Effects of Mixing Intensity on the Kinetics of Flocculation Using Model Colloid with Polyelectrolyte

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OKTAVIANI

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Summary

The method to evaluate mixing intensity in terms of collision frequency of uniform colloidal spheres was revisited to examine the validity of this method in a small stirred vessel equipped with an impeller of four paddles. Rates of salt-induced rapid coagulation of polystyrene latex (PSL) particles with five different diameters were measured as a function of rate of rotation. The ad-hoc assumption of linear additivity of peri- and ortho-kinetics of coagulation was applied in the analysis. The validity of our previously proposed equation of the rate of turbulent coagulation as a function of particle diameter, obtained for end-over-end rotation mixing device was confirmed to be valid. However, the result obtained with small particles for the region of low mixing rate; for low Peclet number region, the rate of coagulation is confirmed to be accelerated by the coupling effect of Brownian motion and fluid flow of the turbulent mixing, even though the rate can be considered to be lowered by the wall effect which produces inhomogeneous distribution of mixing intensity.

The established method has been applied to the analysis of polymer flocculation revealing significant effect of ionic strength on the rate flocculation in the initial stage by using end-over-end mixing device. However, in this method, the mixing of colloid is carried out always in a same manner. Recently, we carried out the experiment of flocculation with polyelectrolyte under extremely high ionic strength. The result suggested that conformation of polymer chains attached to the colloid particle is stretched out by the fluid motion to enhance the rate of flocculation. That is, effect of ionic strength on the rate of flocculation should be analyzed as a function of mixing intensity. In this study, effect of mixing intensity on the kinetics of flocculation of polystyrene latex (PSL) particles with high charge density polyelectrolyte was analyzed using a small mixing stirrer vessel equipped with four paddle impellers. The intensity of mixing was estimated by the effective shear rate evaluated in terms of collision frequency. This estimation was performed by the measurement of salt-induced

rapid coagulation of PSL particles as a function of impeller rotation speed. Acrylamide-(dimethylamino)ethyl methacrylate methyl chloride with nominal molecular weight of 4.9 $\times 10^6$ g mol^{-1} was used as flocculant. An enhancement factor, determined by the ratio of the rate of flocculation of polyelectrolyte in the initial stage to that of salt-induce rapid coagulation, was used as the evaluation index. It was found that the enhancement factor goes through maximum with an increase of mixing intensity implying the presence of optimal mixing intensity. Considerable fluctuation is recognized for the low mixing intensity and slightly increases as ionic strength increases. In the case of low mixing intensity and high ionic strength, the enhancement factor found to be higher than in condition of low ionic strength, implied that polyelectrolyte become soft in condition of high ionic strength and easily extended by applying low mixing intensity.

From the data obtained from the above experiments, we realized the pellet flocs formation in this study. We compared three different mixing devices, i.e. standardized end-over-end mixing apparatus, small stirred vessel, and small end-over-end to study the effect of mixing intensity by means of the rate of salt-induced of rapid coagulation that is equivalent to collision frequency of polystyrene latex (PSL). In the previous study, pellet flocs were found to be formed by using the stirred tank and couldn't be formed by using the small end-over-end mixing device. Thus, we determined the energy dissipation per unit mass (ε) for each mixing device used in this experiment by measured the rate of coagulation in order to clarify the reason obtained by the previous study, i.e. why pellet flocs couldn't be formed by applying different mixing method. The results implied that pellet flocs couldn't be formed by using end-over-end due to the mixing intensity generated by end-over-end was three times higher than mixing intensity that allowing pellet flocs formation, i.e. 110 rpm. By comparing the energy dissipation of each mixing device, the pellet flocs formation can be obtained by using small end-over-end

by applying 18 rpm mixing intensity. Further study should be attempted to get details understanding of pellet flocs formation.