EFFECTS OF HOT DISPERSION WITH REDUCTIVE BLEACHING ON THE BRIGHTNESS OF DEINKED PULP IN BOTH LABORATORY AND MILL MACHINES

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Effects of disperser bleaching using different concentrations of sodium hydrosulfite (SHS) or formamidine sulfonic acid (FAS) at different temperatures at both laboratory and mill scales on the brightness of deinked pulp were examined in this study. In lab bleaching tests, deinked pulp adjusted to a 2.73% consistency was hot-dispersed at 100 ºC with the addition of SHS or FAS at 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.8%, 1.0%, and 1.2% dosages, and at 40, 60 and 85 ºC for 1 h. The mill trials were run at a pulp consistency of 32%, SHS or FAS dosage of 0.8%, and temperatures of 90, 100, 110, and 115 ºC. SHS and FAS dosages of 0.1%, 0.3%, 0.5%, 0.8%, and 1.2% were also run at a hot dispersion temperature of 100 ºC using a mill disperser. The lab results indicated that there were positive correlations between the bleaching effects and both the reductive bleaching agent dosage and operating temperature. At 40 ºC, SHS performed better than FAS. However, at temperatures above 60 ºC, the converse was true. At a FAS dosage of 0.3%, the pulp reached a saturation brightness at the same level as that achieved by 1.2% of SHS. The mill trials with a hot dispersion unit produced similar results. At 100 ºC, the FAS group had better bleaching effects than the SHS group. At a bleaching dosage of 0.8%, the brightness gap between FAS and SHS groups increased with increasing temperature, and reached 2.8% ISO at 115 ºC. An economic efficiency analysis indicated that when reductive bleaching agents were applied to a hot dispersion unit, the FAS group had unit costs 10% lower than those of the SHS group. Therefore, FAS deserves priority in practical applications.

Keywords: deinked pulp, bleaching, hot-dispersion, sodium hydrosulfite, formamidine sulfinic acid

INTRODUCTION

Since the 1980s, hot dispersion systems have become standard equipment for deinking pulp lines. The main functions of a hot dispersion unit are to impart mechanical energy through suitable equipment onto pulp at a high temperature (40~60 or 90~150 ºC) and high consistency (25%~30%), to achieve fiber refining or diminution of ink particles. The main units of the system consist in a pulp thickener, a heating screw, a disperser, etc., as shown in Fig. 1.[1]

In a typical deinking process, the hot dispersion system often combines bleaching stages. Hot dispersion is an effective mixer, which allows mixing of chemicals with the pulp before entering the bleaching tower. Because bleaching often requires a high consistency and high temperatures, there have been attempts since the 1970s to incorporate hot dispersers as a bleaching reactor.[1-3]

Due to the high temperature and consistency characteristics of dispersers, retention times for bleaching can be reduced. They are used for peroxide and sodium hydrosulfite (SHS) bleaching stages.[4] In the interim, reductive bleaching chemicals with high reaction rates have been developed to reduce bleaching times. Formamidine sulfinic acid (FAS) at a dosage of 0.2% and higher temperatures achieved the same bleaching effect as a higher dosage (0.6%) at 50 ºC. The result indirectly proved that by using a hot disperser, less retention time is required.[5] When SHS and FAS were applied to a hot disperser compared to SHS using a bleaching tower, there was only a decrease of 1%~1.5% ISO.[6-8]

FAS is often applied to bleach chemi-mechanical pulps at dosages of 0.1%~0.6%, temperatures of 26, 65, 80, and 90 ºC, and pulp consistencies of 0.3%, 0.5%, 3%, 7%, and 10%. The effects of these parameters on the brightness of the pulp are well reported. At room temperature (26 ºC), the addition of 0.3% FAS produced almost no bleaching effect; whereas at temperatures of 80 and 95 ºC, the brightness gain was of 2.2% ISO.[9]

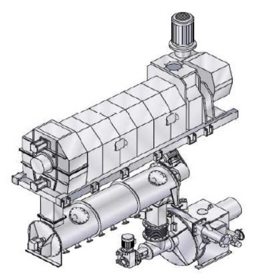


Figure 1: Diagram showing the main units of a hot dispersion system[1]

Both SHS and FAS are reductive bleaching agents. SHS is mainly used in reductive bleaching of mechanical pulps. It dissolves in water and forms active dithionite anions ($S_2O_4^{2-}$). The bleaching reactions are thought to be as follows:[10]

- Dissociation

$S_2O_4^{2-} \leftrightarrow 2SO_2^{-}\cdot$ (sulfur dioxide radical ions);

- Electron exchange

$2SO_2^{-}\cdot \rightarrow SO_2 + SO_2^{2-}$ (sulfur dioxide and sulfoxylate dianion); and

- Bleaching

Pulp + $Na_2S_2O_4$ + H_2O → Bleached pulp + $2NaHSO_3$.

FAS is a fairly strong reductive bleaching agent, mainly used in bleaching deinked pulps. In an alkaline solution, FAS reacts to become the active sulfinate anion ($NH_2C(NH)SO_2^-$), which then reductively bleaches the pulp in the following reactions:[11,12]

$NH_2C(NH)SO_2H + NaOH + 2H_2O$
$\rightarrow NH_2C(NH)SO_2^-Na^+ + 3H_2O$
$\rightarrow 4H^+ + NaHSO_4 + H_2N\text{-}CO\text{-}NH_2$.

From a literature review, it was apparent that although using hot dispersion systems to carry out reductive bleaching has become typical of deinking processes, there is a lack of systematic information on the effects of chemical dosages and temperatures at high consistencies on the performance of brightness gain.

In this study, we mainly investigated the application of SHS and FAS both in the lab and in a mill hot disperser, at different dosages and temperatures, and determined their effects on the brightness of the treated deinked pulp. The information can serve as a reference for economic efficiency evaluations.

EXPERIMENTAL

Materials and methods

The SHS used in this study was purchased from Shiehming Chemicals, Taipei, Taiwan (CAS no. 07775-14-6); FAS was obtained from Derfu Chemicals, Taichung, Taiwan (CAS no. 1758-73-2). The deinked pulp was received from the deinking line of the Chupei Mill of Cheng Long Paper Co. (Chupei, Taiwan). Wastepaper raw material consisted of 100% used computer forms. The deinking process flow begins at a hydropulper, passes through a high-consistency cleaner, a coarse screen, and a screw press, where hydrogen peroxide is added as a pre-bleaching stage, followed by flotation treatment with deinking chemicals and NaOH to adjust the pH and facilitate ink separation. The pulp then passes through low-consistency cleaners, a thickener, and a heating screw press and finally enters the hot disperser (Cellwood, KD-450, Nässjö, Sweden). The disperser operates at a disk gap of 0.1 mm and a back pressure of 1.5 kg cm^{-2}. The consistency of the pulp exiting in the disperser was maintained at 32% by adjusting the exit pressure of the screw press. The in-feed steam temperatures were controlled at 90, 100, 110, and 115 ºC in different runs, and the pulp pH was maintained at 7.95.

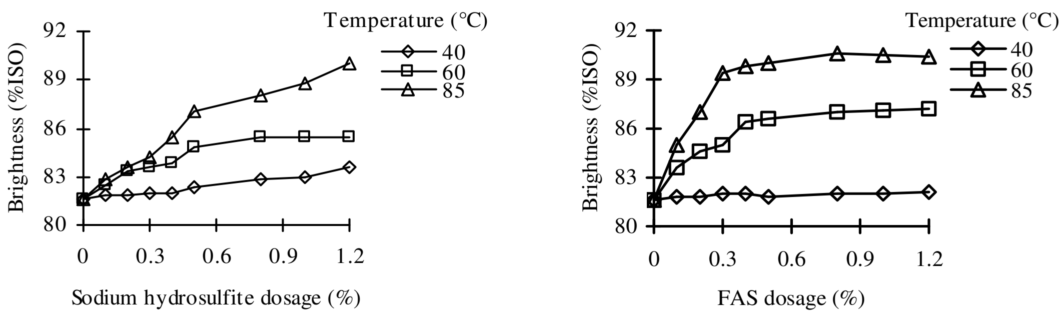
The laboratory bleaching experiment was conducted with the same deinked pulp from 100% used computer forms previously dispersed at 100 ºC. In a temperature-controlled water bath separately set to 40, 60, and 85 ºC, the deinked pulp with a 2.73% consistency was supplemented with SHS and FAS at different dosages of 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.7%, 1.0%, and 1.2% with respect to dry pulp and bleached for 1 h. After bleaching, the pulp was formed into handsheets of 60±1 g m^{-2} grammage and conditioned in a constant temperature and humidity (CTH) room maintained at 23±1 ºC, and 50%±2% relative humidity (RH) for 24 h, before the pulp brightness was measured.

In the mill bleaching experiments, the aforementioned pulps exiting the heating screw at a 32% consistency and heated separately to 90, 100, 110, and 115 ºC were separately supplemented with SHS and FAS at a 0.8% dosage before entering the hot disperser. In addition, at a hot dispersion temperature of 100 ºC, SHS and FAS at dosages of 0.1%, 0.3%, 0.5%, 0.8%, and 1.2% were separately added. After bleaching, the pulps were formed into handsheets of 60±1 g m^{-2} in the lab, and conditioned in a CTH room maintained at 23±1 ºC, and 50%±2% RH for 24 h before the brightness was measured. Handsheets were prepared with a standard sheet mold (Lesson, 306-A, Taipei, Taiwan), according to TAPPI T410 om-98, and brightness was measured according to TAPPI T425 om-96, using Datacolor Elerpho 450x with Color Tools 3.12 software.

RESULTS AND DISCUSSION

Laboratory bleaching experiments

The results of bleaching deinked pulp at a 2.73% consistency with SHS and FAS in the laboratory are shown in Fig. 2.



(A) SHS (B) FAS

Figure 2: Effects of bleaching chemical, dosage, and temperature on pulp brightness in a laboratory test

The results indicate that the bleaching effects are positively correlated with the reductive bleaching chemical dosage and temperature. At 40 ºC, the SHS group performed better than the FAS group. At temperatures of >60 ºC, however, the FAS group had a better bleaching effect than the SHS group. Particularly for FAS at a 0.3% dose, saturation brightening was reached, which produced a brightness equal to that reached by 1.2% SHS. The results were in agreement with those reported in the patent of Denton and Gorgen,[9] and by Galland *et al*.[5]

Mill machine bleaching experiments

Deinked pulp from 100% used computer forms was adjusted to a consistency of 32% and treated in a mill hot disperser at 4 different temperatures with the separate addition of SHS and FAS at a 0.8% dosage. The treatment effects on pulp brightness are shown in Fig. 3. The two chemicals appeared to exert different effects, which tended to increase with increasing temperature. The difference in brightness gains of the two chemicals reached 2.8% ISO at 115 ºC.

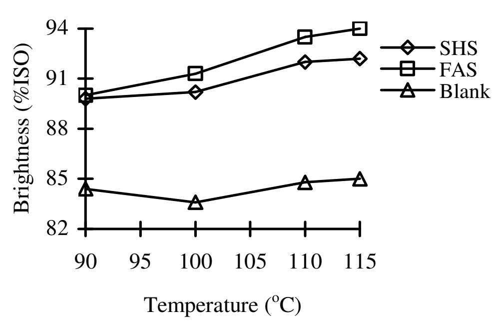


Figure 3: Effects of bleaching chemical and temperature of the mill disperser on deinked pulp brightness at a chemical dosage of 0.8%

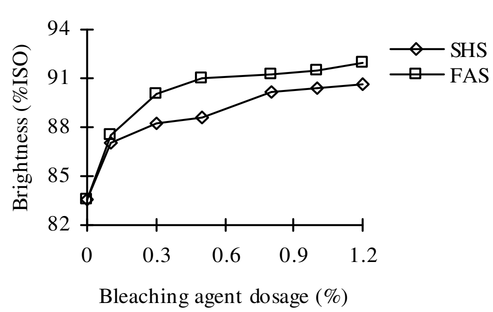


Figure 4: Effects of bleaching chemical and dosage of a mill disperser on deinked pulp brightness at 100 ºC

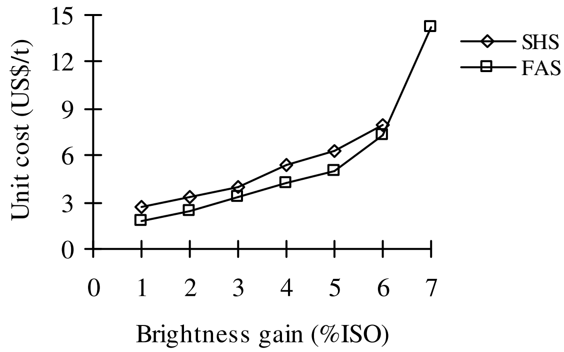


Figure 5: Effects of reductive bleaching brightness gain on the unit production cost

In another experimental set, the hot dispersion temperature was controlled to 100 ºC, then SHS and FAS at different dosages were added to the 32% consistency pulp. The effects of the chemical dosage on the bleaching performance are shown in Fig. 4. The results indicated that at a hot dispersion temperature of 100 ºC, the FAS group had better brightening efficacy than the SHS group at comparable dosages.

These results are in agreement with our lab results. Notably, at an FAS dosage of 0.3%, the brightness gain approached saturation, and again the results are similar to the laboratory trials at a lower consistency of 10% for both FAS and SHS chemicals.[9]

Evaluation of economic efficiency

From our experimental results, different bleaching effects have been found from the two reductive chemicals on the brightness gain of the resulting pulps. Based on current market prices in Taiwan, SHS sells for US$0.80 kg^{-1}, and FAS sells for US$1.73 kg^{-1}. There is a 2.2-fold price differential between the two. When the brightness gains under the 100 ºC condition (Figs. 3 and 4) were used as the basis for an economic efficiency evaluation, and using a 6% ISO brightness gain as an example, the FAS group required a 0.42% dosage, costing US$7.28 t^{-1}; while, the required SHS dosage was 1.0% and cost US$8.00 t^{-1}. Brightness gains from 1% to 7% ISO for the two chemicals are shown in Fig. 5. The figure indicates that for brightness gains of <6% ISO, there was a linear correlation between the dosage and gain, and SHS entailed a higher cost than FAS did. FAS is capable of achieving a brightness gain of 7% ISO, which is beyond the capability of SHS.

CONCLUSION

The experimental results suggest that, in general, bleaching effects have positive correlations with both the dosage of reductive bleaching agents and the reaction temperature. Only at 40 ºC, the SHS group showed a better brightening effect than the FAS group did. At temperatures >60 ºC, the converse was true. At an FAS dosage of 0.3%, near-saturation brightening efficacy was reached equaling the brightness level reached by a 1.2% dosage of the SHS group. The mill hot disperser study indicated that at 100 ºC, FAS produced better brightening effects than the SHS group did, similar to the laboratory results. At a chemical charge of 0.8%, the brightness gain gap between FAS and SHS increased with increasing temperature and reached as much as 2.8% ISO at 115 ºC. The evaluation of the economic efficiency suggested that for comparable bleaching results, using FAS in a hot dispersion line as a reductive bleaching agent would result in about 10% lower cost than using SHS. Thus, FAS deserves priority consideration when choosing chemicals for this application.

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