So, we could assume that if the bypass is mostly present in the first few tanks, that the productivity loss is even less important.

6. Conclusion

A series of comparisons aimed at identifying the importance of several key factors for production in the precipitation area were performed using a spreadsheet simulation tool. The comparisons showed that many of the general assumptions of what influence productivity do not necessarily play as important a role as initially thought.

The role of the tank size and the arrangement in continuous, batch or in parallel is important and could potentially lead to important productivity gains if applied appropriately; particularly for older refineries which are considering converting to continuous while leaving some of the precipitators operating in batch mode. Using a spreadsheet tool like the one demonstrated here, should be seen as a first step. For a better and full analysis of all scenarios, more complex tool like SysCAD or Aspen would be advisable.

7. References

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