The Influence of Filler Content and Process Additives on Wet Web Strength and Runnability

Frank J. Sutman
Ashland Hercules Water Technologies
Wilmington, DE

Abstract

Paper machine runnability is largely determined by the cohesive forces within the wet web and the adhesion of that web to roll and fabric surfaces. Papermakers wish to increase sheet filler content in order to reduce manufacturing costs. It is well known that cohesion of the never-dried web decreases as sheet filler content increases. This phenomenon is easily observable on commercial paper machines but difficult to quantify.

This paper details a laboratory technique for measuring never-dried wet web cohesion. The method is used with PCC-filled copy paper furnish to quantify the decrease in wet tensile strength with increasing filler content. Optimized wet end process additives are demonstrated to mitigate the decrease in cohesion. Use of the right wet end chemistry is shown to help overcome paper machine performance problems caused by increasing filler content.

Objectives

The study objectives were to (1) develop a laboratory technique using standard equipment to measure cohesion or never-dried strength of wet paper webs, (2) quantify the effect of increasing filler content on wet web strength, and (3) determine whether polymeric wet end additives can mitigate the anticipated drop in wet web strength with increasing filler content. The focus of this study was upon PCC-filled uncoated copy paper.

Introduction

Ashland Hercules is currently working with customers and filler suppliers to commercialize a system to significantly increase filler content in wood-free paper grades. Critical constraints for increasing filler content are maintaining finished sheet properties and maintaining paper machine runnability. The current work focuses upon the runnability aspect. Runnability of wet webs is influenced by both the cohesive forces within the web and adhesive forces to surfaces such as a press center roll. This study considers the cohesive effects. It is important to state that “wet tensile strength” in this paper denotes never-dried strength of the wet web. This is an important distinction from “re-wet tensile strength” that is produced through covalent bonding with wet strength resins. Chemistries that provide one type of response will not necessarily provide the other.

A number of excellent studies exist on wet web tensile strength. Seth and coworkers developed wet tensile strength versus stretch curves for a number of different individual pulps and pulp blends as a function of solids content. They used a template placed over the wire of a TAPPI sheet mold to form wet strips that could then be pressed and tested.[1] The template produced individual wet strips, but the edge quality and the effect of imperfections on the testing of each strip is unknown. Page applied a derivation of the "Page equation" for dry sheet strength to develop a theoretical basis for the strength of wet webs. He concluded that wet web strength is directly proportional to mean fiber length and inversely proportional to the square of mean fiber coarseness. This accounted for the surface tension and frictional forces causing cohesion in the wet web. [2]

Using data from previously published studies, Shallhorn demonstrated an inverse linear relationship between the natural logarithm of the web moisture ratio and the natural logarithm of the wet tensile strength for a given pulp.[3] Back and Andersson demonstrated that increasing web temperature decreases wet web strength. An increase in temperature must be compensated for by increased press solids or runnability will suffer. [4]

Researchers have shown the effect of various pulp treatments on wet web strength. Laleg and Pikulik increased both dry and wet tensile strength properties of the web through application of chitosan. [5] Rutledge-Cropsey and Abubakr increased wet web tensile strength of wastepaper furnish by application of a cellulase enzyme treatment. They took web samples after the couch and press on a small pilot machine. The wet samples were bagged and cut into strips while sandwiched in the bag to allow for wet tensile strength testing.[6] Oksanen and coworkers treated pulps with cellulases and xylanases prior to sheet forming on a pilot former. They concluded that enzymatic treatment could either develop or hurt wet web tensile strength relative to an untreated control. [7]

The literature does not specifically provide data on effects of increasing filler content on wet web tensile strength. It is widely accepted that increasing filler content decreases wet tensile strength, but data on the magnitude of the effect are not apparent. The reduction in strength with increasing filler is easily observable as increasing draw, but it is unknown how this relates to the tensile strength of the sheet while wet. Finally, it is unclear whether application of polymeric wet end additives could help overcome the strength reduction caused by the increased filler content.

Experimental

Noble and Wood (N&W) handsheets were made at a target sheet weight of 6 g OD. This equates to an OD basis weight of about 90 lb / 3000 sqft or 145 gsm. The relatively high basis weight was required to facilitate handling of the pressed, wet sheets. Additives were mixed into 600 ml of stock at 1% consistency. The furnish was 70% HWK / 30% SWK, refined separately to targets of 360 ml and 500 ml CSF, respectively. Albacar® LO (SMI) and UltraBulk® II (SMI) slurries were used as the PCC filler. Local tap water with 100 ppm NaHCO3 and 300 ppm NaCl added was used to dilute the stock. Application of the Perform® SP retention aid package and the high sheet weight resulted

in close to 100% of the total suspended solids being retained on the sheet mold wire. Experiments were run at furnish filler contents of 20, 30, and 40%. An unfilled, 0% ash condition was used for comparison.

Additives were mixed sequentially into the 600-ml stock aliquots using a Britt jar and mixer at 1200 rpm for 10 seconds per treatment. Product doses indicated in the results are on a polymer solids basis. The high shear mixing was done to avoid excessive flocculation of the sheet while using the retention aid package. Stock was then transferred to the sheet mold, which was pre-filled with about four liters of tap water. Sheets were formed immediately after the stock transfer. A freshly cleaned wire was used for each handsheet.

The wet sheet and wire were transferred to the N&W roll press. The press felt had previously been saturated with water and the roll loading set at 60 psig in order to have constant pressing conditions. Two pieces of blotter paper and a single press pass were used for each sheet. The pressed sheet was then carefully peeled off the wire and then off the blotter paper. This pressing procedure gave sheet solids of 49 (±2%). A single, pressed sheet was then sandwiched between two photocopy transparencies, pre-cut to match the 8 x 8-inch sheet size. Any stiff, low caliper plastic sheet is suitable for this purpose as long as it can be easily trimmed with a standard paper cutter. A half-inch wide edge was trimmed, and then one-inch wide strips were cut using a paper cutter. It was essential to cut the wet paper while sandwiched between two stiff plastic layers in order to achieve a clean edge. The wet strips were handled so that they were always sandwiched between two plastic sheets of the same dimension.

At least five strips were cut from each sheet for wet tensile strength testing. These were enclosed in a sealed bag and tested immediately for wet tensile strength, stretch, and TEA using TAPPI Method T494. We required a low capacity load cell (50 N) on the tensile tester for adequate resolution. All strength response data were linearly normalized to a constant dry sheet weight of 90 lb /3000 sqft for analysis. A second handsheet for each condition was made, pressed, weighed post-pressing, dried, weighed oven dry, and fired for ash determination at 525 °C. This provided press solids, basis weight, and sheet filler content data.

Results

Based upon five replicates per test, the experimental technique generally allowed test repeatability of about 10% mean value for tensile strength (0.08 lbf/in.), 14% for stretch (0.45% length), and 24% for TEA (0.56 in-lbf/ft2). A typical curve for the decrease in wet tensile strength with increasing filler is shown in Figure 1. The same data are expressed as percent of an unfilled sheet in Figure 2 and displayed along with stretch and TEA values. Up to about 27% sheet ash, the wet tensile strength and TEA loss was roughly linear with ash content and dropped to about 70% of an unfilled sheet. Increasing sheet ash from 27 to 36% caused wet tensile strength to drop by another 30%. The relative tensile strength and TEA responses to increasing filler content were quite similar. Surprisingly, stretch to rupture was maintained to almost 30% sheet ash before it

started to drop. Tensile strength data are reported in the subsequent results due to the similarity of the tensile strength and TEA curves and the better relative precision of the tensile strength data.

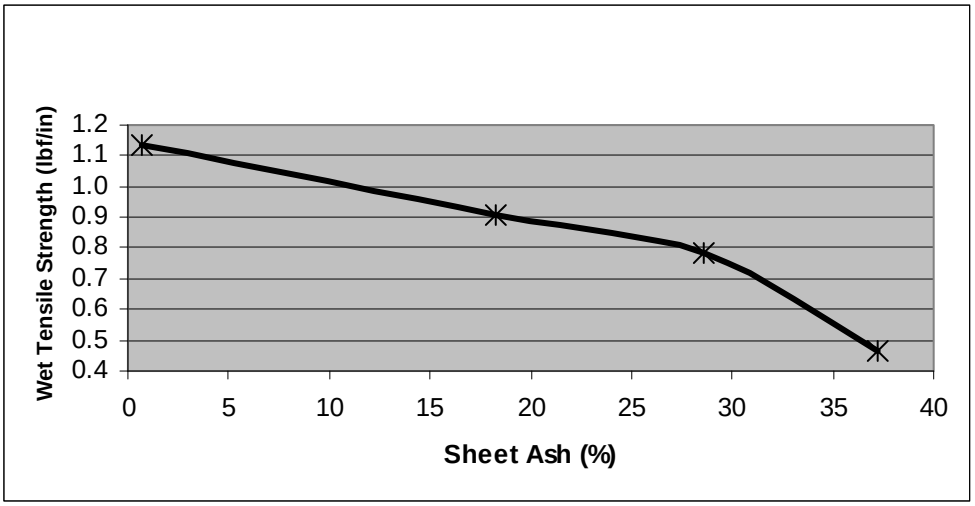

Figure 1. Effect of Increasing Filler Content on Sheet Tensile Strength.

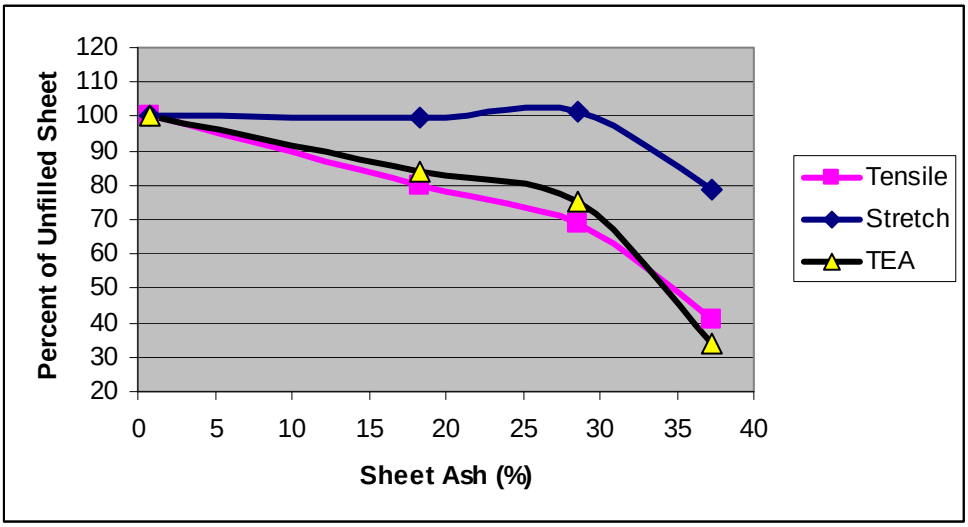

Figure 2. Effect of Increasing Filler Content on Relative Sheet Strength.

One possible benefit of increasing filler content is an increase in press solids due to easier dewatering. Press solids data for a range of wet end conditions at constant press loading are summarized in Figure 3. Increasing sheet ash allowed press solids to increase. On average, increasing sheet ash from 18 to 26% allowed press solids to increase by about 1%. This effect may explain why the observed drop in tensile strength is less drastic than one might expect. The solids data displayed less scatter as sheet ash increased.

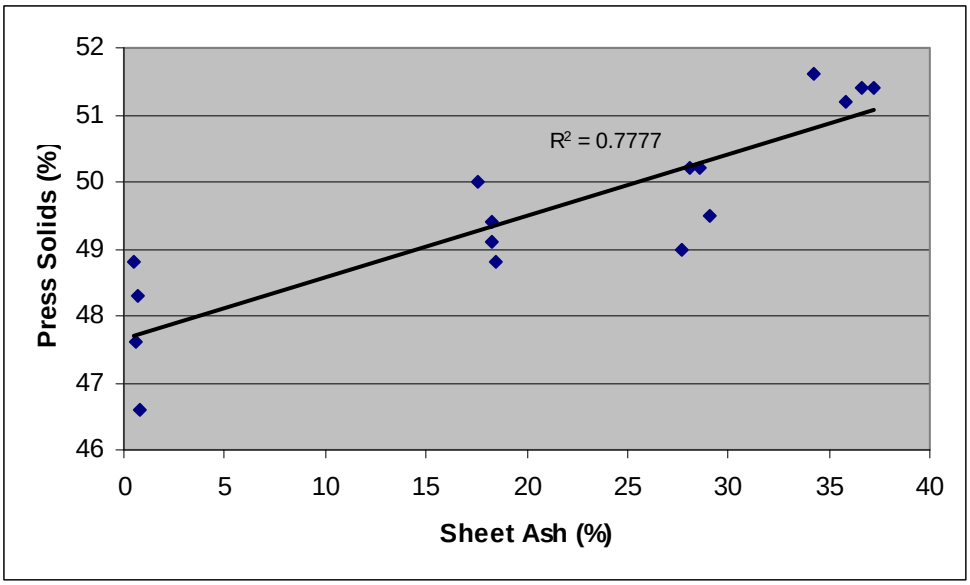

Figure 3. Effect of Filler Content on Press Solids.

Next, the ability of a conventional dual cationic polyacrylamide–anionic polyacrylamide dry strength treatment system was evaluated to maintain wet tensile strength as sheet ash increased. Products used for this evaluation were Hercobond® 1200 and Hercobond® 2023. These data were generated at a target sheet solids of 49 (±2%) and are summarized in Figure 4. The dose shown in the legend is the total dose of both components. At the lower filler level there is some indication that increasing the dual system dose improves wet tensile strength. However, as filler loading increases the three sets of data converge. One cannot see a clear effect.

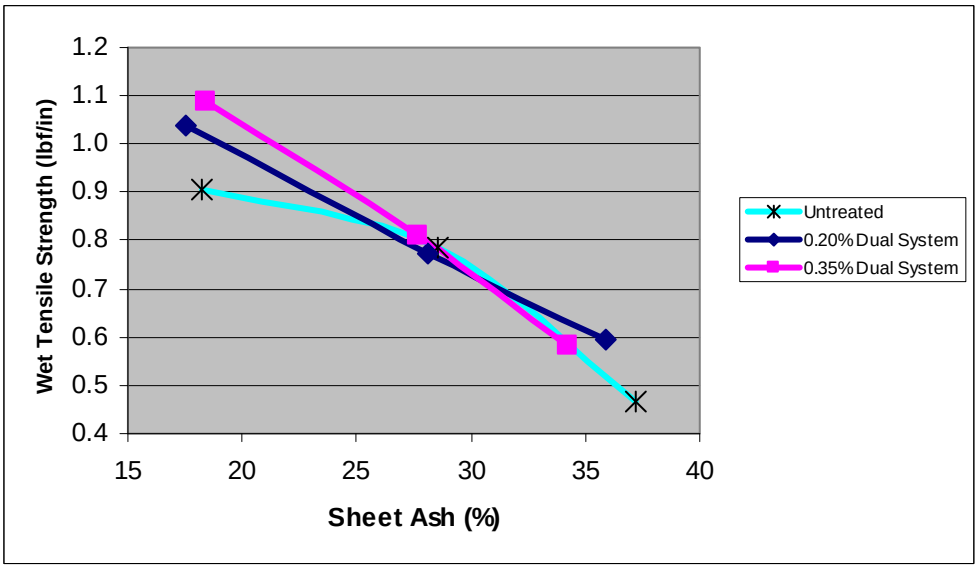

Figure 4. Effect of Dual Polymeric Treatment System on Tensile Strength.

A novel, amphoteric polymeric treatment was developed to permit paper production at increased filler levels while maintaining sheet properties. This treatment is known as Hercobond® HA5305 and is patent pending. The product was applied to filled pulp slurries at different concentrations. Data are summarized in Figure 5. The untreated condition lost almost 60% of its strength as ash increased from 17 to 26%. The magnitude of this drop was greater than observed in the previous experiments. As the product dose increases, the ability to maintain tensile strength at elevated sheet ash improves. The highest polymer dose mitigated two-thirds of the tensile strength loss caused by the increase in sheet ash.

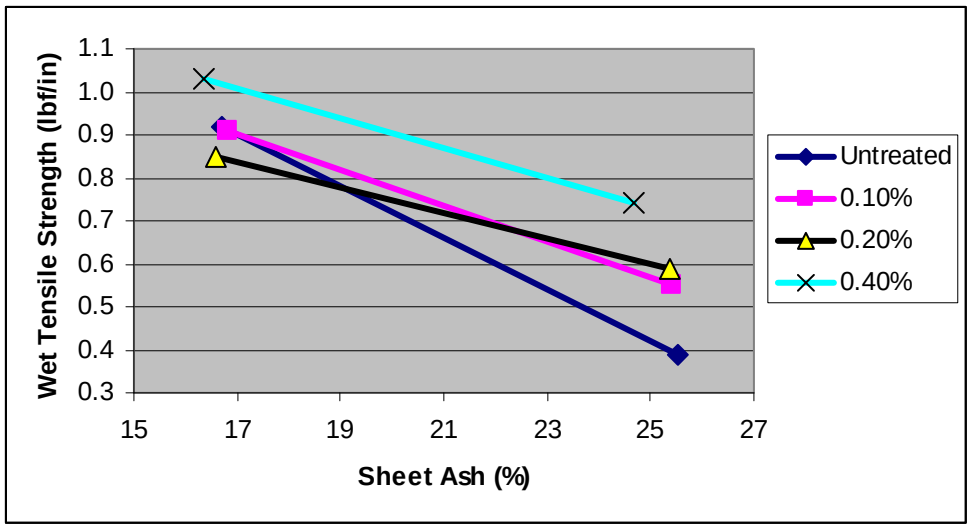

Figure 5. Effect of Novel Polymeric Treatment on Tensile Strength.

This chemistry has now been commercially applied to world class fine paper machines at filler contents up to 30%. Product doses in the commercial applications are typically between 0.5 and 1.5 kg/tonne. The polymer treatment, along with filler morphology changes, maintained sheet properties and end use performance as filler content increased. More detail on the commercial trials is reported elsewhere.[8] Commercial data would be valuable to validate the laboratory wet tensile strength work. It is impossible to measure dynamic wet tensile strength coming off the press on a commercial machine. However, press draw and runnability records lead to the conclusion that the chemistry is helping to maintain sheet cohesiveness as filler loading increases.

Discussion

What potential mechanisms could allow the polymeric treatment to increase wet tensile strength? In terms of particle size, this is a bimodal system with relatively coarse fibers and relatively fine filler particles. On a micro-level, a more uniform and smaller pore structure within the consolidated web would allow higher capillary forces in the dewatering region where surface tension still predominates as a cohesive force. At higher solids, frictional forces and interparticle entanglement would have to increase in order to have a significant effect. On a macro-level, improved sheet formation would help avoid thin spots in the web that would be most prone to breakage.

Conclusions

A technique for never-dried wet web tensile strength testing was developed using common laboratory equipment. The method was used to demonstrate the magnitude of wet tensile strength decrease with increasing filler content. Between 2 and 6% of the wet web tensile strength was lost with each percentage increase in filler content at web solids contents of about 50%. The lab studies demonstrated that application of a novel polymeric additive could mitigate up to 70% of the wet tensile strength loss caused by increasing sheet filler content from 17 to 26%.

Acknowledgements

Tom Parmenter performed the majority of the lab work reported here. The initial concept of cutting wet paper strips encased in plastic was first reported in the literature[6] and refined by Hercules Customer Applications Laboratory personnel in Jacksonville, FL. Joe Mahoney developed the synthesis for the novel polymeric additive.

References

1. Seth, R.S., et al. The strength of wet webs: a new approach. *TAPPI Journal* **1982**, *65*(3), 135–138.
2. Page, D.H. A Quantitative Theory of the Strength of Wet Webs. *Journal of Pulp and Paper Science* **1993**, *19*(4), J175–J176.
3. Shallhorn, P.M. Effect of Moisture Content on Wet-Web Tensile Properties", *Journal of Pulp and Paper Science* **2002**, *28*(11), 384–387.
4. Back, E.L. and Andersson, L.I. The effect of temperature on wet web strength properties. *TAPPI Journal* **1993**, *76*(5), 164–172.
5. Laleg, M. and Pikulik, I.I. Wet web strength increase by Chitosan. In *1990 TAPPI Papermakers Conference Proceedings*, 101–106.
6. Rutledge-Cropsey, K., et al. Performance of enzymatically deinked wastepaper on paper machine runnability. In *1995 TAPPI Pulping Conference Proceedings*, 639–643.
7. Oksanen, A., et al. Improving Papermaking Process by Controlled Modification of Pulp Carbohydrates. In *2009 TAPPI EPE Conference Proceedings* (CD-ROM).
8. Menard, S., et al. High Ash Copy Paper–A New Approach. In *2011 TAPPI PaperCon Proceedings* (CD-ROM).