VACUUM DEWATERING

High-vacuum dewatering of newsprint

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ABSTRACT

This is the latest in a series of studies examining high-vacuum sheet dewatering. Previous works have reported results for kraft and repulped OCC sheets. This work reports results for groundwood sheets at two basis weights, 49 g/m² (10 lb/1000 ft²) and 127 g/m² (26 lb/1000 ft²). The tests produced curves that predict dewatering at various vacuum levels as a function of sheet dwell time over the vacuum area. With the accumulated results of this and the previous studies, it is possible to compare dewatering for a wide range of furnishes at the same basis weight. Using this information, papermakers can manipulate vacuum levels and box geometries to optimize sheet dryness, wire drag, and vacuum use.

Application:

This high-resolution depiction of high-vacuum sheet dewatering allows optimization of vacuum application for existing systems and very efficient designs of new high-vacuum systems.

A DETAILED STUDY OF HIGH-VACUUM sheet dewatering has been in progress for several years. This experimental program was undertaken to develop high-resolution information about flat-box operation that could be used to

- Optimize vacuum generation energy and capacity
- Reduce forming-fabric wear
- Increase sheet dryness
- Reduce the horsepower expended to overcome vacuum-induced drag on the wire.

This is the fifth published report on the progress of the program, which is in its third experimental phase. Results from the previous four reports are in the literature *(1-4)*.

PREVIOUS WORK

The previous experimental work concentrated on two brown paper grades: high-freeness kraft and repulped old corrugated containers (OCC). Basis weights were 127-210 g/m² (26-42 lb/1000 ft²). Previous results provided very good predictive tools for high-vacuum dewatering, but only for the two grades that were tested. While it was clear that basis weight and furnish had a profound impact on dewatering, the test ranges were too limited to draw global conclusions.

Using the results reported earlier *(1, 3, 5)*, it has been possible to greatly improve the operation of the flat-box sections of formers. The techniques for achieving these improvements are outlined in the literature *(2)*, although a detailed understanding of dewatering is required to apply these techniques. Another work *(6)* provides precise information about drag load for various flat-box vacuums and geometries, both of which can be manipulated to achieve maximum sheet dryness and minimum wire drag. Minimizing wire drag will increase wire life and reduce the energy consumed to drive the wire. The high-vacuum section of a former typically accounts for up to 50% of the horsepower consumed by the wire.

To expand the range of understanding, this study used a radically different furnish: newsprint. A conventional 49-g/m² (10 lb/1000 ft²) basis weight newsprint was used, as well as 127 g/m² (26 lb/1000 ft²). The higher basis weight was included for direct comparison with previously obtained data.

EXPERIMENTAL

The test furnish was repulped newsprint consisting of about 70% groundwood and 30% kraft. Headbox freeness was about 100 mL CSF throughout the trial, and stock temperature was always within a few degrees of 46°C (115°F).

Unlike previous studies, which used a range of forming fabrics, only a single fabric was used for this study. The fabric was eliminated as a variable because all previous work had indicated that its effect on dewatering at this end of the former was insignificant.

Likewise, only a single slot width of 19 mm (0.75 in.) was used for the newsprint studies. All previous studies had conclusively demonstrated that slot width was important only because it helped determine the time of sheet exposure to vacuum (dwell time). It was much easier to manipulate dwell in the experiment with machine speed and number of slots, so slot width was held constant.

Table I lists the ranges of the input variables. Note that there are two high vacuums listed. Unfortunately, it was not possible to achieve the highest vacuum of 51 kPa (15 in. Hg) with the lighter sheet because of system limitations. Therefore, 48 kPa (14 in. Hg) was used for the lighter sheet. Not all middle levels of vacuum were used for every case.

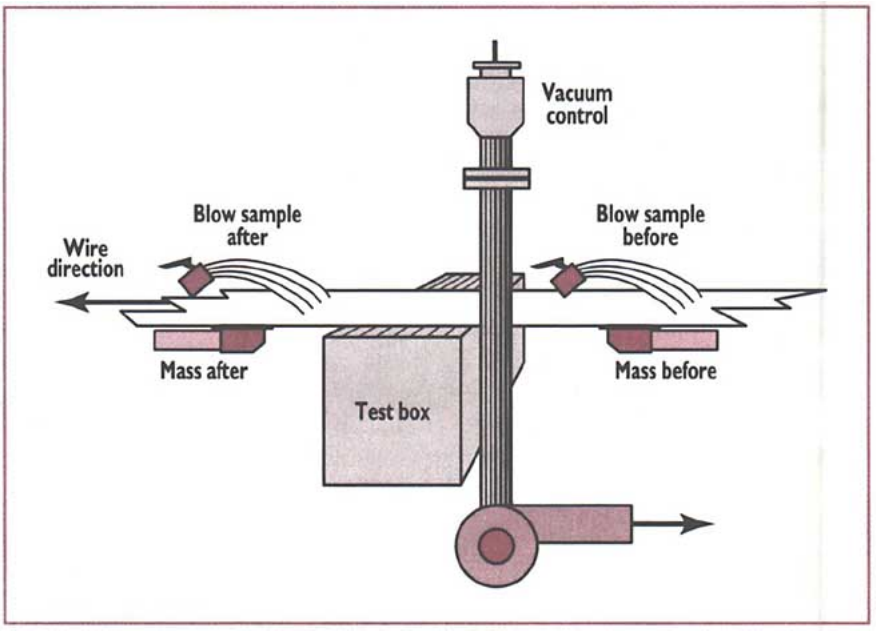
The trials were performed on a pilot machine using a setup like that described in previous works *(1, 3)*. The setup is illustrated in **Fig. 1**. Tests were performed around a single vacuum box, with earlier boxes used to control sheet consistency before the test box. Vacuum level was controlled with an automatic control valve. Full-width deckle strips could be inserted into or retracted from the polyethylene test cover to vary the number of slots. Sheet width was about 508 mm (20 in.).

Experience has shown that sheet-consistency measurements are crucial to the test, so a redundant system was used to measure the water in the sheet. Gamma-radiation mass gauges were rigidly mounted before and after the test box. Blow samples were taken before the box when machine changes were made, and they were taken after the box for each test condition. Finally, the amount of water removed by the box was measured using a bucket and stopwatch.

A near-full-factorial set of data points (except for vacuum level, as discussed previously) was tested using the inputs described in Table I. Replicate points were also tested to develop a sense of experimental error.

Variable	Low	Middle			High	
Solids before flat box, %	6	...			12	
Sheet basis weight						
g/m²	49	...			127	
lb/1000 ft²	10	...			26	
Flat-box vacuum						
kPa	10	21	31	41	48	51
in. Hg	3	6	9	12	14	15
Number of slots	1	3			9	
Speed						
m/s	8.6	...			12.7	
ft/min	1700	...			2500	

I. Range of test conditions



1. Experimental setup

TEST RESULTS

Dwell time

The data were subjected to regression analysis. A previously described technique was then used to combine the data for incoming sheet solids of 6% and 12% (i.e., solids before the test box) *(1)*. This allowed the development of a single data set for each basis weight and vacuum level.

The results clearly demonstrated that machine speed had no effect on dewatering over the test range other than as a determinant of sheet dwell time over the vacuum area. Speed and slot number are not significant when dwell time is included in an analysis of the data. This verifies observations from the previous trials.

Sheet dewatering

Figures 2 and 3 are graphs of the data and the regression fits at various levels of vacuum for the 49-g/m² (10 lb/1000 ft²) and 127-g/m² (26 lb/1000 ft²) sheets, respectively. As in the previous work, the data led to an equation using the hyperbolic tangent, tanh.

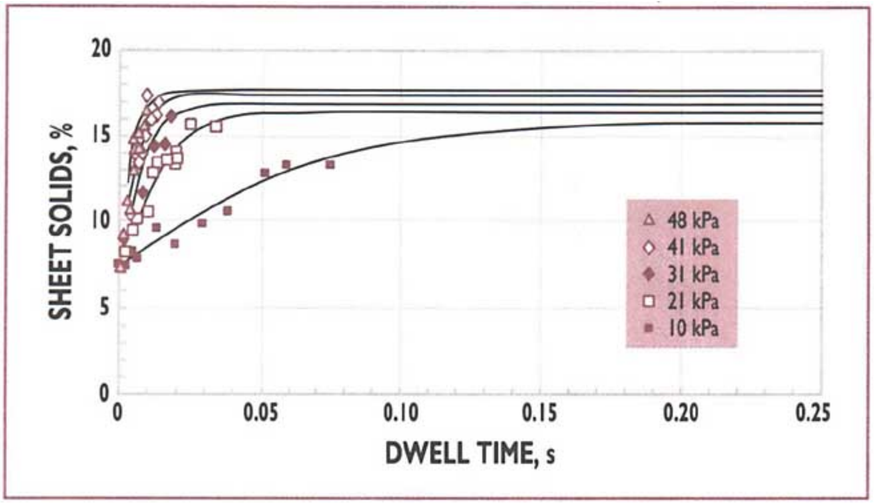
$$y = b + m \tanh(c \text{ dwell})$$

where

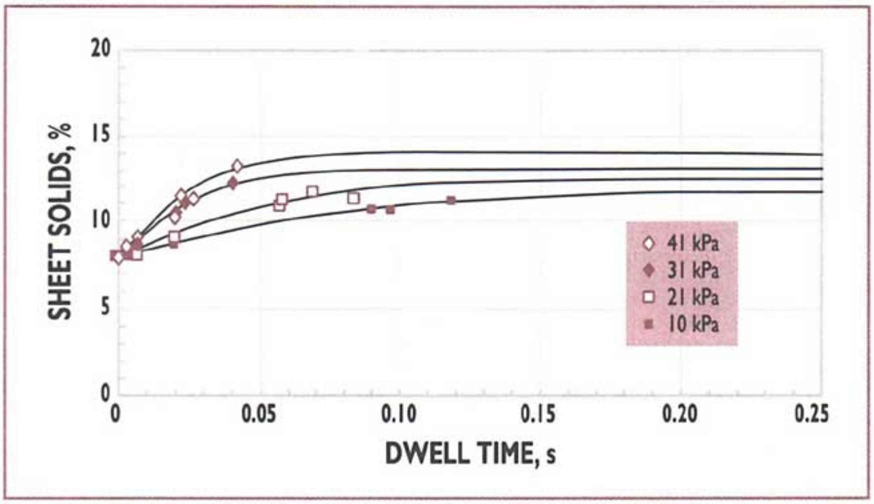
- y = sheet consistency after the box, % solids
- b = intercept—in this case 6%*
- m = solids constant
- c = dewatering-rate constant
- dwell = dwell time, s.

Because tanh varies between 0 and 1 for any positive value, the ultimate achievable sheet dryness for a vacuum is $b + m$. This value defines the asymptote beyond which dryness cannot be driven no matter

*The intercept b is always 6 because of the technique used to combine data for the sheets entering the flat box at 6% and 12% solids *(1)*.



2. Solids vs. dwell at five levels of vacuum, 49-g/m² sheet (10 lb/1000 ft²)



3. Solids vs. dwell at four levels of vacuum, 127-g/m² sheet (26 lb/1000 ft²)

what the dwell time. The constant *c* controls the rate at which the asymptote is achieved, i.e., the steepness of the curve.

Table II shows the regression fits for *m* and *c* at each combination of basis weight and vacuum. Comparison of the values in Table II with the curves in Figs. 2 and 3 illustrates the meaning of the variables *m* and *c*. For example, the highest *c* value (165) is associated with the highest vacuum [48 kPa (14 in. Hg)] and the lowest basis weight [49 g/m² (10 lb/1000 ft²)]. It is clear from Fig. 2 that the sheet reaches its ultimate achievable dryness very quickly at this vacuum because of the high *c* value. In contrast, the lowest *c* value (6.7) is associated with the lowest vacuum [10 kPa (3 in. Hg)] and the highest basis weight [127 g/m² (26 lb/1000 ft²)]. The corresponding curve in Fig. 3 shows that the sheet achieves much lower dryness at a much slower rate.

The asymptote for each curve in Figs. 2 and 3 is defined as $b + m$. For the high-vacuum curve in Fig. 2, this translates to 6 + 11.5 = 17.5. Thus, no matter what the dwell, this newsprint sheet will never be drier than 17.5% solids at the flat boxes if the highest vacuum it sees is 48 kPa (14 in. Hg).

OBSERVATIONS

General

The curves in Figs. 2 and 3 provide an informative view of newsprint dewatering over flat boxes. When contrasted with the data from previous works *(1, 3)*, they also provide some insight for high-vacuum dewatering in general.

A previous work *(3)* discusses the differences among the various curves for the tested vacuums, basis weights, and furnishes. For that population of data, furnish difference (OCC vs. kraft) was about equivalent to weight difference (26 lb vs. 42 lb). For the sheets tested, dewatering rates, i.e., the *c* values, varied about 2:1 to 2.5:1 for vacuums from 41-10 kPa (12-3 in. Hg). The *m* value, the asymptote, generally varied up to about 5% solids.

The trends are very different for the newsprint sheets. At the lower basis weight of 49 g/m²—a typical weight for conventional newsprint—the ultimate dryness (6 + *m*) varied only 1.7% solids over the range of vacuums applied [10-48 kPa (3-14 in. Hg)]. Thus for these sheets, the low vacuum can eventually achieve almost the same dryness as the high vacuum. However, the dewatering rate, *c*, varied over a huge range compared with the kraft and OCC sheets. For the extreme vacuums, *c* varied from 12 to 165, a difference of almost 14:1.

Effect of sheet weight

The difference in achievable dryness (6 + *m*) for the two weights produced from the newsprint furnish was consistent with the results of previous studies of OCC and kraft. As seen in Table II, the lighter sheet was dried to a much higher level—about 4 points drier—than the heavier

KEYWORDS
Basis weight, forming sections, fourdrinier machines, mechanical papers, newsprint, paper grades, paper machines, printing papers, separation, vacuum boxes, water removal, weight.

Vacuum		BASIS WEIGHT 49 g/m² (10 lb/1000 ft²)		127 g/m² (26 lb/1000 ft²)	
kPa	in. Hg	m	c	m	c
10	3	9.8	12	6.0	6.7
21	6	10.3	48	6.5	11.6
31	9	10.8	85	...	...
41	12	11.3	125	7.0	23
48	14	11.5	165	...	...

II. Dewatering constants m *and* c *for newsprint sheets produced at each combination of vacuum and basis weight*

sheet. This is similar to the trends observed for the two weights made from the OCC furnish. As with the kraft and OCC sheets, to dry a heavier sheet to the same extent as a lighter sheet, higher vacuums must be used, no matter what the dwell time.

The big story with the newsprint furnish, though, is the difference in dewatering rate for the lighter-weight sheets. At very high vacuums, dewatering is almost a step function, as can be seen in Fig. 2. While for the kraft and OCC sheets the rate usually varied 2.5:1 for vacuums from 41-10 kPa (12-3 in. Hg), for the newsprint sheet it varied over 10:1.

Effect of furnish

Table III shows the regression constants m and c obtained at equivalent levels of vacuum for the three tested furnishes—newsprint, OCC, and virgin kraft—at the reference basis weight of 127 g/m² (26 lb/1000 ft²). The data summarized here are from the current work and from two previous works *(1, 3)*. Several trends are apparent from the data in the table. First, the high-freeness kraft sheet was the easiest to dewater, while the newsprint sheet was the most difficult. This is true both in dewatering rate and in ultimate achievable dryness. The 100-mL-CSF newsprint sheet could be dried only to $6 + m = 13\%$ at 41 kPa (12 in. Hg). The kraft sheet could be dried to over 19% by the same vacuum ($6 + m = 19.3\%$).

The difference in rate is also large. If the sheet is to achieve its ultimate dryness, then the term $\tanh(c \cdot \text{dwell})$ must be unity. The hyperbolic tangent is 0.99 when $c \cdot \text{dwell} = 2.65$. Thus to reach 99% of ultimate dryness at 41 kPa (12 in. Hg), the kraft sheet needs a dwell of $2.65/c$, or

$$2.65/125 = 0.021 \text{ s}$$

At the same vacuum, the newsprint sheet needs a dwell time of

$$2.65/23 = 0.114 \text{ s}$$

Thus the dwell time for the newsprint is more than five times longer than the dwell for the kraft sheet. Bear in mind that a 127-g/m² (26 lb/1000 ft²) newsprint sheet is not something commonly manufactured. Nevertheless, the difference in dwell time at equal basis weight does illustrate the effect of furnish on dewatering.

APPLICATIONS

Previous works *(1-4)* outline methods for applying these results to improve the design and operation of production paper machines. These generally involve staying on the steepest parts of the dewatering curves to maximize dewatering and minimize drag, airflow, and wire wear. The dramatic change in dewatering rate for the newsprint sheet offers a great opportunity for optimization. Figure 2 shows that long dwell is needed to capitalize on the cheaper, gentler low vacuums, and only very short dwells at high vacuums are needed to dry the sheet to its full potential. At 48 kPa (14 in. Hg), only

$$2.65/165 = 0.016 \text{ s}$$

is needed to reach the plateau. At 10 kPa (3 in. Hg),

$$2.65/12 = 0.221 \text{ s}$$

is required. Thus the high-vacuum box (or compartment for multiple compartment boxes) only needs about 1/14 the length of the low-vacuum compartment. Additional dwell only increases drag, accelerates wire wear, and wastes vacuum. The drag can be easily quantified using information available in the literature *(6)*. Drag predictions from that work can also be used to optimize vacuum and dwell for dewatering and drag load.

CONCLUSIONS

There are profound differences in the dewatering characteristics of different paper grades. The results presented here, combined with previous work *(1-4)*, provide important guidelines for the design and operation of flat boxes, paving the way for significant operational savings. The approaches are applicable to existing as well as new installations.

Vacuum		Newsprint (100 mL CSF)		OCC (400 mL CSF)		Virgin kraft (650 mL CSF)	
kPa	in. Hg	*m*	*c*	*m*	*c*	*m*	*c*
10	3	6.0	6.7	6.8	25	8.2	50
21	6	6.5	11.6	9.8	30	11.2	65
41	12	7.0	23	12.2	50	13.3	125

III. Dewatering constants* m *and* c *for 127-g/m² sheets produced from three furnishes at three levels of vacuum

- Higher vacuums inevitably achieve higher dryness, but high-vacuum dewatering also provides diminishing returns. Thus vacuum levels should always be set progressively higher for subsequent boxes. Attacking the sheet with initially high vacuums and then progressively lowering the vacuum is very inefficient for dewatering, unnecessarily increases the drive load, and shortens wire life.
- Depending on the furnish and basis weight, it is generally most efficient to apply higher vacuums for short durations. This is especially true for lightweight sheets. It therefore is most efficient to vary compartment lengths of flat boxes. Multicompartment boxes maximize efficiency because they provide the narrow compartments that make short, high-vacuum dwells possible.
- A machine that manufactures a range of basis weights, even within the same grade structure, can maximize wire life by adjusting vacuums to "tune" the machine for each weight. Heavier weights need more aggressive dewatering than lighter weights. If the machine's vacuum is set for heavy grades, the excessive vacuum applied during production of lighter grades is a waste of power, and the unnecessary drag shortens wire life. **TJ**

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