Evaluating paper sizes using a Turbulent-pulse Sheet Former

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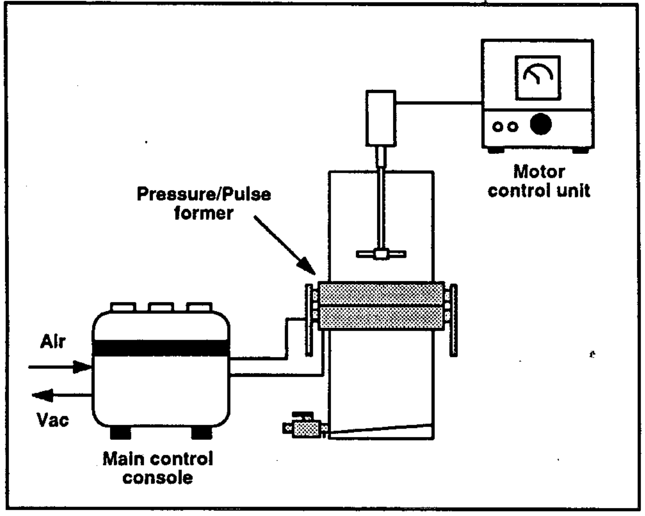
A compact sheet mold capable of preparing sheets under dynamic drainage conditions proved to be an efficient way to evaluate paper sizes. Turbulence and vacuum pulsation during drainage, which both impaired sizing in the finished sheet, were easily controlled.

While developing and evaluating paper size products in our laboratories, we sought an alternative to the conventional Noble and Wood handsheet machine for producing sized sheets. Handsheets prepared under mild drainage conditions using British Standard or Noble and Wood sheet molds do not accurately represent machine-made paper, particularly with respect to fines retention, formation quality, and stock consistency. This can lead to misleading results about the performance of chemical additives such as retention aids and paper sizes. On the other hand, most devices that simulate highly turbulent drainage (*1-3*) or pulsed drainage (*4, 5*) suffer from the inability to produce a well-formed, testable sheet.

The Turbulent-pulse Sheet Former (TPSF) from Paper Research Materials, Inc. (Syracuse, N.Y.) overcomes both sets of disadvantages. This paper describes the successful evaluation of commercial rosin and alkyl ketene dimer (AKD) paper sizes using the TPSF, including an examination of the effects of recycling white water and of the degree of turbulence during sheet formation. Comparisons with Noble and Wood (N&W) handsheet evaluations are given.

1. Diagram of the Turbulent-pulse Sheet Former



Experimental

Sheet forming

The principal advantage of the TPSF (**Fig. 1**) was its ability to produce testable sheets from stock at near-headbox consistencies under a variety of turbulent conditions. Sheets were formed from pulp slurries at consistencies in the jar up to 0.1%. Pulp consistencies in the deckle box of the N&W handsheet machine were much lower, generally below 0.03%. The TPSF was capable of producing sheets with basis weights ranging from about 40 g/m^2 for softwood bleached kraft pulp (about 60 g/m^2 for unbleached kraft pulp) to over 200 g/m^2. For a 65-g/m^2 sheet, only 0.5 g of o.d. pulp was required.

Before sheet formation, a positive pressure was applied below the forming fabric in the jar to prevent premature drainage of the stock. The combination of rotating impeller, baffle plates, and a continuous rising stream of air provided high turbulence before drainage. Drainage could occur in two stages, similar to conditions on a commercial fourdrinier. The first stage was a high shear, pressure-vacuum pulse cycle, or "turbulent thickening" phase. Vacuum and air-pressure levels and the duration and number of pressure/vacuum pulse cycles could be accurately controlled to provide the desired levels of turbulence. A continuous low-shear, vacuum-assisted dewatering ("filtration") followed. This two-stage drainage will be referred to hereafter as "dynamic" drainage. Alternatively, sheet formation could occur with simple vacuum-assisted drainage, similar to the Noble and Wood handsheet machine. This will be referred to as "static" drainage. In both cases, the location of the impeller above the forming fabric, the impeller speed, and the amount of agitation occurring during drainage could be varied.

Pressing and drying

Ultimate sheet properties are strongly determined by the degree of consolidation achieved during pressing of the wet mat. Thus, an appropriate pressing scheme using a

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I. Typical wet pressing results

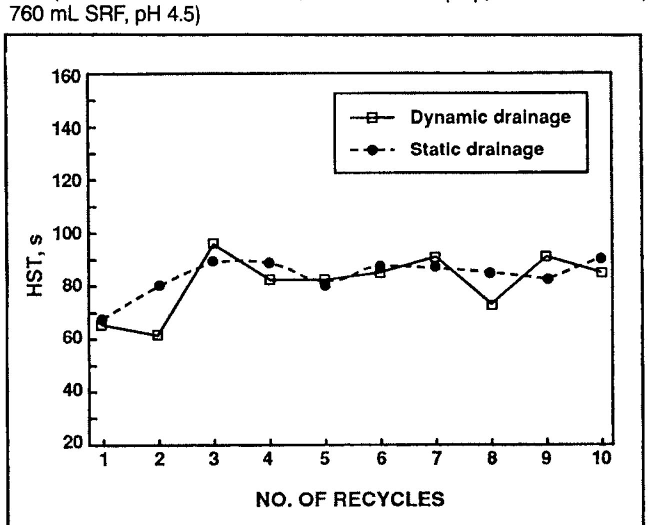
	Bleached kraft, 65 g/m²		Unbleached kraft, 130 g/m²			
	Carver press	Cobb roll	Carver press			N&W roll press
Press pressure, psi	40	...	40	80	160	...
Pressing time, s	5	2 passes	30	30	30	...
Press solids, %	37	30	32	37	41	33
Density, g/mL	0.59	0.54	0.38	0.47	0.51	0.48–0.55

II. Evaluation of paper sizes on the TPSF and the N&W handsheet machine (bleached kraft pulp at 760 mL Schopper-Riegler freeness, 65 g/m² sheets)

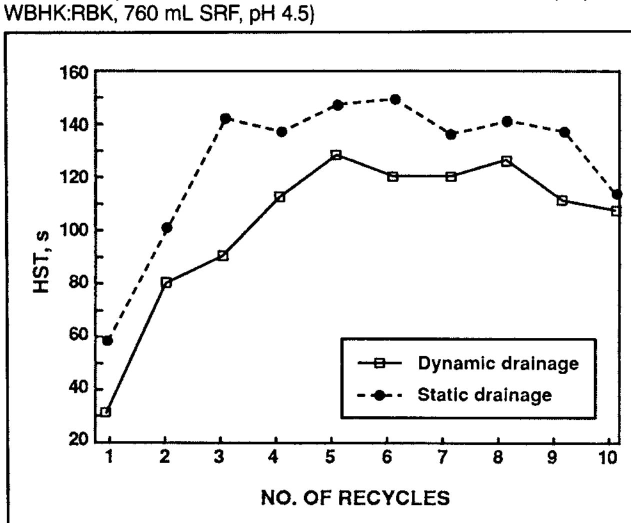
	Dosage, %[b]	Alum, %[b]	pH	White water recirculation[c]	HST, seconds[a] N&W	TPSF Static[d]	TPSF Dynamic[e]
Rosin soap	0.5	2.5	4.5	Yes	64	41	46
				No	91	52	30
Dispersed rosin	0.5	1.8	4.5	Yes	96	106	136
				No	41	54	104
Cationic dispersed rosin	0.5	0.5	6.5	Yes	204	249	202
				No	161	141	244
Dispersed rosin	0.5	0.5	6.5	Yes	143	184	138
				No	100	144	121
AKD emulsion	0.1	...	7.5	Yes	487	949	952
				No	498	591	789

[a]No. 2 ink, 80% reflectance, average of six sheets per condition. [b]Dosages based on o.d. fiber. [c]Yes = equilibrated by recirculating drainage water five times. [d]Static drainage with -20 in. of Hg applied vacuum only. [e]Dynamic drainage with pulses of 25 in. of H_2O air pressure for 0.1 s and -20 in. of Hg vacuum for 0.3 s, in a total of 8 cycles (3.2 s).

2. Effect of recycling white water on the sizing efficiency of rosin soap size (0.5% size and 2.5% alum, based on o.d. pulp, 1:1 WBHK:RBK, 760 mL SRF, pH 4.5)



3. Effect of recycling white water on the sizing efficiency of dispersed rosin size (0.5% size and 1.8% alum, based on o.d. pulp, 1:1 WBHK:RBK, 760 mL SRF, pH 4.5)



Carver laboratory press was developed. Sheets were couched onto blotter paper, and a stack of five alternating layers of sheet and blotter were pressed for the appropriate time and pressure to give the desired solids levels. As an alternative, the 10-kg couch roll from the Cobb sizing test was also employed. Single sheets between two blotter papers were pressed by rolling once back and once forward without exerting any additional pressure on the roller.

For the 65-g/m² bleached kraft pulp sheets used in our sizing evaluations, appropriate solids and density were achieved using the Carver press with a pressure of 40 psi applied for 5 s (**Table I**). The Cobb roller yielded somewhat lower solids and density but could be used for field service evaluations if a laboratory press were not available.

For comparison, 130-g/m² unbleached kraft pulp handsheets were pressed in a similar fashion. Although sheet solids and density varied linearly with press pressure, at 40-psi pressure press solids were lower and the sheets were bulkier than the 65-g/m² bleached pulp sheets. The Carver press also gave a bulkier sheet in unbleached kraft pulp than a standard N&W roll press, which typically yielded sheets with a density between 0.48 g/mL and 0.55 g/mL at 33% press solids.

After wet pressing, the sheets were dried individually on a controlled-temperature hot plate fitted with a felt-covered wire screen. For 65-g/m² sheets, drying at 105°C for 30 s provided a moisture content of 4-8%.

Results of sizing evaluations

Several commercial sizing systems were evaluated with the TPSF, including rosin soap size, dispersed rosin size, cationic dispersed rosin size, and AKD dispersed size. A 50:50 blend of Weyerhaeuser bleached hardwood kraft (WBHK) and Rayonier bleached softwood kraft (RBK) pulps refined to 760 mL Schopper-Riegler freeness (SRF) in a Valley beater was used during the evaluations. Sizing levels were compared to those obtained for sheets prepared on the N&W handsheet machine. The effect of turbulence and dynamic drainage provided by the TPSF as well as recirculation of drainage water (white water) were studied.

Initial sizing comparison

Hercules Size Test (HST) results of concurrent evaluations on the TPSF and the N&W handsheet machine using an identical bleached kraft pulp furnish are given in **Table II**. Drainage conditions on the TPSF and the use of white water recirculation are indicated.

Generally, similar levels of sizing between the two sheet formers were obtained. Recycling white water improved sizing levels for dispersed rosin sized sheets prepared from both formers. White water recirculation substantially increased sizing with the AKD-based size for sheets prepared on the TPSF but not for the N&W sheets. No clear effect of turbulent pulsed drainage on sizing levels could be observed for the TPSF conditions chosen.

This initial study suggested that the TPSF could be used as a suitable alternative to the N&W machine for evaluations of paper sizes. In follow-up experiments, we explored in greater depth how white water recirculation and turbulence could affect sizing on the TPSF.

Effect of white water recirculation

To evaluate paper sizes, it is generally necessary to use the drainage water from preliminary handsheets as dilution water to simulate the accumulation of fine particles (with adsorbed size) which occurs in the white water of a commercial papermaking system. We studied the effect of recycling white water on size performance in bleached pulp using both static (vacuum only) and dynamic (pressure/vacuum pulsed) drainage.

For a typical rosin soap size (with alum), overall sizing levels were relatively low (60-100 s HST), and little difference between static or dynamic drainage was observed (**Fig. 2**). In terms of white water recycling, "equilibrium" sizing was reached after only three iterations. The difference in the equilibrium sizing in this experiment (about 80 s) and in the evaluation summarized in Table II (41-46 s) is within normal experimental error.

For dispersed rosin size with alum at pH 4.5, levels of sizing similar to soap size were obtained initially, but successive recirculation of drainage water rapidly increased these values (**Fig. 3**). After only three recycles, sheets formed with static drainage reached an equilibrium sizing level of 140-160 s HST. Sheets prepared under dynamic drainage conditions required five iterations to reach a stable level of 120-140 s HST.

A typical AKD dispersed size (0.1% AKD) appeared to display continuously increasing sizing levels with successive recirculation of drainage water (**Fig. 4**). Upon closer inspection, equilibrium sizing with poor reproducibility appears to have been reached after seven iterations of white water recycling. As is typical for AKD, sizing levels for sheets cured one week at room temperature were extremely high (540-680 s HST).

Effect of turbulence

We next explored how variable, turbulent-pulsed drainage could affect sizing. The effect of turbulence (created by impeller rotation) on sizing obtained with dispersed rosin size (with alum at pH 6.5) in bleached kraft pulp under static and pulsed drainage conditions is shown in **Fig. 5**.

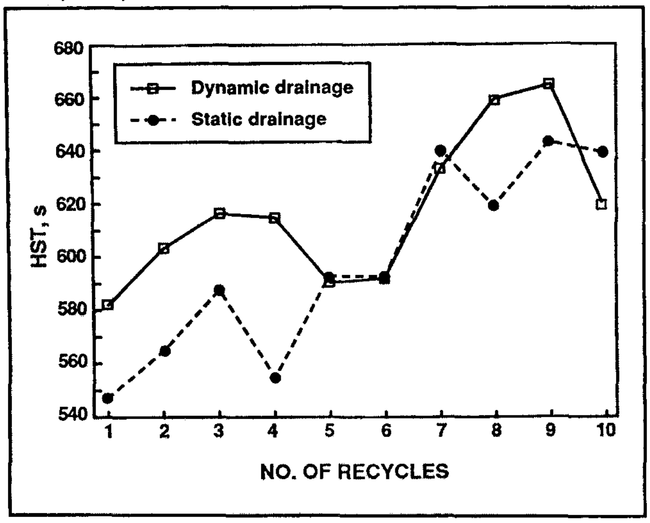
In this experiment, the impeller was located 7.6 cm above the forming screen, and stirring was maintained throughout sheet formation. Thus, during drainage about half of the stock in the 16.5-cm-high jar would be agitated. In the dynamic drainage mode, this would simulate the "turbulent thickening" phase of sheet formation. During the static drainage mode, this would allow the effect of shear (without mat disruption caused by air pulses) to be studied.

As impeller rotation increased from 250 rpm to 3000 rpm, size efficiency under static drainage decreased by 75% (Fig. 5). Under low shear (250 rpm), pulsed drainage resulted in lower sizing (128 s HST) than static drainage (205 s). Very high impeller speed (3000 rpm) created such high shear that little difference between static and dynamic dewatering was observed.

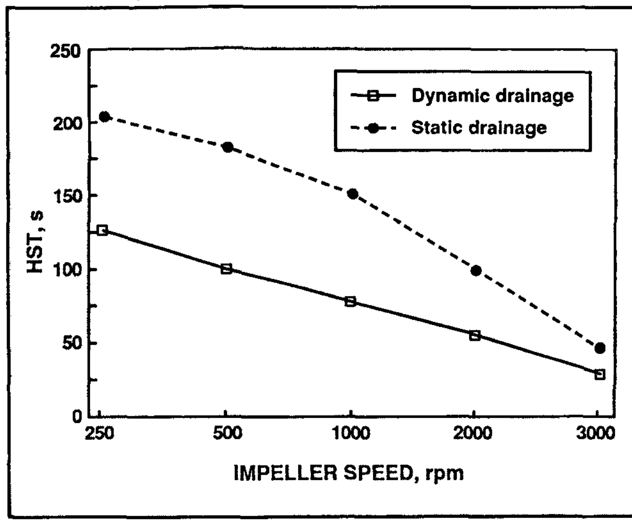
Because of the relatively low level of pulp fines in the laboratory-refined bleached kraft pulp blend (12%), first-pass retentions as measured with the TPSF were generally above 90%. Thus, it is not clear whether the reduced levels of sizing obtained with pulsed and highly turbulent drainage are the result of lower fine particle retention, reduced adsorption of precipitated aluminum-rosin size particles, or a subtle combination of both.

The effect of high-shear drainage on sizing with dispersed rosin was also examined in a 100% stone groundwood newsprint furnish (**Fig. 6**). As impeller rotation during drainage increased, sizing levels decreased, analogous to the results obtained with the bleached kraft pulp. Again, first-pass retention was

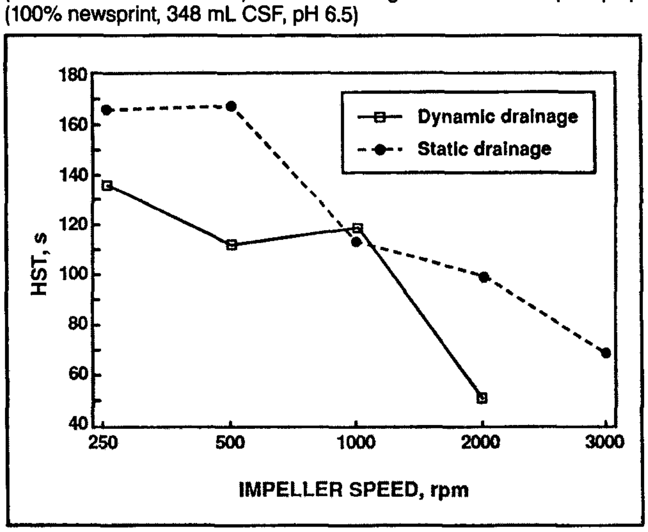
4. Effect of recycling white water on the sizing efficiency of AKD dispersed size (0.1 AKD, based on o.d. pulp, 1:1 WBHK:RBK, 760 mL SRF, pH 7.5)



5. Effect of turbulence on the sizing efficiency of dispersed rosin size (0.5% size and 0.5% alum) in bleached kraft pulp (1:1 WBHK:RBK, 760 mL SRF, pH 6.5)



6. Effect of turbulence on the sizing efficiency of dispersed rosin size (0.5% size and 0.5% alum) in 100% stone groundwood newsprint pulp (100% newsprint, 348 mL CSF, pH 6.5)



uniformly above 90%, suggesting that a mechanism other than fines retention is at work.

As with drainage water recirculation, turbulence before and during drainage is a critical papermaking parameter that should be carefully selected to suit the objectives of the experiment. Unlike the low-shear static drainage that occurs on the N&W machine, the high-shear pulsed drainage capability of the TPSF was ideal for this purpose.

Summary

The purpose of this work was to explore the capabilities of a turbulent-pulsed drainage device for laboratory evaluations of commercial sizing agents and to determine how the dynamic action of commercial papermaking influences the sizing ability of these materials. The TPSF was found to have several advantages over the traditional Noble and Wood handsheet machine. The device was used to prepare well-formed sheets at near-headbox consistencies with a minimum of raw materials. Evaluations were carried out over a broad range of consistencies and basis weights. Turbulence and shear during drainage could be precisely controlled, and white water recirculation was easily accomplished.

Sizing in a standard bleached kraft pulp furnish was found to be dependent on drainage water recycling, particularly with dispersed rosin size. Under dynamic drainage conditions, equilibrium sizing levels were reached only after five recycles. Rosin soap size was found to be less affected by recycling, requiring three iterations. AKD sizing levels were very high with poor reproducibility, but equilibrium sizing appeared to be reached after seven iterations.

Turbulence and vacuum pulsed drainage impaired sizing. High levels of turbulence during static drainage reduced the efficiency of dispersed rosin size in bleached kraft pulp by 75%. This effect was exacerbated when pulsed drainage was employed.

Thus, for careful control of the papermaking conditions needed for meaningful laboratory evaluations of sizing agents, a turbulent-pulsed drainage sheet former appears to be ideal.□

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