

Thickener Technology – Smaller and Smarter

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ABSTRACT

Delivering dilution water and mixing this water with incoming feed slurry, addition of flocculant, maximising flocculant-slurry interaction to build aggregate size, unabsorbed flocculant percentage, volume average of solids volume fraction, momentum dissipation ratio, dilution recycle ratio, volume average shear, maximum shear rate at exit, aggregate size on exit, uniform discharge profile and more — all of these need to occur in the right order and in the right proportions within the thickener feedwell, the secret to thickener performance.

INTRODUCTION

Numerous thickener companies and research institutes have spent many years developing and testing new designs. They continue in their efforts to understand these processes to develop a feedwell that will truly deliver performance change.

Delivering dilution water and mixing this water with incoming feed slurry, the addition of flocculant, maximising flocculant-slurry interaction to build aggregate size, unabsorbed flocculant percentage, volume average of solids volume fraction, momentum dissipation ratio, dilution recycle ratio, volume average shear, maximum shear rate at exit, aggregate size on exit, uniform discharge profile and more — all of these need to occur in the right order and in the right proportions within the thickener feedwell, the secret to thickener performance.

Can one design suit all cases? Unlikely. The last quantum change in feedwell design was more than 15 years ago with the introduction of self-dilution systems – Autodil and E-Duc. The fact that this was more than 15 years ago shows how complex and difficult true feedwell understanding and innovation is.

FEEDWELL DESIGNS BASED ON ASPECT RATIO

Low Aspect Ratio

Low aspect feedwells are typically those with a diameter up to 3 m and overall depth of 2 m, aspect ratios 1:1 to 1:5:1.



Figures 1, 2 and 3 Low, Medium and High aspect ratio feedwells

Recent CFD modelling on a low aspect ratio closed bottom feedwell as depicted in Figure 4 demonstrates that performance meets the design requirements with no structural modifications from current designs. Key issues here are correct sizing and configuration including appropriate baffling. Correct baffling provides the momentum dissipation and shear profiles.

The shear rate profile is important to achieve good mixing and subsequent aggregate growth in the feedwell. High shear in the top of the feedwell is associated with energy dissipation of the feed. It is the area where slurry dilution (if included) is achieved and flocculant starts to disperse into the slurry. Further down in the feedwell lower shear rates are associated with continued flocculated aggregate growth. Shear needs to be moderate to allow for growth but not breakage. Finally, the flocculated material exits the feedwell into the body of the thickener. Maintaining large aggregate size is important to achieve high settling rates and maximum density, i.e. low shear on exit.

The following modelling of low aspect ratio feedwell was performed by CSIRO as part of the AMIRA P266E project. The feedwell was 3m in diameter with a feed of 5% w/w solids and no dilution stream included.

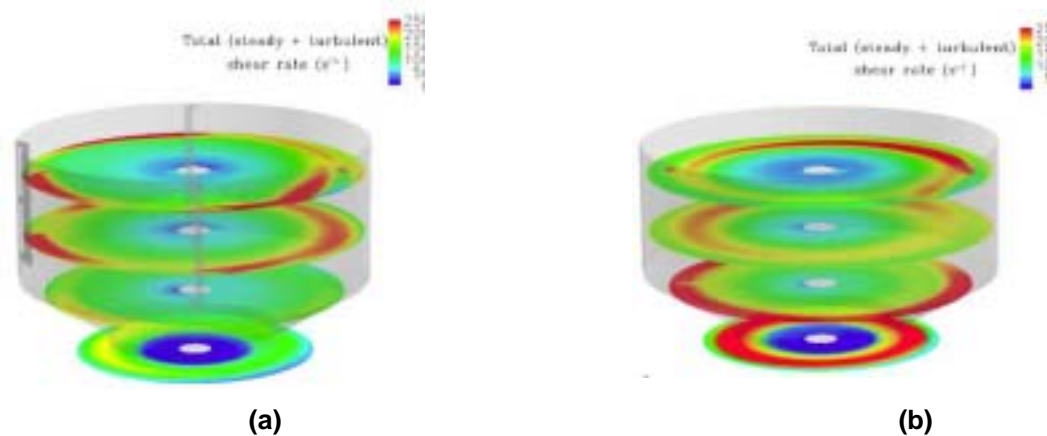


Figure 4 Shear plot, feedwell (a) with baffles (b) without baffles (CFD simulation by CSIRO Minerals – P266E 4th progress report)

Note that with baffles the high shear areas are located in the upper half of the feedwell, while the lower half experiences low shear – as per the requirement conditions described above. The feedwell without baffles displays the opposite shear profile and so is less than ideal. An understanding of sizing, configuration and baffling makes a significant difference to feedwell performance.

Modelling aggregate growth, after flocculant addition, shows how the above momentum dissipation and shear affects performance, shown in Figure 5 and 6.

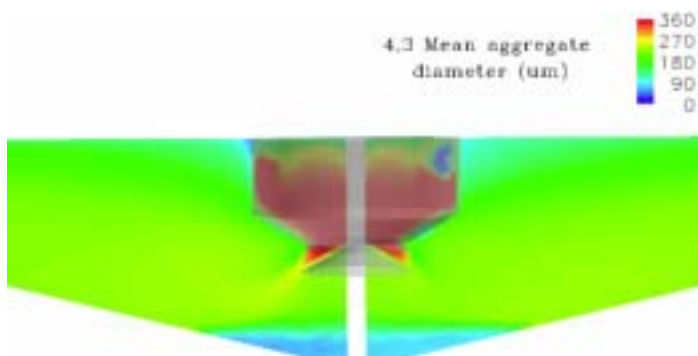


Figure 5: Aggregate size within and exiting the feedwell – no baffles, flocculant added in top half (CFD Simulation by CSIRO Minerals – P266E 4th progress report)

With low initial shear in the upper half of the feedwell followed by high shear in the lower half, due to no baffling, aggregate growth occurs lower in the feedwell. However, the high shear on exit results in aggregate breakage prior to entry into the body of the thickener. Smaller aggregates entering the thickener leads to lower thickener underflow densities, lower settling rates and less efficient use of flocculant.

Figure 6 shows an outstanding aggregate profile entering the thickener. This highlights the effect and importance of correct shear profile in combination with correct / multiple flocculant dosing points. Add to this the resulting uniform 360° discharge into the thickener and this design package delivers the coup de grâce.

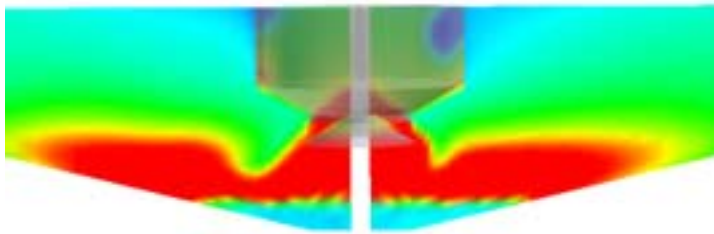


Figure 6: Aggregate size within and exiting the feedwell – with baffles and multiple floc dosing points (CFD simulation by CSIRO Minerals – P266E 4th progress report)

Medium Aspect Ratio

Medium aspect ratio feedwells are typically those with a diameter up to 7 or 8 m and overall depth of 2 m, respect ratios 2:1 to 4:1.

The following medium aspect ratio closed bottom feedwell modelling was based on a gold tailings thickener that required feed dilution for effective flocculation and was 6.5 m in diameter and 2 m deep. The dilution system being modelled is Autodil, which uses the head difference between inside and outside the feedwell to allow water to flow inwards through open slots.



Figure 7: Base line (typical) (a) upper flow pattern (b) exit flow pattern (view from below)

This design incorporates feed entry 'to the side' to promote feed rotation and mixing in the feedwell and dilution slots for water flow from the outside of the feedwell to the inside (Autodil). The modelling results as shown in Figure 7 indicate that dilution flow is not particularly strong (length of the radial vectors in Figure 7a) which suggests a lack of uniform density within the feedwell. The lack of dilution flow indicates little hydraulic head difference between the outside and the inside of the feedwell, which is the basis for Autodil. Short-circuiting of the incoming feed stream can cause lack of uniform internal density. The feed entering the feedwell drops out, instead of mixing within the feedwell volume. This is supported by Figure 7b, which shows incoming solids exiting the feedwell from a localised area.

From the above modelling, it can be concluded that feed flow rotating within the feedwell and radial dilution water flow do not complement each other causing unmixed slurry exiting from one side of the feedwell. As a result of this, feedwell performance would clearly be poor.

Shelves

Essentially, the incoming dense feed stream must be 'held up' to enable effective dissipation to take place within the feedwell volume.

Inclusion of a feed shelf (or shelves) into feedwells has been shown to reduce solids short-circuiting, especially in larger diameter applications with high solids SG and dense feed slurries. Achieving longer solids retention, efficient mixing, correct shear profile, etc. is again the key to thickener performance — clarity, underflow density and efficient use of flocculant.



Figure 8: Baseline plus $\frac{1}{4}$ circumference shelf (a) upper flow pattern (b) exit flow pattern
(viewed from below)

Note from Figure 8a the hold up of solids over the shelf and stronger radial flow of dilution water when compared to Figure 7a. This stronger flow implies a better mixing and distribution of solids within the feedwell. Note, however, that tangential flow of feed stops once it meets the radial flow of dilution water.

The exit flow pattern and solids distribution as shown in Figure 8b is also a marked improvement on Figure 7b.

Directional Dilution Flow

Changing the dilution ports so that they guide the water into the feedwell in a tangential direction complementing the feed flow has been termed Directional Autodil.

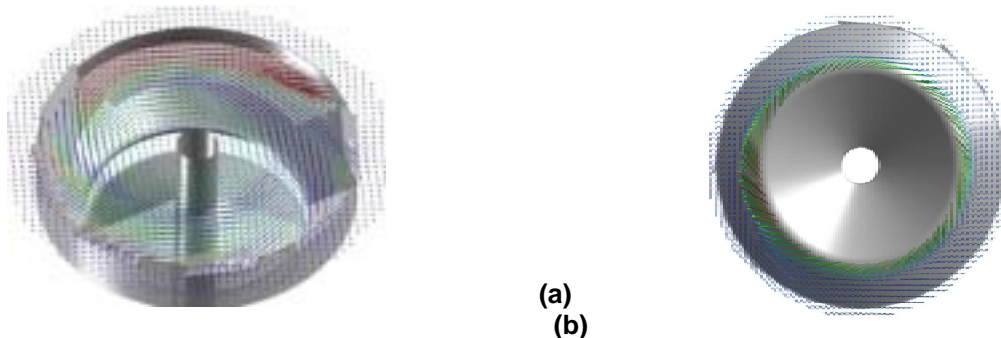


Figure 9: Base line plus $\frac{1}{4}$ circumference shelf and 'directional dilution' (a) upper flow pattern, and
(b) exit flow pattern (viewed from below)

A much stronger flow pattern can be seen for the top section of the feedwell. Solids are now making their way around most of the feedwell circumference. Dilution water flow is strong and is complementing the incoming feed flow momentum.

Although some high density exit slurry remains, the exit distribution can now be considered to be relatively even over the full exit circumference of the feedwell.

The combined momentum of feed and dilution flow is essential to have adequate energy to mix the two streams. There still remains the need to balance the shear required for mixing and the need to dissipate the majority of this energy prior to exit. Baffling and 'top and bottom' zones as per the low aspect ratio are still required, especially as the feedwell size grows with corresponding large feed rates.

Directional Autodil and shelves provide significant improvement to medium aspect ratio feedwells. Correct sizing, configuration and baffling, as per low aspect ratio feedwells remain important.

Large Aspect Ratio

These are typically feedwells with a diameter of 8 m plus and overall depth of 2 to 2.5m, aspect ratios 4:1 and greater.

Vanes

The concept of vanes was introduced to act as a shelf to hold-up the high density feed slurry for as long as practically needed, to act as baffles and remove energy from the feed and create the turbulence for mixing at the same time and effectively split the feedwell into an upper and lower zone.

The theory behind the concept being:

- To increase the amount of shelf area while allowing material to evenly disperse within the feedwell.
- To avoid large flat shelf areas which could cause material build-up.
- To create a top zone of high shear mixing and at the same time dissipate this mixing energy.
- To create two zones within the feedwell – an upper and a lower zone.

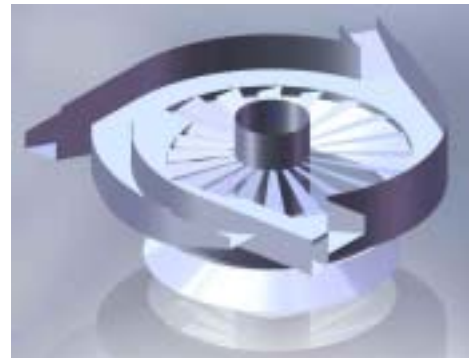
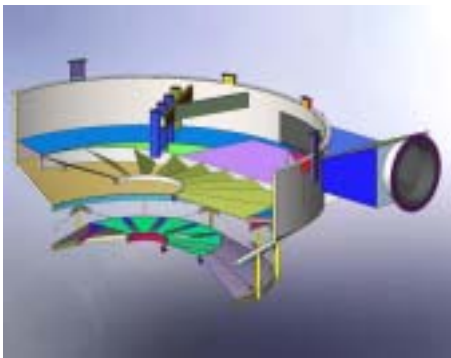


Figure 10 A 'full vane' feedwell with Autodil slots

Constant Feed Velocity

Another issue that becomes increasingly important as aspect ratio increases is feed inlet velocity. On larger plants with multiple mills or autoclaves feeding a common thickener, the issue of performance at lower than design throughput is becoming very important. How efficient and effective is the feedwell at half flow rate?

What has also been considered in the next series of modelling with a vane style feedwell is the effect of both maintaining and not maintaining feed entry velocity whilst the overall feed rate is reduced.

Constant feed entry velocity can be achieved by simply altering the feedpipe exit cross-sectional area as shown in Figure 11.

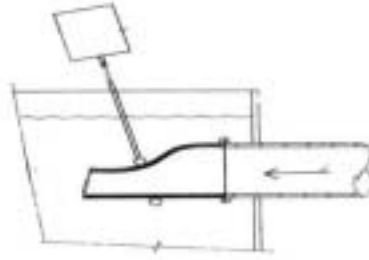


Figure 11: Constant feed velocity system

Combine Directional Autodil, Shelf, Vanes and Constant Feed Velocity

What if:

- All of the concepts discussed so far to improve performance were combined?
- All the ideas and gained knowledge were incorporated into one feedwell design?
- What would a “Next Generation Feedwell” look like?



Figure 12: Next Generation Feedwell design (subject to four separate patents)

The feedwell in Figure 12 is 10m in diameter by 2m deep, designed for process conditions of 36% w/w feed requiring dilution to 12% w/w at an overall feed rate of 5000m³/hr. This has been modelled extensively to consider all design criteria:

- Unabsorbed flocculant, Volume average of solids volume.
- Momentum dissipation, Dilution or recycle, Volume average shear.
- Maximum shear rate at exit, Performance at lower than design flow rate.

The results and conclusions of the modelling of this large aspect ratio feedwell are discussed below.

Flow and Volume Fraction

Figure 13 shows a strong flow pattern of feed and dilution water throughout the volume in the upper section of the feedwell. These flows are also shown to be mixing well within the upper volume.

Although the shear exit profile, as per Figure 14, is not exactly uniform over the 360° exit, for a large aspect ratio feedwell this distribution pattern is quite a success.

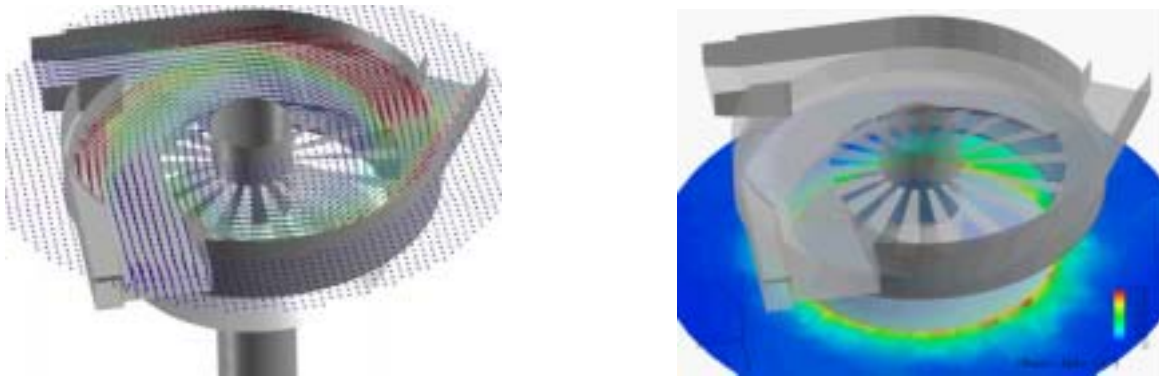


Figure 13 & 14 Upper solids volume fraction and Exit shear rate bottom section profile

Lower Feed Rate with Same Feed Pipe Size Verses Same Inlet-Velocity

Figures 15a and b, which compares volume fraction on exit, demonstrate the advantages achieved by maintaining feed entry velocity when overall flow rate is reduced.

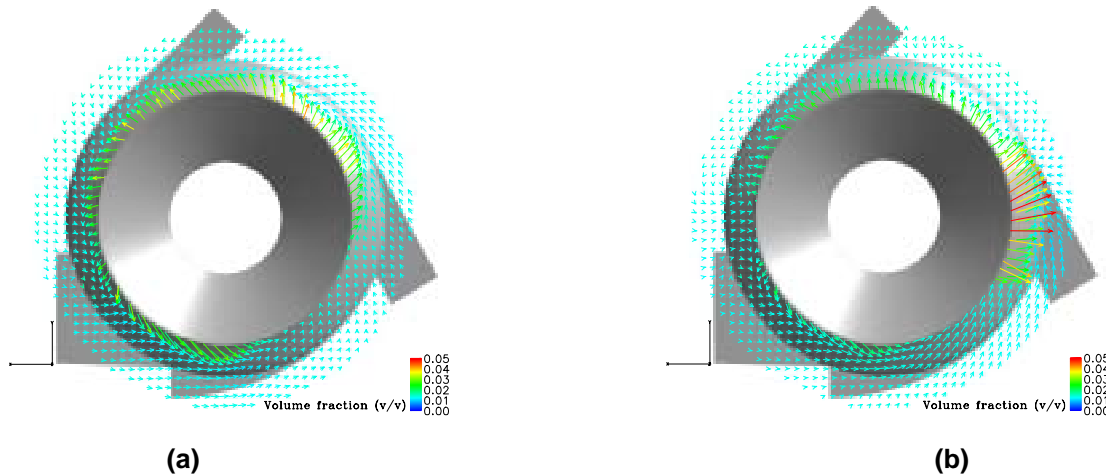


Figure 15 Lower flow rate (a) velocity maintained (b) velocity not maintained

CONCLUSION

The apparent lack of feedwell innovation in the past 15 years is testament to not only the difficulty involved in understanding what is required for good feedwell performance but also the difficulty to apply what is required in the right proportions and sequence. No easy task, especially when the laws of gravity work against you with high density feed streams and it becomes further complicated as aspect ratios increase.

The challenge is to try to combine all these theories and results together to create the most optimal solution. Mixing, diluting, flocculating, shearing and energy dissipation whilst growing aggregates and then releasing them uniformly without aggregate breakage into the body of a thickener, all within and via a large aspect ratio feedwell. Can it be done?

From the results obtained to date, and reported in this paper, there is a much greater understanding of the requirements for feedwell design and the quantum jump in feedwell performance is upon us.

The conclusion drawn is that feedwells must have two zones, an upper and lower zone. An upper zone within the feedwell in which there is high shear and energy dissipation. Dilution water and some flocculant are also added into this upper zone, taking advantage of the strong mixing.

The well mixed, diluted, distributed and partially flocculated slurry then requires gentler mixing with additional flocculant to generate large aggregates. This is achieved in a lower zone within the feedwell, which also evenly and without aggregate breakage, distributes the aggregates to the body of the thickener.

Whether it is thickened or paste tailings or any other thickener application, effective and efficient use of flocculant is the key to economic, process and rheology performance. It is not true that all thickeners perform in a similar manner; the truth is there is an operating cost and consequence based on the performance of the feedwell.

The feedwell is the key to unlocking thickener performance and current designs do need improvement. The belief now is that this improvement is within current capabilities by understanding and innovating feedwell design.

ACKNOWLEDGEMENTS

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REFERENCES

Heath, A.R. (2007). "CFD Modelling and Optimisation of Outotec Design Vane Feedwell" Parker CRC for Integrated Hydrometallurgy Solutions (CSIRO Minerals), DMR-3280.

White, R.B, Sutalo, I.D. and Nguyen, T. (2003). "Fluid flow in thickener feedwell models, Minerals Engineering" Vol 16, pp. 145-150.

Heath, A.R. and Koh, P.T.L. 2003, 'Combined Population Balance and CFD Modelling of Particle Aggregation by Polymeric Flocculant', Third International Conference on CFD in the Mineral and Process Industries, CSIRO, Melbourne, Australia, 10 - 12 December, pp. 339 - 344.

Nguyen, T.V. Heath, A.R. and Witt, P.J. 2006, 'Population Balance – CFD Modelling of Fluid Flow, Solids Distribution and Flocculation in Thickener Feedwells', Fifth International Conference on CFD in the Mineral and Process Industries, CSIRO, Melbourne, Australia, 13-15 December.