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IMPULSE DRYING OF BOARD GRADES: STATUS OF COMMERCIALIZATION

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ABSTRACT

The development of an understanding and creation of a database for the commercialization of advanced water removal systems based on high intensity drying principles is one of the research goals of the Institute of Paper Science and Technology. This new technology, termed impulse drying, has the promise of reducing capital costs, increasing machine productivity, reducing virgin fiber use, reducing the amount of energy used, and improving paper physical properties.

Over the past few years much progress has been made toward solving the sheet delamination problem, which had previously been the major stumbling block to the commercialization of impulse drying for board grades of paper. These solutions, which have been demonstrated in laboratory experiments, have not as yet been described in terms of a configuration that can be commercially implemented.

This paper describes experimental research that has assisted in bridging the gap between the laboratory and the pilot scale.

BACKGROUND

Over the past few years, much progress has been made toward solving one of the major stumbling blocks to the commercialization of impulse drying. That problem is sheet delamination. In a paper by Crouse, Sprague, and Woo [1], impulse drying of linerboard was shown to have the potential of disrupting and delaminating (breaking of fiber bonds) of a linerboard sheet. They found that delamination could only be avoided when their sheet-fed pilot press was operated at temperatures below 150°C. Conditions that only resulted in sheet strength and press dryness and that could as easily been achieved by conventional pressing at elevated ingoing sheet temperatures. Hence, it was concluded that delamination must be fully understood and alleviated in order for impulse drying to become a commercial technology that is applicable to the manufacture of board grades of paper.

In response to the work of Crouse, Sprague, and Woo, research to overcome the sheet delamination problem was undertaken at a number of corporate and academic research centers. Recently, it was recognized that improvements in impulse drying technology would need to come from modifications of the pressure profile of the nip during nip opening. Orloff [2] proposed modifications to the impulse drying simulator to allow process modifications during and immediately following nip opening. Orloff hypothesized that delamination occurred when subcooled water, at high pressure and temperature in the sheet, flashes to vapor when the nip opens to ambient pressure. To test the significance of the pressure that the sheet is exposed to upon nip opening, Orloff designed a simulator so that at nip opening, the sheet could be exposed to pressures well above one atmosphere. If the hypothesis was correct, then sheet delamination would be influenced by the ambient pressure at nip opening.

Using the modified simulator, Orloff et al. [3] patented a method of impulse drying at elevated ambient nip-opening pressures. The method exposed the web to ambient pressures above atmospheric and provided for increasing cooling rates when the press load was released. The patent revealed that sheet delamination can be prevented by opening the nip to a sufficiently high "critical" ambient gas pressure. The gas used can be any gas as long as it is at a temperature below 100°C. Based on simulations, "critical" pressures were found to increase with increases in the temperature of the heated press surface, basis weight, ingoing sheet moisture content, and specific surface of the sheet.

In recent research, Orloff [4-6] used thermocouples imbedded in sheets to record internal temperature profiles during nip opening. Using thermodynamic reasoning, it was shown under what conditions those temperatures could be used to infer local internal pressures. In such a manner, it was shown that by opening the nip to higher ambient gas pressures, the pressure difference between the inside and outside of the sheet was reduced. One can then say that we are holding the sheet together while the internal pressure decays. While one can hold the sheet together with an external gas pressure, a simpler way would be to provide an external mechanical force. Based on this reasoning, the Institute of Paper Science and Technology filed a US patent [7] to cover the application of elevated pressures by such techniques as post-nip roll wraps and post-nip shoes. The remaining task, was to determine ramp pressure profiles having a practical duration and magnitude.

EXPERIMENTAL

The focus of the work presented in this paper was to explore the influence of the shape of the decompression phase of the pressure pulse on the onset of internal vaporization and the peak pressure differences experienced by the web as the nip opens. This was accomplished by simulating the impulse drying process on a one-dimensional hydraulic platen press, where the pressure pulse shape could be accurately programmed. In order to measure internal temperatures and infer internal pressures, five-ply sheets containing thermocouples between plies were impulse dried. The ply closest to the heated platen had a basis weight of 15 g/m^2, while the ply closest to the water receiving felt had a basis weight of 100 g/m^2. The three center plies each had a basis weight of 30 g/m^2. The multi-ply sheets were pressed to 40% solids prior to impulse drying. Figure 1 shows the configuration.

The goal of the experiments was to determine the effect of the shape of the nip decompression profile on sheet delamination. For this purpose the decompression was separated into two regimes defined as:

- Pulse Period = The period from the peak load to the time of maximum rate of depressurization; and
- Ramp Period = The period from the time of maximum rate of depressurization to the time when the load has decreased to an ambient pressure of one atmosphere.

The different pulse and ramp profiles studied in this work are shown in Figure 2 and 3 and pertinent details are also shown in Table 1.

The experiment was started by determining a platen temperature where the sheet delaminated when pressed with standard pulse (0) and no ramp (0). This was found to be 275°C for the particular furnish of this study. Various other pressure profiles were then investigated at this temperature and with both multi-ply sheets (with embedded thermocouples) and with single-ply sheets having a basis weight of 205 g/m^2.

RESULTS

Delamination

After preliminary tests, a 275°C platen temperature was chosen. That platen temperature caused large blisters to the sheet when the standard pulse no ramp was used. The result was the same for both single-ply and multi-ply sheets. On the contrary, all of the modified profiles suppressed sheet delamination. With ramp 3, the platen temperature was raised to 350°C without signs of visible delamination. When different pulse shapes were tried, it was expected that the square pulse (+1) would cause more severe delamination than the standard one (0). On the other hand, the chopped pulse (-1) was expected to suppress delamination because the applied pressure was unloaded more gradually. The results, however, were quite contrary. The square pulse eliminated visible sheet delamination in all but one case, while the sheet delaminated using the chopped pulse. However, delamination was not as bad as with the standard pulse.

Internal pressures

To be able to determine the causes for delamination, internal pressures were determined for different positions within the sheet. When the nip-pressure is released, the subcooled liquid in the sheet will warm up until the boiling point is reached. Then the water evaporates very quickly and the temperature falls due to evaporation. Starting when the temperature drops, the local pressure equals the saturation pressure at the measured temperature. The peak internal pressure points for levels 2, 3, and 4 within the sheet were determined from the temperature data. The pulses were encoded as follows: standard pulse = 1, square pulse = 1, chopped pulse = -1. Ramp coding corresponds to the take-off pressure, ramp duration, and ramp impulse as shown in Table 1.

Analysis of variance was conducted for the effect of ramp and pulse shape on the timing and magnitude of the peak pressures experienced at various locations within the sheet. The data suggested that at a 95% confidence level, neither pulse shape nor ramp shape has an influence on the peak internal pressure in any location within the sheet.

Internal pressures were also recorded at three distinct times during the ramp in order to find out if the ramp or pulse shapes affected the internal pressures during nip opening. The chosen points were 15, 20, and 35 milliseconds after the moment of peak applied pressure. The first of these points was just inside the standard nip, where the applied pressure was already close to zero. The second point was just after the nip opening at the start of the ramp. To determine the effect of ramp and pulse shape, an analysis of variance was conducted.

At the first time point, 12 ms after the peak applied pressure, the square ramp gave higher internal pressure at level 2 within the sheet. Deeper into the sheet, the pulse shape did not affect the internal pressures. At the other time points (18 and 35 ms after the peak load), the pulse shape had no statistically significant effect on the internal pressures in the sheet. This implies that whatever differences in heat transfer there are in the nip, they are evened out by the evaporation that occurs when the nip opens.

The ramp profile has an elevating effect on the internal pressures. Even at 12 ms after the peak load, the ramp profile had an effect because now the applied pressure stays higher than without a ramp. At early stages of the ramp, the internal pressure at level 2 was 70 to 210 kPa higher than without a ramp. Later the difference diminishes to under 70 kPa. Deeper into the sheet, the effect was smaller but still statistically significant.

Pressure difference

With the standard pulse and no ramp the pressure difference between the inside and outside of the sheet becomes large, up to 140 kPa, and sheet delamination occurs. With ramps, the difference in pressure stayed low or even became negative (which assists in minimizing rewet), and delamination was suppressed. Figures 4 through 6 show the peak pressure difference for various pulse and ramp shapes. Referring to Figure 6, it was observed that by increasing the duration and impulse of the ramp, the peak pressure difference could be greatly reduced. In fact by adding a 15 ms duration ramp to a standard pulse, the peak pressure difference could be reduced by about 50%. Assuming a paper machine speed of 760 m/min, this would require a ramp length of about 0.2 m.

REFERENCES

1. Crouse, J. W., Sprague, C. H., and Woo, Y. D., 1989, Delamination - Stumbling Block to Implementing Impulse Drying Technology for Linerboard, Tappi J. (72), 10, pp. 211-215

2. Orloff, D.I., 1994, Commercialization of Impulse Drying, 1994 IPST Executives' Conference Proceedings, pp. 23-25

3. Orloff, D.I., et al., 1997, Method and Apparatus for Drying a Fiber Web at Elevated Ambient Pressures, U.S. Patent Number 5,598,642

4. Orloff, D.I., et al., 1997, Opening the Operating Window of Impulse Drying - I. The Effect of Ambient Pressure at Nip Opening, TAPPI Proceedings 1997, Engineering & Papermakers: Forming Bonds for Better Papermaking, TAPPI Press, Atlanta, GA, pp. 1457-1466

5. Orloff, D.I., et al., 1997, Opening the Operating Window of Impulse Drying: II. Pressure Differential as a Source of Delamination, TAPPI Proceedings 1997, Engineering & Papermakers: Forming Bonds for Better Papermaking, TAPPI Press, Atlanta, GA, pp. 1467-1488

6. Orloff, D.I., et al., 1997, Opening the Operating Window of Impulse Drying: III. Controlled Decompression Experiments, TAPPI Proceedings 1997, Engineering & Papermakers: Forming Bonds for Better Papermaking, TAPPI Press, Atlanta, GA, pp. 1489-1500

7. Orloff, D.I., et al., 1997, Method and Apparatus for Drying a Fiber Web at Elevated Ambient Pressures, U.S. Patent Number 5,669,159

TABLES AND FIGURES

Table 1. Pulse and Ramp Shape Parameters

Pulse	Ramp	Peak Pressure, MPa (gage)	Take-Off Pressure, MPa (gage)	Ramp Time, ms	Ramp Impulse, kPa sec
0	0	5.53	1.83	4	1.7
0	1	5.54	2.03	30	5.5
0	2	5.51	2.15	30	6.7
0	3	5.53	2.07	47	11.8
0	4	5.53	1.74	19.5	6.2
0	5	5.53	1.90	19.0	4.8
1	0	5.53	2.15	30	6.7
-1	0	5.56	2.15	30	6.7
1	3	5.56	1.90	19	4.8
-1	3	5.53	1.90	19	4.8

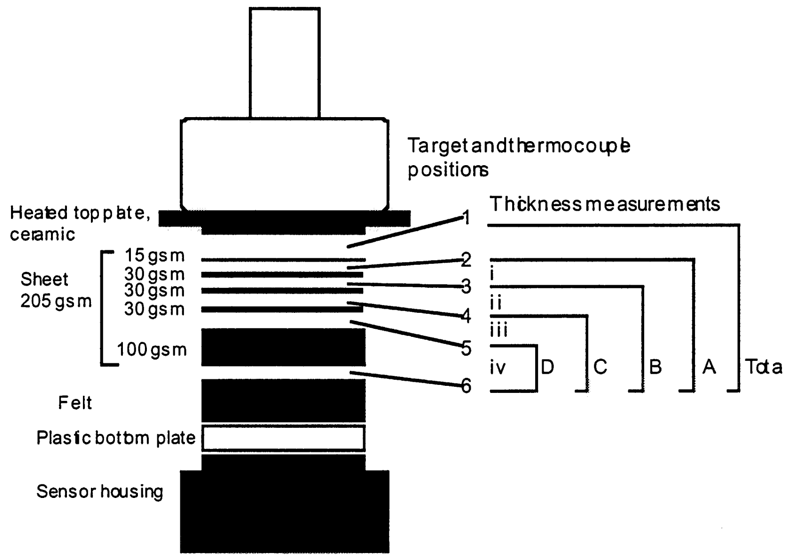

Figure 1. Pressing configuration for a 5-ply sheet having thermocouples between plies.

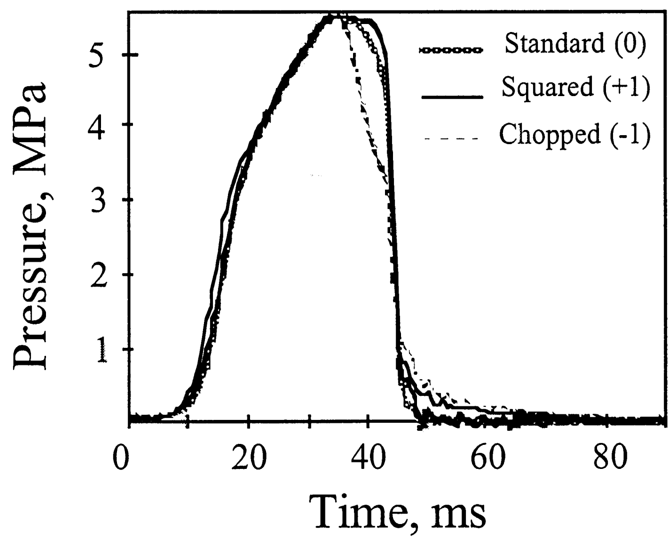

Figure 2. Applied pressure versus time showing the three pulse shapes.

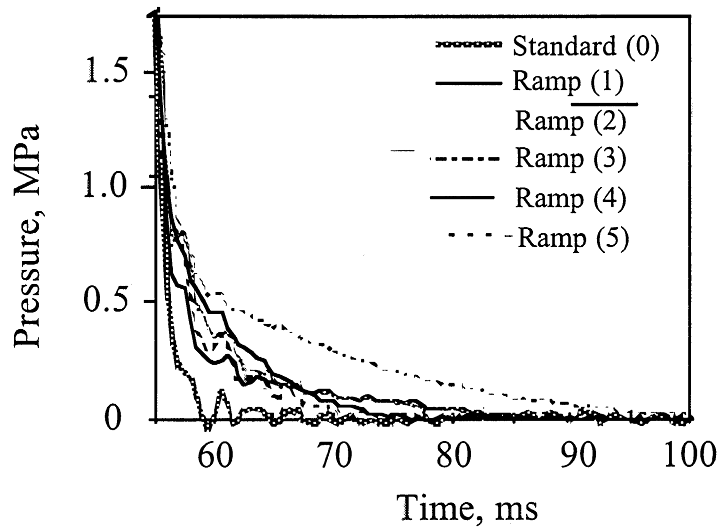

Figure 3. Applied pressure versus time showing the three pulse shapes.

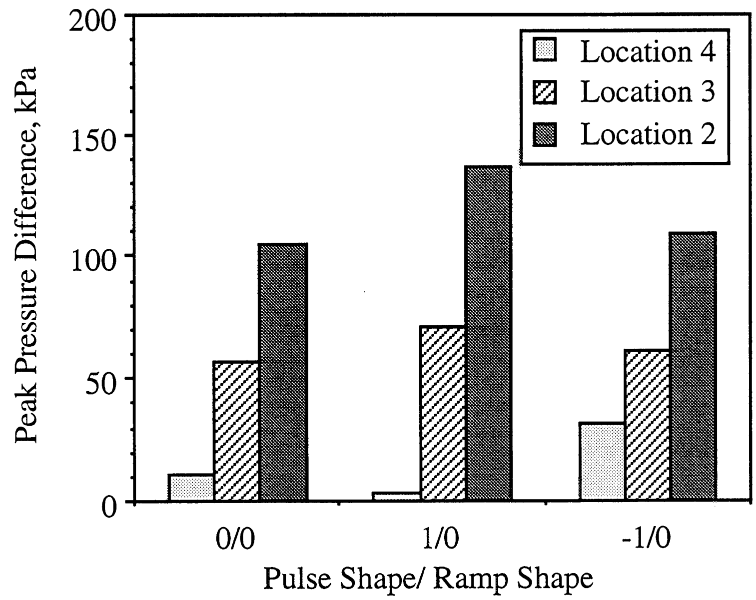

Figure 4. Peak pressure difference for various pulse shapes with no ramp.

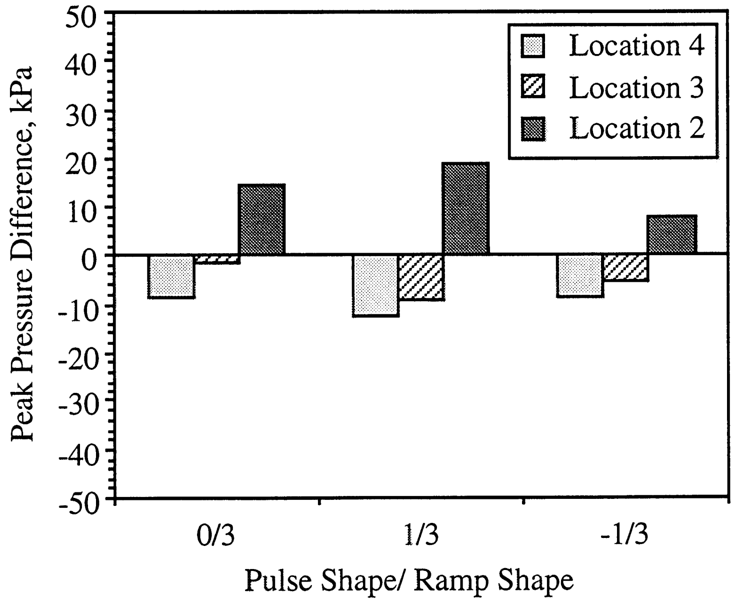

Figure 5. Peak pressure difference for various pulse shapes with ramp 3.

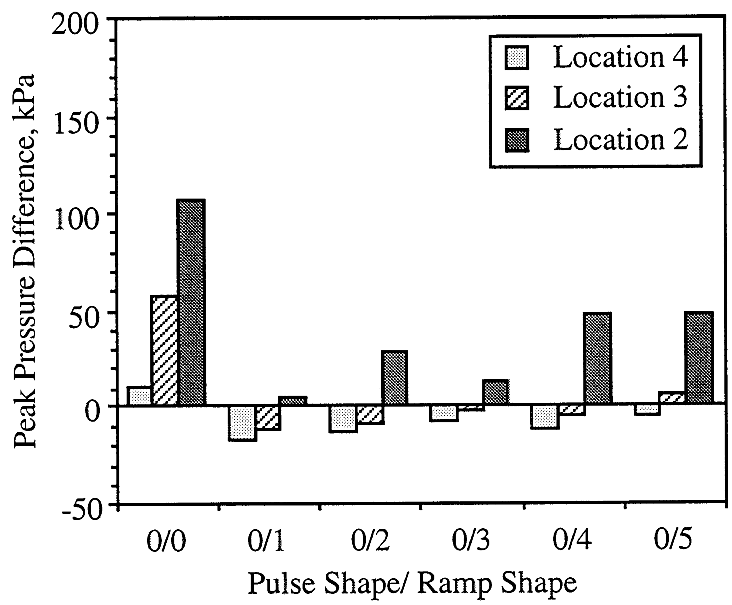

Figure 6. Peak pressure difference for various ramp shapes with the standard pulse shape.