Plate Settler Spacing - current work spring '11

Current Team Research Focus - Spring '11

Effect of a Floc-Rollup Phenomenon on Flocs

Introduction

Traditionally, inclined plate and tube settlers are used to create compact sedimentation tanks. Conventional design guidelines are based on obtaining a desired sedimentation design capture velocity. Theoretically, this capture velocity can still be achieved while greatly reducing conventional plate spacing or tube diameter. Yet, the greatest concern with small plate spacing is the danger of settling sludge being swept out with the finished water – the phenomenon known as the floc-rollup. It is the purpose here to estimate the effect of the floc-rollup inside the plate settlers.

Particle Capture by a Lamella

The experimental testing was performed on tube settlers with the design capture velocity of tube settlers in which the ends of the tube are perpendicular to the axis of the tube. Theoretically, it is possible to reduce L by decreasing the diameter of the tube settlers, D. After a floc settles on the lower surface of a plate or a tube it continues to experience an upward drag caused by the fluid flow. The velocity at the centerline of the floc increases if the spacing between plates or the diameter of the tube is decreased while maintaining a constant average fluid velocity. Gravitational force will cause flocs to roll or slide down the incline while the fluid drag will tend to cause the floc to roll or slide up the incline. When the fluid drag and the gravitational forces balance, the floc remains stationary. This balance point is approximated by determining the point at which the velocity caused by fluid drag at the centerline of the floc is the same as the opposing component of its terminal velocity along the slope (as seen in Figure 1).

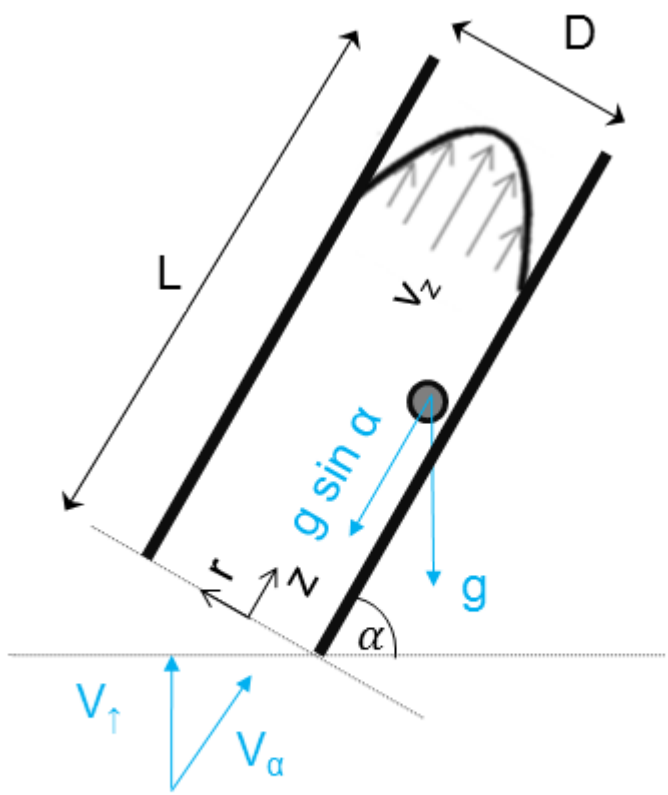


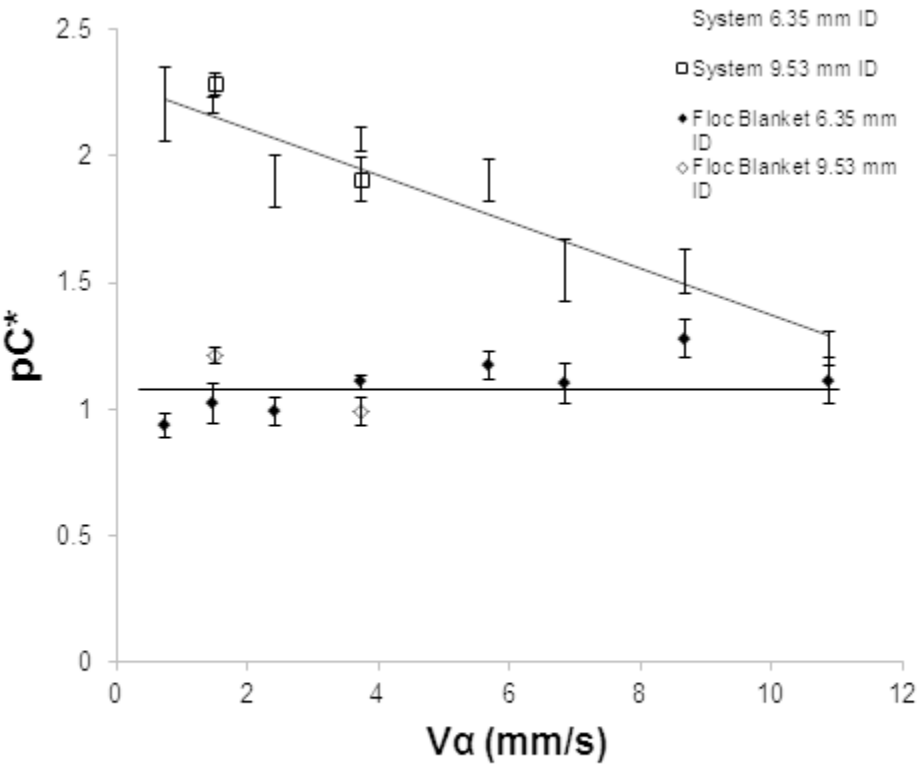
Figure 1 Definition for the geometry and velocity profile experienced by a floc on the bottom surface of a tube or plate.

By using the velocity gradient at the wall, we then obtain the expressions both for velocity at the center of a floc resting on the wall and for the diameter of a floc. Finally, we solve for the terminal velocity. The floc terminal sedimentation velocity represents the slowest settling floc that can slide down an incline. Flocs with a terminal velocity lower than will be carried out the top of the tube (i.e., “roll up”) even if they settle on the tube wall. Thus, this terminal velocity represents an additional constraint on the capture velocity for tube settlers. Unlike the design sedimentation capture velocity, which is exclusively a property of the geometry and flow characteristics of the sedimentation tank, the capture velocity needed to prevent flocs from rolling up and out of the tube (referred to here as the “roll up capture velocity”) is a property of the floc as well as the sedimentation tank geometry and flow characteristics. This complexity is a result of the interaction between the size of the floc and the linear velocity gradient.

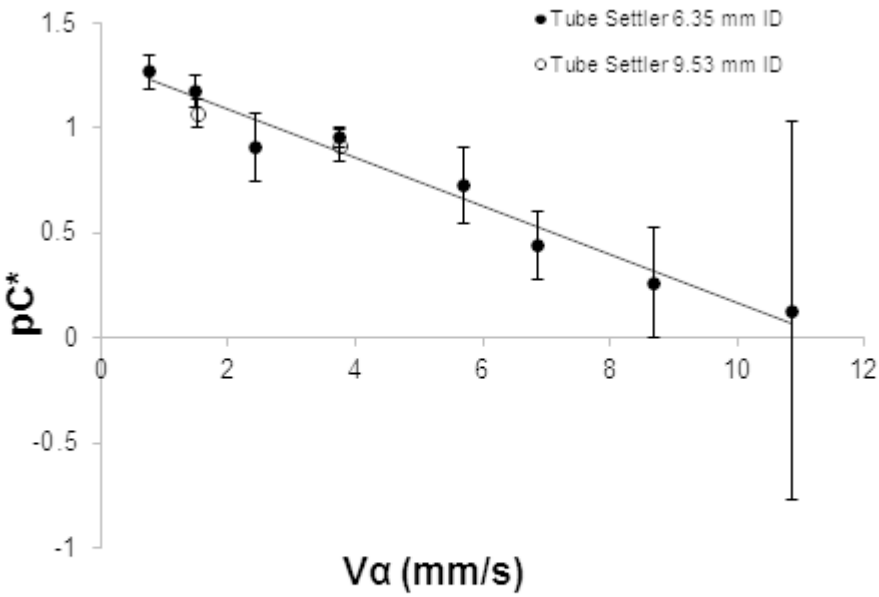
Additionally, we estimate the floc roll up capture velocity as a function of tube diameter, D, for the case of three different upflow velocities. However, for a given upflow velocity, a decrease in tube diameter results necessitates in a higher particle settling velocity for particle capture to occur.

Experiments and Results

Constant 0.10 mm/s design capture velocity experiments have been conducted using tube settlers of two different inner diameters, 6.35 mm and 9.53 mm respectively, for a range of V-alpha. The figure below shows the measured pC*s as a function of V-alpha. When V¬ increases, the performance of the system decreases, while the performance of the floc blanket remains relatively consistent with the increasing V¬ for an average value of pC* of 1.12. The graph shows a first order decreasing trend of the system performance.



Graph 1 The floc blanket pC* remained very constant over the whole range of experiments except for one point.



Graph 2 The tube settler pC* decreases and becomes more unstable as the velocity gradient increases.

Conclusions

All the above results are given for tubes. V-rollup is dependent on the velocity gradient, which is ¾ less for plates than for tubes. All equations with the linearized velocity gradient at the wall are therefore changed by a factor of ¾ for plates. Thus for a given V_, for plates will be of a smaller magnitude than the V-rollup for tubes. Thus plates are slightly less vulnerable to floc roll up than are tubes given the same diameter and spacing.

The floc roll up model delineates a failure mechanism that prevents flocs from sliding along an inclined surface in the countercurrent direction. This failure is caused by fluid drag resulting from velocity gradients at the plate or tube wall that oppose gravity forces. Velocity gradients increase as the plate settler spacing or tube diameter is decreased and as the upflow velocity is increased. We expect that high velocity gradients will cause flocs to “roll up” an inclined surface and act to increase effluent turbidity. If the tube settler diameter or plate settler spacing is too small, high velocity gradients can cause roll-up of flocs that would otherwise be captured. Evaluated this phenomenonm utilizing a combined tube-settler floc blanket system to characterize the removal effectiveness for colloidal particles at different flow conditions, but at a constant design capture velocity of 0.1 mm s-1. Experimental data suggests that plate spacing as small as 1 cm for an upflow velocity of 1 mm/s can be implemented without causing performance deterioration.
Tube settler performance deteriorated when the the floc roll up capture velocity was larger than the sedimentation design capture velocity.

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More Information
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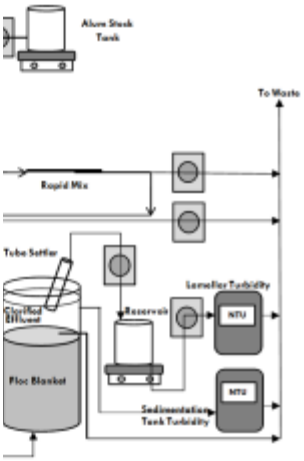
Alum Stock Tank
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Rapid Mix
Tube Settler
Lamellar Turbidity
Reservoir
NTU
Floc Blanket
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