Single procedure for measuring drainage, retention, and response to vacuum of pulp slurries

ABSTRACT
Changes in basis weight, furnish, consistency, and polymeric additive usage affect sheet forming and dewatering processes on the paper machine. While some off-machine procedures can measure several aspects of drainage, retention, and web-vacuum dewatering response, no one procedure combines measurement of these three parameters in a single test. The procedure is based upon use of a modified water release analyzer. Modifications are directed at making the formed web the principal resistance to flow. Reproducible quantitative information is obtained, and the effect of polymeric additives on drainage, retention, and vacuum dewatering response is readily measured. Increasing polymeric additive levels increases drainage rates and retention but decreases web dryness in response to vacuum. Basis weight has a greater effect on drainage rate than does consistency.

KEYWORDS
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No universally-agreed-upon, off-machine test adequately predicts the drainage behavior of pulp slurries on the paper machine. This is especially true with furnishes containing polymeric additives, which affect not only drainage but also fines retention and wet-web dewatering response to vacuum. While procedures exist for measuring some aspects of drainage, retention, and vacuum response, no single procedure until now has given a combined measurement of these three process parameters. Here, we describe such a procedure.

For retention, the more widely accepted procedure uses the Dynamic Drainage Jar (DDJ) developed by Britt (1). This measures the colloidal effects of the fine particles but does not measure drainage. Because no pad is formed, the retention effects resulting from filtration are not included. For response of a wet web to vacuum, Britt and Unbehend developed the Water Release Analyzer (WRA) to simulate vacuum dewatering on the paper machine (2).

For drainage, freeness testers such as the Canadian Standard tester have been used, but the results do not necessarily correlate with experience. The TAPPI Fluid Mechanics Committee published a survey of drainage tests and concluded that there was not a standard test (3). Recently, Britt et al. (4) modified the DDJ in order to measure the increase in pulp slurry consistency with time, as an indication of drainage behavior.

In this report, we (a) describe a procedure for measuring drainage, retention, and web-vacuum response in a single test, (b) determine the reproducibility of the test, and (c) determine the effect on drainage of polymer additives, basis weight, and consistency. With this procedure, we simulate sheet-forming and dewatering processes on the paper machine wire. The procedure can be modified readily to take into account specific parameters such as type and amount of polymeric additive, polymer contact time, vacuum level, pulp furnish consistency, and basis weight.

Procedure and apparatus modifications
The procedure involves (a) determining average drainage rate by measuring time to drain a given volume during
web formation, (b) determining fines retention using the filtrate collected and knowing the fines content of the furnish, and (c) determining pad dryness. The test apparatus (Fig. 1) is a modified WRA, but the procedures are similar only in that pad dryness in response to vacuum is determined. Determining drainage rate and fines retention is not in the WRA procedure.

Modifications to the WRA were aimed at making the formed web the principal flow resistance by (a) replacing the wire screen at the bottom of the jar with paper machine wire (19.2% open area, mesh size 59 × 52) and (b) opening the bottom of the jar to accept a 19-mm inside-diameter (ID) pipe with a quick opening ball valve of equivalent ID. To measure drainage rate, liquid-sensing electrodes were installed into the jar to automatically turn off a timer when water no longer contacted the electrodes. The depth of the electrodes was adjusted so as not to contact the web formed on the wire. Three vertical vanes spaced equally around the jar circumference aided in giving a random flow pattern.

Parameters were selected to approximate conditions on the paper machine:

- Basis weights as used in board grades (205, 273, and 337 g/m²)
- Consistencies of 0.23% to 0.70%
- Vacuum level during web formation representative of levels attained using drainage devices (4.22 kPa)
- Vacuum level after web formation representative of levels attained after dry line and on the couch roll (33.8 kPa).

Results and discussion

Reproducibility

The reproducibility with this procedure is given in Table I. With no polymeric additive, the top liner furnish, which gave an average drainage rate of 49.8 cm³/s, had a coefficient of variation of 5.2% for the 10 trials. Total retention, fines retention, and web dryness in response to vacuum were similarly reproducible.

Reproducibility, with addition of a polymer to the furnish, was also good (Table I). Addition of polymer increased drainage rate, total retention, and fines retention. Web dryness in response to vacuum decreased, despite an increase in drainage rate. This decrease in web dryness results from flocculation caused by the polymer (5, 6). Flocs promote faster drainage but also create a web that does not seal well. This allows air to break through large pores and results in lower web dryness.

Consistency

With no polymeric additive, essentially equivalent drainage rates were obtained for different consistency levels (0.23%–0.50%) using a recycled neutral sulfite semichemical (NSSC) furnish. With addition of polymer, drainage rates increased (Fig. 2). Over the range of supplier-recommended polymer levels, essentially equivalent drainage rates were obtained for the differing consistency levels. At higher-than-recommended polymer levels, differences in drainage rates for different consistency became evident. Measurements were carried out at constant basis weight. Thus, decreasing consistency required larger amounts of water. This caused measured drainage times to increase even when overall drainage rate remained constant.

Basis weight

Varying basis weight while holding consistency constant gave differing drainage rates (Fig. 3). Over the range of 205–337 g/m², drainage rate decreased as basis weight increased. Addition of polymeric additive increased drainage rate for all the basis weights (Fig. 3). At higher levels of polymer, the 205-g/m² and 273-g/m² basis weights gave equivalent drainage rates. In addition, the difference in drainage rate between the 205-g/m² and 337-g/m² basis weight decreased as polymer level increased.
PAPERMAKING

Conclusions

1. The procedure described, using a modified WRA, can be used to obtain measurements of drainage, retention, and web-vacuum response in a single test.

2. The procedure yields reproducible quantitative data on drainage rate, retention, and web dryness.

3. Increasing polymeric additive increases drainage rates and retention but decreases web dryness in response to vacuum. Drainage rate is affected more by basis weight than by consistency.

We have not compared results obtained from this combined procedure with those obtained from the DDJ (retention without pad formation) and the WRA (web-vacuum response). However, the usefulness of this or any other off-line measurement is in its ability to predict on-machine performance. Such a comparison is needed, of course, but that was beyond the objectives of this study.

Experimental Procedure

Other test parameters had to be pre-selected in addition to those already mentioned. Stirrer speed (300 rpm), polymer contact time (30s), and pH (5.5 or 7.0) were chosen to approximate conditions encountered on the paper machine. These selections may be changed if desired.

The step-by-step procedure is to (a) fill the jar to the wire with water, (b) add the furnish at the desired consistency, (c) stir the furnish at 1600 rpm for 1 min, (d) reduce stirrer speed to 300 rpm for 2 min while adjusting pH to the desired level; (e) add the polymeric additive (if one is used) and stir for 30 s; (f) open the ball valve to drain the jar (stirrer stops and timer starts; timer automatically shutting off when liquid drops below the level-sensing electrodes), (g) increase the vacuum level (to 33.8 kPa) for 6 s, (h) remove the fiber pad and measure dryness (percent solids), (i) filter the filtrate through a Whatman’s No. 40 filter paper and determine total and fines retention, and (j) calculate drainage rate from the measured drainage time and volume change from the starting level to the bottom of the level-sensing electrodes.

The exact conditions chosen should be patterned after the machine to be simulated.

Important procedural points are to (a) fill the jar to the wire slowly to prevent air from being trapped and to do this before adding the furnish, (b) keep the vacuum level constant during drainage, or reproducibility will be poor, and (c) disperse the furnish by stirring adequately before adding polymer, or reproducibility may be poor.

Furnish

Two furnishes were used in this work. For reproducibility tests, a topliner-board furnish consisting of 50% ledger waste and 50% solid bleached sulfate cuttings was used. Freeness level was 320 mL CSF; fines content was 39.5%, as determined by TAPPI provisional method T261 pm-80; furnish pH was 7. The second furnish, used to determine effect of consistency and basis weight, was a recycled NSSC pulp (75.1% yield) of 50% birch and 50% southern red oak. It had a freeness level of 425 mL CSF and a fines content of 15.9%. Furnish pH was adjusted to 5.5 using hydrochloric acid. Measured drainage rates were much higher with this furnish because of lower fines content. Two polymeric additives (A and B) were used. They were cationic polyacrylamides of high molecular weight, produced by different suppliers, and used in the manufacturers’ recommended pH (4–7) range. Dosage levels were based on weight percent oven-dry fiber.

Literature cited


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