CFD Modeling Proves up Novel Ideas in Thickener Feedwell Design

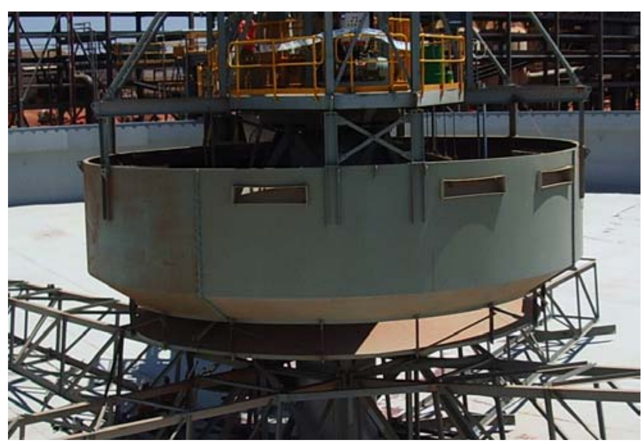
Author: Ian Arbuthnot

The well-known Outotec (Supaflo) closed bottomed thickener feedwell provides a flow regime which produces good flocculation and feed distribution. However, on larger "flat aspect" feedwells, there is a tendency for high density feed material to short-circuit to the feedwell exit, resulting in insufficient floc aggregation and momentum dissipation.

Significant short-circuiting in the feedwell creates a number of operational problems in High Rate Thickeners. These include:

1. Excessive use of flocculant which increases operating costs and can lead to "donuts" forming in the thickened bed.
2. Uneven distribution of feed into the thickened bed which can lead to slumping and high torque excursions for the rake drive.
3. Poorly flocculated feed exiting the feedwell that forms a plume on the surface of the thickener and results in solids carry over into the clean water launder.

(It should be noted that despite the phenomenon described above, the Outotec design with its restricted outlet configuration is nevertheless superior to an open bottomed cylindrical feedwell, in which the bypassing of feed material is much worse.)



Two design ideas were proposed to improve the flow regime in large feedwells:

1. The introduction of vane-type baffles, radially disposed within the feedwell at the level of the feed pipe invert.
2. Re-orientation and extension of the patented Outotec "Autodil" slots to produce "directional flow" of dilution water, hence enhancing the flow dynamics within the upper mixing zone of the feedwell defined by the radial vanes.

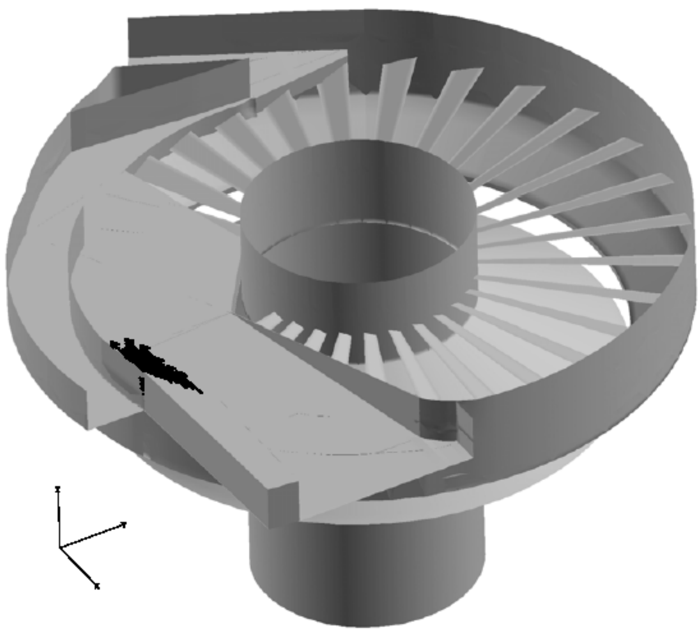


Fig. 1: Baseline geometry used in runs 1-3. Feed comes in tangentially as per black vectors, centre left

A baseline feedwell design was done using a real set of process parameters, typical feedwell size and incorporating the above ideas. CFD analysis was applied to test the effect of the ideas, and then arrive at an optimum physical configuration. After some 12 months of in-house CFD modeling with variations in layout and reconfiguring the design, Outotec approached CSIRO for validation. The validation work was carried out by the CSIRO in Melbourne using as a basis the CFD Models developed and tested in the AMIRA P266 (Improving Thickener Technology) Project, of which Outotec is a sponsor.

The baseline design is shown in Fig 1, which was used to set up the model and the first simulation, then analysed to identify limiting factors, e.g. short circuiting.

The first CFD simulation, Run 1, using the baseline geometry and a feed rate of 2158m^3/h, produced the following flow and shear rate pattern:

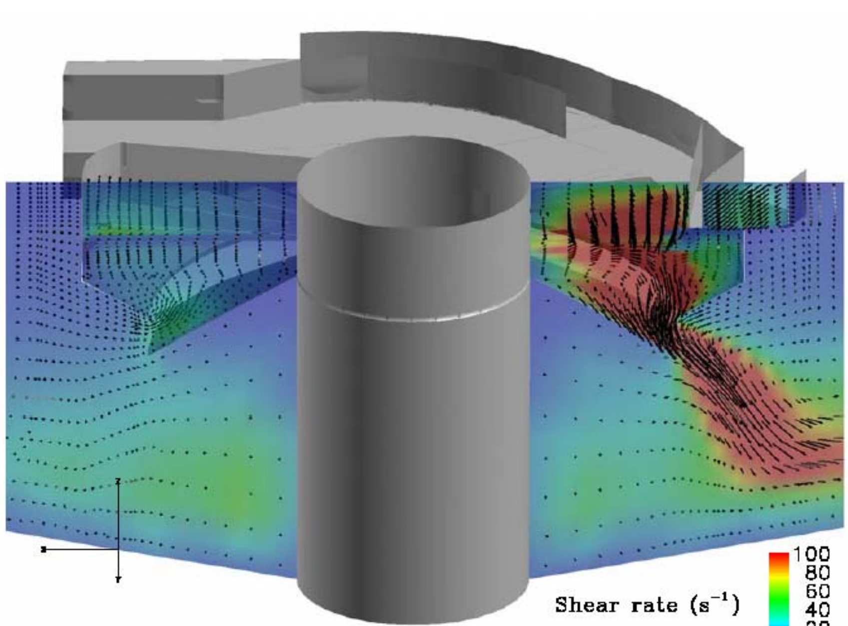


Fig 2: Run 1 flow and shear rate, xz plane

Run 2 was carried out using the baseline geometry and a feed rate of 3300m^3/h:

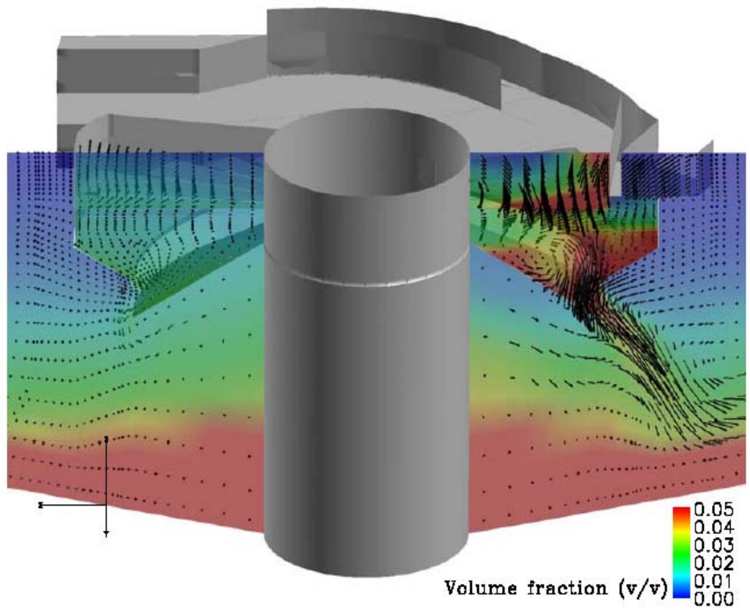


Fig 3: Run 2 flow and volume fraction, xz plane

It can be seen from Fig. 2 and Fig. 3 that the flow in both cases is strongly skewed to one side of the feedwell as indicated by the black velocity vectors, producing high shear rates (Fig. 2) and disproportionate concentration distribution (Fig. 3).). High shear rates are undesirable as they are the main cause of floc destruction in the feedwell. The negative impacts of uneven solids distribution were outlined in the introduction.

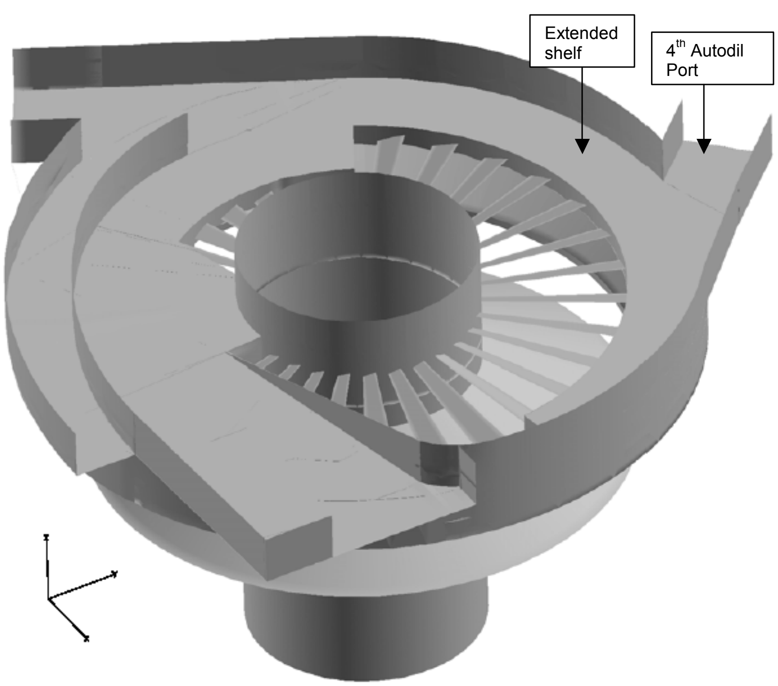


Fig 4: Feedwell Geometry for further CFD Runs

A series of subtle changes were made to the feedwell geometry, and CFD Runs 3-11 conducted. These showed improvements to the flow and concentration distribution, however further improvement was still required to optimise the conditions within the feedwell. Ultimately some significant geometry changes were made:

Compared to the baseline geometry Fig. 1, the arrangement shown in Fig. 4 incorporates an extended shelf and a fourth Autodil port at 270° to the feed port, as well as some more subtle changes.

The CFD analysis for this configuration was run at three different feed rates, and the resulting flow, concentration and shear profiles were found to be excellent at all feed rates:

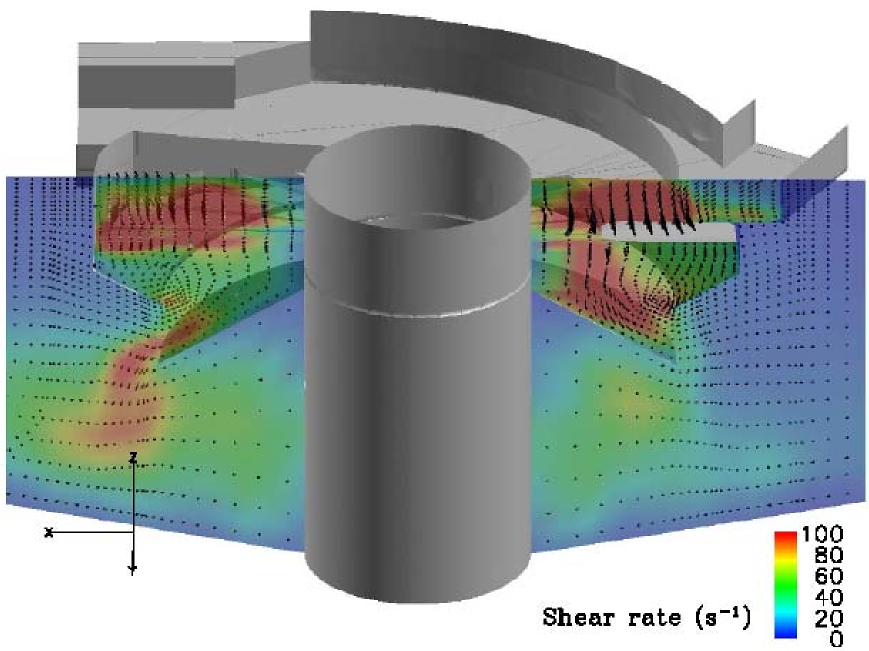


Fig 5: Run 12 flow and shear rate, xz plane (feed rate 5000m^3/h)

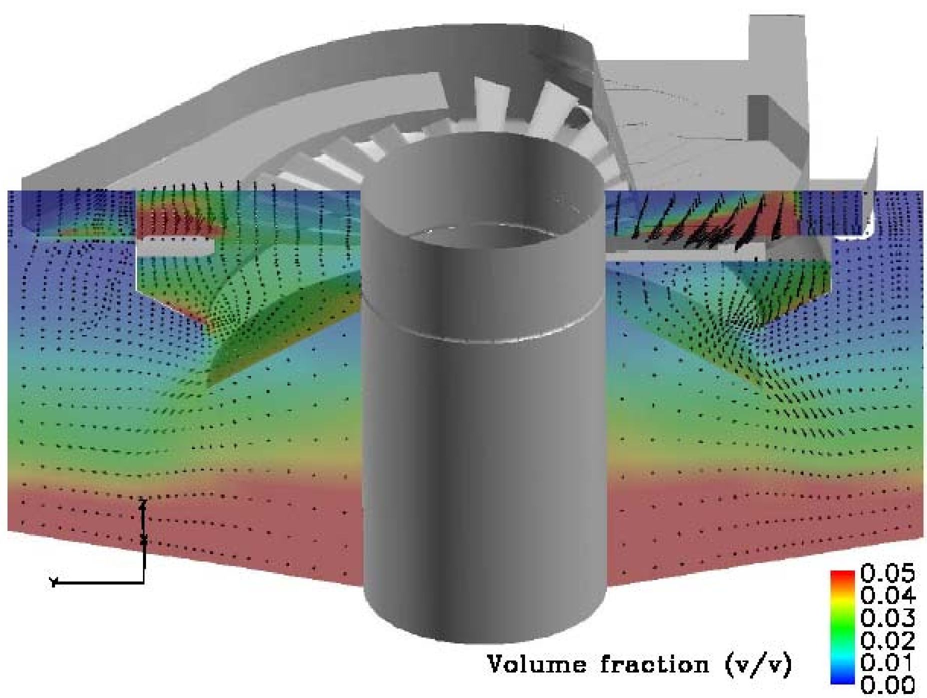


Fig 6: Run 13 flow and volume fraction, yz plane (feed rate 3300m^3/h)

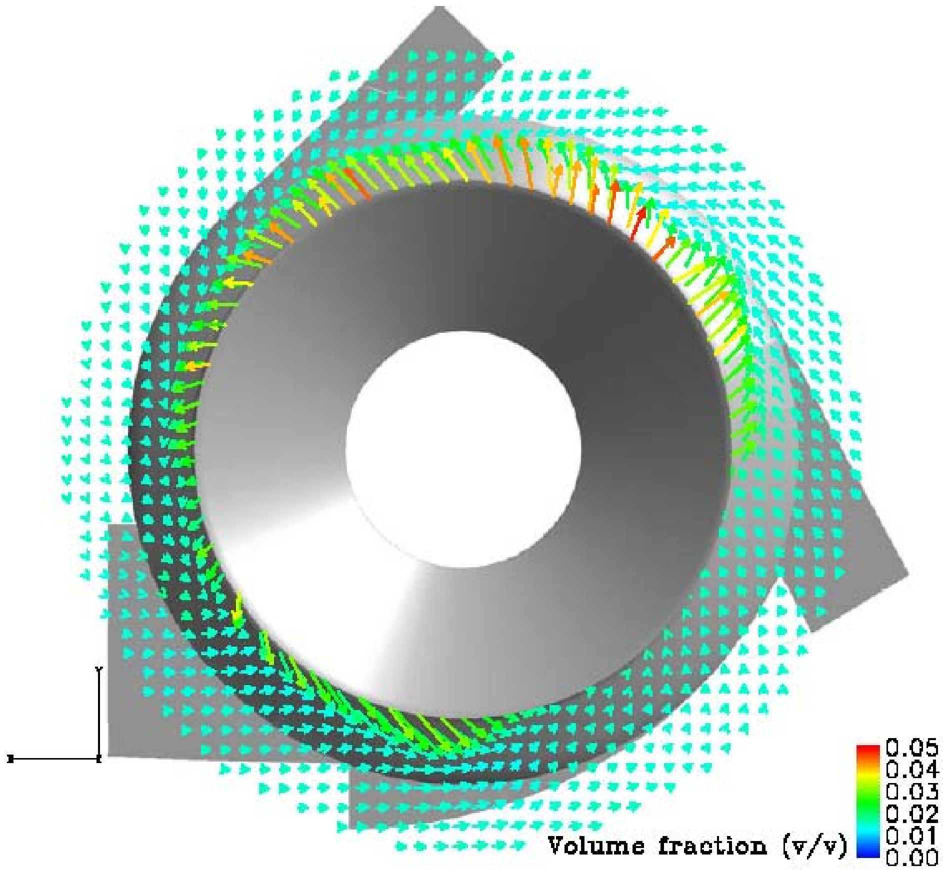


Fig 7: Run 15 flow and solid concentration out of exit gap, view from below (feed rate 4100m^3/h)

Fig. 5 shows the distribution of flow and shear rates for Run 12, at a feed rate of 5000m^3/h, Fig. 6 shows flow and volume fraction for Run 13, at 3300m^3/h, and Fig. 7 shows the flow and solid concentration in plan view at the exit gap (viewed from below) for Run 15, at 4100m^3/h. These profiles all compare very favourably with the baseline configuration: the shear vectors and volume concentration profiles are much better distributed.

Hence by using CFD analysis, the influence on the performance of various physical design elements on the performance of the feedwell at different feed rates has been clearly demonstrated. In particular the benefit of the novel features introduced, i.e. vane-type baffles and "directional" Autodil ports, has been confirmed and optimised for large feedwells.

A summary of CSIRO's conclusions for the conditions used in the CFD models is;

> "The final geometry (Runs 12, 13 and 15) gave good feedwell performance by all modelled criteria.
>
> Sufficient auto-dilution flow was provided for good flocculation, and the dilution water was well mixed with the feed solids. The solid residence time was maintained by retaining the solids in the feedwell and the final discharge symmetry was good, although not entirely uniform.
>
> In terms of the momentum and energy dissipation, the feedwell appears to be excellent. Very low values were given for the energy and momentum ratio, and this is despite the high feed solids and high dilution liquor flows. Although most of the feed energy was dissipated in the feedwell the shear rates were moderate in most regions.
>
> Importantly the shear rates in the exit region were moderate, avoiding potentially disruptive aggregate breakage. By keeping most of the energy dissipation and shear high in the feedwell, around the shelf and vanes, mixing was provided early in the flocculation process to aid flocculant dispersion and effective dilution."

What does it all mean?

- More efficient and effective use of flocculant
- A lower flocculant consumption
- Increased throughput and/or increased density for the same flocculant consumption
- Increased density means higher water/reagent recovery
- Underflow with a lower yield stress
- And maybe – lower flocculant consumption for higher throughput, increased density and higher water/reagent recovery, all at a lower underflow yield stress

Outotec's work on applying the first significant change to feedwell design in over 15 years is continuing, both with CSIRO and other companies. In the near future we will have the vane and directional Autodil feedwell in operation as well as other innovations currently being studied.

Ian Arbuthnot has a wide range of experience in process engineering, acquired over 35 years. His current position is Director - Special Projects. Outotec Pty Ltd.

Previous roles have included general management, sales and marketing, project management and process engineering design. He has specialised experience in solid/liquid separation including filtration and thickening and has been responsible for a number of design patents in this area. Ian has been involved in industries including mining and minerals processing, water and wastewater treatment and chemical/industrial.

If you would like more information, click here to contact

Ian.Arbuthnot@outotec.com