performance parameters analysis in 2D - simulation experiments

Parameters analysis in 2D - simulation experiments

Objectives and Hypothesis

The preliminary simulations had encouraging outcomes about the dependence of performance parameters on h/b ratio. In further experiments described below, we simulated a series of cases with h/b ratio of 2, 3, 4, 5, 8, 10, 15, 20 and 40 and plotted each performance parameters as a function of h/b ratio. We would expect:

1. K_baffle is a measure of energy loss within each baffle spacing. It will converge as h/b ratio increases, and will also converge in a single baffle for successive turnings. Shultz and Okun has suggested its value is between 3 and 4.
2. Pi_cell will increase as h/b ratio increase, which measure the active volume of flocculation tank. Pi_cell/(h/b) can be a measure of the active fraction of flocculation tank, which is expected to decrease as h/b ratio increases.

Methods and Procedures

h/b ratios of 2, 3, 4, 5, 8, 10, 15, 20 and 40 were tested with 5 baffles. The completed test are summarized in the following table:

Summary of simulation experiments (Completed simulation marked by "√")

h_over_b ratio		2	3	4	5	8	10	15	20	40	note	
wall top BC	converge to e-5	√	√	√	√	√	√	√	√	√		iterate directly to e-6 using 2nd order
	converge to e-6	√	√	√	√	√	√	√	√	√		
	performance parameters	√	√	√	√	√	√	√	√	√	(using e-6 data)	

Some of the important parameters are summarized below:

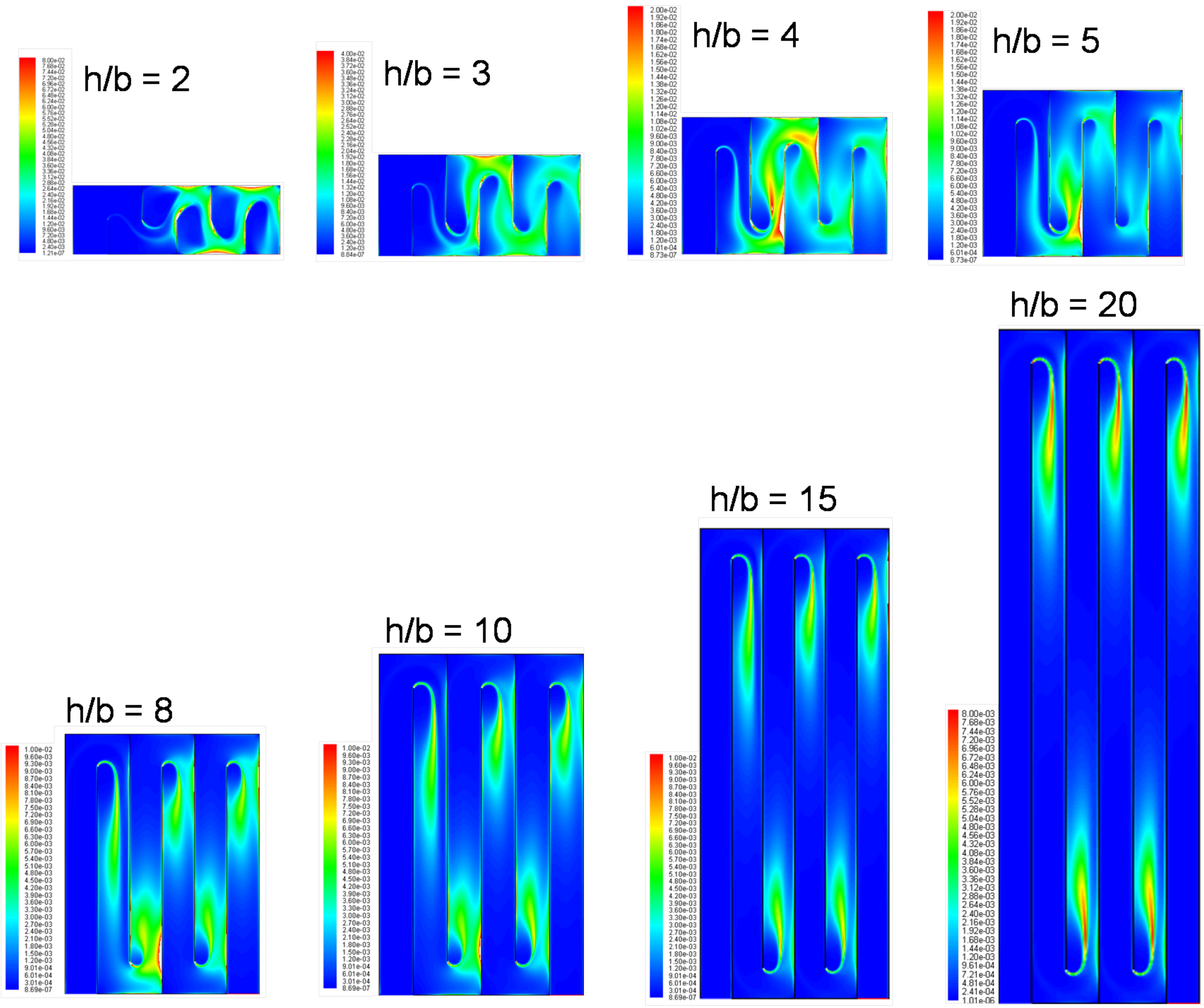
Important Boundary Conditions						
material	water-liquid	density=	1000kg/m^3	visicosity= 0.001003kg/(m*s)		
inlet		v_y=	0.1m/s	turbulence intensity: 10%	turbulence length scale: 0.004	
outlet	gauge pressure =	0		turbulence intensity: 10%	turbulence length scale: 0.004	
top	wall	no slip				

Geometry and other parameters	
width w	0.1m
clearance b	0.1m
Reynolds number	9970.09

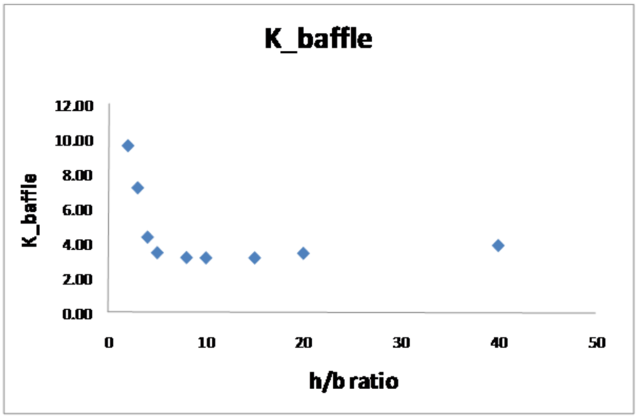
The various geometry and mesh are created from journal file, by varying the flocculation tank height. All the FLUENT settings including turbulence model, boundary conditions, solutions schemes etc. can be found in a sample of report summary for h/b=2 case.

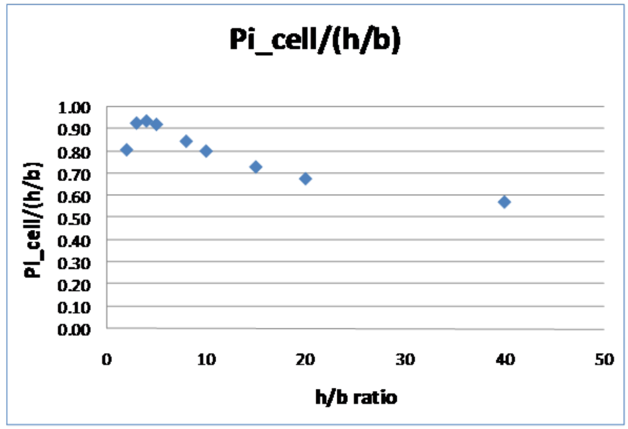
Results and Discussion

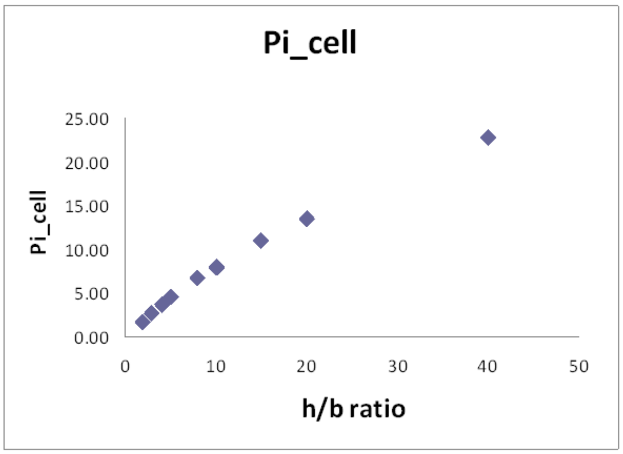
Click here for the results of the series of simulation experiments and parameter analysis, completely summarized in an Excel workbook. Only parts of the results are given graphically below.

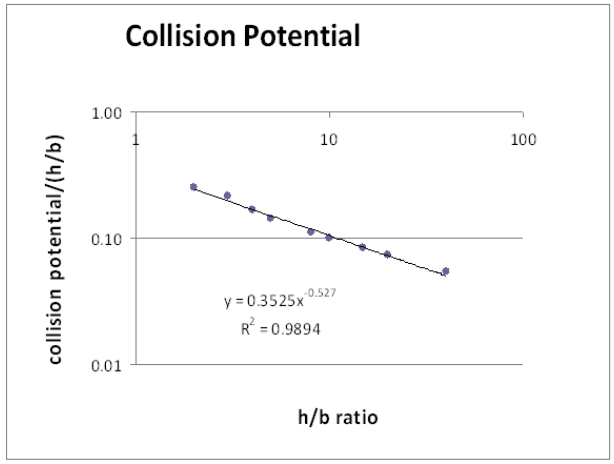


Take the values calculated from the 4th baffle, and plot each parameter as a function of h/b:









Number of baffles
Note that in the Excel workbook, the performance parameters were calculated for both the 4th and 5th baffles. There are minor differences in numerical values while the general trend stays the same. Particularly, a more pronouncing difference is observed for h/b=4. Thus simulations with more baffles and a sensitivity analysis of the number of baffles could be included in the future work.

K_baffle
As shown in the plots above (and the Excel workbook), the trend of K_baffle values is consistent with the hypothesis. It decreases rapidly for h/b = 2~5 and stabilizes around 3.2. An upward trend appear around the tail of the K_baffle vs h/b curve, which indicates the major loss in addition to minor losses is playing a more significant part in the total energy loss.

Pi_cell
Pi_cell was shown to increase continually as h/b ratio increases in preliminary experiments, which was also reported in Fall 2008 research. This trend is further confirmed with a large h/b ratio of 40. As reported in Fall 2008 research, Pi_cell value keeps increasing because energy is dissipated along the wall as well as around the 180 degree turning region.

Pi_cell/(h/b)
The plot of Pi_cell/(h/b) as a function of h/b is also consistent with the hypothesis. As a measure of active fraction of the total volume of the flocculator, it reaches a maximum of 95% for h/b=4, and keeps decreasing as h/b increases. However, the curved flattens out at the tail. This also suggests although an optimal value exists for h/b, it wouldn't be the most critical constraint for design, since even for an un-pratically tall flocculator of h/b=20, it still has an active volume fraction value around 70%.

Collision potential/(h/b)
The power function fit for collision potential (theta*epsilon^(1/3))/(h/b) was suggested by Dr Monroe Weber-Shirk. It shows a unexpectedly simple relationship with a power of about -0.5 and a coefficient of 0.33. Further investigation is needed to better interpret this relationship.

Conclusion

- The number of baffle used are not enough for the cases of h/b= 2~5 to converge.
- The formulation of the K_baffle and Pi_cell are valid and consistent. They captures some of the characteristics of flocculator performance.
- Optimal values of h/b=4 is observed in terms of Pi_cell/(h/b) value.
- Relationships between (theta*epsilon^(1/3))/(h/b) and h/b is unexpectedly simple and needs further investigation.

Future Work

- Simulations with more baffles and investigate the sensitivity to the number of baffles used, especially for h/b=4.
- More detailed comparison between symmetry boundary conditions and the wall boundary condition at the water-air interface.
- Simulations with different Reynolds numbers.
- Non-dimensionalize the results.
- Characterize the maximum energy dissipation rate to characterize floc break-up