Energy savings through hot pressing

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Heating the sheet in the press section can significantly reduce steam requirements in the dryer section.

Water is mechanically removed from the wet web in the press section. Mechanical water removal during wet pressing is limited by three factors:

- The flow resistance of water through the fiber mat
- The fiber mat's resistance to compression
- The sheet's tendency toward rewetting.

The effect of each of these limiting factors is mitigated when the temperature of the sheet is increased. The hot-pressing process enhances the mechanical removal of water by increasing the sheet temperature.

Flow resistance is the dominant factor limiting the removal of water from sheets with high moistures or high basis weights and from low-freeness furnishes. Increasing the temperature reduces the water's viscosity and thus its flow resistance.

The fiber mat's resistance to compression is another factor that limits the removal of water from a fiber mat. When the mat resists compression, it absorbs some of the press load. This reduces the amount of available pressure that can be applied to the hydraulic phase. Fiber compression resistance is a dominant factor for low-moisture sheets and higher-freeness, higher-yield furnishes. Increasing the temperature softens the fibers and reduces their compression resistance.

Sheet rewetting can be a major factor in limiting water removal on lightweight sheets. Several mechanisms have been proposed to explain this phenomenon, but the central physical property in each of the proposed mechanisms is the surface tension of the water. Increasing the water temperature reduces its surface tension and thus helps to reduce rewetting.

Steam showers are commonly used to increase the temperature of the sheet during wet pressing. (There are more than 600 steam showers operating worldwide on all grades of paper.) The steam shower increases sheet temperature by condensing steam on and in the sheet, where the steam's latent heat is converted to sensible heat. Thus the steam functions as an energy-transfer medium.

Steam is also used as an energy-transfer medium in the dryers after the press section. In the dryers, however, steam is used to heat the sheet and increase water removal by evaporation. A dryer that uses 1.3 kg of steam to evaporate 1.0 kg of water is considered to be efficient. However, this ratio commonly exceeds 1.5 in many dryers.

The hot-pressing process can save energy only if the amount of steam used to mechanically remove water in the press section is less than the amount of steam used to evaporate water in the dryer section. (This is not a completely true statement, since steam showers use lower-quality steam than the dryer section. An equal ratio would still provide a minor benefit.) In essence, we are comparing the relative energy efficiencies of two water-removal processes: mechanical vs. evaporative.

Theoretical discussion

A sheet's response to the increased temperatures of hot pressing is influenced by sheet moisture content. Once we quantify this relationship, it should be possible to construct a simple energy balance to compare the energy efficiency of mechanical vs. evaporative water removal.

Table I provides a theoretical basis for evaluating the energy savings provided by hot pressing. The example presented here is based on a paper machine producing 500 o.d. metric tons/day. Moisture content at the reel is 6%. Table I shows that, without hot pressing, the moisture content entering the dryer section is 58%.

The calculated results following steam application at four wet-end locations are presented. These four locations were chosen to illustrate the effect of sheet moisture on the steam's ability to increase sheet temperature. As the sheet becomes wetter, there is more water to heat, and so the temperature increase obtained for each unit of energy applied to the sheet becomes smaller.

Table I was constructed by applying a fixed amount of energy at the wet end and then calculating the temperature increase in the sheet. This provided the basis for calculating the improved dryness leaving the press section. The reduced evaporative load to the dryer section yields a gross steam savings. The gross savings, less the steam applied in the wet end, equals the net steam savings.

The five assumptions used in these calculations merit some explanation:

1. The specific heat value of dry fiber was assumed to be 0.5. This value is subject to slight variation, depending on the furnish type, yield, species, etc.

2. The transfer of energy from the steam to the sheet was assumed to be 100% efficient. In other words, it was

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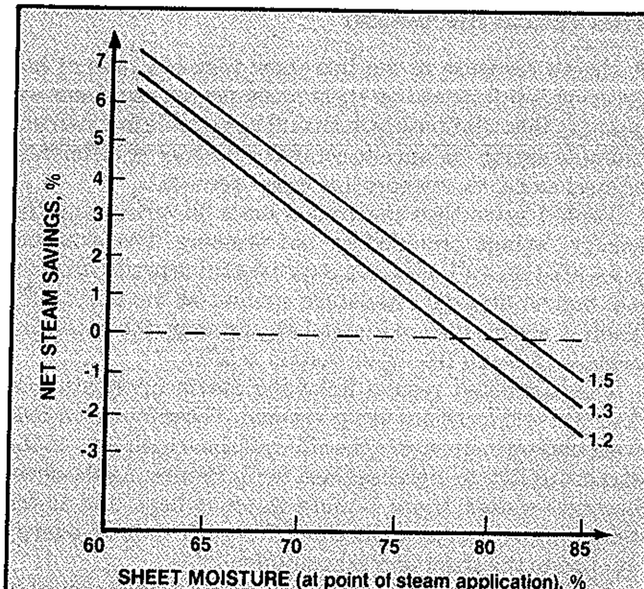
I. Theoretical basis for energy savings through the use of hot pressing for a paper machine producing mechanical pulp free grades. Steam applied at one of four wet-end locations

	No steam shower	Location of steam shower: Last press	Second press	First press	Fourdrinier
At point of application					
Fiber, tons/day	. . .	500	500	500	500
Water, tons/day (moisture, %)	. . .	816 (62)	1167 (70)	2000 (80)	2833 (85)
Steam applied, tons/day	. . .	50	50	50	50
Exiting last press:					
Fiber, tons/day	500	500	500	500	500
Water, tons/day (moisture, %)	690(58)	611(55)	629(55.7)	652(56.6)	663(57)
Temperature, °C	40	70.5	62.7	54.1	50.2
At reel:					
Fiber, tons/day	500	500	500	500	500
Water (6% moisture), tons/day	32	32	32	32	32
Water evaporated, tons/day	658	579	597	620	631
Dryer steam use, tons/day	856	753	776	806	820
Dryer steam saved, tons/day	. . .	103	80	50	35
Net steam saved, tons/day (1%)	. . .	53(6.2)	30(3.5)	0(0)	-15(-1.8)
Energy efficiency, kg steam/kg water	. . .	0.63	0.82	1.30	1.85

Assumptions:
1. Specific heat value of dry fiber = 0.5.
2. Energy conversion of steam to sensible heat = 100% (i.e., no steam is spilled).
3. Sensible heat gain going to dryer section is neglected.
4. Sheet moisture decrease from hot pressing = 1%/10°C.
5. Specific steam use in dryer section = 1.3.

1. Net available steam savings as a function of the sheet's moisture at the point of steam application. The three curves depict three levels of dryer efficiency. The dryer efficiencies represent the number of kilograms of steam needed to evaporate 1 kg of water in the dryer section.



II. Hot-pressing results reported by three mills

	United States	Sweden	Japan
Paper grade	liner	news	news
Basis weight, g/m^2	98 – 336	49	49
Furnish type	Virgin	Virgin	Virgin/ recycled
Machine speed, m/min	500	1020	800
Steam shower location	Fourdrinier	2nd press	3rd press
Production results			
Moisture increase at reel, %	N/A*	0.4	0.8
Speed increase, %	4.7	5.9	0
Production increase, %	5.5	N/A	N/A
Quality rejects saved, %	0.9	N/A	N/A
Steam use			
Steam shower, %	N/A	7.	9.
Specific, %	-27.	-4.2	N/A
Net, %	N/A	N/A	-14.6

*N/A = no available data.

assumed that there was no steam spillage. Some users of steam showers may consider this to be a liberal assumption. Perhaps the next assumption will compensate for this generosity.

3. The effect of heat gain in the sheet going to the dryer section was neglected. Of course, a hotter sheet does not have to be heated as much by the dryer section. Our experience indicates that a 10°C increase in sheet temperature reduces the use of steam in the dryer section by about 1%.

4. The decrease in sheet moisture exiting the press section was assumed to be 1% per 10°C. Our experience suggests this is a minimum response. (We have documented hot-pressing responses as high as 2.0% per 10°C.) This response would be increased in the case of:

- A sheet with a more open structure
- A higher-yield furnish
- Early application of energy in the wet end, which would enhance sheet consolidation and allow more press nips to work on the hot sheet.

5. Specific steam use in the dryer section was assumed to be 1.3 kg steam for each kilogram of water evaporated.

The calculated net energy savings (net steam saved) and energy efficiencies for the four wet-end locations are listed in Table I. It is clear that, theoretically at least, net energy savings are possible. This indicates that energy spent on hot pressing removes water more efficiently than energy spent on evaporation.

Figure 1 illustrates the linear relationship between the sheet's moisture content at the time of steam application and the available net energy savings. The energy efficiency of the dryer section is sensitive to this relationship. At dryer section efficiencies of 1.2, 1.3, and 1.5 there should be a positive net energy savings if the steam is applied at sheet moistures below 78%, 80%, and 82%, respectively.

Practical realities

Comparing theoretical considerations with practical realities is always a useful exercise. **Table II** presents results from three mills. These three cases were selected for presentation from a variety of cases because (a) the data for these cases were more complete than the others, and (b) the speed increases were not great, which made the energy savings more comparable.

The first case is a duplex fourdrinier machine in the United States producing linerboard from virgin furnish. The steam shower is located over the flatboxes on the fourdrinier, where the average sheet moisture is likely higher than 85%. The amount of steam applied was not reported, but it is likely in the range of 20–25%, i.e., 0.20–0.25 metric tons of steam per metric ton of o.d. paper.

Theoretical considerations suggest that a net energy savings would not be likely under these conditions. However, the mill reported a decrease in total steam use from 2.75 metric tons of steam per metric ton of paper to 2.00. This suggests that the temperature response (reduction in sheet moisture) was much better than the assumed value of 1% per 10°C.

The second case is a twin-wire machine in Sweden producing newsprint from virgin furnish. The steam shower is located before the second nip in a three-nip (four-roll) press, where the sheet moisture would be near 70%. The amount of steam applied was 7%.

Theoretical considerations suggest that the net steam savings would be about 2.5% (3.5% × 0.7). The specific steam savings were nearly twice as high, 4.2%. Part of the energy savings would be due to the higher reel moisture, made possible by the improved moisture profile. A higher temperature response, quite normal with mechanical pulps, would explain the remaining extra energy savings.

The third case is a fourdrinier machine in Japan producing newsprint from a mixed furnish of virgin and recycled fibers. The steam shower is located before the third press nip. The press configuration includes a bi-nip followed by a straight-through third nip. The amount of steam applied is 9%. Sheet moisture at the point of steam application is 62%.

Theoretical considerations suggest the net energy savings would be 5.6% (6.2% × 0.9). However, the mill reported 14.6%. This higher savings would be due partly to the increased moisture at the reel and partly to the better temperature response of mechanical pulps.

Conclusion

Theoretical considerations indicate that the hot-pressing process can provide energy savings. Several selected results demonstrate that, under favorable conditions, practical results exceed theoretical predictions.

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