ENGINEERING ANALYSIS OF LIGHTWEIGHT HIGH-OPACITY NEWSPRINT PRODUCTION BY FIBER LOADING

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ABSTRACT

We estimated the capital effectiveness of fiber loading in regard to producing lightweight high-opacity newsprint. Fiber loading enhances fiber bonding at increased precipitated calcium carbonate levels without significant loss in Canadian standard freeness or additional use of energy. We investigated the return on investment (ROI) for fiber loading precipitated calcium carbonate for a hypothetical 600 metric ton/day newsprint mill. Saving were obtained from substituting lower cost fiber-loaded precipitated calcium carbonate (FLPCC) for higher cost fiber, reducing grammage and drying energy costs. and obtaining a premium for lightweight paper. Fiber loading produces a positive ROI given typical engineering costs. Assuming that a 4-g/m^2 reduction in fiber and a 6% addition of precipitated calcium carbonate is a reasonable goal for fiber-loaded newsprint high ROIs can be reached. Assuming that FLPCC is available at $150/metric ton and 1% hydrogen peroxide is added along with typical stabilizing chemicals, the ROI is estimated to be 59.7%. If the cost of FLPCC is $75/metric ton, the ROI is estimated to be 73.4%. Other ROIs are calculated for various scenarios. Given the high possible ROIs of fiber loading for newsprint, the capital effectiveness of this process should be assessed for mottled and white-top linerboard as well as printing & writing grades.

INTRODUCTION

According to a recent feature article on paper industry needs, "research on breakthrough technology that significantly increases the capital effectiveness of papermachines and papermaking should rank among the highest pulp and paper industry research priorities"[1]. We believe that fiber loading can be a key factor in producing lightweight high-opacity newsprint at an attractive ROI.

Fiber loading, which was developed at the Forest Products Laboratory (FPL), consists of at least two steps [2]. First, calcium hydroxide is mixed into pulp fibers and water. Then, the pulp and calcium hydroxide mixture is reacted using a high consistency pressurized reactor (refiner or disk disperser) under carbon dioxide pressure to precipitate calcium carbonate. The fiber-loaded precipitated calcium carbonate (FLPCC) is deposited within, on the surface of, and outside the pulp fibers. As a result of fiber loading fiber bonding is increased as shown by increased handsheet strenghs. Fiber-loaded pulps are stronger than similar direct-loaded pulps at the same precipitated calcium carbonate levels as a result of three independent mechanisms: (a) deposit of FLPCC within the fiber wall and lumen [2], (b) gentle refining of fiber at high pH [3], and (c) gentle refining of fiber at high consistency [3,4]. The low energy (approximately 6.84 % 10^4 kJ/metric ton) needed for the reaction process during fiber loading causes only small drops in pulp Canadian standard freeness (CSF) (30 to 40 mL) [3,5]. Measurement of fiber length, kink, curl, and fines (<0.2 mm) content after fiber loading revealed no change in fiber characteristics [6]. By allowing fiber

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bonding without any significant loss in freeness, fiber loading is thus a key factor in producing lightweight high-opacity paper.

Newspaper publishers are well aware of the economic benefits of 1ightweight newsprint: As stated in a recent newsletter, "Over the past decade newspapers on the West Coast have shifted to lighter grammage newsprint as producers have pushed to save on fiber costs... Today, West Coast publishers and producers are looking at reducing grammages further to 43 g/m^2 newsprint, in line with a trend catching on in Europe and Asia" [7].

We investigated the ROI for fiber loading for a hypotietical newsprint mill. The investment analysis covered savings resulting from reduced fiber needs, substitution of low-cost FLPCC for higher cost fiber, and reduced drying costs, as well as a premium for lightweight paper. We balanced these savings with the added capital costs for new equipment, energy needed to operate the new process, additional personnel, depreciation, maintenance, and bleaching chemical cost.

ENGINEERING ANALYSIS

The assumptions and estimated costs associated with a hypothetical newsprint mill producing 600 metric tons of newsprint/day, operating 350 days/year are shown in Table I. The mill is assumed to use a mix of 80% softwood thermomechanical pulp (TMP) and 20% deinked pulp (DIP). The fiber-loading process consists of four major operations: fiber fractionation, dewatering of long fiber fraction, mixing of bleach chemicals and calcium hydroxide into pulp, and reacting of pulp with carbon dioxide in high-consistency pressurized reactor (refiner).

We assumed that the 600 daily tons are fractionated into equal amounts (300 tons) of long and short fibers. Only the 300 tons/day of long fiber are processed through the fiber-loading equipment The additional cost for purchasing and installing the equipment is estimated at $4.396 million. An additional 25% of installed cost for engineering and soft expenses comes to $1.934 million, for a total capital cost of $6.333 million. Depreciation of total installed cost was calculated on a 10-year straight-line basis as $439,650/year. The cost of additional personnel was estimated at $50,000/year. Energy for operating the fiber loading equipment was estimated at 2.4 % 10^{10} kJ/year. We also included a $65,946/year maintenance fund of 1.5% of the installed cost.

Savings caused by reduction in grammage and increased FLPCC content were calculated assuming the cost of FLPCC at both $75 and $15O/metric ton. The cost of FLPCC varies depending on the availability of carbon dioxide and calcium hydroxide at the mill site. We did not attempt to estimate the impact of the many factors involved in the FLPCC raw material costs, and merely used a cost at both the high and low ends. The estimated savings per year for reduced grammage and increased FLPCC content included the additional cost of bleaching chemicals with standard stabilizers. Additional bleaching chemicals are needed to prevent alkaline darkening when alkaline calcium hydroxide is added to lignin-containing mechanical pulps. We assumed a cost of $0.66/kg for hydrogen peroxide, $0.37/kg for magnesium sulfate, and $0.22/kg for sodium silicate.

Savings resulting from reduced drying were also estimated. For the reduced grammage, values were obtained by multiplying a ratio of grammage at the lower level to grammage at the original level (assumed to be 49 g/m^2) by energy needed for drying paper (Table 1) [8]. The energy was then converted to a dollar value by using the heating value and cost of natural gas

The beneficial effect of FLPCC in increasing solids content prior to drying has been determined experimentally and published [6,9]. Thus, we multiplied the drying energy needed for drying pulp by a factor proportional to the fiber fraction of the total solids.

Table I. Assumptions and estimated costs of fiber-loading newsprint	
Production (600 metric tons/day newsprint)	cost
Process equipment and costs Fiber fractionation, two stage pressure screening Dewatering, two belt presses Chemical addition and pressurized reactor	 $256,000 $700,000 $998,000
Total equipment costs	$1,954 million
Installation (total % 1.25)	$2,442 million
Total installed costs (TIC)	$4,396 million
Engineering, etc. TIC % 0.44	$1,934 million
Total capital costs	$6,333 million
Maintenance (1.5% installed cost)	$65,946/year
Depreciation	$439,650/year
Additional personnel	$50,000/year
Electric power	$0.04/kW
Energy for operating equipment	2.4 % 10^{10} kJ/year
Energy for drying paper	1.98 % 10^{6} kJ/metric ton (dry basis)
Cost of natural gas	$2.82/m^2
Value of fiber	$242/metric ton at mill
Premium for reduced grammage paper	$2.24/metric ton/g grammage
Bleaching chemicals (based on fiber) 1 % hydrogen peroxide 3% sodium silicate 0.05% magnesium sulfate	 $0.66/kg $0.37/kg $0.22/kg

As noted in Table I, fiber in the mill was valued at $242/metric ton [10]. Manufacturers of lightweight newsprint have claimed a premium in the tonnage price. Price differentials of $45 to $63/metric ton have been reported for reducing grammage from 48.8 to 43.9 g/m^2 [10]. Another source reports that 45 g/m^2 newsprint costs 6% more per metric ton than its 48.8-gm^2 counterpart, but yields an additional 8% of printable surface [2]. However, the newsprint grades with reduced grammage probably do not have increased strength and opacity coupled with high Canadian standard freeness, which are possible with fiber-loaded newsprint. Rather, the premium for lightweight newsprint is probably for the additional cost of bleached softwood kraft pulp required for reducing grammage. Our calculations for savings include only 20% of the repotted average lightweight premium. That is, we added a premium of $2.24/metric ton for each gram reduced. This is a conservative estimate and tends to underestimate the value of fiber loading to the paper manufacturer. Also, we did not include a value for reduced shipping charges, which could be a considerable added value for overseas shipments.

Our ROI calculations were based on total savings divided by total capital costs. Savings included reduced drying. tiller for fiber substitution. and premium for light weight. From these savings we subtracted costs for additional personnel. running the process, depreciation, and maintenance.

RESULTS AND DISCUSSION

Figures 1 and 2 show estimated yearly cost savings for reduced fiber and increased FLPCC use. We obtained savings for both the reduced grammage and increased FLPCC content, but the reduced gammage had the greatest impact on savings. As Figure 1 shows. only the additional 8% FLPCC approached a positive value, assuming that FLPCC costs $73/metric ton and gammage is not reduced. If FLPCC is assumed to cost $150/metric ton, fiber reduction of about 2 g/m^2 is needed to obtain savings (Fig. 2).

Table II. Savings resulting from reduced drying.

Filler	wt. decrease	kJ saved/yr	$ saved/yr
4% ash	2 g/m²	3.29E+10	73540
	4 g/m²	4.91E+10	109932
	6 g/m²	6.54E+10	146323
6% ash	2 g/m²	4.08E+10	91357
	4 g/m²	5.68E+10	126990
	6 g/m²	7.27E+10	162623
8% ash	2 g/m²	4.88E+10	109173
	4 g/m²	6.44E+10	144048
	6 g/m²	8.00E+10	178923

The reported rate of return on capital investment includes the cost of bleaching chemicals at both 1% and 0.5% hydrogen peroxide levels (Tables III and IV). The amount of bleaching chemicals to be added to the fiber loading process depends on many factors [4]. For example, the pulp for fiber loading may have been highly bleached and only sufficient chemicals to prevent alkaline darkening are required to obtain relatively low brightness newsprint. Another possibility is that value-added newsprint grades may require especially high brightness and so a high level of hydrogen peroxide is needed to obtain the additional brightness. Therefore, we calculated ROIs at both the 1% and 0.5% hydrogen peroxide levels. For both levels. we obtained positive ROIs for all levels of grammage reduction and FLPCC increase.

Assuming that a reduction of 4 g/m^2 and an additional 6% of FLPCC is a reasonable goal for fiber-loaded newsprint, high ROIs can be reached. Assuming that FLPCC is available at $150/metric ton, the ROI is estimated to be 59.7%; at $75/metric ton FLPCC. the ROI is estimated to be 73.4%. If only 0.5% hydrogen peroxide is used with typical stabilizing chemicals, the corresponding ROIs are further improved. At $150/metric ton FLPCC, fiber reduction of 4 g/m^2 and FLPCC increase of 6%, the ROI is 81.9% at $150/metric ton FLPCC and 96.5% at $75/metric ton FLPCC. These ROIs are significantly higher than the typically reponed ROIs of 5% to 10% for papermaking capital investments [1].

Table III. Rate of return on capital investment with 1.0% peroxide.

Filler	wt decrease	$75/ton filler	$150/ton filler
4% ash	2 g/m²	14.1%	4.5%
	4 g/m²	62.9%	53.8%
	6 g/m²	111.8%	103.1%
6% ash	2 g/m²	25.0%	10.7%
	4 g/m²	73.4%	59.7%
	6 g/m²	121.8%	108.7%
8% ash	2 g/m²	35.9%	16.8%
	4 g/m²	83.8%	65.5%
	6 g/m²	131.8%	114.3%

Our engineering analysis for estimating cost reduction is based on producing lightweight high-opacity newsprint by fiber loading. Similar applications of fiber loading are possible for mottled and white-top linerboard and printing & writing grades. We have not included the engineering analysis of how the taster paper machine speeds used to produce lightweight high-opacity paper increase the rate of production. Nor have we included the benefits of reduced greenhouse gas emissions [11], reduced process water solids that result from improved FLPCC retention [12], and pacification of pitch and stickies [13], all of which accompany fiber loading. Nor have we investigated the effect of improved printing surface that is potentially possible with partially filled fibers and increased levels of FLPCC achieved with fiber loading. All of these advantages of fiber loading have an associated economic value that can be estimated and all are potential topics for future engineering analyses.

Table IV. Rate of return on capital investment with 0.5% peroxide.

Filler	wt. Decrease	$75/ton filler	$150/ton filler
4% ash	2 g/m^2	36.3%	26.8%
	4 g/m^2	85.2%	76.0%
	6 g/m^2	134.0%	125.3%
6% ash	2 g/m^2	47.2%	32.9%
	4 g/m^2	95.6%	81.9%
	6 g/m^2	144.0%	130.9%
8% ash	2 g/m^2	58.1%	39.0%
	4 g/m^2	106.1%	87.8%
	6 g/m^2	154.0%	136.5%

CONCLUSIONS

- We calculated the returns on investment (ROIs) for two FLPCC prices ($75 and $150/metric ton) and two levels of hydrogen peroxide (1% and 0.5%). Positive ROIs were estimated for all levels of grammage reduction and increase in FLPCC investigated.
- Assuming that reduction of 4 g/m^2 and an additional 6% of FLPCC is a reasonable goal for fiber-loaded newsprint, high ROIs can be reached. Assuming that FLPCC is available at $150/metric ton and 1.0% hydrogen peroxide is added, the ROI is estimated to be 59.7%; at $75/metric ton FLPCC, the estimated ROI is 73.4%.
- If only 0.5% hydrogen peroxide is required. the corresponding ROIs are further increased. At $150/metric ton FLPCC, grammage reduction of 4 g/m^2, and FLPCC increase of 6%, the ROI is 81.9% at $150/metric ton FLPCC and 95.6% at $75/metric ton.

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