Improving TMP pulp properties by sulfonation

Optimization of sulfonation process alternatives

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In addition to reducing operating costs, sulfonation can be used as a retrofit to existing mills to maximize production.

Different chemical treatments of thermomechanical pulps are being used and researched to try to produce pulps that will meet or exceed quality expectations while using lower amounts of low-yield chemical pulps. For many grades, this approach has eliminated chemical pulps in the product furnish and has reduced production costs.

The chemical modification of mechanical pulps through treatment with sodium sulfite has been an area of active interest over the past several years. Ultra-high-yield pulps can be produced in several ways, including:

1. Sulfonation of wood chips followed by refining, screening, and reject refining
2. Sulfonation of pulp between the first and second stages of refining (interstage sulfonation) followed by screening and reject refining
3. Sulfonation of the screen rejects (rejects sulfonation) followed by reject refining.

Each of these processes are presently being used in full-scale operation for the production of newsprint. Interstage sulfonation treatment has been running on a commercial scale at Q.N.S. Paper Co. since 1983 (*1*) and has shown success in eliminating low-yield chemical pulp in a groundwood newsprint furnish. Several rejects sulfonation systems are presently operating, including, since 1985, a two-stage rejects sulfonation system at the Bear Island Paper Co. (*2*).

The sequence in which sulfonation, refining, and screening are performed greatly affects the final pulp properties. Each process has advantages and disadvantages, depending on the final strength and optical properties required in the product sheet. Using the general energy and materials balance system (GEMS) computer system, we studied the effects of interstage and rejects sulfonation for several process configurations. GEMS is a modular computer system that entails an executive program linked with a set of process subroutines which model the individual unit operations of the mechanical pulping system (*3*).

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Process models

The unit operations of mechanical pulping systems are:

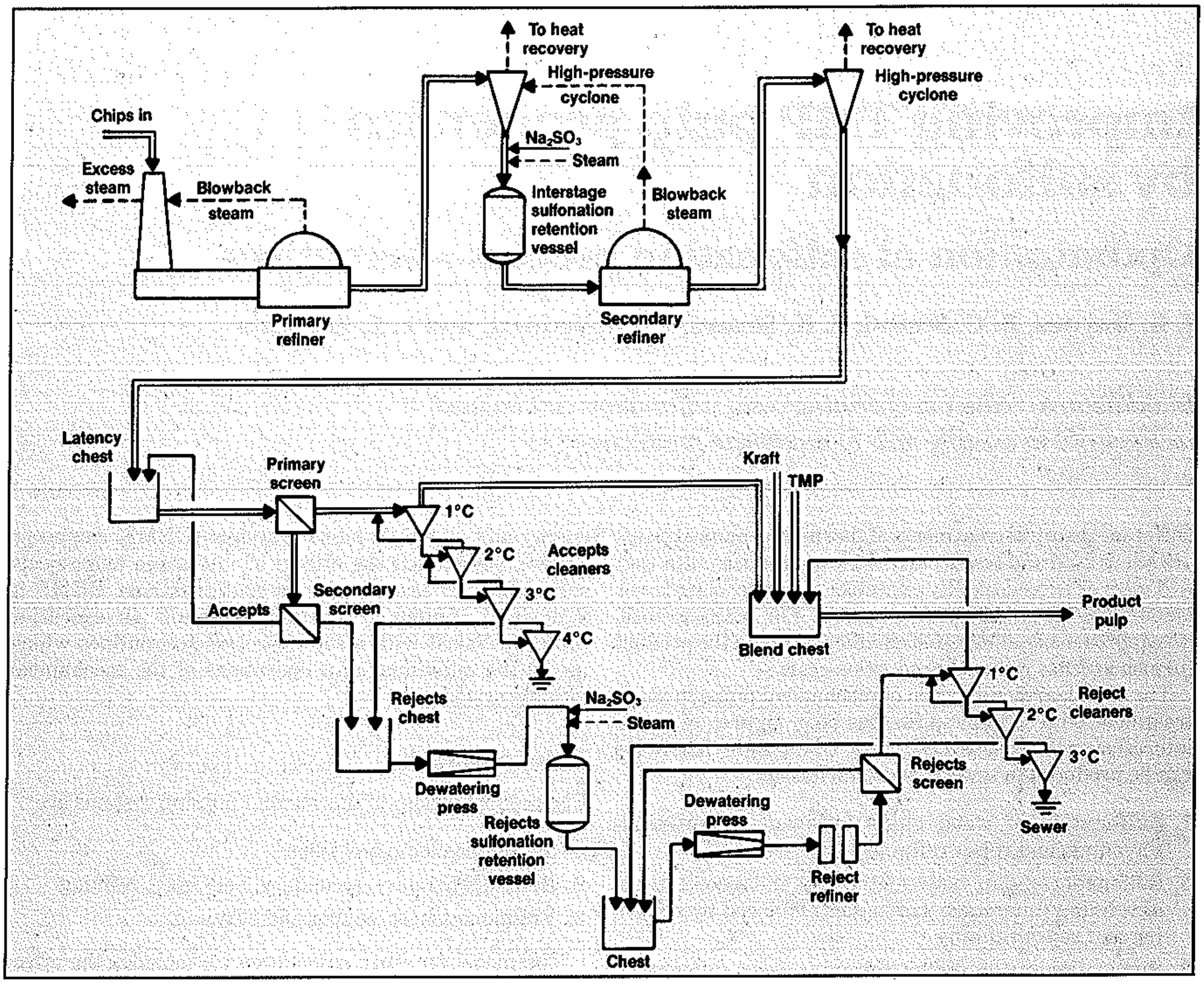
1. Sulfonation: chip and fiber
2. Refining: primary, secondary, and reject refining
3. Fractionation: screening and cleaning.

The model for fiber sulfonation (*4*) includes the effect of time, temperature, pH, and sulfite concentration on the extent of sulfonation, and the pulp yield. The refining models were adapted from a previous study (*3*) to include the effect of the extent of sulfonation on the refining performance. The models used to describe the performance of screening and cleaning operation were also taken from previous work (*3*).

In addition to the unit operations models which have been incorporated into the GEMS system, it is also necessary to develop detailed models that relate the additive fiber properties to the nonadditive strength and optical properties. The additive fiber properties are shives content, fiber size distribution, specific surface area, the extent of sulfonation (% sulfur on wood), and pulp yield. Tensile index, tear index, density, and light-scattering coefficient describe the nonadditive strength and optical properties.

The method of factor analysis that describes both the interrelationships between pulp properties and the effect on intrinsic fiber properties on the strength and optical properties has been included in the GEMS system (*5*). All of the models used in this study are both predictive and descriptive. Without specific data from a specific mill, the models will give the best possible prediction of process performance and pulp quality. However, if mill or

1. Process flow sheet for the TMP refiner line



laboratory data are available, all of the mathematical models, including the pulp quality relationships, can be easily tuned to improve the accuracy of the overall process simulation.

Procedure

A Scandinavian TMP refiner line and screen room were used as the basis for the process flow sheet. A computer simulation was generated using GEMS and "tuned" with extensive mill data. It included a detailed mainline refiner balance (*6*) and a detailed screen room balance. For the analysis of sodium sulfite addition, two hypothetical sulfonation reactors are added to the flow sheet, one between the first and second stages of mainline refining and the other just prior to reject refining.

The overall process flow sheet is shown in **Fig. 1**, and the GEMS block diagram derived from it is shown in **Fig. 2**. The process conditions and the predicted pulp properties for the "tuned" base case, without sulfonation, are presented in **Table I**. No kraft pulp addition is required at this mill to produce pulp of newsprint grade.

Optimum with no sulfonation

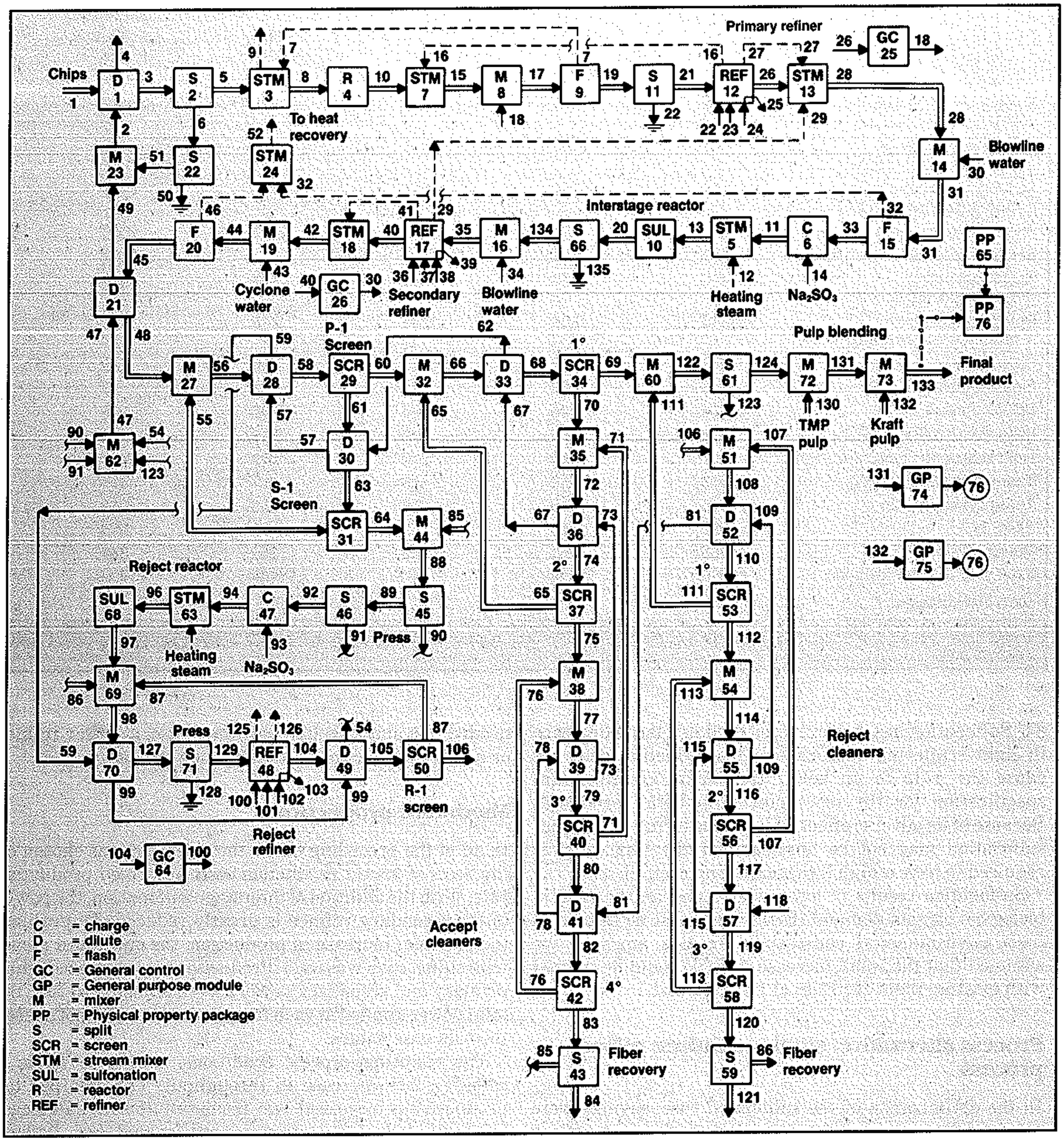
Sequential linear programming techniques (*7*) were used to determine the optimum values of the independent variables:

- Specific energy consumption for the primary refiner
- Specific energy consumption for the secondary refiner
- Reject rate for the primary screen
- Reject rate for the secondary screen
- Specific energy consumption for the reject refiner
- Reject rate for the reject screen
- Kraft pulp addition.

The optimum is the set of operating set points that yielded the least cost per ton of pulp while still meeting final pulp quality.

The optimum values for the independent variables and the pulp properties and cost are summarized in Table I. The savings over the base case are about a dollar per ton, which reflects the quality of operation in the Scandinavian mill.

2. GEMS block diagram for the TMP refiner line



Optimization with sulfonation

Once the optimum TMP case was determined, two new independent variables were added—interstage and reject sodium sulfite additions. Again, sequential linear programming techniques were used to determine the optimum values of the independent variables. The results from this optimization are shown in Table I also.

The optimum sulfonation case results in a savings of \$3.79/ton over the optimum TMP case and \$4.91/ton over the base case. Comparing the optimum unsulfonated and optimum sulfonated cases, it is more economical to obtain the pulp quality with chemical treatment via the addition of sodium sulfite than it is to apply electrical power via the refiners to the pulp. In addition, the optimum place to add the sodium sulfite is between the primary and secondary refiners as opposed to reject sulfonation. The added cost of treating all the pulp versus treating only the reject pulp is more than offset by the overall improvement in final pulp characteristics.

Long fiber has been increased as a result of sulfonation, which resulted in tear strength being increased by over

I. Operating conditions, pulp properties, and costs

	Base case	Not sulfonated	Sulfonated	Primary refiner only	Maximum production with sulfonation
Primary refiner power, MW • h/o.d. metric ton	1.16	1.16	1.16	1.41	0.95
Interstage sulfonation, % SO_3/o.d. metric ton	0.0	0.0	1.6	...	2.0
Secondary refiner power, MW • h/o.d. metric ton	0.78	0.64	0.37	...	0.64
Primary screen reject rate, %	35.0	45.0	25.0	30.0	25.0
Secondary screen reject rate, %	30.0	40.0	30.0	...	30.0
Reject sulfonation, % SO_3/o.d. metric ton	0.0	0.0	0.0	3.9	0.0
Reject refiner power, MW • h/o.d. metric ton	0.40	0.35	0.35	0.45	0.55
Reject screen reject rate, %	26.0	30.0	16.0	16.0	30.0
Final freeness, mL CSF	75	80	82	83	90
Shives content, %	<0.06	<0.06	<0.06	<0.06	<0.06
Long fiber fraction (+28), %	22.3	23.5	29.8	30.2	27.2
Light scattering coefficient, m^2/kg	59.7	59.1	55.2	55.5	55.1
Tear strength, Nm • m^2/g	7.8	7.9	8.6	8.7	8.7
Tensile strength, Nm/g	40.5	40.5	40.5	40.6	42.3
Yield, %	96.0	96.0	94.5	97.0	94.4
Density, kg/m^3	363	361	352	352	361
Final pulp cost, $/metric ton	119.42	118.30	114.51	111.84	117.19

100% TMP newsprint.
Note: Costs were calculated based on 66 U.S. $/metric ton for chips, 0.03 U.S. $/kW • h for power, and 150 U.S. $/metric ton for sodium sulfite. Steam credits were calculated at 5.50 U.S. $/metric ton and the cost for sulfonation reactor steam was taken at 7.70 U.S. $/metric ton. No equipment costs were included.

8%. Sulfonation has, however, resulted in a large decrease in light scattering coefficient. This reduction does not cause the pulp to go below the 55 m^2/kg minimum specification for the newsprint pulp being produced. Because of its adverse effect on light scattering coefficient, sulfonation may not be applicable if the final pulp is required to have a high light scattering coefficient.

Sulfonation results in lower yields and an increase in biological oxygen demand (BOD) that must be treated to meet environmental constraints. In this analysis, we assumed that the small increase in BOD could be treated with existing plant facilities at no extra cost.

Process alternative: single mainline refiner process

In the optimization of the sulfonated case, savings were obtained by reducing the secondary and reject refiner power. The reject rates were also minimized, resulting in a further reduction of power. To evaluate the possibility of further power reduction and further potential cost savings, the secondary mainline refiner was removed from the simulation. The flow sheet for this process is shown in **Fig. 3**. The simulation was altered to reflect this flow sheet, and the results are summarized in Table I.

The simulation indicates that a single large mainline refiner and reject sulfonation can produce pulp of a quality equal to that produced with two mainline refiners and can do so at a savings of $7.58/ton. In previous cases, the primary refiner was at its maximum power application, as observed in the actual process. To obtain the power needed in a single mainline refiner case, a larger refiner or a lower production rate would be required.

Maximum production

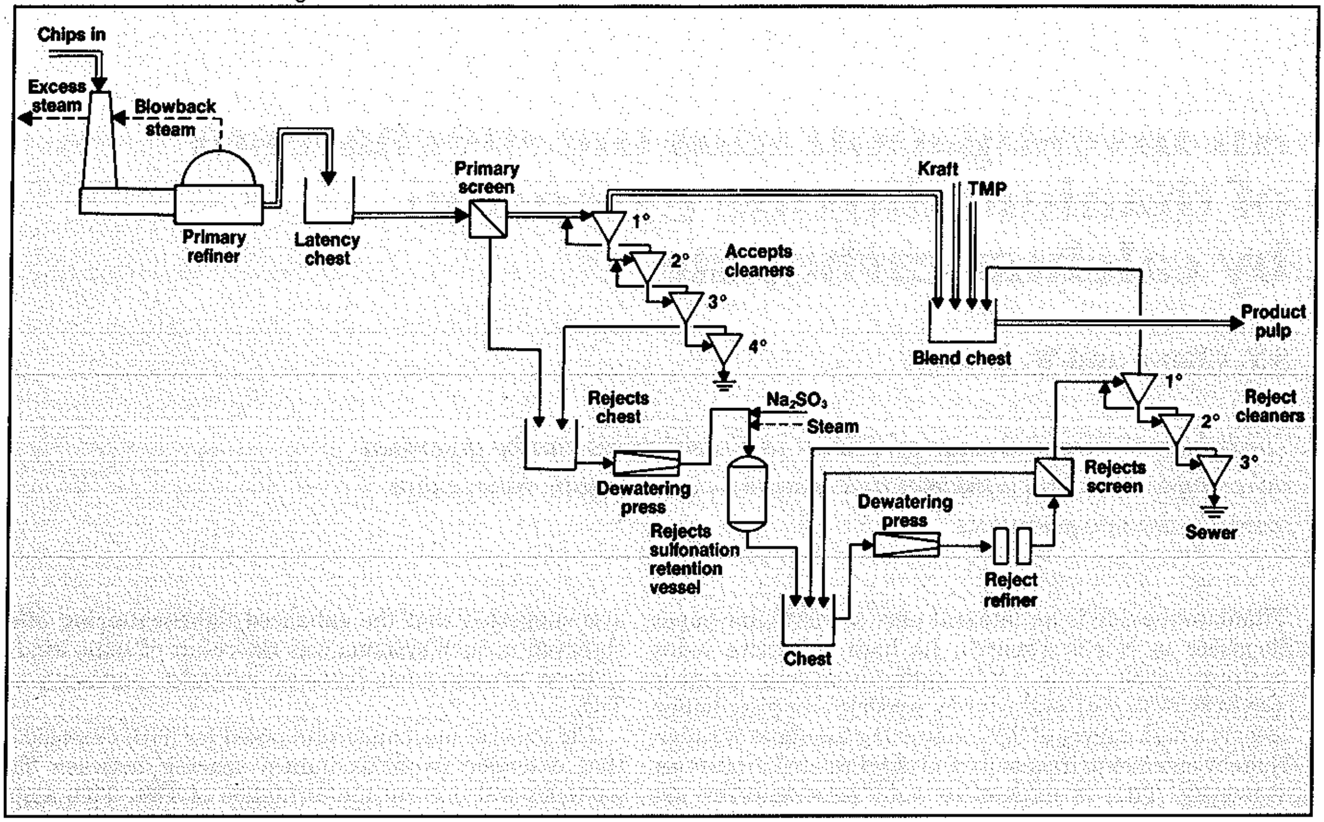
In all of the preceding cases, the optimum was chosen on the basis of lowest production costs at a fixed production rate. With the addition of interstage sulfonation, the power to the secondary refiner is greatly reduced. To evaluate the potential increase in production, the optimized model with sulfonation was used. Production was increased while primary and secondary powers were adjusted so that the total power applied at each mainline refiner did not exceed the base case values.

The resulting process conditions, shown in Table I, reflect a 20% increase in throughput. The cost per ton produced has increased over the optimum sulfonated case but is still below the optimum unsulfonated case. As long as product margins are much greater than the cost savings, a 20% increase in production represents a substantial annual return.

Conclusions

A sulfonation model has been incorporated into GEMS and has been used with sequential linear programming to determine optimum process operating variables. If interstage sulfonation is added as a retrofit, savings of nearly $5/ton over the unoptimized, unsulfonated base case have been demonstrated with no adverse effect on pulp quality.

3. Process flow sheet for a single mainline refiner



In addition to reducing operating costs, sulfonation can be used as a retrofit to existing mills to maximize production. This study indicates that a 20% production increase could be attained.

An alternative flow sheet configuration using a single mainline refiner and reject sulfonation should be able to produce pulp with comparable quality at a savings of $7.50 over the unoptimized base case.

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