Measuring Floc Size Evolution During Jar Tests

Jar tests are a routine tool to establish the concentrations of flocculation additives that optimize the flocculation process. It is left to the operator to select, by visual inspection of the floc particles formed in the test jar, which process parameters optimize the process. The entire dynamics of floc formation is typically ignored. We use the Jar FlocCAM® (Durasens, Pleasantville, NY) to measure floc size, apparent floc density, floc shape, average floc speed, etc. during the flocculation process. The Jar FlocCAM® fits onto a standard test jar and six units can be simultaneously deployed to observe the flocculation process in all six test jars of a standard jar test fixture. We report our findings based on the measurements using the same stock water, but varying dosage of additives.

Introduction

The aim of the flocculation process is to aggregate microscopic particles called micro flocs suspended in water into larger particles called flocs. The suspended micro flocs generally bear static (typically negative) electric charges, so they electrically repel each other and therefore distribute themselves uniformly throughout the water column. Around each particle there is a layer of (typically positive) charged ions. This positively charged layer consists of ions that stick to the particle's surface and are therefore permanently bound to it and a fluid layer of positive ions that are not permanently bound to the particle. The thickness of this fluid layer depends on the concentration of positive ions in the water. The higher the concentration the smaller the thickness so the particles can come closer together increasing the chance of getting permanently fused. By fusing in collisions, the floc particles grow in size until the process exhausts all the micro flocs and the water becomes clarified. Then the large flocs are left to settle to the bottom and the remaining clarified water is filtered.

There are many parameters that affect flocculation dynamics. Some of these parameters are input water quality, water temperature, pH, concentration of coagulant, rate of stirring, etc. In this note we focus on coagulant concentration.

Experiments

The Jar FlocCAM® fits on a standard rectangular jar. During the course of experiment it collects information on floc size, number of flocs, shape of flocs, floc average velocity, and others. These parameters are recorded every N (user selectable) seconds. In this work we used N = 5 seconds. All six jars in a standard jar test fixture can be monitored simultaneously.

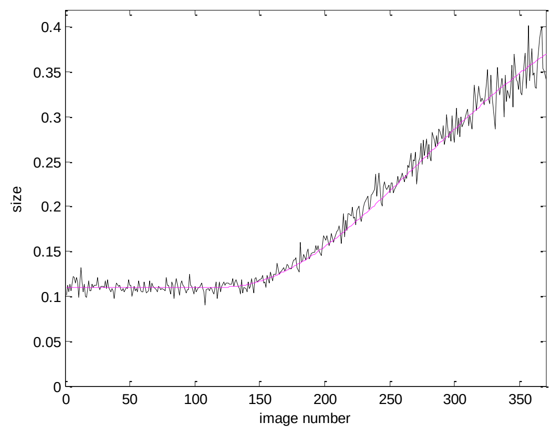
141 Tompkins Ave, Pleasantville, NY 10570
T 844-FLOCCAM (356-2226)
E info@floccam.com
www.floccam.com

Figure 1: Standard jar test fixture equipped with six Jar FlocCAM®s

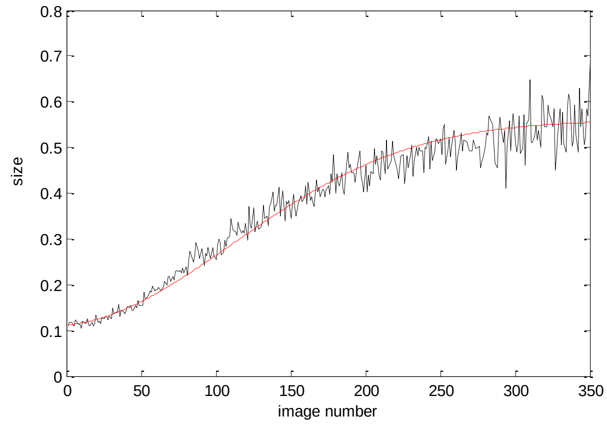
Test No.	PACl dose (ppm)	Arcylamide dose (ppm)	Pre-Test Turbidity (NTU)	Residual Turbidity (NTU)*	pC*
1	20	10	1.39	1.08	0.110
2	40	10	1.42	0.48	0.471
3	60	10	1.70	0.33	0.712
4	80	10	1.79	0.25	0.855
5	100	10	1.58	0.26	0.784
6	20	10	1.50	0.73	0.313
7	40	10	1.55	0.44	0.547
8	60	10	1.43	0.30	0.678
9	80	10	1.73	0.30	0.761
10	100	10	1.68	0.36	0.669

TABLE 1: Summary of the two separate experiments

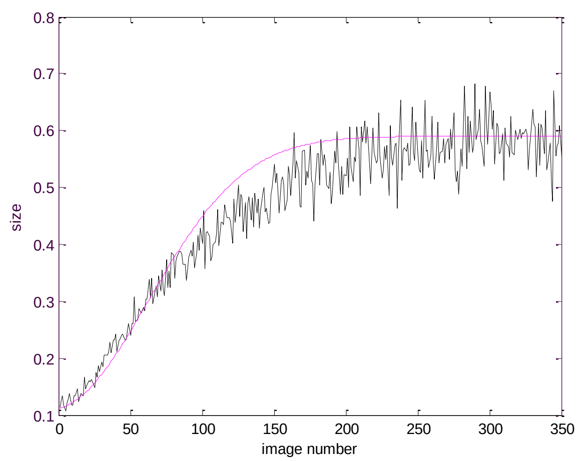
The experimental curves are shown as black, the corresponding fit to (1) is shown in red.



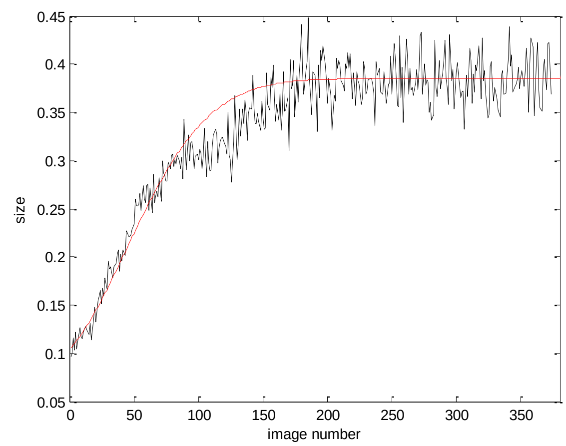
First experiment, PACl dose 20 ppm



First experiment, PACl dose 40 ppm



First experiment, PACl dose 60 ppm



First experiment, PACl dose 80 ppm

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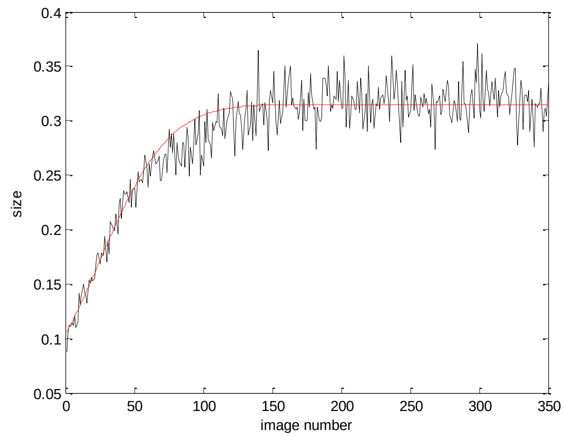
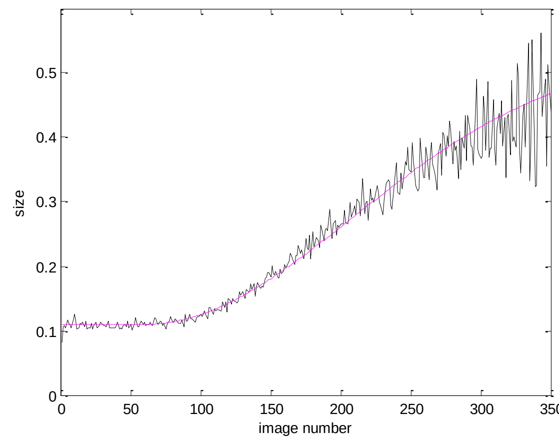
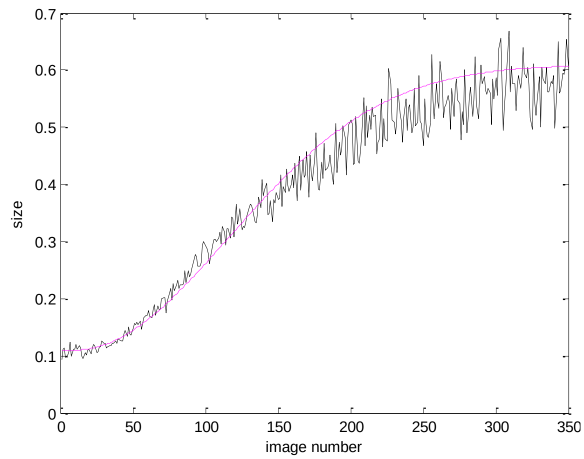


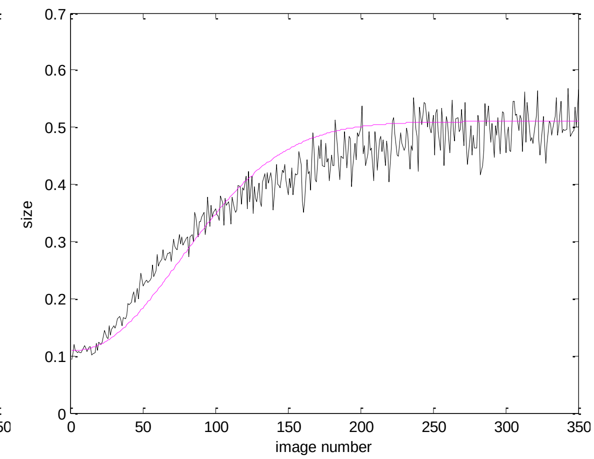
First experiment, PACl dose 100 ppm



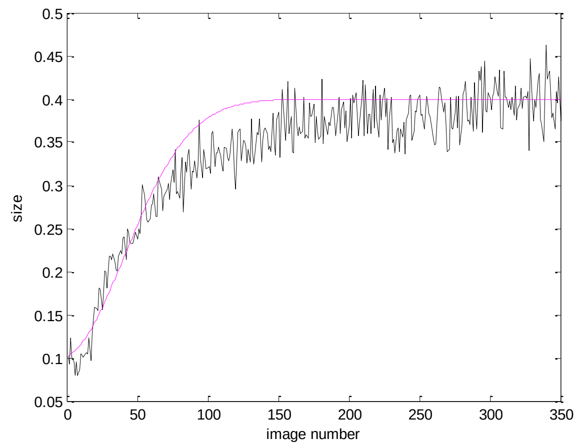
Second experiment, PACl dose 20 ppm



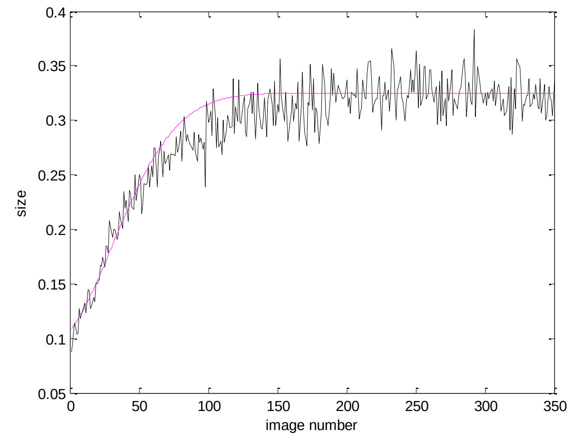
Second experiment, PACl dose 40 ppm



Second experiment, PACl dose 60 ppm



Second experiment, PACl dose 80 ppm



Second experiment, PACl dose 100 ppm

We see the floc growth curve in a jar test starts at a certain pre-flocculation particle size $D(0)$, then grows during flocculation at some rate, and reaches the final size after which further mixing yields no size changes. This is sketched in Fig. 2.

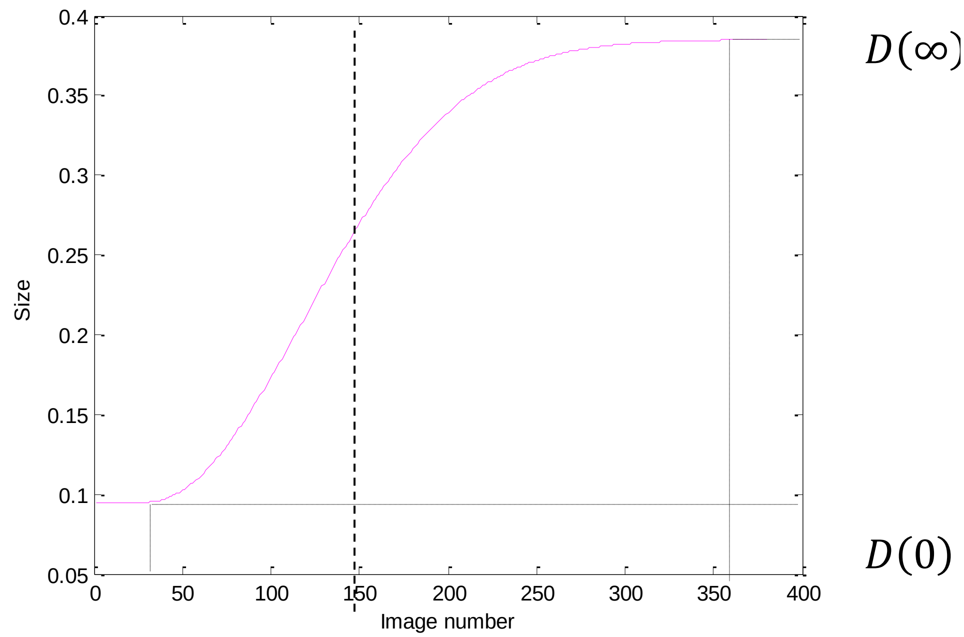


Figure 2: Expected floc evolution curve

We fitted the observed experimental curves to the following analytical form:

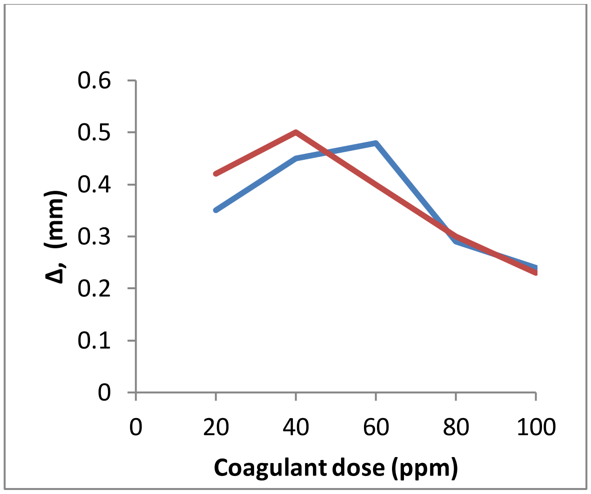
$$D(t) = D(0) + \Delta\left(1 - e^{-\left(\frac{t}{T}\right)^2}\right) \qquad (1)$$

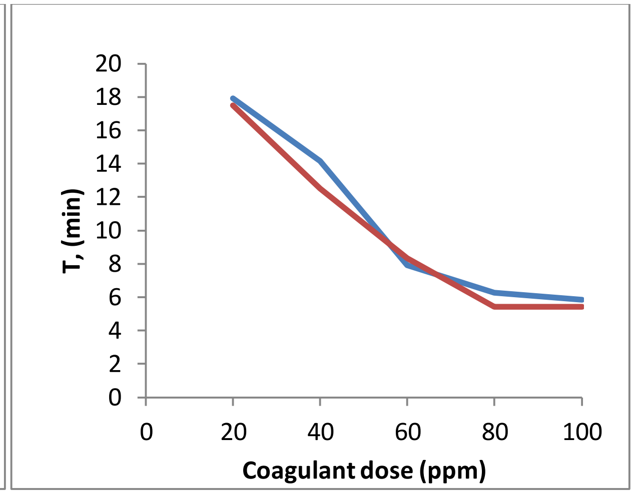
D(t) is floc size at time *t*,
Δ is the increase in floc size during the experiment
T is the time it takes the floc size to reach $D(0) + \Delta\left(1 - \frac{1}{e}\right) = D(0) + 0.632\Delta$
The above analytical form contains only the parameters that are directly related to the measured curves. Again, this is not the actual curve shape, but it is similar enough that the curve parameters can be used to summarize the experiment.

Results

Test No.	PACl dose (ppm)	time *T* *(min)*	Δ	D(0)
1	20	17.92	0.35	0.11
2	40	14.17	0.45	0.11
3	60	7.92	0.48	0.11
4	80	6.25	0.29	0.095
5	100	5.83	0.24	0.075
6	20	17.50	0.42	0.11
7	40	12.50	0.5	0.11
8	60	8.33	0.4	0.11
9	80	5.42	0.3	0.1
10	100	5.42	0.23	0.095

Table 2: The results of experiments





Size vs. coagulant dose. Experiment 1 (blue)

Mean time vs. coagulant dose. Experiment 1 (blue)

Above figures show the results from Table 2. We see that floc size reaches a maximum for a coagulant dose of between 40 and 60 ppm. We also see that the mean time of the flocculation process is strongly influenced by the coagulant dose. The time of the flocculation process in a water treatment plant is essentially determined by the transit time the water takes from the point where the coagulant is dispensed, to the point where it enters sedimentation pools. The transit time is mostly dictated by the architecture of the plant and is not a parameter that can be readily used to control the reaction. However, the demand influences the transit time so this is a process parameter that should be monitored by operators and adjusted for by tweaking the coagulant dose to match the coagulation time to the transit time.

It is not clear why, after reaching the maximum floc size, adding more coagulant leads to smaller flocs. Understanding the dynamics of the flocculation process would yield more precise process optimization, thus reduce the load on filters, eliminate coagulant overdosing, reduce sludge volume, etc.

Conclusion

The reason we needed multiple jars in a test fixture is that we have no way to compare the floc in the jar test currently running with one that finished an hour ago. Until now, jar tests were not quantitative. So the only way they could be run is by having multiple jars running simultaneously so the flocs in different jars could be compared in real time. Since there was no quantifiable outcome to jar tests, there was no record of previous tests. The previous jar test results existed only in the memory of a tester. With Jar FlocCAM® these tests can be made much more useful since we don't only gain quantitative outcomes of a current test, we also can compare the current results with those from a week or a month or a year ago.

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