Opening the operating window of impulse drying—Part III: Controlled decompression experiments

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ABSTRACT

Recent Institute research has shown that changes in the nip-opening process can significantly impact sheet delamination during impulse drying. Empirical evidence shows that by opening the nip to ambient pressures in excess of 1 atm, delamination can be avoided. While this method may prove to be practical, methods that were easier to implement are being sought.

Further experimental work showed that by properly controlling the load applied to the sheet as the nip opens, sheet delamination could be inhibited. The experiments identified nip-opening load conditions that were sufficient to suppress the delamination of 205-g/m² linerboard handsheets having a freeness of 400-mL CSF at 35% ingoing solids.

Application:

This work showed that sheet delamination can be avoided by properly designing the decompression phase of the pressure profile. This can be implemented by modifying the shape of the conventional press shoe or by providing a postnip mechanical load.

In this experimental work, we show that by properly controlling the load applied to the sheet as the nip opens, sheet delamination can be inhibited.

EXPERIMENTAL

Controlled decompression impulse drying

Based on the Institute's previous research *(1–4)*, experiments were performed to access the idea of controlling the decompression of the sheet during the nip-opening process. In this concept, the ambient pressure surrounding the impulse dryer would be maintained at 1 atm (101 kPa absolute), while the nip-opening pressure profile would be modified by adding a long decompression to the standard nip pressure profile. For simplicity, this long decompression is referred to as a "ramp profile" in the discussion that follows.

The shape of the ramp profile is defined by the applied load pressure at the instant that the nip begins to open and the time at which the applied pressure equals the ambient pressure, and the functional relationship between applied pressure and time. **Figure 1** shows the ramp profiles that were investigated.

Using the same handsheets as were used by Krause *(1, 3)*, a series of impulse drying experiments were performed in which all conditions were maintained constant, except for the ramp profile and the platen setpoint temperature. **Table I** shows the parameters that were fixed during these experiments.

Figure 2 shows outgoing solids as a function of platen setpoint temperature. It should be noted that the ramp profile adds to the total impulse applied to the sheet. Hence, it is understandable that outgoing solids increased when the ramp profile was changed from the absence of a ramp (Ramp=NO) to the longest ramp (Ramp=A).

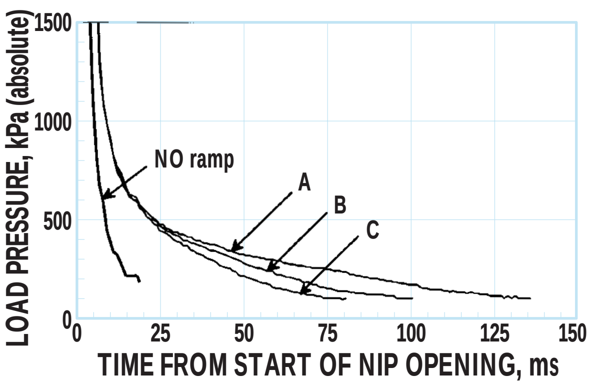
The impulse-dried sheets were tested using out-of-plane ultrasound. The coefficient of variation of the specific elastic modulus was determined and is plotted as a function of platen setpoint temperature and ramp profile in **Fig. 3.** In agreement with all earlier work, delaminated sheets were found to have coefficients of variation in excess of 10–15%. A review of Fig. 3 showed that sheets impulse dried with no ramp profile delaminated at all platen setpoint temperatures investigated. Samples impulse dried using Ramp C failed to delaminate only at the lowest platen setpoint temperature of 200°C, while Ramps A and B did not delaminate at any of the platen setpoint temperatures investigated.

Figure 4 shows specific elastic modulus as a function of platen setpoint temperature. It was observed that sheets impulse dried with ramp profiles that prevented delamination had improved strength relative to any other condition investigated. Hence, by using the proper ramp profile, the press surface temperature may be increased to obtain higher sheet strength as well as higher solids.

Measurement of internal sheet temperature

In additional experiments, which were otherwise identical to those presented in the previous section, the sheets were formed from three equal layers with 0.05-mm-diam thermocouples between layers and on the top and bottom surfaces of the sheet.

Figures 5–8 show these experimental temperature profiles. The temperature on the heated surface of the sheet is designated as T1, those between sheet layers are T2 and T3, and that on the surface of the sheet in contact with the felt is T4. The platen setpoint temperature, as



1. Nip-opening decompression profiles

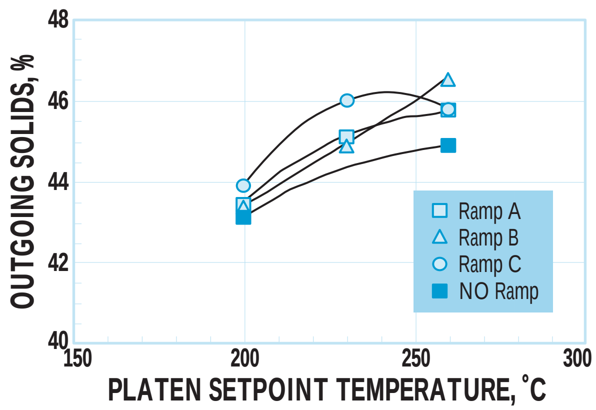
Stage	Parameter	Result
Pulp	Species	93% southern hard pine, 7% gum
	Kappa no.	102
	Weight-weighted fiber length, mm	2.3
Sheet	Basis weight, g/m^2	205
	Ingoing solids, %	34
	Ingoing density, g/cm^3	0.7
	Freeness, mL CSF	400
	Hydrodynamic specific surface, m^2/g	29.5
	Hydrodynamic specific volume, cm^3/g	0.823
	Ingoing temperature, °C	85
Felt	Sample designation	BXC5
	Ingoing moisture, %	16
Impulse drying	Platen material	Carbon steel
	Peak nip pressure, kPa	4300
	Nip dwell time, ms	40

I. Fixed parameters

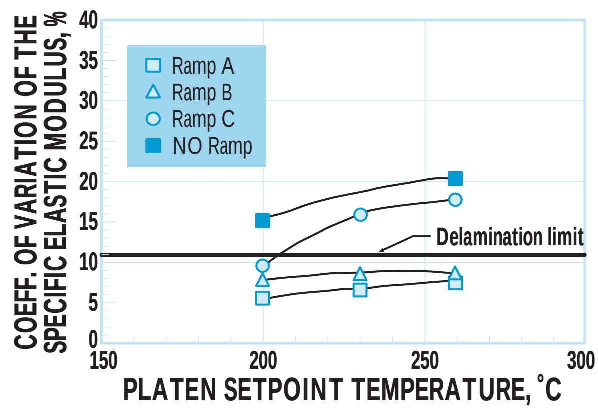
measured and maintained constant by a thermocouple on the back side of the platen, is designated as Ts.p. The instantaneous platen surface temperature, as measured by a vacuum-deposited thermocouple, is designated as Tp.s.

The following important observations can be made from the experimental temperature profiles:

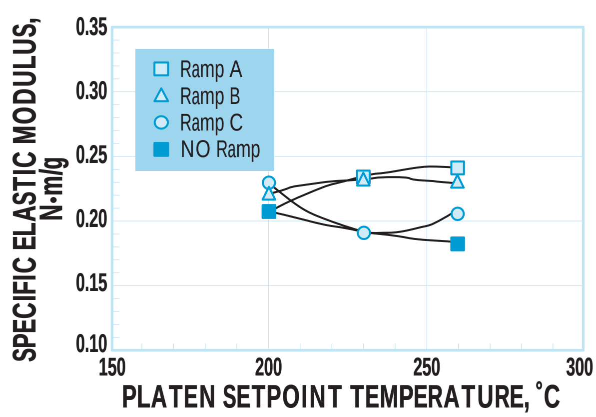
- The temperature at the interface between the top layer and middle layer of the sheet generally tended to decrease with time during the nip-opening



2. Outgoing solids as a function of platen setpoint temperature for nip-opening ramp profiles



3. Coefficient of variation of the specific elastic modulus as a function of platen setpoint temperature for nip-opening ramp profiles



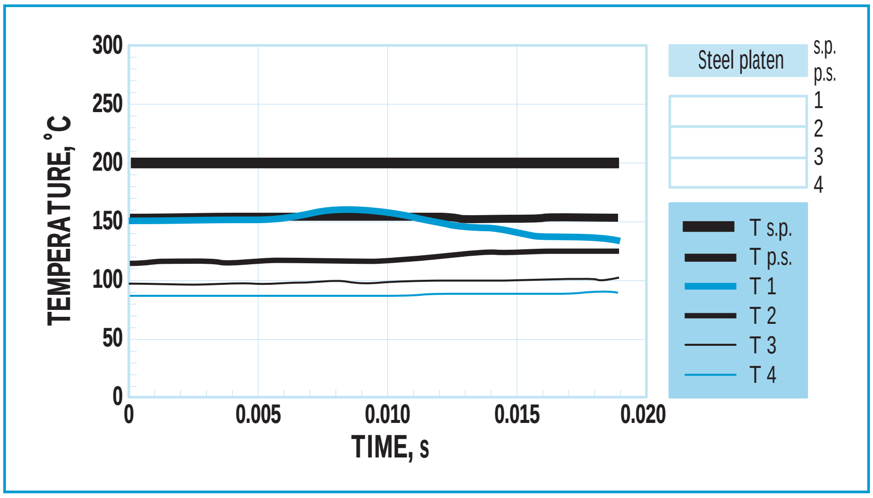
4. Specific elastic modulus as a function of platen setpoint temperature for nip-opening ramp profiles process. This is consistent with evaporative cooling.

- At any given time during nip opening, sheet temperature decreases with increasing depth into the sheet. Hence, it is anticipated that flashing and venting would occur from the top surface of the sheet downward.
- During nip opening, the internal sheet temperatures often went through a period where the temperature increased before following the general decreasing trend. This temperature increase occurs while the system is still a subcooled liquid.

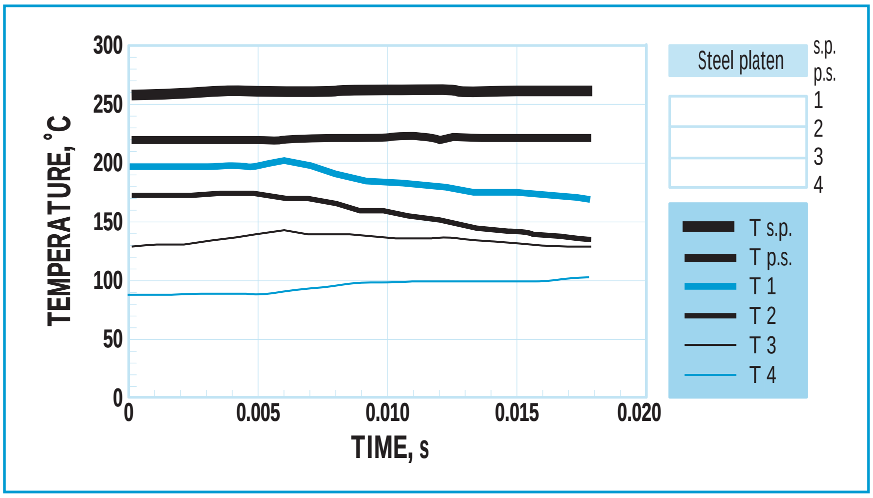
Interpretation of the internal sheet temperature data

Referring to the experimentally determined internal sheet temperatures, Figs. 5–8, and the experimental transition times reported in **Table II,** we may identify regions of the experimental temperature profiles as being at saturation conditions. Hence, the internal temperature measurements can be used as a measure of the local internal sheet pressure. This was done by calculating these local pressures as the saturation pressures corresponding to the measured temperatures for the experiments, as shown in **Figs. 9–11.** Also shown is the figures, for comparison, are the corresponding load decompression profiles.

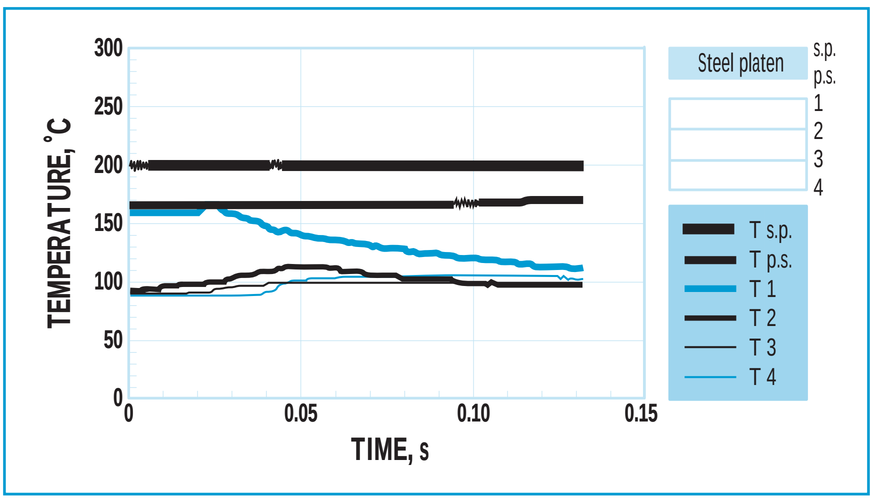
The pressure differential across the top ply of the sheet may be calculated as P2-Load Pressure. The maximum pressure differential and its time of occurrence are reported in **Table III.** These measurements may be used as a test of the hypothesis that a sufficient pressure imbalance causes delamination. We observed that a pressure imbalance of about 200 kPa occurred for the Ramp=NO 260°C case, while there was no imbalance of pressure observed in the Ramp=A cases for 260°C. As the Ramp=NO 260°C case



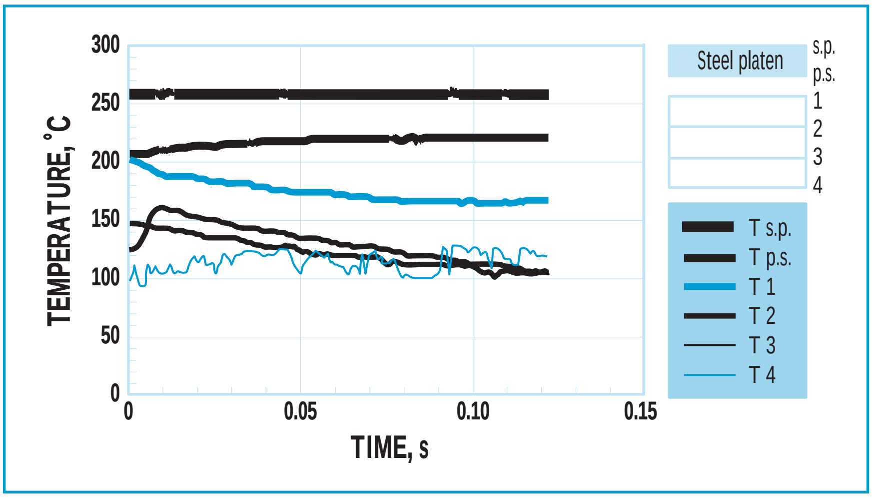
5. Measured temperature as a function of time during nip opening using Ramp=NO at a setpoint temperature of 200°C



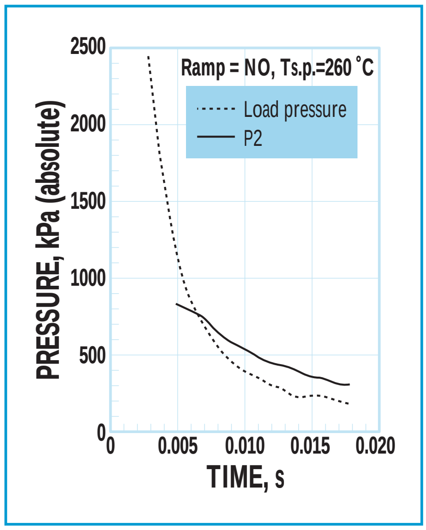
6. Measured temperature as a function of time during nip opening using Ramp=NO at a setpoint temperature of 260°C



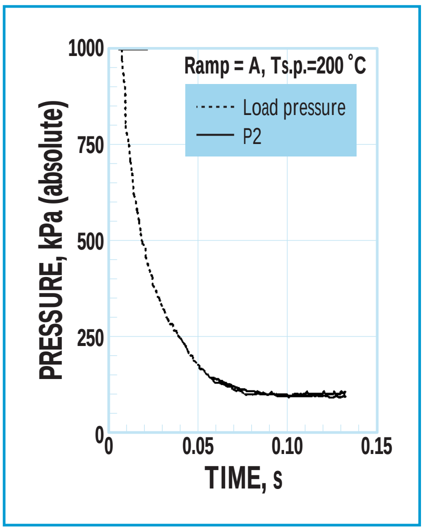
7. Measured temperature as a function of time during nip opening using Ramp=A at a setpoint temperature of 200°C



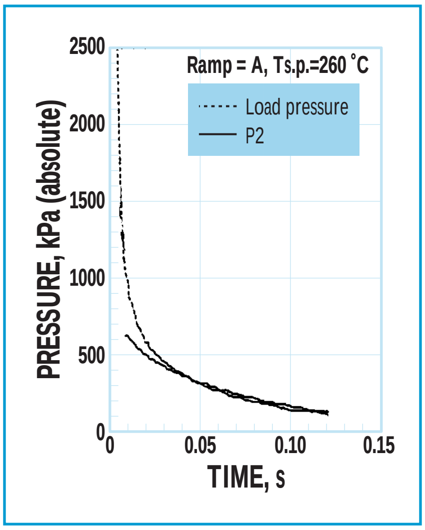
8. Measured temperature as a function of time during nip opening using Ramp=A at a setpoint temperature of 260°C



9. Sheet pressure as deduced from measured temperatures at location 2 in the sheet as a function of time during nip opening using Ramp=NO at a setpoint temperature of 260°C



10. Sheet pressure as deduced from measured temperatures at location 2 in the sheet as a function of time during nip opening using Ramp=A at a setpoint temperature of 200°C



11. Sheet pressure as deduced from measured temperatures at location 2 in the sheet as a function of time during nip opening using Ramp=A at a setpoint temperature of 260°C

Case	Experimental transition time at position 2 between first and second layer, s
NO/200°C	>0.019
NO/260°C	0.005
A/200°C	0.060
A/260°C	0.010

II. Experimental transition times from subcooled liquid to saturated mixture for the ramp experiments

delaminated while the Ramp=A cases did not, we support the hypothesis that the long ramp prevents delamination by reducing the imbalance between internal sheet pressure and the load pressure. Further experiments along these lines are needed to fully understand this delamination mechanism.

KEYWORDS

Acacia, *delamination, linear load, liner boards, mechanical properties, nip,* Pinus, *platens, presses, pressure reduction, shock drying, surface temperature.*

CONCLUSIONS

This work demonstrated that delamination could be inhibited by applying a controlled decompression during the nip opening. Internal sheet temperature profiles were converted to pressure profiles, and pressure imbalances were determined. The results are in agreement with the hypothesis that delamination results from a pressure imbalance between the inside and outside of the sheet during nip opening. TJ

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Case	Maximum pressure differential, kPa (absolute)	Time of maximum pressure differential, s
A/200°C	0	NA*
NO/260°C	200	0.014
A/260°C	0	NA

*Not applicable

III. Mean pressure difference at the end of the ramp

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