EFFECT OF HEAT-DISPERSING ON STICKIES AND THEIR REMOVAL IN POST-FLOTATION

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The effect of heat-dispersing on sticky substances in a deinking pulping line was studied under different conditions including varying temperature, disc clearance, and pulp consistency. Sticky substances were quantitatively investigated before and after the heat-dispersing, and categorized into macro-, mini-, and micro-stickies as well as dissolved and colloidal substances. Meanwhile, their extents of removal in post-flotation were evaluated. The results showed that raising temperature, reducing disc clearance, or increasing pulp consistency significantly improved the dispersion of sticky particles, an effect that will be beneficial to their removal in the subsequent flotation process. Under temperature of 100 °C, disc clearance of 0.3 mm, and pulp consistency of 30%, macro- and mini-stickies decreased by 92% and 83%, respectively. Due to being dispersed to smaller sizes, removals of mini- and micro-stickies were enhanced in post-flotation to 25-26% and 68-70%, respectively. Only a small amount of dissolved and colloidal substances was removed in flotation.

Keywords: Heat dispersing; Mini-stickies; Micro-stickies; Dissolved and colloidal substances; Post-flotation

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INTRODUCTION

Stickies remain one of the major obstacles in the manufacturing of quality newsprint paper from recycled fibers. Generally, they may be divided into macro-, micro-stickies, and dissolved and colloidal substances, as well as primary and secondary stickies (Johansson et al. 2003; Doshi et al. 2008). Macro-stickies refer to tacky particles that are retained on a laboratory screen with slots of 100 μm or 150 μm. Stickies smaller than 100 μm or 150 μm, but larger than 1 μm to 5 μm are called micro-stickies. Primary stickies originate directly from lipophilic wood extractives released during the repulping processes, and various synthetic adhesives introduced during processing or using of papers, for example, coating and printing, etc. Secondary stickies come mainly from dissolved and colloidal substances (DCS) in deinked pulps; they may be converted to sticky substances when pH, temperature, or the chemical environment of the pulp changes (Brun et al. 2007; Blanco et al. 2010).

Usually, fine screening in a deinking pulping line can remove most of the macro-stickies. However, during fine screening a portion of the large sticky particles may pass through the slots of the screen and remain in the pulp. This is caused by the pressure and shear force during the operation of fine screening, and it occurs frequently in a mill practice. It is these sticky particles remaining in the pulp that may cause the stickies problems in the paper machine system if they are not efficiently removed from the system in the subsequent processes.

According to the literature (Gallan et al. 2009; Lascar et al. 2010; Delagoutte et al. 2010), most stickies in the portion remaining in screened pulp range between 100 μm and 1000 μm, and these stickies can be categorized as mini-stickies. If they have not undergone further dispersion, mini-stickies may not be effectively removed in the subsequent post-flotation process, and they will consequently remain in the pulp and cause obstacles to running of paper machines (Lee et al. 2006; Sarja et al. 2007; Hamann et al. 2005).

Only the particles with sizes suitable for flotation can be efficiently removed during the flotation process. Therefore, the purpose of implementing a heat-dispersing process in a deinking pulping line is to effectively disperse ink particles and sticky substances with large sizes and still remaining in the pulp, so that they can be removed as much as possible in the subsequent post-flotation process (Zhao et al. 2008; Frantisek et al. 2007; Zhu et al. 2010).

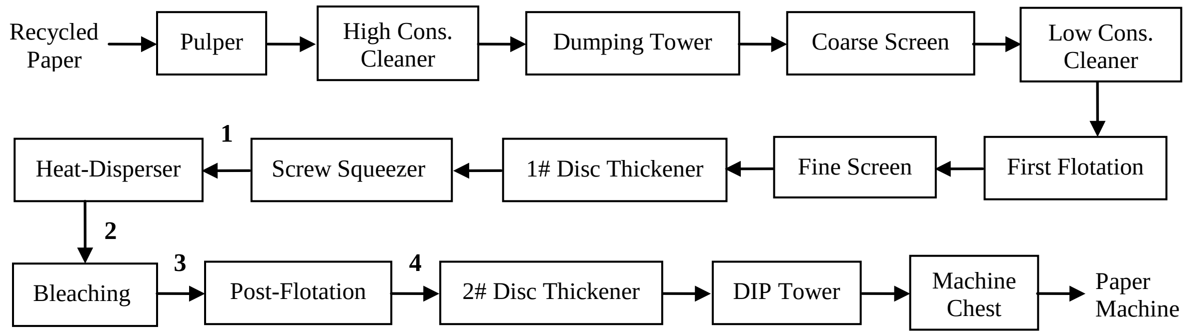
This study was combined with a trial in a commercial deinking pulping line and focused on the optimization of a heat-dispersing operation, to investigate dispersion of sticky substances by varying operating temperature, disc clearance, and inlet pulp consistency. Effects of these operating factors on the status and contents of sticky substances in the pulp before and after the heat-dispersing, as well as their removal by the subsequent post-flotation, were examined and discussed in this paper. It is hopeful that the results obtained from this investigation will provide some useful information for paper mill practices which employ recycled fibers.

EXPERIMENTAL

Pulp Sample, Heat-Dispersing and Flotation

This study was performed in a commercial newsprint paper production line that employs 100% of deinked pulp from old newspapers. The work was incorporated with a trial in the mill to minimize the obstacles caused by sticky substances. The effects of operating factors of the heat-dispersing on status and contents of sticky substances in the deinked pulp were investigated. The pulps were sampled from four major points, i.e. before and after the heat disperser, and before and after the post-flotation.

A flowchart of the deinking pulping line is as shown in Fig. 1. The system was equipped with a Voith heat disperser and a Voith EcoCell flotation system. The capacity of the production line is currently about 1,000 to 1,100 ton/day. In the trial, operating temperature in the heat-dispersing was varied from 70 °C to 100 °C, in an interval of 10 °C. Disc clearance was adjusted respectively at 0.3 mm, 0.4 mm, 0.5 mm, and 0.6 mm. Inlet pulp consistency included the levels of 20%, 25%, and 30%, respectively. The post-flotation runs were conducted under temperatures of 50 to 60 °C, pulp consistencies of 1.0 to 1.5%, and at pH values of 7.4 to 8.0.



Sampling Point: 1 and 2, Before and after Hear Dispersing; 3 and 4, Before and after Post-Flotation

Fig. 1. Sampling points

Analysis of Macro- and Mini-stickies

Analyses of macro-stickies and mini-stickies were basically carried out according to the INGED No.4 Method. 10 g of pulp sample (o.d.) was diluted to 1% concentration, and screened by using a Pulmac MasterScreen. A 20 mesh wire and a 100 μm slotted plate were applied for separating macro-stickies, mini-stickies, and fiber fractions. Macro-stickies (remain on the 20 mesh wire) and mini-stickies (remain on the 100 μm slotted plate) were respectively transferred to a black filter paper, and then covered with a sheet of silicone-coated paper. Under pressure of 95 KPa, the sheets were dried at 94 °C for 10 min. The sheet was dyed black with black water-based ink, then dried again. Subsequently, the specimen was covered with a thick layer of white special fused alumina powder. Then the top and bottom sides were covered with couching board, and the assembly was dried for 10 min at 94 °C. At the end, loose powder was removed with a soft cosmetic brush, and the specimen was examined with a scanner-based image analysis system (Verity IA Master-Screen). The contents of stickies were reported as mm^2/kg, and an average of 5 measurements was recorded as the result.

Analysis of Micro-stickies and DCS

10 g of pulp sample (o.d.) was diluted with deionized water to a concentration of 1% and agitated at 60 °C for 1 hour. The pulp suspension was then filtrated with a Dynamic Drainage Jar (100-mesh screen) to remove fiber fractions. 50 mL of filtrate was centrifuged at 450 g for 20 min. to obtain the supernatant which contained dissolved and colloidal substances (DCS), while the sediments contained micro-stickies. The supernatant was evaporated and dried at 105 °C, and the weight of remains was accounted as DCS. The sediments were dried and extracted with 100 mL of tetrahydro-furan (THF) for 6 hours. The extracts were concentrated through evaporation and dried with a stream of N_2 gas, then again in a vacuum desiccator at 40 °C for 20 min. The weight increase was accounted as micro-stickies (Sarja et al. 2004; MacNeil et al. 2006; Doshi 2009). An average of 10 measures was recorded as the result.

RESULTS AND DISCUSSION

Heat-Dispersing vs. Status and Content of Sticky Substances

Temperature vs. macro- and mini-stickies

First, the disc clearance of the heat disperser was set to 0.3 mm and the inlet pulp consistency was set to 30% to investigate status of sticky substances and their content. It can be seen from Fig. 2 that the content of macro-stickies was decreased by raising the operating temperature. About 88% of macro-stickies were dispersed to smaller sizes at 100 °C. Mini-stickies increased slightly at 70 °C, then they began to decrease with further increase in temperature. About 78% of mini-stickies were dispersed at 100 °C.

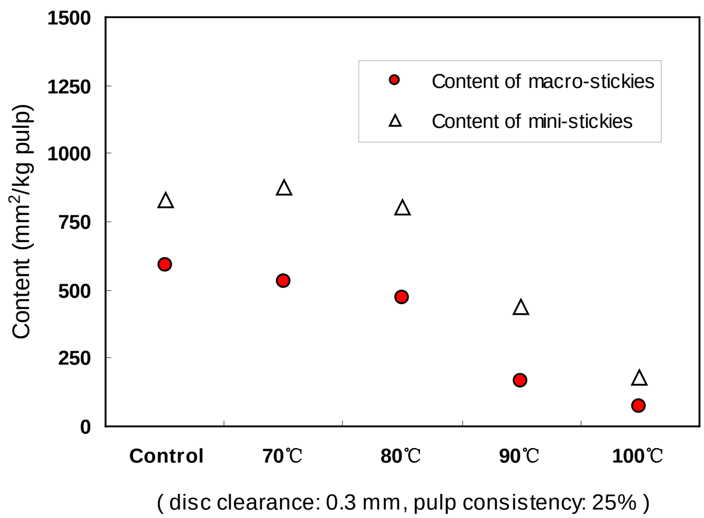


Fig. 2. Temperature vs. macro-stickies and mini-stickies

It is easy to understand that sticky substances were not sufficiently softened at lower temperatures. Particles having larger sizes still maintained after dispersion, and such particles were retained on the 100 µm screen. When the temperature was raised to the range 90 to 100 °C, sticky substances were well softened and could be dispersed into smaller sizes, i.e. forming micro-stickies or DCS. Therefore, contents of macro- and mini-stickies decreased significantly after heat-dispersing. This is in agreement with the literature (Liu et al. 2005), which indicates that the softening temperature of most adhesives, i.e. stickies originated substances such as ink binding adhesives, coating adhesives, hot melt adhesives, and pressure-sensitive adhesives, are substantially softened above 85-90 °C. Therefore, to achieve better dispersion of stickies, heat-dispersing should be performed at temperatures of 90 to 100 °C.

Disc clearance vs. macro- and mini-stickies

Keeping temperature at 100 °C and pulp consistency of 30%, the disc clearance was adjusted to investigate its effect on the dispersion of sticky substances, and the results were as shown in Fig. 3.

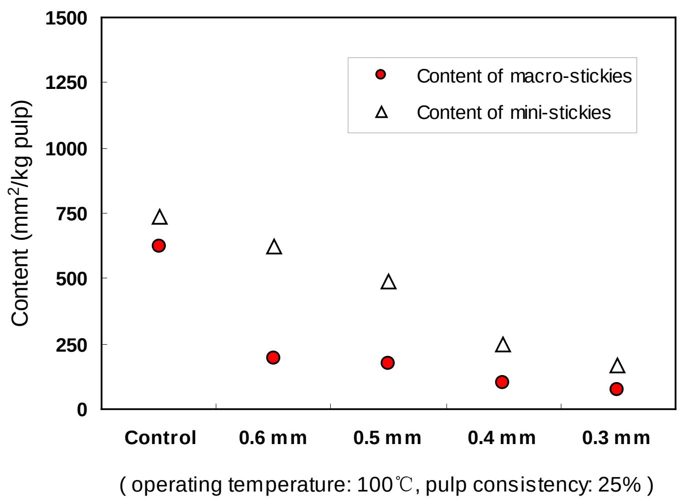


Fig. 3. Disc clearance vs. macro-stickies and mini-stickies

Reducing the disc clearance significantly decreased the amount of macro- and mini-stickies, especially the latter. Compared to dispersion at a clearance of 0.6 mm, about 77% of mini-stickies were dispersed to smaller sizes at a disc clearance of 0.3 mm. Reducing disc clearance improved rubbing and curlating of pulp fibers, which consequently enhanced dispersion of stickies. It should be noted that reduced clearance also led to increased energy consumption and fiber strength loss. Therefore, it is suggested that heat-dispersing should be run at a disc clearance in the range of 0.3 to 0.4 mm.

Pulp consistency vs. macro- and mini-stickies

Setting the temperature at 100 °C and the disc clearance at 0.3 mm, the inlet pulp consistency was varied to investigate effect of dispersion on sticky substances, and the results were as shown in Fig. 4.

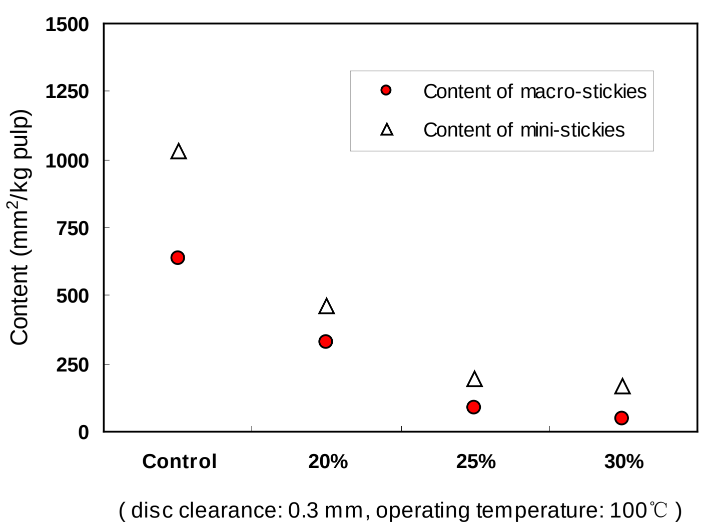


Fig. 4. Pulp consistency vs. macro-stickies and mini-stickies

Results in Fig. 4 show that macro- and mini-stickies decreased remarkably with increasing pulp consistency. It is understandable that at a higher pulp consistency, stronger rubbing and curlating between pulp fibers were achieved. Meanwhile, sticky substances were more effectively dispersed (Zhu et al. 2010). By running at a pulp consistency of 20%, the contents of macro- and mini-stickies were decreased by 48% and 33%, respectively. Furthermore, by running at a consistency of 25%, macro- and mini-stickies decreased by 89% and 81%. Therefore, a higher pulp consistency provided better dispersion of sticky substances.

At a temperature of 100 °C, a disc clearance of 0.3 mm, and a pulp consistency of 30%, about 92% of macro-stickies and 83% of mini-stickies were dispersed to smaller sizes. In conclusion, raising operating temperature, reducing disc clearance, or increasing pulp consistency effectively improved dispersion of sticky substances. In a mill practice, these three factors should be properly controlled for achieving effective dispersion of sticky substances. Meanwhile, attention needs to be paid to running the system under economical conditions.

Effect of Heat-Dispersing on Size Distribution of Mini-Stickies

Based on examination, macro-stickies entering the heat-disperser accounted for about 5% of the total amount of macro- and mini-stickies, and they were easily dispersed to smaller sizes. Therefore, it is important to consider how the heat-disperser can be used to disperse mini-stickies as much as possible. The size distribution of mini-stickies after heat-dispersing is listed in Figs. 5 to 7.

It can be seen that by raising temperature, reducing the disc clearance, or increasing pulp consistency, the sizes of mini-stickies were decreased effectively. After heat-dispersing, most mini-stickies had sizes in the range of 0.02 to 0.04 mm^2. At a temperature of 100 °C, disc clearance of 0.3 mm, and pulp consistency of 30%, more than 60% of mini-stickies were within the range of 0.02 and 0.04 mm^2, and only 2 to 3% of the stickies were larger than 0.08 mm^2.

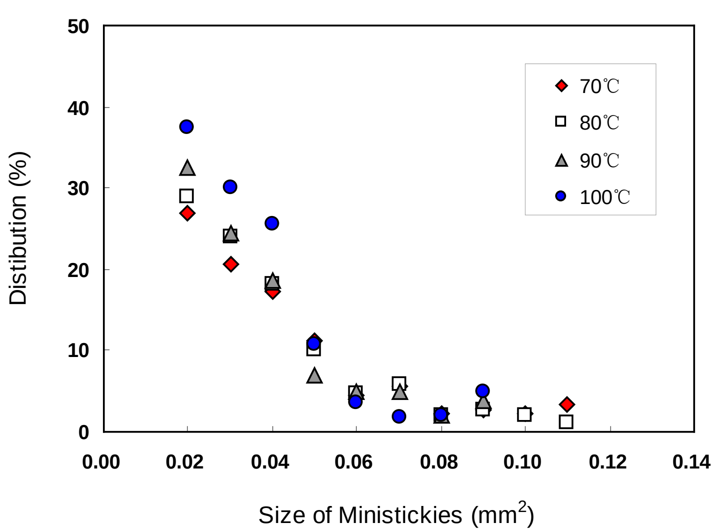


Fig. 5. Temperature vs. size distribution of mini-stickies

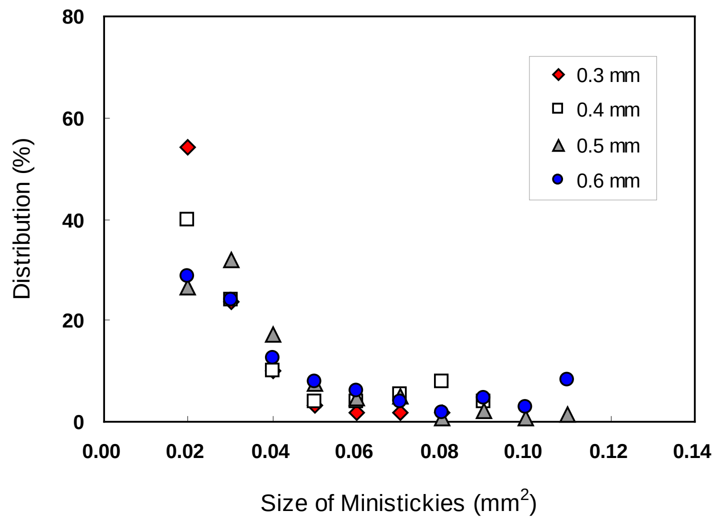


Fig. 6. Disc clearance vs. size distribution of mini-stickies

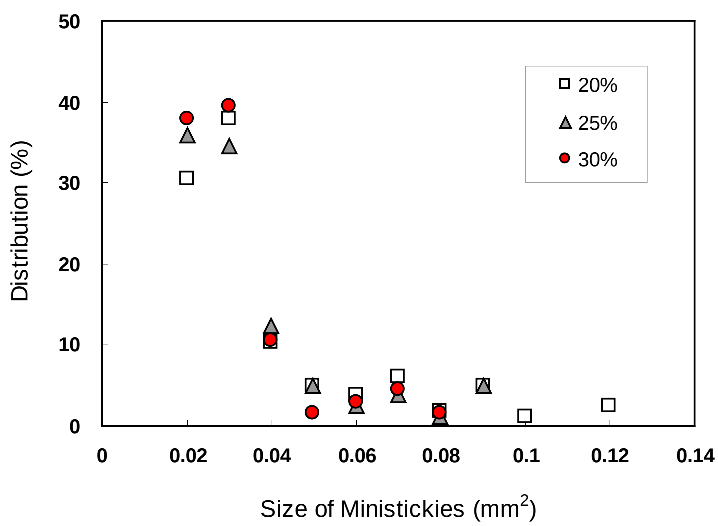


Fig. 7. Pulp consistency vs. size distribution of mini-stickies

Effect of Heat-Dispersing on Mini-Stickies and Their Removal

It was well known that effective removal of sticky substances by flotation depends directly on sizes of particulates. Papermaking with recycled fibers involves both removal of ink particles and tacky particulates. Sticky substances with suitable sizes for flotation are removed together with ink particles in deinking flotation (Sarja et al. 2007; Hamann 2005). Therefore, heat-dispersing should be well controlled to disperse sticky substances to smaller sizes, so that they can be removed as much as possible in the subsequent post-flotation. Tables 1 to 3 show removal rates of mini-stickies in flotation subsequent to varying heat-dispersing conditions.

Table 1. Temperature vs. Mini-stickies Size and Their Removal

Temperature (°C)	Size (mm^2)	Content bef. Flotation (mm^2/kg)	Content aft. Flotation (mm^2/kg)	Removal (%)
70	0.040	878	702	20.1
80	0.038	806	634	21.3
90	0.034	439	330	24.8
100	0.028	136	101	25.7
Note: disc clearance at 0.3 mm, pulp consistency of 30%				

Table 2. Disc Clearance vs. Mini-stickies Size and Their Removal

Disc Clearance (mm)	Size (mm^2)	Content bef. Flotation (mm^2/kg)	Content aft. Flotation (mm^2/kg)	Removal (%)
0.6	0.035	623	488	21.7
0.5	0.033	487	372	23.6
0.4	0.030	248	187	24.6
0.3	0.025	129	96	25.6
Note: temperature at 100 °C, pulp consistency of 30%				

Table 3. Pulp Consistency vs. Mini-stickies Size and Their Removal

Pulp Consistency (%)	Size (mm^2)	Content bef. Flotation (mm^2/kg)	Content aft. Flotation (mm^2/kg)	Removal (%)
20	0.031	464	359	22.6
25	0.024	165	122	26.1
30	0.021	103	76	26.2
Note: temperature at 100 °C, disc clearance at 0.3 mm.				

Before entering the heat-disperser, most macro-stickies in the pulp were in the size range of 0.66 to 0.69 mm^2. It can be seen that by raising temperature from 70 °C to 100 °C, and keeping disc clearance and pulp consistency constant, sizes of sticky substances were reduced to the range 0.040 to 0.028 mm^2. Similarly, by reducing disc clearance from 0.6 mm to 0.3 mm, and keeping temperature and pulp consistency constant, sizes of sticky substances were reduced to 0.035 to 0.025 mm^2. Furthermore, increasing pulp consistency from 20% to 30% and keeping temperature and disc clearance constant reduced sizes of sticky substances to the range 0.031 to 0.021 mm^2. In other words, elevated temperature, reduced disc clearance, or increased pulp consistency can significantly improve disintegration and dispersion of stickies, benefitting their removal in the followed post-flotation.

Only about 2.4 to 3.0% of macro-stickies were removed in post-flotation, which was in agreement with the literature (Sarja et al. 2007; Hamann et al. 2005), i.e. particle sizes suitable for removal by flotation were in range of 10 μm to 150 μm. This was because macro-stickies are not easy attached onto microbubbles. On the contrary, they are easily released from bubbles by shear force. The area of mini-stickies is usually in range of 0.02 to 0.04 mm^2 or particle sizes of 100 to 250 μm. It can be seen from Table.1 to Table 3 that removal of mini-stickies was increased by raising temperature, reducing disc clearance, or increasing pulp consistency. Although about 25 to 26% of mini-stickies were removed by post-flotation, the removal rate was still limited due to their sizes.

Effect of Heat-Dispersing on Micro-Stickies and Their Removal

Tables 4 to 6 list contents of mini-stickies before and after heat-dispersing, and their removal rates by the subsequent post-flotation.

Table 4. Temperature vs. Micro-stickies and Their Removal

Temperature (°C)	Before heat-dispersing (mg/g pulp)	After heat-dispersing (mg/g pulp)	Increase （%)	Before flotation (mg/g pulp)	After flotation (mg/g pulp)	Removal (%)
70	7.14	7.83	9.7	8.15	2.63	67.7
80	7.14	8.39	17.5	8.71	2.86	67.2
90	7.14	9.38	31.4	9.69	3.11	67.9
100	7.14	9.70	35.9	10.3	3.36	67.4
Note: disc clearance at 0.3 mm, pulp consistency of 30%.						

Table 5. Disc Clearance vs. Micro-stickies and Their Removal

Disc Clearance (mm)	Before heat-dispersing (mg/g pulp)	After heat-dispersing (mg/g pulp)	Increase （%)	Before flotation (mg/g pulp)	After flotation (mg/g pulp)	Removal (%)
0.6	7.81	8.9	14.1	9.21	2.89	68.6
0.5	7.81	9.4	20.5	9.63	2.91	69.8
0.4	7.81	10.1	29.5	10.3	3.16	69.3
0.3	7.81	10.3	32.1	10.5	3.21	69.4
Note: temperature at 100 ^{o}C, pulp consistency of 30%.						

Table 6. Pulp Consistency vs. Micro-stickies and Their Removal

Pulp Consistency (%)	Before heat-dispersing (mg/g pulp)	After heat-dispersing (mg/g pulp)	Increase （%)	Before flotation (mg/g pulp)	After flotation (mg/g pulp)	Removal (%)
20	7.57	8.88	17.3	9.21	3.04	67.0
25	7.57	9.85	30.6	10.1	3.32	67.2
30	7.57	10.2	34.8	10.5	3.43	67.3
Note: temperature at 100 ^{o}C, disc clearance at 0.3 mm.						

As mentioned above, the amounts of macro- and mini-stickies were reduced after heat-dispersing, as they were converted to micro-stickies or even smaller sizes. It was found that the amount of micro-stickies increased from 9.7% to 35.8% as the temperature was raised from 70°C to 100°C; or from 14.1% to 32.1% with reducing disc clearance from 0.6 mm to 0.3 mm, or from 17.3% to 34.8% with increasing pulp consistency from 20% to 30%. Apparently, raising operating temperature promoted dispersion of stickies, reducing disc clearance enhanced disintegration of stickies, and increasing pulp consistency improved rubbing and curlating. All the above factors caused more of the stickies to become dispersed to smaller particulates.

It could also be concluded from the above tables that removal of micro-stickies by post-flotation was distinctly improved after heat-dispersing. Dispersed under varied conditions, about 66 to 70% of micro-stickies were effectively removed in the subsequent post-flotation.

It should be pointed out that the values of mini-stickies measured in pulp samples before heat dispersing and before the post-flotation fluctuated to some extent in Tables 4 to 6. That is due to the fact that this investigation was carried out based on a trial in the 1,000-1,100 ton/day production line, and it can be expected that parameters actually vary within a range. A period of time is needed for each run of varying operating temperature, disc clearance or pulp consistency. For the purpose that the resulted data are comparable, pulps are not sampled from the sampling points until the system reaches stable conditions. The same explanation also applies for the data in Table 7 to 9.

Effect of Heat-Dispersing on DCS and Their Removal

The effects of heat-dispersing on DCS and their removal in post-flotation were as shown in Tables 7 to 9.

Table 7. Temperature vs. DCS and Their Removal

Temperature (°C)	Before heat-dispersing (mg/50 mL)	After heat-dispersing (mg/50 mL)	Increase (%)	Before flotation (mg/50 mL)	After flotation (mg/50 mL)	Removal (%)
70	49.1	51.6	5.1	145.4	143.7	1.2
80	49.1	53.0	7.9	147.7	145.6	1.4
90	49.1	55.0	10.3	150.4	148.5	1.2
100	49.1	55.9	13.9	151.9	149.7	1.4
Note: disc clearance at 0.3 mm, pulp consistency of 30%.						

Table 8. Disc Clearance vs. DCS and Their Removal

Disc Clearance (mm)	Before heat-dispersing (mg/50 mL)	After heat-dispersing (mg/50 mL)	Increase (%)	Before flotation (mg/50 mL)	After flotation (mg/50 mL)	Removal (%)
0.6	43.4	46.6	7.4	136	135.1	0.7
0.5	43.4	48.1	10.8	137.5	136.4	0.8
0.4	43.4	48.9	12.8	138.3	137.4	0.7
0.3	43.4	49.3	13.6	138.7	137.8	0.6
Note: temperature at 100 ^{o}C, pulp consistency of 30%.						

Table 9. Pulp Consistency vs. DCS and Their Removal

Pulp Consistency (%)	Before heat-dispersing (mg/50 mL)	After heat-dispersing (mg/50 mL)	Increase (%)	Before flotation (mg/50 mL)	After flotation (mg/50 mL)	Removal (%)
20	53.7	57.0	6.1	149.0	145.1	0.7
25	53.7	61.3	14.2	153.3	150.7	1.6
30	53.7	62.7	16.8	154.7	152.2	1.6
Note: temperature at 100 °C, disc clearance at 0.3 mm.						

It is clear that raising temperature, reducing disc clearance, or increasing pulp consistency increased DCS, which showed that sticky substances were dispersed not only to mini-stickies or micro-stickies but further to dissolved and colloidal substances. As shown in the above Tables, only about 1% of DCS were removed in post-flotation. This agrees with the literature, confirming that DCS cannot be substantiallyy removed through flotation. That is why stickies remain as a major obstacle in papermaking with recycled fibers, even though screening and flotation have been extensively applied for removing ink particles and stickies.

In view of the observed difficulties in removing colloidal-sized stickies by means of flotation, other approaches should be considered for their removal. For example, one could use fixing agents to attract dissolved and colloidal substances and attach them onto pulp fibers, enabling their removal from the papermaking system. Alternatively, one could employ destabilizing chemicals to clarify the process water in the deinking plant, so that more of the DCS can be effectively separated out as solids from the system. The attributes of stickies issues, the existing process configuration, and the overall products requirements should be taken into consideration for a mill to choose their stickies control strategy.

CONCLUSIONS

1. Temperature of heat-dispersing should be higher than the softening temperature of adhesives, i.e. in a recommended range of 90 to 100°C. Disc clearance should be controlled in the range 0.3 to 0.4 mm. A larger clearance may lead to insufficient dispersion of stickies, while a smaller clearance may deteriorate the strength properties of pulp. The inlet pulp consistency can be controlled to 25 to 30% for both better stickies dispersion and energy savings.
2. Raising temperature, reducing disc clearance, or increasing pulp consistency markedly improved the dispersion of macro-stickies, and especially mini-stickies, converting them to micro-stickies and DCS. At a temperature of 100 °C, a disc clearance of 0.3 mm, and a pulp consistency of 30%, macro-stickies decreased by about 92%, and the major component in sticky substances, mini-stickies, decreased by about 83%.

3. Flotation is effective for removal of micro-stickies, but is limited to removal of mini-stickies and macro-stickies. Therefore, the heat-dispersing should be well controlled to disperse sticky substances to particulates with sizes suitable for removal in flotation. 68-69% of micro-stickies were removed in post-flotation, but flotation is not effective for removal of DCS.

ACKNOWLEDGMENTS

The authors are grateful for the support of Taishan Scholar Program (TS200637022) by the Shandong Province Government, the National Natural Science Foundation of China (Grant No: 30972327), and the Program for New Century Excellent Talents at Universities (NCET-08-0882) for this research. We would also like to thank Wenzhong Cai, Youcheng Wang, Kunpeng Zhao, Xiaoqing Ma, and Haowei Feng of Huatai Group Co. Ltd. for providing technical support in the mill trial.

REFERENCES CITED

Blanco, A., Miranda, R., Negro, C., Garcia-Suarez, C., Garcia-Prol, M., and Sanchez, A. (2007). "Full characterization of stickies in a newsprint mill: The need for a complementary approach," *APPITA Journal* 6(1), 19-25.

Brun, J., Delagoutte, T., and Carre, B. (2007). "Origins and effects of dissolved and colloidal materials," *Progress in Paper Recycling* 17(1), 12-21.

Delagoutte, T., Fabry, B., Guyard, A., and Kumar, S., (2010). "Mini-stickies: A family of macro-stickies difficult to control," *2010 TAPPI PEERS Conference*, Norfolk, VA USA, October 17-20, 2010.

Doshi, M. R., Jong, de R., Aziz, S., Li, B., and Houtman, C. (2008). "Macrostickies and microstickies measurement in the same sample using macro/micro stickies classifier," *94th PAPTAC Annual Conference*, CD: B509-B512, Montreal, Canada, February 5-7, 2008.

Doshi, M. R., (2009). "A review of stickies measurement methods," *Progress in Paper Recycling* 18(3), 20-30.

Frantisek, R., Zhao, H., and Bennington, C.P. J. (2007). "Characterizing ink dispersion in newsprint deinking operations using specific edge load," *APPITA Journal* 6(1), 23-27.

Gallan, G., Fernandez de Grado, A., Delagoutte, T., Lascar, A., and Kumar, S. (2009). "Mini-stickies or the challenge of small macro-stickies management: Characterization, mill survey and removal strategy," *Progress in Paper Recycling* 18(4), 12-23.

Hamann, L. (2005). "The role of deinking-flotation and micro-flotation for stickies reduction," *7th PTS Stickies Seminar*, Paper No.11, Dresden, April 5-6. 2005.

Johansson, H., Wikman, B., Lindstrom, E., and Osterberg, F. (2003). "Detection and evaluation of microstickies," *Progress in Paper Recycling* 12(2), 4-12.

Lascar, A., Yang, M., and Feng, K. (2010). "Macro, mini, micro stickies: New challenges," *14th China TAPPI Conference*, Wuxi, China, July 5-8, 2010.

Lee, H. L., and Kim, J. M. (2006). "Quantification of macro and micro stickies and their control by flotation in OCC recycling process," *APPITA Journal* 59(1), 31-36.
Liu, B., and Han, Y. (2005). *Secondary Fibers and Deinking Technology*, Chemical Industry Press, Beijing, 2005.
MacNeil, D., Sarja, T., Reunanen, M., Xu, C.-L., and Holmbom, B. (2006). "Analysis of stickies in deinked pulp. Part 1: Methods for extraction and analysis of stickies," *Professional Papermaking* (1), 10-14.
Sarja, T., MacNeil, D., Huber P., and Niinimaki, J. (2007). "Removal of stickles in flotation," *Progress in Paper Recycling* 16(3), 5-11.
Sarja, T., Zabihian, M., Kourunen, P., and Niinimaki, J. (2004). "New method for measuring potential secondary stickies in deinked pulp filtrates," *Water Science and Technology* 50(3), 207-215.
Zhao, L. (2008). "Disc heat-disperser: Structure principles and its application," *China Pulp and Paper* 27(10), 55-57.
Zhu, X., and Liu H. (2010). "Modeling the stickies dispersing mechanism in disk dispersers," *China Pulp and Paper* 29(5), 11-14.

Articles submitted: March 30, 2011; Peer review completed: May 8, 2011; Revised version received and accepted: January 26, 2012; Published: January 28, 2012.