

Explosion pulping—exploratory trials

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ABSTRACT *Explosion pulping is an attempt to reduce energy consumption in high-yield pulping. In laboratory-scale experiments all wood was impregnated with sodium sulfite and then charged in a reactor where steam at 33 bar (230°C) was injected for 12 s and held for 90 s before discharge. The sulfite exploded pulp showed superior strength properties at a low sulfur content.*

Plant-scale explosion trials concluded that, compared with standard CTMP, the explosion pulp showed a higher tensile tear index, and approximately 25% electrical energy savings are possible.

KEYWORDS

CTMP
Sulfite
impregnation
Explosion
pulping
Energy saving
High-yield
pulping

The conventional method of chemithermomechanical (CTMP) pulp manufacture is based on preimpregnation of chips with sodium sulfite, heating the chips to 130°C and defibering in a disc refiner. The process power consumption is 1.5–2 MW·h/ton, of which 50% is recoverable as steam. Rising electrical power cost has intensified the search for power reduction methods for high-yield pulping.

The explosion method of defibering wood, known since the 1920s, has been used mainly for building board manufacture. Renewed interest in this method has been reported by Mamers (1), Kokta (2), and Law (3) for reducing power consumption and enhancing pulp quality.

Recently patented in Sweden, a modification of the explosion process preimpregnates chips with sodium carbonate, whereafter the chips are loaded in the gun and SO₂ gas is injected to convert sodium carbonate to sodium sulfite *in situ*. The released carbon dioxide remains in solution. Upon heating the chips with high-pressure steam (50 bar), pressure builds up within the chips due to CO₂ formation. The contents of the gun are then blown to a cyclone kept at 5 bar. This sudden expansion of steam and CO₂ tears up the chips and produces

a coarse fiber. The released steam is condensed in a reboiler to produce 4 bar of fresh steam. The condensate from this dirty steam is distilled to recover methanol, which is reused to facilitate impregnation of chips.

This paper summarizes the exploratory laboratory and pilot-plant experiments conducted to verify the feasibility of this process. Due to the limitation of the equipment used in the experiment, only sodium sulfite impregnated chips were used. Further work is in progress to generate sodium sulfite *in situ* and more accurately estimate power consumption.

Laboratory trials

Impregnation

Chips from spruce were steamed for 10 min in autoclaves. Impregnation liquor at 20°C was added to fill up the autoclave, and a pressure of 8 bar (over) nitrogen was applied for 30 min. The impregnation liquor was a sodium sulfite solution (150 g Na₂SO₃/l, pH = 9.4).

Explosion

The explosion was carried out at the Technical University of Lund, Sweden.

About 250 g of impregnated chips were put into a steaming reactor. The

temperature was raised to 240°C (33 bar) in 12 s and kept at this temperature for 90 s. The valve in the bottom of the reactor was then quickly opened and the chips blown out.

Beating in PFI-mill

Before beating in the PFI-mill, the pulp was run at low consistency (2–3%) through an open 12-in. Sprout-Waldron laboratory refiner to separate the larger pieces of chips.

The pulp was beaten in a PFI-mill at 10% consistency. The unscreened pulp was hot disintegrated and tested for freeness (CSF), strength properties, and brightness. The sulfite explosion pulp was also tested for the amount of bound sulfur to determine the degree of sulfonation.

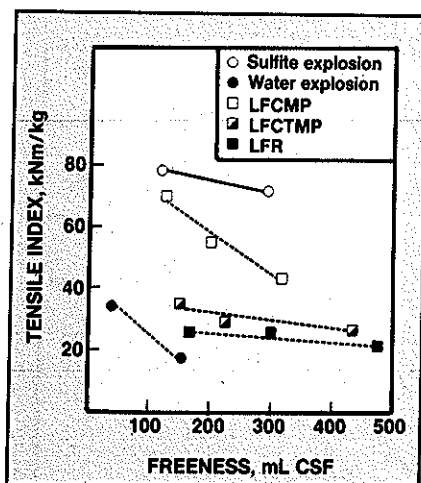
Results

The pulp properties are summarized in Table I and compared with other pulps in Figs. 1, 2, and 3.

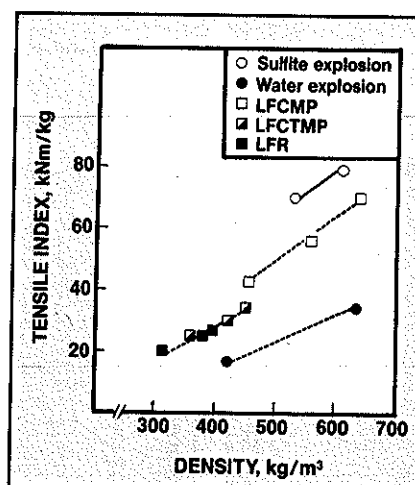
The charge of sodium sulfite was approximately 10% based on bone-dry wood. The amount of bound sulfur in the pulp was 0.44%. However, the yield could not be determined.

As a reference to the two explosion pulps in Fig. 1, three other pulps are shown, which have also been beaten in the PFI-mill after chemical treatment. The original pulp was a coarse

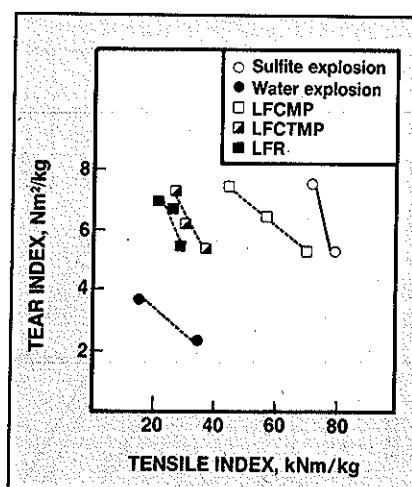
1. Laboratory trial (tensile/freeness)



2. Laboratory trial (tensile/density)



3. Laboratory trial (tear/tensile)



I. Explosion pulping

Pulp	Free-ness, mL CSF	Tensile index, kNm/kg	Elonga-tion, %	Burst index, MN/kg	Tear index, Nm²/kg	Density, kg/m³	ISO bright-ness, %
Water impregnated spruce							
4,000 rev.*	148	17.8	0.7	0.7	3.6	412	18.6
10,000 rev.	41	34.2	1.1	1.2	2.3	635	18.8
Sulfite impregnated spruce							
10,000 rev.	290	70.7	2.2	4.9	7.4	530	42.6
15,000 rev.	118	79.1	2.1	5.3	6.4	603	38.7

*Revolutions in PFI-mill.

reject at 525 mL CSF from a thermomechanical pulp (TMP) screen room which was treated in three ways:

1. 15% sodium sulfite on bone-dry pulp was added, and the pulp was digested at 150°C for 60 min. The amount of bound sulfur was 0.78%, and the yield was approximately 90%. This pulp is denoted long-fiber chemimechanical pulp (LFCMP).
2. Treated with 2.3% sodium sulfite on bone-dry pulp at 125°C for 5 minutes. The amount of bound sulfur was 0.24%, and the yield was approximately 95%. This pulp is denoted long-fiber chemithermomechanical pulp (LFCTMP).
3. No treatment at all. This pulp is

called long-fiber reference (LFR). All pulps were beaten for 2000, 6000 and 10,000 revolutions, respectively, in the PFI-mill.

In spite of the fact that the sulfite explosion pulp in Fig. 1 has a lower degree of sulfonation (0.44% bound sulfur) compared to LFCMP (0.78% bound sulfur), the tensile index is higher at a given freeness value. Also, LFCTMP (0.24% bound sulfur) has a lower tensile index compared to LFCMP. It seems that the sulfite explosion pulp has a higher strength potential compared to conventional chemimechanical pulp.

The relationship between tensile index and density is far better for the sulfite explosion pulp (Fig. 2). Also,

the relation between tensile index and density is more or less unaffected by the degree of sulfonation for conventional chemimechanical pulping. However, the sulfite explosion pulp differs from this relationship. It has a higher tensile index at a given density. The tear index of the sulfite explosion pulp is at the same level as that of the conventional chemimechanical pulp (Fig. 3). At a given tear index, the tensile index is higher for the sulfite explosion pulp.

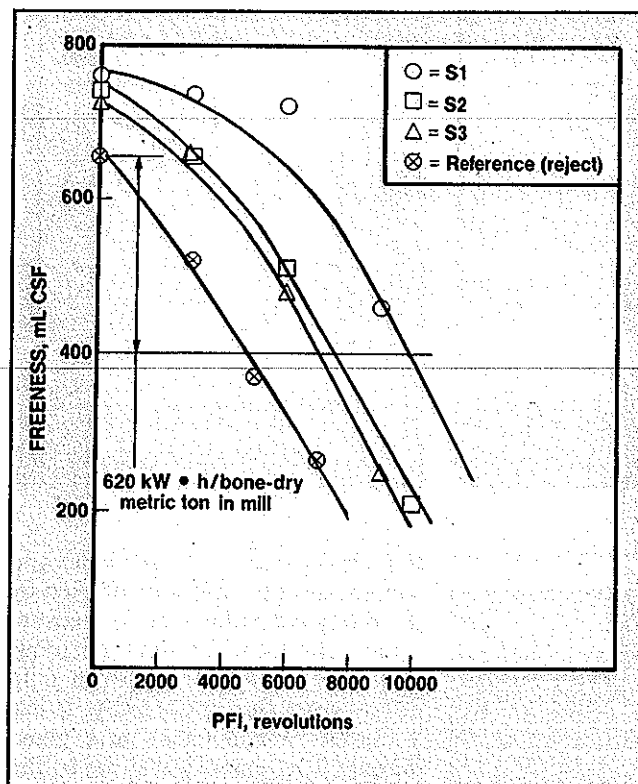
Pilot-plant experiments

Encouraged by the laboratory results, a pilot-plant test was planned. It was conducted at the Swanboard Masonite AB plant at Rundvik, Sweden.

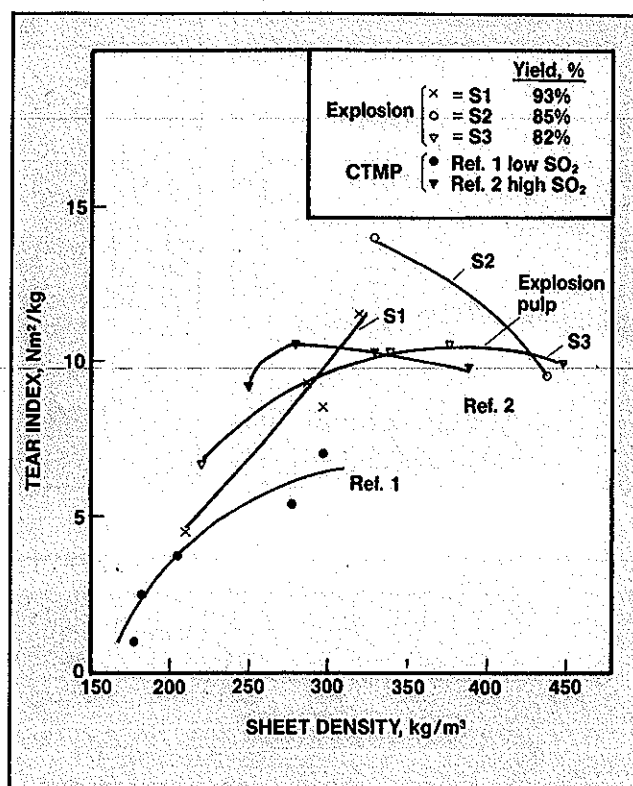
Impregnation

Approximately 300 L of chips (45 kg) were put in an open container and presteamed atmospherically for 15 min. Afterwards, the container was filled from the bottom with cold impregnation liquor, and the chips were covered completely. The impregnation time was 10 min in all trials. The impregnation liquor was a sodium sulfite solution at three different concentrations. Construction material for the pressure vessel (gun) was carbon steel, so the chelating agent DTPA was added to the liquor (0.5% on bone-dry wood). This DTPA (Kelatex 80) contained 1-5% sodium hydroxide, which resulted in a pH in the impregnation liquor of approximately 11.0. During impregnation,

4. Freeness vs. revolutions in PFI-mill for explosion pulps from spruce and a reference pulp



5. Explosion pulping tear index vs. density comparison with CTMP



II. Explosion pulping conditions

Pulp number	Charge Na_2SO_3 on bone-dry wood, %	Degassing time/pressure, s/bar	Steaming time/pressure, s/bar	Retention time/pressure, s/bar
S1	3.6	10/5	30/30	5/50
S2	8.7	10/5	30/30	15/50
S3	14.8	10/5	30/30	30/50

III. Explosion pulping yield

Pulp number	COD in pulp, kg/bone-dry metric ton	Yield calculated from COD, %
S1	96	93.1
S2	232	84.8
S3	281	82.2

0.52 L of liquor per kg wood was sucked in. The Na_2SO_3 charges for the different impregnations were 3.6%, 8.7%, and 14.8% on bone-dry wood.

Explosion

After impregnation the pressure vessel (gun) was completely filled up with the chips from the top of the vessel. The amount of chips in the vessel was 42 kg. The time in the vessel was divided into three sequences: degassing, steaming, and retention time before blowing.

Degassing

Steam was introduced to heat the raw material and evacuate air. The pressure was raised to 5 bar (160°C) and kept at this temperature for 10 s.

Steaming

After degassing, the steam pressure was raised to 30 bar (235°C) instantaneously and maintained at this pressure for 30 s.

Retention time before blowing

In the last sequence the pressure was raised to 50 bar (265°C) and maintained at this level for 5, 15, or 30 s, depending on the sodium sulfite charges (5 s for the lower charge and 30 s for the higher charge). The valve in the bottom of the vessel was then quickly opened and the chips blown out.

Refining after explosion

A sample of coarse fiber from each batch at Swanboard Masonite was refined at the laboratory in three or

four stages to reach different CSF levels (440–750 mL CSF). Unfortunately, the coarse fiber had to be stored over a period of six weeks before refining.

The exploded coarse fiber was preheated in the steaming tube at the refiner, at 100°C for 5 min. The pulp was then refined at a pressure of approximately 2 bar and discharged through the cyclone.

All samples were hot disintegrated and analyzed for physical properties, CSF, shives, and long-fiber content (Bauer-McNett).

Reference CTMP

Reference CTMPs were produced at the laboratory from the same raw material (spruce) as was used at

IV. Strength properties of explosion pulps

Pulp number	Free-ness, mL CSF	Shives, Somerville, %	Tensile index, kNm/kg	Elongation, %	Burst index, MN/kg	Tear index, Nm ² /kg	Density, kg/m ³
S1	761	1.60	7.1	0.5	...	4.7	210
	740	0.20	21.6	1.1	1.1	9.1	289
	700	0.20	24.0	1.2	1.2	8.7	295
	640	0.30	28.4	1.3	1.5	11.5	322
S2	744	1.40	28.4	1.3	1.6	14.2	330
	583	0.40	47.8	1.8	2.9	9.7	439
	440	0.20	55.5	2.1	3.7	9.5	470
S3	725	0.70	32.5	1.5	2.2	10.5	339
	700	0.30	40.9	1.7	2.6	10.7	383
	633	0.20	49.0	2.0	3.4	9.8	451
	489	0.20	57.0	2.2	3.9	8.8	495

V. Strength properties of reference CTMP pulp

Pulp	Free-ness, mL CSF	Shives, Somerville, %	Tensile index, kNm/kg	Elongation, %	Burst index, MN/kg	Tear index, Nm ² /kg	Density, kg/m ³
Reference	775	12.80	...	...	...	1.2	176
CTMP, 2.8%	747	1.20	4.1	1.0	...	2.4	177
Na ₂ SO ₃ on bone-dry wood	737	0.60	8.3	0.7	...	3.7	208
	649	0.20	17.5	1.2	0.9	5.4	278
	570	0.20	22.6	1.4	1.2	7.0	299
Reference	755	1.20	10.9	0.8	...	6.9	214
CTMP, 9.9%	750	0.20	17.4	1.1	1.0	9.3	251
Na ₂ SO ₃ on bone-dry wood	743	0.20	23.1	1.4	1.3	10.7	282
	689	0.10	28.6	1.6	1.6	10.5	331
	570	0.10	38.1	1.9	2.3	9.7	388

Rundvik. The chips were presteamed and impregnated in a similar way as the exploded pulps and then refined in the laboratory refiner. Two different Na₂SO₃ charges were used, 2.8% and 9.9% Na₂SO₃ on bone-dry wood.

The impregnated chips from the lower charge were preheated in the steaming tube at the refiner at 130°C for 5 min and then refined in five stages. The chips from the higher charge were preheated at 150°C for 30 min and refined in five stages.

The yields for the two refinings were estimated to be 95.7% (2.8% Na₂SO₃) and 93.0% (9.9% Na₂SO₃).

Energy consumption

To estimate energy consumption, the pulps produced by explosion and

refining and a reference pulp were beaten in a PFI-mill. The pulps were beaten at 10% consistency and then hot disintegrated and tested for freeness (CSF). Figure 4 shows the PFI revolutions and CSF of all the tested pulps.

In a full-size reject refiner, the energy consumption was approximately 620 kW·h/bone-dry metric ton to refine the reference TMP pulp from 655 mL CSF to 395 mL CSF. Figure 4 shows that approximately 5000 revolutions are needed to reach the same CSF level in a PFI-mill for the reference pulp, while the explosion pulps S1, S2, and S3 needed 10,000, 7800, and 7200 revolutions, respectively. According to this comparison, the explosion pulps demand more revolutions than the reference

pulp to reach 395 mL CSF. On the other hand, these pulps had a higher starting CSF level.

Power consumption in a refiner and the PFI-mill revolutions are not exactly comparable. However, in absence of better methods this comparison is made to obtain an idea of the order of magnitude of power consumption. Accordingly, pulps S1, S2, and S3 consumed 1300, 1030, and 950 kW·h/ton to be refined to 390 CSF.

Conventional CTMP requires approximately 1600 kW·h/ton when refined to 400 CSF. By explosion pulping, power can be reduced to 300–600 kW·h/t. In other words, steam explosion contributes, on average, to 450 kW·h/ton of defibration work.

Results

The results are summarized in Tables II–V and shown in Figs. 5–7.

Tables II and III show conditions and results from the explosion operation.

Tables IV and V show physical properties after refining of exploded pulps and reference CTMP.

Conclusion

We reached the following conclusions:

1. Laboratory and pilot-plant tests of spruce by chemical impregnation with sodium sulfite and steam explosion can produce a pulp with properties superior to CTMP.
2. Electrical energy savings of 25% are possible.
3. The process merits further systematic investigation in pilot-scale and testing of the pulp in papermaking.□

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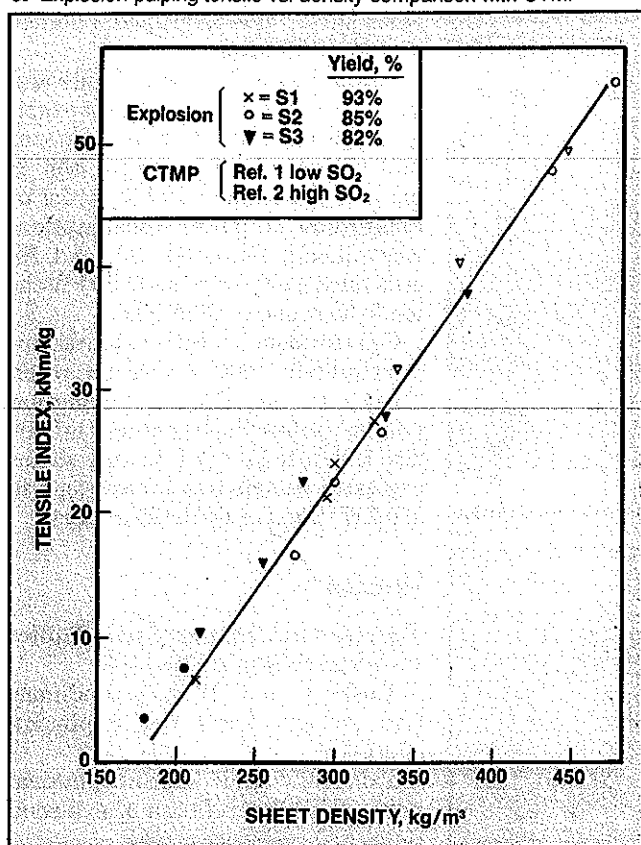
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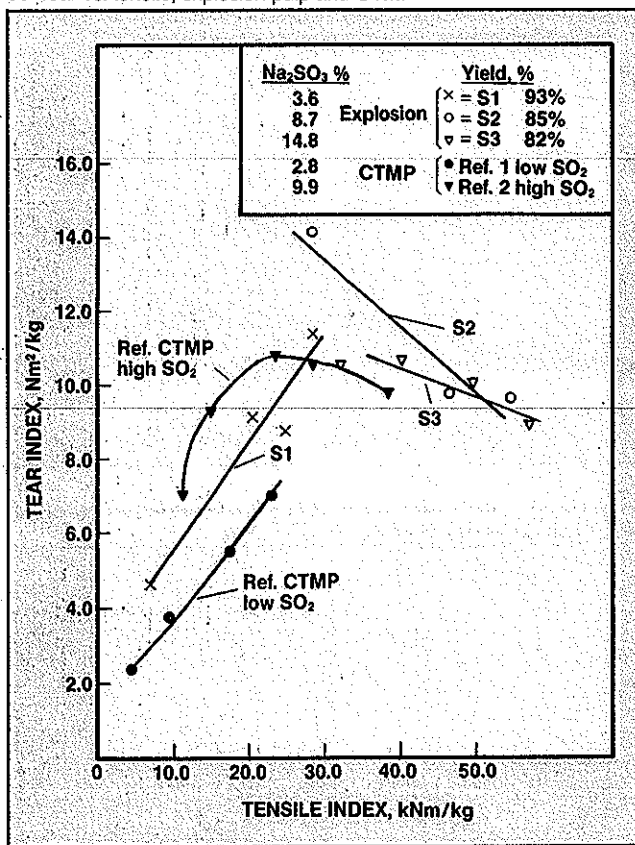
Presented at the TAPPI 1989 Pulping Conference.

Figures continued next page.

6. Explosion pulping tensile vs. density comparison with CTMP



7. Tear vs. tensile, explosion pulp and CTMP



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