

Predicting the press dewatering of heavyweight grades

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ABSTRACT

The decreasing permeability model of wet pressing was used to calculate water removal in commercial corrugating medium and linerboard machines. The two furnish-dependent coefficients in the model were determined by pressing handsheets in a laboratory press. Equations were developed for double-felted press nips and two-layer boards. The model predictions were in agreement with measurements made on a commercial corrugating medium machine before and after several press rebuilds and on a linerboard machine.

Application:

The decreasing permeability model provides a simple and accurate method to evaluate changes to wet press operation and to design new press sections. The model can also be used to assess the water removal of different grades and products in an existing press by characterizing the pressability of different furnishes.

A WET PRESSING MODEL BASED ON the decreasing permeability of the web to water flow (1) has been shown to correspond to data from commercial newsprint, bond, and market pulp machines (2). With an additional rewet term, the decreasing permeability (DP) model can account for press dewatering over a wide range of basis weights (3). Using this approach, the two regimes that are traditionally labeled *flow* and *compression controlled* are connected by a smooth transition between a domain governed by either the permeability of the web or the rewet in the expanding nip. This has consequences for pressing models. For heavyweight grades (>100 g/m²), where rewetting is not significant, two coefficients are sufficient to characterize the furnish; for lighter grades (<100 g/m²), an additional rewetting coefficient is required.

In this report, we describe a laboratory method for determining the DP model coefficients for heavyweight grades (>100 g/m²) and adapt the model equations for double-felted nips and to sheets composed of two layers of material having different press dewatering characteristics. This approach is demonstrated with examples from commercial machines making corrugating medium and linerboard.

THEORY

Using the decreasing permeability model (1), the press dewatering of a furnish can be specified by means of two coefficients: a permeability fac-

tor defined at the ingoing moisture and a compressibility factor. These factors, when combined with the ingoing moisture and the press impulse, can be used to predict the outgoing moisture of the pressed web, as follows:

$$\frac{m}{m_0} = \left(1 + \frac{nfI}{m_0}\right)^{-1/n} \quad (1)$$

where

m = outgoing moisture ratio
 m_0 = ingoing moisture ratio
 I = press impulse, kPa·s
 = press load/speed, (kN/m) / (m/s)
 n = compressibility factor
 f = permeability factor, (kPa·s)⁻¹.

The permeability factor depends on the ingoing moisture ratio (m_0) and can be defined as:

$$f = \frac{A}{vW^2} (m_0)^{n+1} \quad (2)$$

where

A = specific permeability, g/m
 W = basis weight, kg/m²
 v = kinematic viscosity of water, m²/s.

Equations 1 and 2 can be combined to give the following equation:

$$\frac{m}{m_0} = \left(1 + \frac{Anm_0^n I}{vW^2}\right)^{-1/n} \quad (3)$$

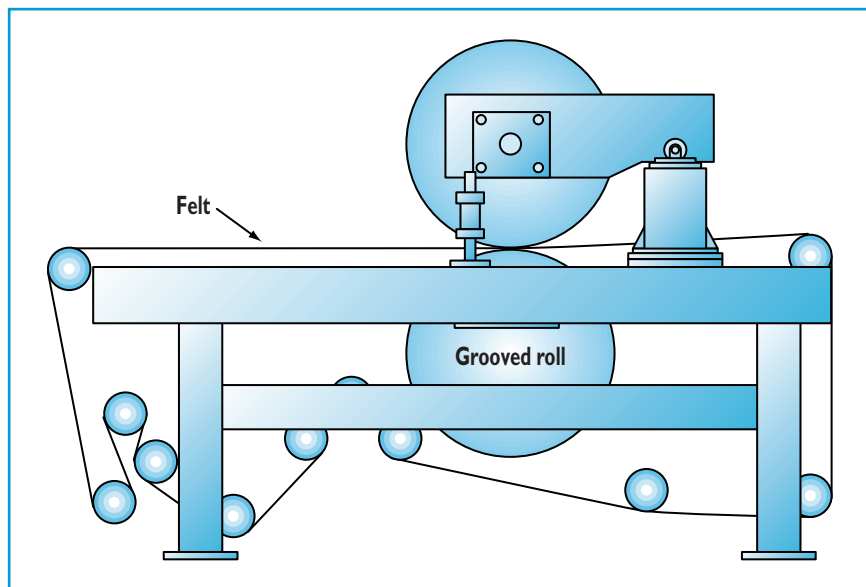
Fitting water removal data from pressing to Eq. 3 gives two coeffi-

cients that characterize the furnish: A and n .

Equation 3 applies to a single-felted nip where all the water flow is toward the felt. This equation can be modified to represent a double-felted nip in which the water in the sheet can move to either the top or bottom surface. If we assume equal flow through both surfaces, there is a neutral plane in the center of the sheet through which water does not flow. In essence, a sheet of basis weight W in a double-felted nip behaves like a sheet of basis weight $W/2$ in a single-felted nip. Thus, double felting gives an additional factor of 4 because of the W^2 term.

The equation for a double-felted nip is as follows:

$$\frac{m}{m_0} = \left(1 + \frac{4Anm_0^n I}{vW^2}\right)^{-1/n} \quad (4)$$

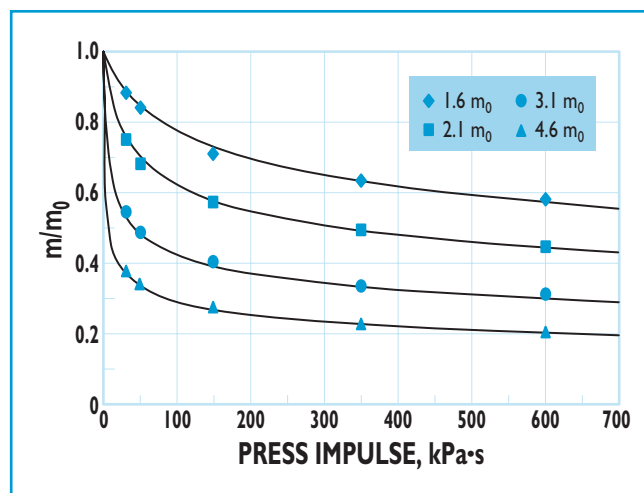


1. The dewatering experiments were performed on a single-felted, two-roll press.

Furnish	CSF, mL	$A \times 10^{-12}$, g/m	n	r^2
Semichemical	433	6.75 ± 0.37	5.12 ± 0.13	0.998
OCC	502	5.29 ± 0.78	5.87 ± 0.39	0.987
Mixture	-	7.85 ± 0.77	5.28 ± 0.26	0.991

*Determined at 25°C; $n = 8.93 \times 10^{-7}$ m²/s

1. Corrugating medium coefficients for the decreasing permeability pressing model*



2. Press dewatering data and fitted lines for the decreasing permeability model for semichemical pulp

EXPERIMENTAL

The furnish-dependent coefficients were determined by pressing handsheets on a two-roll press, using a single felt similar to those on the commercial machines (Fig. 1).

The top roll was granite, and the bottom felted roll had a grooved, rubber cover (roll diameters=0.75 m). Standard circular handsheets with a basis weight of 130 g/m² were prepared for each furnish component separately. The corrugating medium furnish was a mixture of OCC (old corrugated containers) and semichemical pulp. The linerboard was a 205-a.d. g/m² two-ply sheet consisting of a 160-g/m² filler layer with a 45-g/m² top liner, either white or brown.

A press speed of either 60 or 100 m/min was chosen to be within an order of magnitude of the commercial machine speeds but manage-

able for the pressing and handling of the laboratory handsheets. The ingoing moisture ratios (m_0) of the handsheets were controlled by couching, and the press impulse was set by varying the nip load of the press. The values of both m_0 (with nominal values of 1.5, 2.0, 3.0, and 4.5) and press impulse were chosen to uniformly span the range of interest. With the press running, each handsheet was dropped on the felt. Immediately after passing through the nip, the press was stopped, and the handsheet was peeled from the granite roll and weighed. Each handsheet was subsequently oven-dried to measure moisture-free basis weight. The moisture at each condition is the average of three handsheets.

RESULTS

Corrugating medium

The dewatering data for the three furnishes (100% OCC, 100% semichemical, and their mixture) were fit to Eq. 3 using a nonlinear least-squares method (4) to obtain the compressibility factor (n) and the specific permeability (A) (Table I). The fit to the model equation is excellent, as shown by the coefficients of determination in Table I and the fitted lines in Fig. 2.

To evaluate the accuracy of the model using these coefficients, measurements were made on a commercial machine as the pressing capacity was increased in two stages (see Table II). In the first stage, two straight-through presses (A) were replaced with a twinver followed by a third press (B). In the second stage, the third press was rebuilt to increase the nip load by almost a factor of 2 (C). The modifications to the press section were accompanied by higher machine speeds to increase production. The operating conditions for these three press configurations and the calculated press impulses are shown in Table II.

The solids content after the final press was calculated from Eq. 3 using the operating conditions in Table II and pressing coefficients listed for the mixture in Table I, assuming that the sheet temperature in the press was 55°C. Recognizing that the solids content is difficult to measure accurately on a commercial press, there is good agreement between the measured and predicted values.

Linerboard

Dewatering measurements on the three linerboard furnishes (filler, brown liner, and white liner) are shown in Fig. 3 with fitted lines from the decreasing permeability model. Using the data and the model coefficients in Table III, we show that the brown liner and filler have similar press dewatering characteristics, but the white liner is significantly easier to dewater. On the commercial machine, the linerboard is composed of a 160-a.d. g/m² filler layer and either a white or brown top liner with a basis weight of 45 a.d. g/m².

The commercial linerboard machine in this study had two top-felted press nips followed by two bottom-felted nips operating with the conditions listed in Table IV. As a first approximation, the solids content of a 205-a.d. g/m² board composed entirely of each component has been calculated using Eq. 3, the furnish coefficients in Table III, and the operating conditions in Table IV. The filler is the most difficult furnish to dewater (38.6% solids). Both the brown liner (39.7% solids) and the white liner (42.8% solids) dewater more easily.

The press dewatering of linerboard is complicated by the fact that there are two layers of material, which can have different dewatering characteristics. The dewatering can be approximated by weighting the moisture ratio of each layer calculated previously by their relative fiber masses, as follows:

$$m = (m_1 W_1 + m_2 W_2) / (W_1 + W_2) \quad (5)$$

where

m = outgoing moisture of both layers

m_1 = outgoing moisture of layer 1

m_2 = outgoing moisture of layer 2

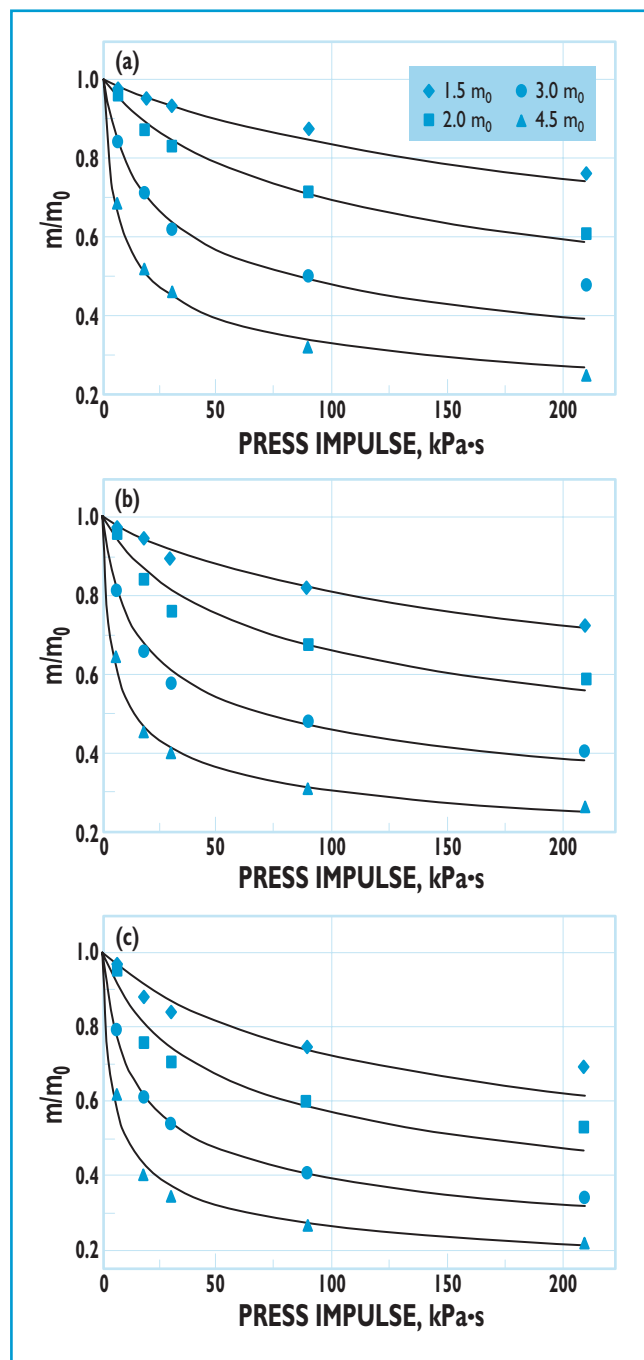
W_1 = basis weight of layer 1

W_2 = basis weight of layer 2.

Using this approximation gives a solids content of 38.8% for the brown liner and 39.4% for the white liner. These values agree well with the measured solids after the final press of approximately 39%.

SIMULATIONS WITH THE DP MODEL

The power of a model is that it allows the prediction of the sheet solids leaving the press for a variety of operat-



3. Press dewatering data for linerboard furnishes. (a) filler, (b) white liner, and (c) brown liner. The solid lines are from the DP model equations at the indicated ingoing moisture levels (m_0).

ing conditions. Having confirmed that the existing conditions can be duplicated with the DP model, we can now predict the effect of different operating conditions on press-section water removal with confidence. For example, double-felting both presses of the original corrugating medium machine would increase the solids to 46.8% (Table V). This gain in solids content is consistent with conversions that have been reported for commercial machines (5, 6). Double-felting and increasing the sheet temperature from 55°C to 80°C would increase the solids

Press configuration	Machine speed, m/min	PRESS LOADS, kN/m			Total press impulse, kPa·s	SOLIDS CONTENT AFTER FINAL PRESS, %	
		First	Second	Third		Measured	Predicted
A	535	79.0	122	-	22.5	39.0	40.4
B	580	74.4	105	105	29.5	41.0	41.6
C	640	78.8	105	193	35.3	41.5	42.5

*Web temperature=55°C
 $n=5.11 \times 10^{-7}$ m²/s
 Couch solids content=24%
 Basis weight=0.127 a.d. kg/m²; 0.120 o.d. kg/m²

the press loading required for a given machine speed based on the known capacity of the dryer section. Increasing the press impulse reduces the amount of moisture in the sheet, which would allow the machine to be run faster.

SUMMARY

The two coefficients for the decreasing permeability model can be determined for a specific furnish by pressing handsheets in a pilot press under controlled conditions of ingoing

II. Corrugating medium machine: Measured and predicted solids for different operating conditions*

Furnish	$A \times 10^{-11}$, g/m	n	r^2
Filler	1.60±0.23	3.75±0.16	0.983
Brown liner	1.73±0.28	3.89±0.19	0.973
White liner	3.54±0.51	3.51±0.18	0.970

*Determined at 20°C; $n=1.00 \times 10^{-6}$ m²/s

moisture and press impulse. These coefficients can be used for heavyweight grades to predict press dewatering in commercial machines for different press loadings, machine speeds, web temperatures, and felting arrangements. Thus, the decreasing permeability model can be used to evaluate the effect of changes to press design and operation. **TJ**

III. Linerboard: Coefficients for the decreasing permeability press-model*

to 48.4%. A double-felted shoe press would give 53.8% solids for a web at 55°C.

Many machines that produce heavier grades, such as corrugating medium and linerboard, are dryer limited. Another way of using the model would be to calculate

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Machine speed, m/min	PRESS LOADS, kN/m				Total press impulse, kPa·s	SOLIDS CONTENT AFTER FINAL PRESS, %		
	First	Second	Third	Fourth		MEASURED	Brown liner	White liner
330	44	42	88	123	53.8	~39	38.8	39.4

*Web temperature=55°C
 Basis weight: filler=149 o.d. g/m², liner=42 o.d. g/m²
 Couch solids content=15%

IV. Linerboard machine: Measured and predicted solids content*

Press configuration	Felting	Impulse, kPa·s	Temp., °C	Kinematic viscosity (v), m ² /s	Solids, %
A	Single	22.5	55	5.11×10^{-7}	40.5
A	Double	22.5	55	5.11×10^{-7}	46.8
A	Double	22.5	80	3.65×10^{-7}	48.4
Shoe press	Double	100.0	55	5.11×10^{-7}	53.8

*Basis weight=0.127 a.d. kg/m², 0.120 o.d. kg/m²
 Couch solids content=25%

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V. Simulations using the DP model for corrugating medium*