Turbulent Tube Flocculator and Fluidized Bed Flocculator

Turbulent Tube Flocculator Challenges

The first major task is to get the entire apparatus designed and fabricated. Design and build the once through constant head, temperature-controlled water supply system. This will require a hydraulic design to make sure that you are using the right size of tubing to deliver the required flow rate.

- This system includes manual and solenoid valves that connect to the hot and cold water supplies,
- a method to power the solenoid valves using the control box we use with Process Controller (done Fall 2013)
- an air release Tee at the top of the flocculator (vented straight up to above the hydraulic grade line)
- a constant head tank where the hot and cold water will be blended and the temperature and water level will be measured
- A system to control the flow through the flocculator. Likely based on the constant head tank and an adjustable effluent discharge level
- A system to measure the flow through the flocculator. Likely based on an automated "bucket and stopwatch" - tank that fills and empties based on a pressure sensor that measures water depth and a solenoid valve that drains the tank. One option for this is to use the constant head tank to measure the flow rate. The effluent flow rate from the constant head tank can be measured by measuring the rate of reduction in depth of water when the inlet valves are both turned off.
- Design the rapid mix for this system. The coagulant could be injected into the center of the pipe at an orifice right before the flocculator?
- Need a solution to keep tubing from collapsing (kinks and bends).

We need a solution to get the air out of the intermediate high spots in the flocculator created by the tubing constrictions. One option is to ignore this problem and see if it causes any adverse effects. If there are adverse effects of the trapped air then we need a solution.

- Use a large valve to close both the inlet and outlet of the flocculator. Connect a vacuum line to the air release tube and apply a strong vacuum. This will cause the tubing to collapse and will remove the air.

Then close the vacuum connection, open the inlet valve very slightly to allow the flocculator to fill with water. This should significantly reduce the amount of trapped air. This method could be tested with the flocculator initially filled with water or with air.

- Suspend the flocculator from a point on its vertical axis above the flocculator. Pull the bottom of the flocculator off center enough to cause the air to move toward the top side of the angled flocculator

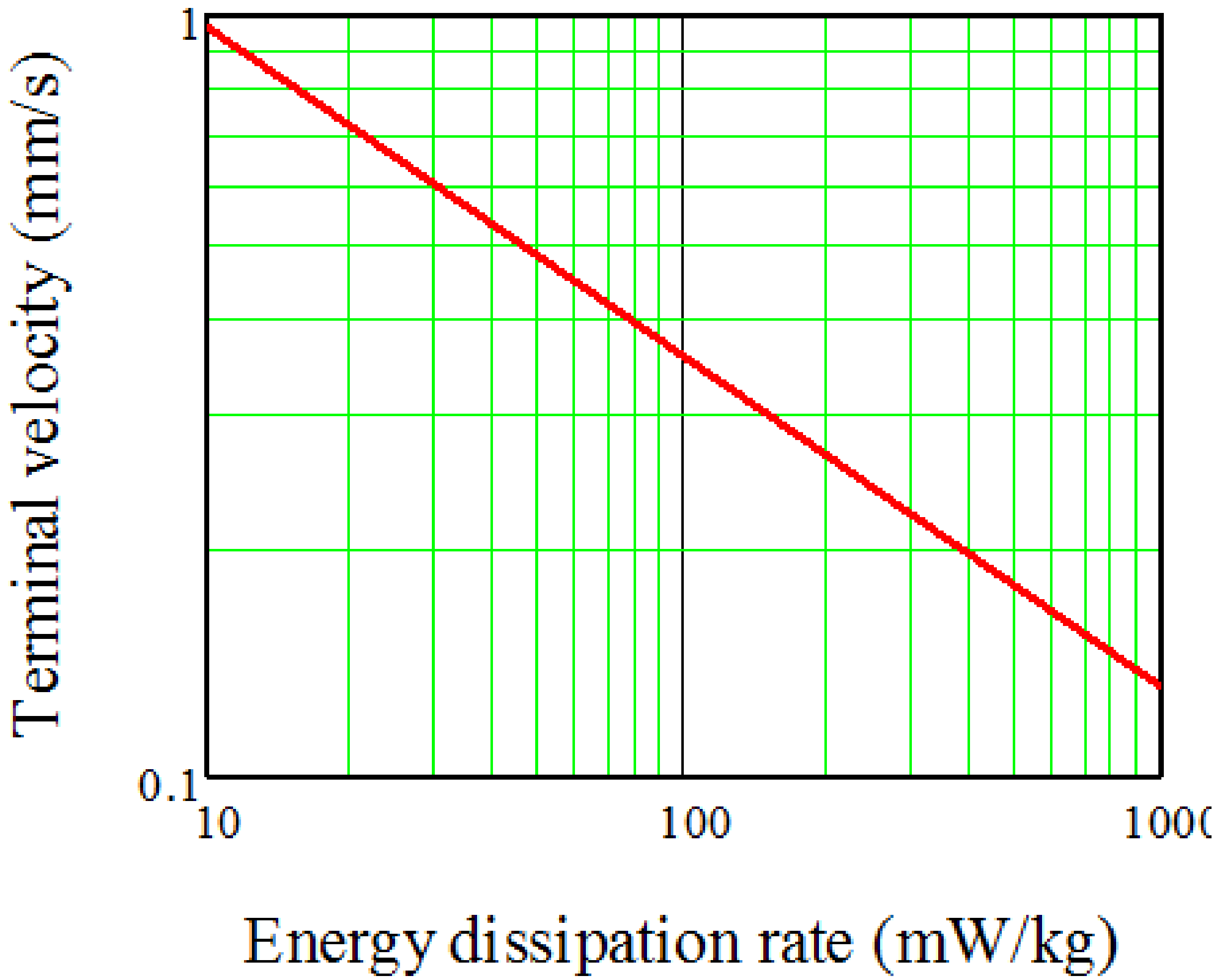
Design a SWaT measurement system. Given that the flow rates are higher for the turbulent flow flocculator than for the laminar flow flocculator it may be advantageous to use a higher flow rate tube settler to reduce the residence time in the turbidimeter. However, this would require using either multiple small diameter tube settlers (complicated design) or a larger diameter tube settler (hence longer and although the velocity can be increased with diameter, the net result will be a longer residence time in the tube settler). Thus it will likely be simplest to use an identical SWaT measurement system to that used for the laminar flow flocculator.

Fluidized Bed Flocculator Challenges

Flocculation using mechanical mixers requires 30 minutes of residence time. AguaClara hydraulic flocculators use approximately 10 minutes of residence time and approximately 25 cm of head loss. The residence time in the AguaClara sedimentation tank is approximately 30 minutes and that is the slowest process used by AguaClara. Flocculation is the 2nd slowest and hence 2nd largest AguaClara process. The goal of the fluidized bed flocculator is to explore alternative reactor configurations that could accelerate the flocculation process.

At low turbidities the time between particle collisions is extended because the particles are so far apart. Aggregation of particles could be accelerated if there were additional surfaces for collisions with raw water particles. The floc blanket is one technology for increasing the concentration of particles to increase the collision rate. A floc blanket is a fluidized bed of flocs. Why not use a fluidized bed of sand as a flocculator? Primary particles could collide with and attach to sand grains. A layer of primary particles could adhere to each other and then when they become too thick the surface shear will remove the attached particles. If the removal process removes an aggregate of primary particles, then the process will have resulted in flocculation. The size of the shed flocs will be a function of the shear on the sand grain surface. The shear on the sand grain surface is set by the buoyant density of the sand grain the diameter of the sand grain. High density and large sand grain diameters result in high surface shear. Thus the size of flocs shed from a fluidized bed flocculator is expected to increase for lower density media and for smaller grain sizes.

The energy dissipation rate for a fluidized bed can be calculated by the energy loss through the fluidized bed divided by the residence time. For a rapid sand filter in backwash mode the energy dissipation rate is approximately 150 mW/kg. This is much higher than the energy dissipation rate currently used in AguaClara flocculators, but it is low enough to produce flocs that should be removed efficiently by the plate settlers given a capture velocity of 0.12 mm/s (see figure below).



Given the high energy dissipation rate it is possible to achieve a high collision potential with a relatively low hydraulic residence time. In addition the sand grains provide additional surfaces for particle aggregation and thus the effective collision potential in a fluidized sand bed is potentially much higher than in a hydraulic baffled flocculator.

Goals

Design and build experimental apparatus to test the fluidized bed flocculation. Use SWaT to measure the resulting settled water turbidity and when possible add the floc size measurement capability.

Develop analytical approximations for the shear on the sand grain surfaces (based on a force balance) and for the maximum (based on shear on the sand surface) and average energy dissipation rate in the reactor (based on total head loss and residence time). Use these models to calculalte the effect of sand size on the resulting floc size.

Preliminary tests could be conducted with a 1” diameter PVC column with 1 m of sand fluidized to 1.3 m. This will require an upflow velocity of approximately 11 mm/s. The sand could be 500 µm in diameter or smaller. The influent turbidity could be 100 NTU. The coagulant dose could be approximately 5 mg/L of PACl. The flocculation effect of the fluidized bed can be compared with a control with the same residence time but without any sand to see if the sand accelerates the aggregation process. It might also be appropriate to use a tube flocculator with the same head loss and residence time as the fluidized bed to more accurately determine if the sand is beneficial.

References

- Suspended solid abatement in a conical fluidized bed flocculator