JA221

Aughinish Improves Alumina Processing

By Edward Throp, Fluent Europe Ltd., and Curtis Marsh, Aughinish Alumina

Computational Fluid Dynamics (CFD) gives the ability to virtually analyze fluid flows accurately in a relatively short time-frame, and can be applied to all manner of chemical engineering problems. In this example, its application to the optimization of a separation process at one of Europe's biggest refineries is explained.

Aughinish Alumina, a subsidiary of Glencore, is an alumina refinery situated on Aughinish Island between Askeaton and Foynes, on the west coast of Ireland, 20 miles downstream from Limerick city. The company uses the Bayer process to produce alumina (Al_2O_3), a substance that is used in the production of aluminum and also in industrial ceramics. Over the period the refinery was constructed (1978 - 1983), Aughinish was the largest construction project in Europe, representing an investment of €1 billion, making it the largest ever single private investment in the Irish economy to that date. In the first year of operation, the refinery was producing approximately 640,000 tons of alumina per year. However, the success of the plant and the demand for its alumina product has led it to a steady increase in production, to the current level of 1,600,000 tons per year. A major capital investment is currently underway that will further increase production to 1,800,000 tons per year by 2006.

The company has faced a problem, however, in that the final flash tank in a series of eleven was designed to operate at a capacity well below that needed for such an ambitious increase in production.

In the Bayer process used to extract alumina, bauxite ore is ground up and dissolved in sodium hydroxide at a pressure of 5000 kPa, and at a temperature exceeding 250°C, forming a liquor of sodium aluminate. At this point, the liquor is passed through a series of flash tanks to recover the energy invested in the process and separate the hot vapor from the liquid. The liquor is then placed in a precipitator and seeded with alumina hydrate particles. Crystallization takes place, and larger particles are formed that are subsequently separated from the liquid. The final product is formed by calcining the alumina hydrate at very high temperatures to remove the water molecules, producing the end product of alumina.

The flash tanks work by facilitating the separation of the steam from the caustic liquor solution. The liquor enters the flash tank through an inlet tee

Figure 1: A CFD simulation of the original design, showing the problem of liquor entering the flash tank through the inlet tee and bouncing back off the liquor residing in the bottom of the tank and up the flash tank wall

running off the entry pipe. As the liquor enters the tank, the lower pressure and velocities within the vessel allows the steam vapor to separate from the liquor droplets. The steam gravitates upwards to an exit pipe at the top of the tank where it is drawn off to a series of heat exchangers to recover the energy. The liquor falls to the bottom of the tank where it is collected and directed into the next flash tank.

The final flash tank in place in the refinery is relatively small considering the planned increase in capacity. However, replacing it with a larger tank was dismissed as an option as it would prove extremely costly. The main issue with keeping the smaller tank as presently designed was that problems already occurring would be exacerbated with an increase in production. These problems were as follows: the steam was not efficiently separating from the liquor solution, leading to a poor quality, particulate-laden steam being drawn off; the particulate matter in the steam was then prone to deposition on the walls of the tank as scaling. This further reduced the volume of the tank, which impacted upon the efficiency of the separation process within the tank, and restricted access to the tank to repair worn fittings due to the instability of the overhead scale.

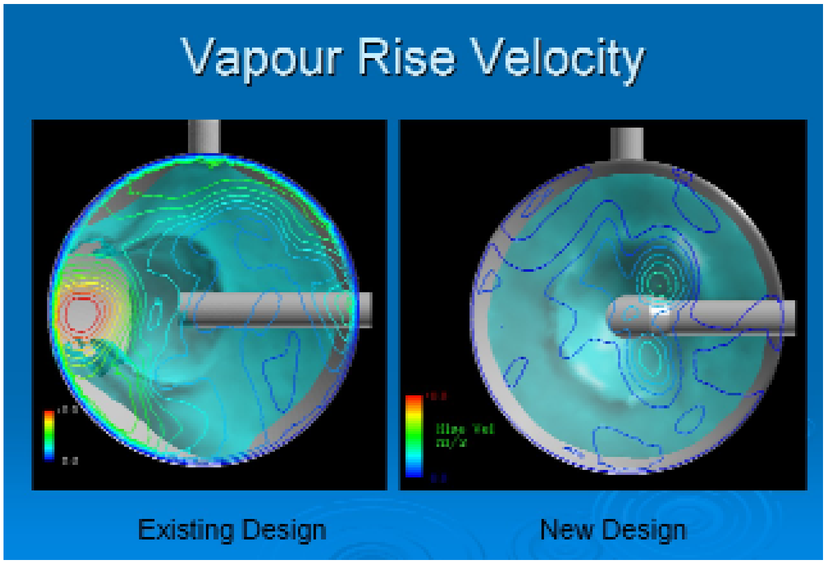

Figure 2: CFD simulation showing the existing design on the left, with the flow forced up the flash tank wall towards the exit pipe at the top of the flash tank, and the new design to be fitted on the right, with pathlines showing even distribution of flow throughout the middle section of the flash tank

Additional scaling was occurring around the outlet nozzle at the top of the tank and narrowing the exit piping, increasing the pressure within the tank. This produced higher velocities of steam flow leaving the tank, again resulting in a reduced quality of drawn off steam. Furthermore, this produced scaling problems affecting the operation and maintenance of the connected shell and tube heat exchangers. The thickness of the scaling at the outlet piping necessitated the annual replacement of valves in these lines, at significant cost to the company.

A separate, yet significant problem experienced was that of erosion of the inlet tee by the particulate matter contained in the liquor. Both this problem and those of the inefficient separation leading to scaling, are magnified by the increase in volume of liquor passing through the flash tanks at the higher production rates.

The Aughinish refinery keeps more than 250,000 m^3 of process solution continuously circulating through tanks, pressure vessels, and pipes for 364 days a year. For just 24 hours per year, operations stop to allow for repairs and maintenance. Any further stoppages in production are unacceptable due to the loss in revenue that would be incurred. This means that opportunities to implement or test alternative design options are extremely limited, particularly when the tank size and amount of scaling that requires removal are taken into account. It also means that any unsuccessful design changes implemented would have to remain in place for 12 months before they could be corrected.

Prior to using CFD, the design of this type of equipment was limited to past experience and knowledge of existing plant performance (scaling rates/condensate quality/erosion rates). There are rules of thumb for what size tank is required in order to achieve good separation, but very limited information on how to improve the existing tank given the design criteria. Since replacing the tank had been dismissed as an option, CFD became the only viable option to find a solution.

Aughinish Alumina used FLUENT to conduct its CFD study. Initially the existing flash tank was studied, to give an understanding of the dynamics of what goes on within the vessel where separation should occur. The flow of the droplet-laden vapor into the flash tank was investigated using a

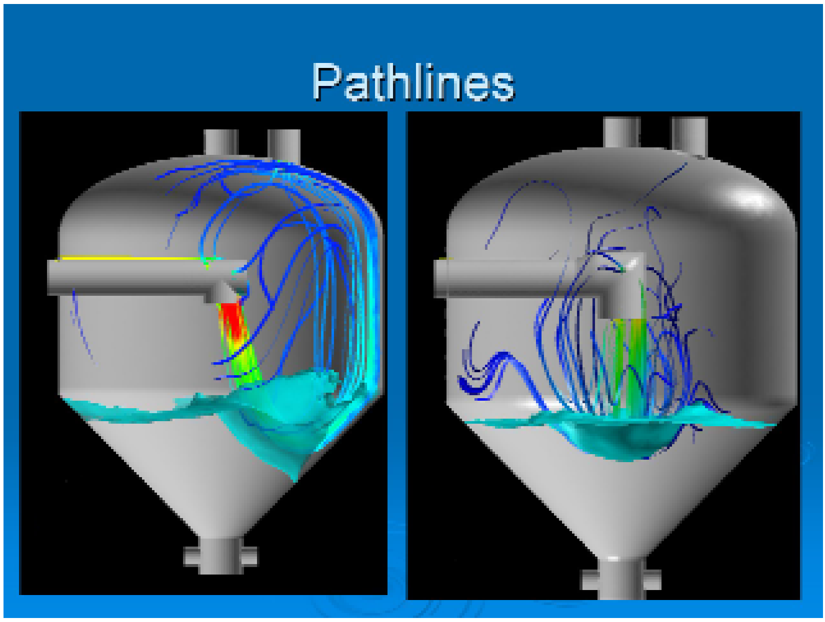

Figure 3: CFD simulation showing the existing design on the left, with high velocity of vapor rising around the walls of the flash tank, and the new design on the right, with an evenly distributed, reduced vapor velocity

multiphase model, in a transient simulation with relatively small time steps. The model contained 700,000 tetrahedral cells and took several days to arrive at a stable solution. The results showed engineers for the first time, exactly what was happening inside the flash tank. New insights were gained into the interaction between the inlet jet and liquid surface in the lower section of the tank, and demonstrated the effects of operating at different liquid levels in the tank. Engineers were also able to see the importance of the internal geometry of the inlet tee, and how the direction of the vapor jet affects the upward velocity profile of the vapor and turbulence in the upper sections of the flash tank. Using the DPM model in FLUENT, they were also able to study the erosion effect of the particulate matter on the inlet tee.

From the CFD analysis it was clear that the design of the inlet tee on the entry pipe was such that the droplet/vapor liquor stream was entering the tank at high velocity, and from an angle that meant it was penetrating the liquor solution residing in the tank, and forcing an increased amount of liquid drops back up the tank walls towards and then exiting the steam outlet at the top of the tank. This was preventing efficient separation of steam and liquid droplets, leading to the poor steam quality and considerable scale build up.

The speed and ability of CFD to virtually simulate fluid flow proved particularly useful in investigating a final design to minimize the problems described, and enable the flash tanks to operate successfully during increased production. A variety of design ideas were interrogated to test the effect on outlet velocity profile, jet trajectory, and flow profiles within the tank. The erosion rates of the new designs were also estimated and compared to the erosion rates experienced with the existing design. This allowed high-wear areas to be identified, allowing specific materials designed to combat this to be selected. From this data and the 3-dimensional visualizations produced, a final design solution was identified that indicated a reduction of velocity exiting the internal discharge tee within the tank from 100 m/s to an evenly distributed 60 m/s. The upward flow of vapor was also shown to have become evenly spread around the vessel, with the peak upward velocity of vapor reduced by a factor of five.

The installation of the design changes was implemented in the latter half of 2004. The benefits of using the virtual approach offered by CFD are clear. The option of halting production and installing a larger flash tank was avoided, along with the costs involved. As various design alternatives could be developed and evaluated without stopping production, the unpalatable prospect of creating a single new design, implementing it, and evaluating it over the next year to check its success, was avoided. A far better understanding of the flow dynamics inside the vessels was gained, benefiting the new design work and continued operation of the equipment. Using the erosion model available also allowed the most effective erosion resistant material to be selected. Finally, there are expected to be significant savings in the money that has to be spent on removing scale and replacing operational parts.

The case study outlined here is just one of many projects for which CFD has proved invaluable in optimizing separator or filter operations, quickly and cost effectively. Other examples include the optimization of cyclone classifiers and in-line filters.