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Simulation Study of Papermaking Process Affected by Dry Broke Ratio

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1. Introduction

Papermaking process is subject to frequent perturbations. The most frequent and most important perturbation is the break of the web on the paper machine. During a web break, a large amount of brokes results and the brokeis diverted to a pit under the machine, and dispersed in white water. This repulped broke is then pulped and stored in the broke tank. It is progressively reinjected in the main pulp stream. Repulping of the broke requires large amounts of water. This large and sudden consumption of water modifies the white water inventory and creates cascading effects throughout the network. When there are frequent breaks, the management of broke and white water inventories becomes a delicate task. Broke inventories may require higher recirculation rates to avoid broke tank overflow, thus affecting pulp composition and eventually paper machine retention.Although mills expect these circumstances after a break, they are unable to adapt themselves rapidly for process restabilization. For a high speed paper machine, the rapid correction to fluctuations of process after breaks is essential. For this reason, it is important that the actual effects about web breaking and broke reusing on process are exactly known in real scale.

Simulation of paper processes has become a very valuable tool to the paper industries. Whether used for predictive analysis of the consequences of process configuration changes, for process optimization by virtually changing combinations of process parameter settings, or simply for gaining better understanding of an existing process, simulation is now one of the most powerful tools for these purposes. Process simulation can improve the quality and reduce the costs of designing a process. In addition, properly documented simulations are simpler for someone else to understand, especially for large and complex problems. Also, process alternatives can easily be evaluated with little additional effort. Perhaps more important, process simulation provides a powerful, standardized method for people on a project to do mass and energy balances. This provides improved and faster communication among process engineers, and it may give rapid responds as a change.

A computer simulation study was made based on a drawing of a commercial fine paper machine. Especially the characteristics of the wet-end behavior in response to broke reuse was studied by steady state simulation.

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2. Literature Review

There are some papers about the effects of web breaks on paper manufacturing processes. Orccotoma et al(1). studied dynamic behavior of white water networks during web breaks by steady and dynamic simulation. Their study focuses on key process modeling issues like the process flow sheet, steady-state mass and energy balances, and a dynamic model and its control system. During simulations, the manipulated variable used to manage broke inventories was the broke reuse rate. According to the results, though average daily breaks are low in frequency, the breaks may cause severe perturbations in actual papermaking process. The white water networks had long-term dynamics, and the effect of perturbations may continue through the system for hours and sometimes days. Same authors(2) studied dynamic analysis of fibrous material and dissolved solids distribution in the wet-end of a newsprint mill. Their simulation was performed to illustrateand quantify the effects of various feedstock fines content and broke reuse on one pass retention. In their results, the fibrous material profile indicated a fines buildup as a result of the successive dilution of the pulp with white water.

Bussière *et al*(3). studied an analysis and control of white water network perturbations in an integrated newsprint mill. They simulated the operation of a Quebec newsprint mill and, specifically, its broke and white water system. Their simulation provides better understanding of the dynamic response of the mill, in particular the white water system, to production upsets and different control strategies. Major paper machine breaks were found to be the only production upset to significantly affect the amount of finesrecirculated to the furnish.

Miyanishi *et al*(4). simulated the efficiency of paper machine grade change in dynamic status. Operational parameters such as chest volumes, first-pass retention, and broke ratio are crucial factors that largely determine the extent of grade change loss. They showed that the system dynamics approach is a useful system-analysis tool.

Simulation has been most extensively used in the conceptualization on and design of the steady-state operation of process. Subsequently, it has been found useful for debugging and debottling process operations and analyzing proposed refit alternatives. The advent and availability of practical dynamic simulators have not only extended the usefulness of simulation for the original purposes but have also opened up new and valuable fields of applications.

Tseing *et al*(5). applied simulation to the selection of optimal process design about stock dilution. To do this, they tested five process designs by simulation and calculated the frequency response from the inlet stock stream entering the high density stock chest, through to the stock leaving the last chest, using both adetailed first-principles model and a simplified linear model of that system. Then, their models were used to investigate alternative process design which may enhance the attenuation characteristics of that system.

Process simulation is a preferred tool to evaluate the mass balancein the wet end. Steady state simulations of white water networks have been frequently used to evaluate the effect of closure strategies. Nöel *et al*(6). studied the reduction of fresh water consumption and the side effects of some closure strategies such as the reuse of white water on the paper machine showers and modifications to the white water circuit. Asselman *et al*(7) identified potential energy savings via the reuse of some process effluents and studied their side effects on the dissolved solids buildup at the headbox. Dynamic simulation is used to predict the effects of various disturbances on the process operation and to test control strategies. Studies by Croteau and Roche(8), Bussiere, et al(9). analyzed issues surrounding white water and broke inventories management. An application of dynamic modeling for process control is presented by Jones and Koepke(10). In their study, they examined feedback and feedforward techniques used to control pulp properties and basis weight in a two-ply paper machine.

Smith *et al*(11). describes in their paper asystematic, cost-effective way to use dynamic process simulation to thoroughly test the hardware and software of a modem computer-based process control system-large or small. The authors have witnessed an 80% reduction in field problems using this method over the past eight years. According to Strand's research(12), factor network analysis is used to build a model which characterizes the interrelationships among both the input variables (furnish quality, furnish blend and paper machine operation) and the output variables (paper quality). A newly developed optimization technique is then used to optimize the furnish blend to achieve the target paper quality while minimizing the overall cost of producing the paper. The analysis indicates that there are significant cost benefits in using this technique on-line for open or closed loop optimization.

3. Process Modeling and Simulation

3.1 Model Paper Machine

In this study, the model mill produced a conventional fine paper grade with wire width 5,100 mm. The basis weight of produced fine paper was 80 g/m^2 and machine speed was 880

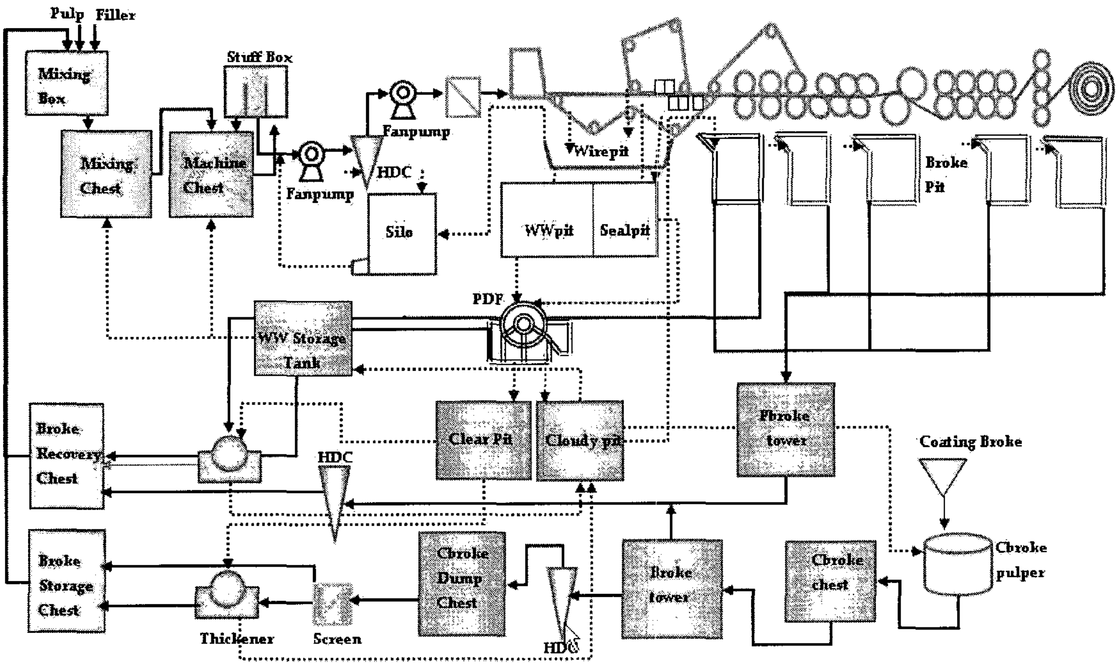


Fig. 1. The draw of model process.

m/min. The production rate was 580 AD T/day.

The paper machine consists of a twin wire former, 4-nip press, two roll inclined size press, general dryer, calender and reel. The virgin pulp consisted about 70% of the total fibrous furnish (broke was 30%), and virgin pulp were composed about 5-10% softwood bleached kraft pulp (SBKP), about 70-80% hardwood bleached kraft pulp (HBKP) and 15-20% bleached thermomechanical pulp (BCTMP).

3.2 Process Flow Sheet

In general, fine paper stock has many constituents that include various grades of pulps, fillers, chemical additives, etc. In this study, the furnish was assumed to be consisted of three major elements pulp, fines, and filler.

- Hypothesis in this study was as follows

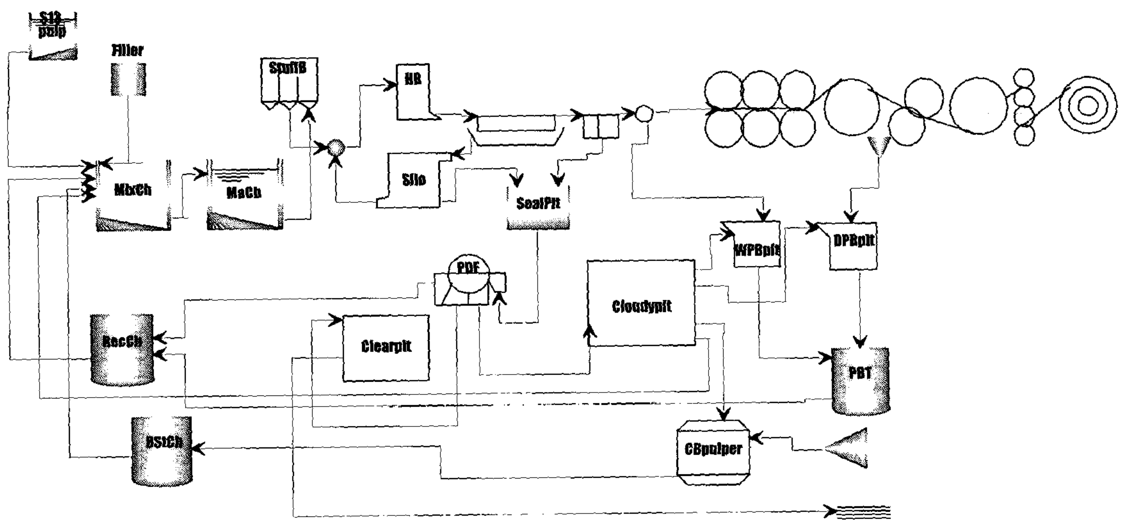
• Pulps were consisted of fiber and fines, and fines content of fresh pulp was 15%. The effect of the pulp type was neglected.

• Ash content of the produced paper was fixed at 20%.

• Ash content of coated broke was set at 36%.

• Filler slurry was added to the stock at 40% concentration atthe mixing chest.

The flow sheet of the fine paper mill used as a model in this work is shown in Fig. 1 and Fig. 2. The flow sheet corresponds to the wet end of a typical paper machine. The single-line fine paper mill with a production capacity of 580 tons/day includes the followings: the stock preparation and approach area, the paper machine forming zone, the machine white water network, and the broke repulping system. Feedstocks to the preparation area were fresh SBKP, HBKP, and BCTMP at 3.5% consistency. The fresh pulp is stored in the mixing chest and then diluted using white water from the white water storage chest. The pulp is subsequently mixed in the mixing chest with repulped trimmings, paper broke, coated broke and fiber recovered from polydisk



(RecCh: broke recovery chest, BStCh: broke storage chest, CBpulper: coating broke pulper, PBT: paper broke tank, WPBpit: wet paper broke pit, DPBpit: dry paper broke pit MixCh: mixing chest, MaCh: machine chest, HB: headbox, PDF: poly disk fillter)

Fig. 2. The simulated flow sheet

filter. This mixed pulp is then conditioned for papermaking utilizing such operations as homogenizing, cleaning, and screening.It is also further diluted at this stage with white water from the machine white water storage chest and with white water from the machine directly collected in the silo. The main pulp stream is at 0.8% consistency when it delivered to the headbox.

During normal machine operation, only the wet trimmings, representing approximately 3% of the total paper production, are collected in the couch broke pit. When a web break occurs, the paper sheet is diverted to the couch broke pit, and cloudy white water is then added for dilution. The repulped broke is delivered to the paper broke storage tank.

Then the paper broke is returned to the mixing chest via the recovery storage chest.

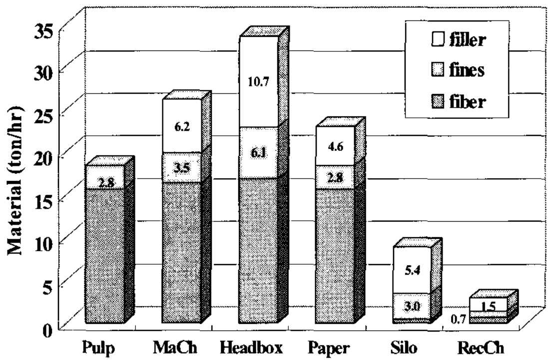
The one pass retention model used in this simulationthe modified equations of Orccotoma *et al*'s modeling(2). In simulation, a commercial computer simulator, Aspen Custom Modeler 10.2 (made by Aspen Technology) was used. Simulation programmingand model coding were carried out based on the statements of Aspen Custom Modeler Language Reference. Material mass balance equations were solved using the solver contained Aspen Custom Modeler. On most cases default solver option values were used and the general mode tolerance was set to 1×10^{-11}. The value of the tolerance affects the speed and accuracy of the solution.

4. Results and Discussion

4.1 The Simulation of Normal Condition

To understand the mass balance of fibrous material and filler and their contents in the network, six locations including pulp, machine chest, headbox, paper, recovery chest, and silo were selected. Pulp is fresh inlet pulp stream to the network, and the machine chest is the mixing point of the fresh pulp with other components such as paper broke, coated broke, filler and white water. The headbox is where the pulp stock is once more prepared to target consistency with white water from the wire part of paper machine. The paper position is the point leaving the forming zone with a fibrous and filler composition that will remain unchanged during the subsequent paper pressing and drying process. The recovery chest is a disintegrated paper broke chest. The components in silo are mostly white water along with some fines and filler and small amount of fibers.

At the normal condition, the amounts of fibrous material (fiber, fines) and filler in the network shows a considerable variation depending upon the process units as shown in Fig. 3. As seen in Fig. 3., the fines amount in fresh pulp was 2.8 ton/hr, but it increased to 3.5 ton/hr in machine chest which contained coated broke, paper broke, fillers, and white water. The fines and filler buildup reaches its highest value at the headbox. At the headbox, the amounts of fines



(MaCh : Machine chest, RecCh : Broke recovery chest)

Fig. 3. Material distribution in the network.

and filler in pulp stock showed maximum values to 6.1 ton/hr and 10.7 ton/hr, respectively. This increase is almost entirely due to the amount of fines not retained in the former.

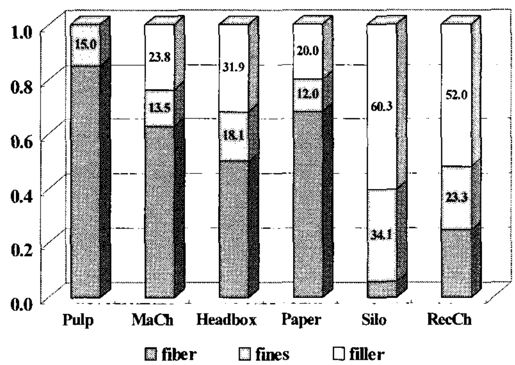
This is the result of low fine and filler retention in the machine, successive pulp dilutions, and recirculation of many white water streams as previously shown in Fig. 2. Since white water from the machine contains mainly the fines and filler that were not retained in the paper web, therefore, all the processes involving dilution will preferentially increase the fines content in the main pulp stream.

Fig. 4 is the mass fraction of fibrous material and filler in the network. As Fig. 4 indicates, though fines content of fresh pulp feed was 15%, the fine content observed in the headbox increases to 18.1%. On the other hand,the paper web leaving the forming section of the paper machine contains fewer fines (12%) and less fibrous material (464 ton/day) than the fresh pulp entering the process (15% fines; 441 ton/day). These differences are explained by the low fines retention in the web causing the preferential distribution of fines in the white water, and the rejects leaving the wet-end from the screen and the cleaners system. In terms of retention, 46.7% for fines, 96.0% for fibers and 44.2% offiller are obtained, and total material one pass retention was 70.6%.

4.2 The Simulation of Web Breaks Occurrence

In fine paper mill, when production is disrupted by web breaks, it may become difficult to maintain the stability of the network. If web breaks occurin a paper machine, a large quantity of undesirable brokes comes into being. Broke is reutilized in the papermaking process. Because of this operation, fibrous material and filler composition of the approach part of the paper machine are changed. To understand these changes, it was simulated in steady state that a large quantity of broke is fed to paper machine. For this purpose, input amounts of dry broke (DB) to model process network are changed from 1 ~ 30 ton/hr and the results are shown in Figs. 5~7.

In Fig. 5, the addition level of fresh pulp is considerably decreased as the dry broke addition increased. When compared with initial condition at which dry broke addition was 1 kg/hr, fresh



(MaCh : Machine chest, RecCh : Broke recovery chest)

Fig. 4. Mass fraction of material in the network.

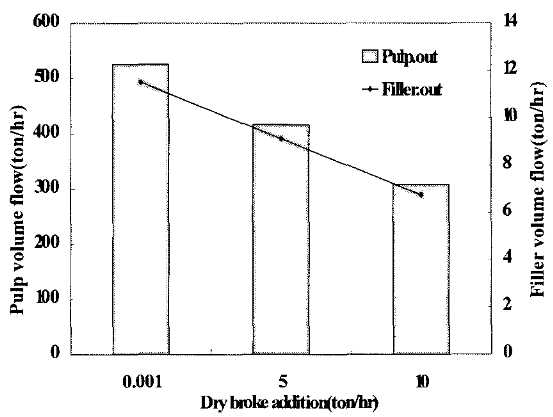


Fig. 5. Input amount change of fresh pulp and filler by increasing of dry broke addition.

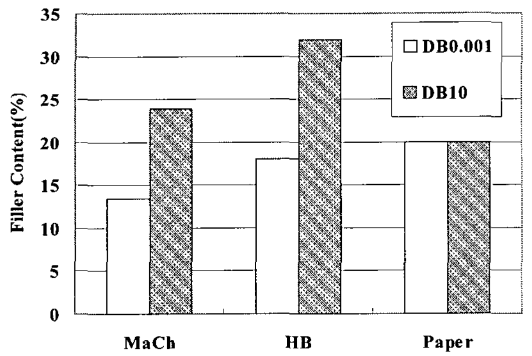


Fig. 6. Filler content of process unit by increasing of dry broke.

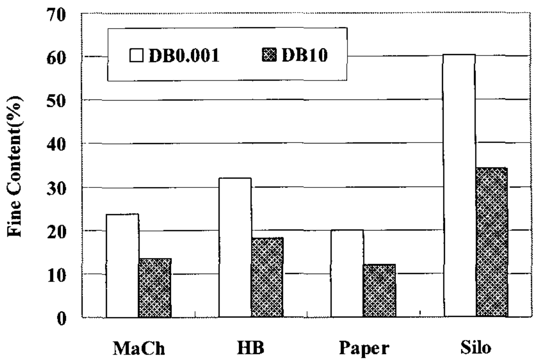


Fig. 7. Fine content of process unit by increasing of dry broke.

pulp and filler addition droppedrapidly. The decrease in fresh pulp and filler addition has a relationship with premises of this simulation, which is caused by the mass balance model of this simulation model. Results in Fig 6 and Fig 7 substantiate this reason. Therefore, as web breaks was occurred and reuse of dry broke was continued, the amountof fibrous material and filler in network increased, and fresh pulp addition diminished which might bring about decrease of paper strength.

5. Conclusions

This study has described the fibrous material and filler distribution in the wet end of a fine paper machine and paper machine one pass retention as a function of the severity web break. If web breaks occur in a paper machine, a large quantity of undesirable broke enters the process. This broke isreused to the papermaking process. For such reason, fibrous material and filler composition of the approach part of paper machine is changed. It was simulated in steady state with an assumption that large quantities of broke are fed to the paper making process. The addition level of fresh pulp drops considerably according to increase of dry broke addition. Fines and filler in model process were maintained at even level.

Acknowledgement

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