

Influence of Several Physicochemical Conditions on the Flocculation of Micro Stickies

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ABSTRACT

Behavior of micro stickies was analyzed using model micro stickies prepared with PVAc emulsion adhesive. Flocculation of micro stickies increased with temperature. Acidic state also induced greater flocculation of micro stickies since they became more unstable under these conditions. Flocculation of micro stickies increased as calcium ion concentration increased. But the presence of calcium carbonates made micro stickies dispersed indicating that calcium carbonates cause two different effects on the behavior of micro stickies. Talc increased flocculation of micro stickies because of its hydrophobic nature. Cationic polymer increased flocculation of micro stickies. Especially cationic starch has far greater effect in flocculating sticky particles by forming bridging flocculations.

Keywords : *micro stickies, flocculation, filler, cationic polymer*

1. Introduction

Micro stickies are defined as the sticky contaminants smaller than 0.15 mm which cannot be removed by screening. Since the density of micro stickies is close to that of water, micro stickies cannot be removed effectively by cleaning process. The difficulties of removing micro stickies causes serious problems in papermaking process. To make the problem even more difficult is the fact that the amount of stickies contained in recycled papers increases these days because the use of pressure sensitive adhesives, hot melt adhesives, etc increases. Also the practice of papermaking system closure causes accumulation of the micro stickies in white water.

Controlling micro stickies in papermaking processes is a very difficult task. When they are allowed to present in the papermaking system their physicochemical properties might change as system environments including pH, temperature, salts, and additives changes, which results in stickies deposit formation (1).

Many researches have been made to elucidate the properties and behavior of micro stickies, and their changes caused by the variation of system environment. These researches have established grounds for the control of micro stickies.

Studies on the behavior of micro stickies have been made by measuring such variations as flocculation,

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deposit formation, turbidity etc. Model micro stickies or emulsion adhesives have often been employed as substitutes for real micro stickies that are found in mill stocks. Nelson (2) and Abraham(3) investigated the characteristics of micro stickies as a function of pH, temperature and ion consistency, and showed that micro stickies became unstable under the condition of acidic state, high temperature, and high ionic concentration. Forgarty (4) proposed dispersion, detackification, cationic polymer, and passivation methods for stickies control. Grossmann and Klein (5) fractionated stickies with flotation cell and DDJ, and showed that the effectiveness of coacervation using cationic starch in stickies control. Abraham (6) made experiments for separating micro stickies using flotation cell and DDJ, and claimed that DDJ was more effective in separating micro stickies than flotation method. Huo et al. (7) examined the turbidity of the stocks containing micro stickies and showed that cationic polymers flocculated micro stickies. They also showed that fiber and micro stickies could form intermixed flocs.

Rebarber (8) reported that PAC could be a good controlling agent for micro stickies because it tends to make stickies be absorbed on fiber comparatively. But he claimed that cationic polymers with high molecular weight produced large tacky flocs of stickies. Heucher and Butterbach (9) researched about hot melt adhesive. Patel and Banerjee (10) studied about deposits by hot melt adhesive and wax. Chi et al. (11) analyzed flocs formed with talc and tonner with SEM and AFM.

Behavior of micro stickies was analyzed using model micro stickies prepared by PVAc emulsion adhesive.

2. Materials and Methods

2.1 Materials

Polyvinyl acetate emulsion adhesive, made by Sam

Table 1. Properties of poly-DADMAC and cationic starch

	Viscosity (cPs at 25°C)	Charge density (meq/g)
poly-DADMAC	15 (0.5%)	1.904 (0.01%)
Cationic starch	44 (0.5%)	0.1825 (0.01%)

Won. Co. Ltd, was used as a model of micro stickies. Zeta potential of the adhesive at pH 7 was -27.91 mV. GCC (diameter 1.22 μm, ISO brightness 93.4%) and talc (diameter 1.61 μm, ISO brightness 90.3%) were used as filler. CaCl₂ was used to evaluate the effect of hardness on stickies deposition. Polyaluminum chloride (PAC), poly-DADMAC and cationic starch were used as coagulating and flocculating agents. Table 1 shows the properties of poly-DADMAC and cationic starch.

2.2 Methods

2.2.1 Analysis of behavior characteristics

Deionized water was placed in a DDJ and stirred at 500 rpm. Then, PVAc emulsion was added to prepare 1% emulsion and stirred for 1 min at a constant temperature of 45°C. While stirring the pH was kept at

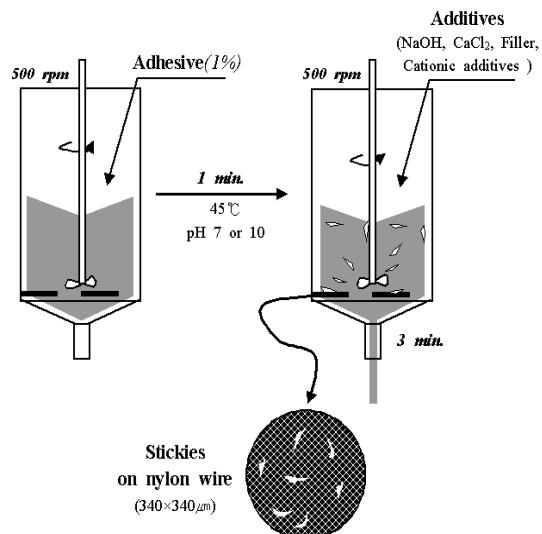


Fig. 1. Analysis method of behavior characterization for micro stickies.

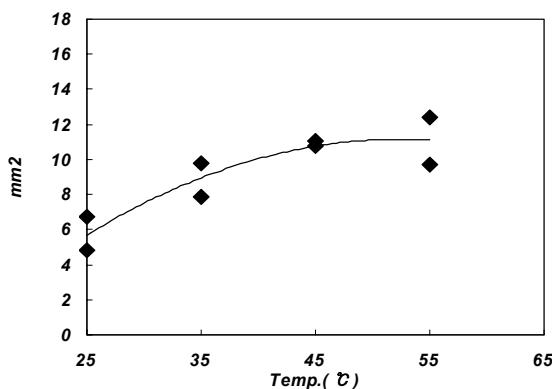


Fig. 2. Deposit area of micro stickies by flocculation as a function of temperature (pH 7).

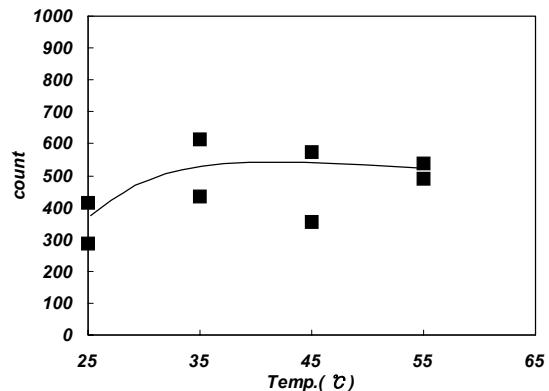


Fig. 3. Deposit counts of micro stickies by flocculation as a function of temperature (pH 7).

7 or 10. After 1 min of stirring, poly-DADMAC or other additive was added to change the chemical environment of the stock in DDJ. After 3 min of reaction, the stock was drained. The component retained on black nylon wire was dried at a room temperature and scanned for image analysis (Fig. 1). Images that were scanned at a resolution of 150 dpi were analyzed using an image analyzer. Gray scale images were transformed into black and white images by applying a threshold value of 65. The area and counts of stickies were determined. Small cells were eliminated by median filtering. This was carried out to eliminates the effects of contamination.

3. Results and Discussion

3.1 Effect of stock temperature and pH on the flocculation of micro stickies

Micro stickies soften as temperature increases, which causes an increase in coagulation and wetting property of the micro particles. Figs. 2 and 3 show the area and count of micro stickies deposited on the wire as a function of temperature.

Effect of pH on the area of micro stickies deposited on the wire by flocculation are shown in Fig. 4. As shown here, deposit area and count increased at low pH indicating that the stability of PVAc emulsion

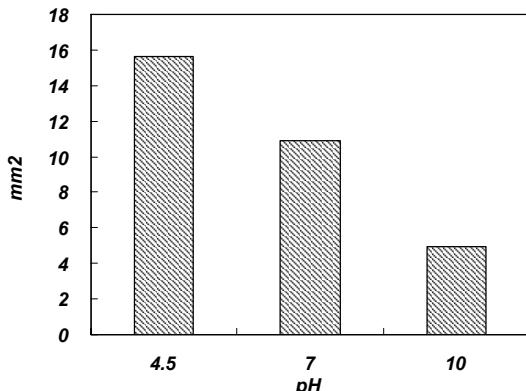


Fig. 4. Deposit area of micro stickies by flocculation as a function of pH (Temp. 45°C).

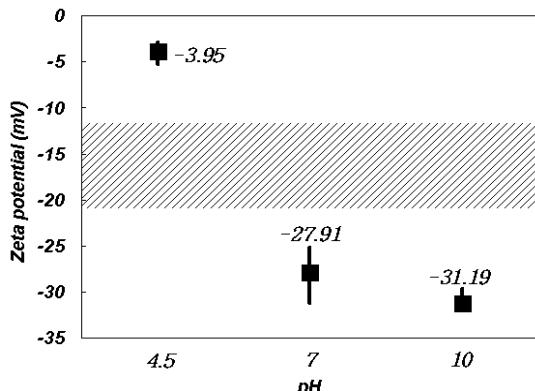


Fig. 5. Zeta potential of micro stickies as a function of pH.

decreased under acidic conditions. Loss of emulsion stability under acidic condition appeared to be caused by reduced zeta potential of the emulsion particles as shown in Fig. 5. Zeta potential of the emulsion was determined using Zeta-Meter 3.0+. Averages of the zeta potential of PVAc emulsion at three different pH's were depicted along with the range in Fig. 5. When pH was 4.5, zeta potential of the emulsion decreased to -3.95 mV, which reduces repulsion between emulsion particles and causes coagulation and deposition of the stickies.

3.2 Flocculation by ion

Fig. 6 shows the deposit area of micro stickies as a function of calcium ion concentration. The dotted line indicates the point of charge neutralization of the stock. Deposit area and count increased and decreased as calcium concentration increased. This shows that anionic PVAc emulsion flocculates and deposits on the plastic wire as calcium ion concentration increases. But when calcium ion concentration exceeded 400 ppm, micro stickies redispersed again because of the reversion of zeta potential.

3.3 Flocculation by filler

Fig. 7 shows the area of micro stickies deposit formed on the plastic wire as a function of talc addition

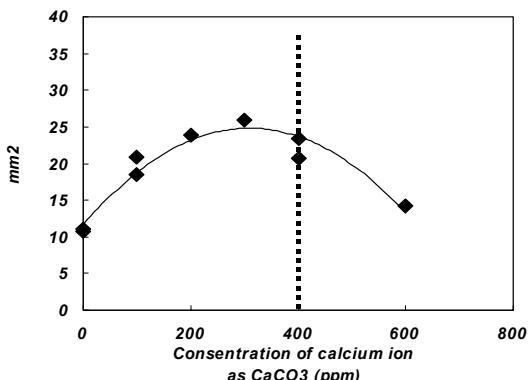


Fig. 6. Deposit area of micro stickies by flocculation as a function of Ca^{2+} concentration (pH 7, Temp. 45°C).

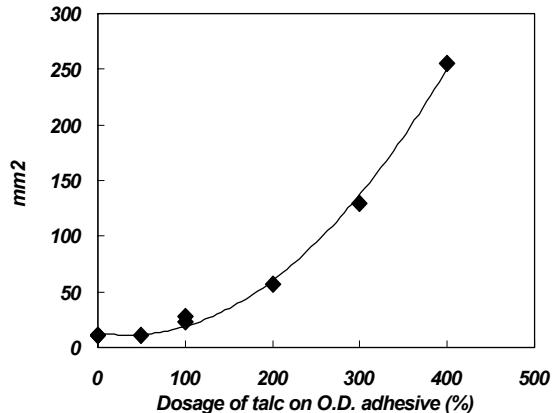


Fig. 7. Deposit area of micro stickies by flocculation as a function of talc (pH 7, Temp. 45°C).

rate. It shows that hydrophobic talc caused substantial increase of deposit area. Talc has a three-layered structure with a magnesium oxide layer sandwiched between two hydrophobic silica layers. Because of this structural characteristics of talc it is used as coflocculating agent for hydrophobic colloidal micro stickies. Coflocculation of talc and colloidal stickies increases the size and weight of particles so that they can be more easily removed by cleaning and screening.

Fig. 8 shows the results when CaCO_3 was used instead of talc. Deposit area decreased as addition of CaCO_3 increased indicating that CaCO_3 was

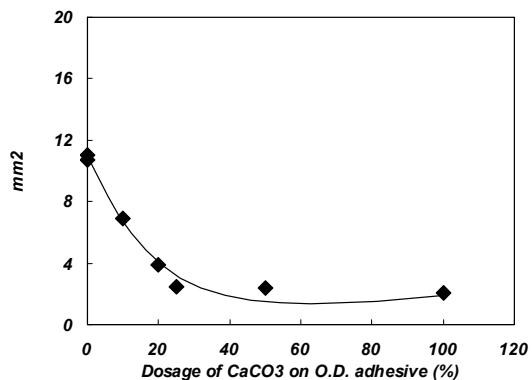


Fig. 8. Deposit area of micro stickies by flocculation as a function of CaCO_3 (pH 7, Temp. 45°C).

detrimental for flocculation of micro stickies. The reduction of stickies deposition when CaCO_3 was added does not mean the elimination of stickies from the papermaking process. Micro stickies just remained dispersed in white water. Thus the content of micro stickies in white water increases as the level of system closure increases along with potential problem of stickies deposition.

3.4 Flocculation by cationic polymers

Polyaluminum hydroxy chloride (PAC) is being used as anionic trash catcher and retention aid in papermaking because of its high cationic charge. Fig. 9 shows the area and count of micro stickies deposit

founded on the wire when PAC was used as flocculant. The area count of stickies deposits increased as PAC addition increased to 2% of the O.D. weight of adhesives, and decreased slightly afterwards.

Figs. 10 and 11 show the area and count of deposits found on the wire as a function of poly-DADMAC dosage. It is interesting to note the deposit area increased continuously with poly-DADMAC addition even though the addition rate was greater than that required for charge neutralization. However, the number of stickies deposits reached maximum at charge neutralization point as shown in Fig. 11 indicating that the increase of deposit area is due to the formation of large flocs of micro stickies.

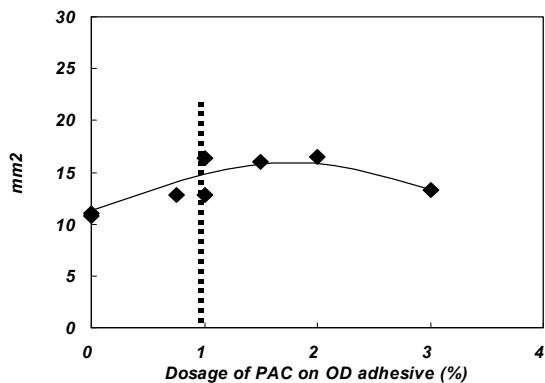


Fig. 9. Deposit area of micro stickies by flocculation as a function of PAC (pH 7, Temp. 45°C).

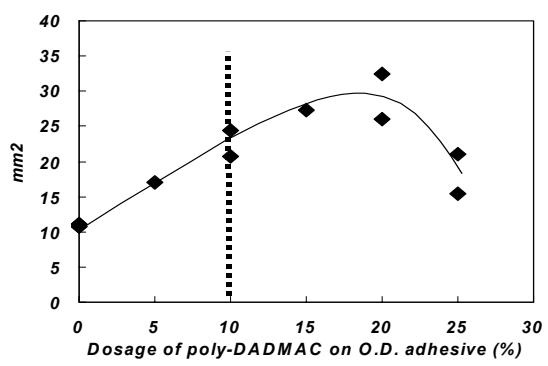


Fig. 10. Deposit area of micro stickies by flocculation as a function of p-DADMAC (pH 7, Temp. 45°C).

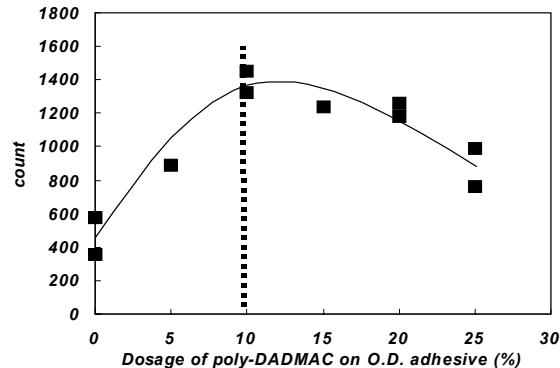


Fig. 11. Deposit counts of micro stickies by flocculation as a function of p-DADMAC (pH 7, Temp. 45°C).

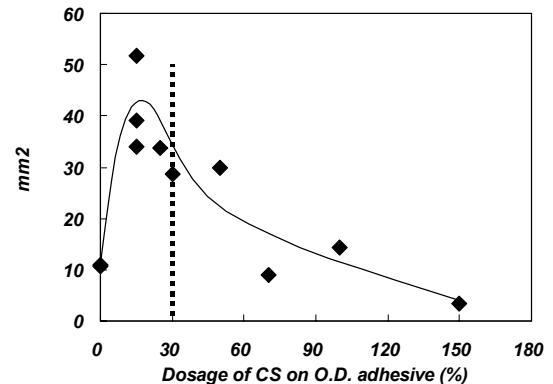


Fig. 12. Deposit area of micro stickies by flocculation as a function of cationic starch (pH 7, Temp. 45°C).

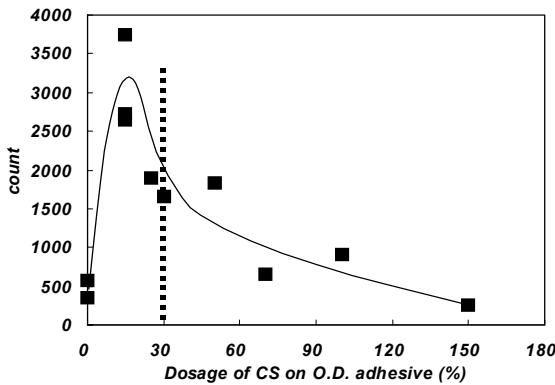


Fig. 13. Deposit counts of micro stickies by flocculation as a function of cationic starch (pH 7, Temp. 45°C).

Figs. 12 and 13 show the area and count of micro stickies deposits when cationic starch was used as a flocculant. Cationic starch is widely used in paper industry to improve strength, dewatering and retention. When cationic starch was added, flocculation of stickies occurred very effectively, and the area and count of deposits increased quite rapidly compare to the case of PAC or poly-DADMAC. The area and count of micro stickies deposits decreased rapidly when the amount of starch addition was greater than 15%, even though the charge neutralization has not been reached. This was different from two case of PAC and poly-DADMAC.

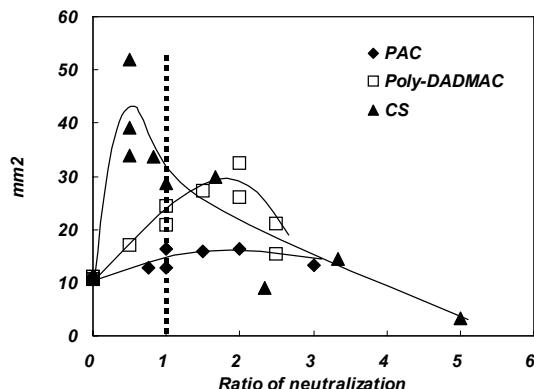


Fig. 14. Comparison of three deposit area results using ratio of neutralization (pH 7, Temp. 45°C).

The relationship between charge neutralization point and maximum deposit formation depended upon the type of polyelectrolytes. To make comparison of the effects of polyelectrolyte types on deposit formation of micro stickies, the area and count of the stickies deposits were plotted against the ratio of charge neutralization in Figs. 14 and 15. The ratio of neutralization was calculated as shown in the equation shown below.

$$\text{Ratio of neutralization} = \frac{\text{Dosage amount}}{\text{Dosage amount on neutralization}}$$

It is clear that cationic starch gave the largest area and count of stickies deposits while PAC was least effective. In addition, the amount of polyelectrolytes required to obtain maximum deposit formation decreased below the addition level for charge neutralization as the molecular weight increased.

This shows that the flocculation of micro stickies by cationic polymers is related to the charge neutralization and bridging. As the molecular weight increases, the effect of polymer bridging also increases. Deposit formation by cationic starch decreased before the point of neutralization. This is probably because cationic starch tends to make large but soft flocs of micro stickies, which tend to break down under shear (8).

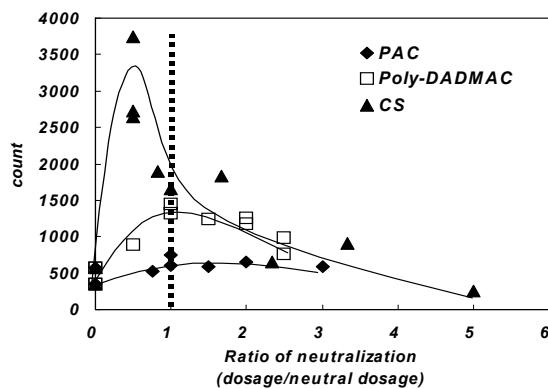


Fig. 15. Comparison of three deposit count results using ratio of neutralization (pH 7, Temp. 45°C).

4. Conclusions

Behavior of micro stickies was analyzed using model micro stickies prepared with PVAc emulsion adhesive. Micro stickies flocculated greater at higher temperature because the wetting and coagulating property increases with temperature. Acidic state also induced greater flocculation of micro stickies since they became more unstable under acidic conditions.

Flocculation of micro stickies increased as calcium ion concentration increased. But presence of calcium carbonates made micro stickies dispersed. These two phenomena indicated that calcium carbonates can cause two different effects on the behavior of micro stickies.

Talc increases flocculation of micro stickies substantially since it carries hydrophobic property as stickies, which makes talc a collector for micro stickies. When the size and weight of the flocs formed between micro stickies and talc increases it can be removed rather easily by cleaning.

Cationic polymer increased flocculation of micro stickies. Especially cationic starch has far greater effect in flocculating sticky particles by forming bridging flocculations.

Acknowledgements

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