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TECH FEATURE

Multifunctional dry strength additives for improved production efficiency

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ABSTRACT

The strength of paper has always been a critical sheet parameter; however, it is rarely the ultimate driver for the use of dry strength additives. Often, dry strength additives are used as a tool to balance negative impacts that can come from attempts to lower the total cost of operation. The desire to improve production rates while also reducing raw material costs is driving a growing trend towards lighter basis weights and the increased use of recycled furnishes. This paper examines multifunctional dry strength additives used to improve paper strength per unit of basis weight while lowering the total cost of operation in board and packaging grades.

INTRODUCTION

Dry strength is the most fundamental property that can be imparted to a paper sheet. Without a reasonable ability to complete an intended function, all other properties are of no consequence. The need for an absolute increase in strength, however, is rarely the ultimate driver to pursue improved strength parameters. While some papermakers are in need of a strength boost to meet product specifications or develop new grades, many use strength in ways that allow them to increase their operational efficiency and still satisfy their customers' needs. They are, in effect, trading strength to increase production.

The drivers for higher operational efficiency are both internal and external. Every paper manufacturer is interested in improving the operational efficiency of their mills. Enhanced on-machine efficiency, reduced raw material cost, lower energy and fresh water usage, and the desire to consistently meet a tight product specification (e.g. reduced product variability) are self-imposed drivers to improve the overall economic viability of a paper mill. External drivers come from more focused efforts around sustainability initiatives. Large consumers of containerboard and packaging materials are requiring lighter packaging weights and the increased use of easily recyclable materials. These drivers are continuously pushing the papermaker towards producing lighter basis weights (or at least delivering the nominal basis weight specification) while achieving the same product performance.

Unfortunately, these drivers are only congruent with lower strength attributes of the paper sheet. Lighter basis weights and increased use of recycled fibre will result in poor strength performance. Furthermore, traditional methods to improve strength are counter to what is driving the current needs of the paper industry. Table 1 lists many ways in which a papermaker can increase dry strength.

Table 1. Opportunities to Increase Dry Strength	
Raw Material Opportunities Response	**Comments**
Add Weight	Cost increase Slower machine Mill capacity may be limited Higher paper weight is undesirable
Improve fibre source	Cost increase Availability of alternative source Logistics (fibre delivery and handling)
Use starch/dry strength resin	Can allow operational changes Starch requires a cooker Furnish characteristics can limit effectiveness
Operational Opportunities Response	**Comments**
Add refining	Slower machine due to fines generation and fibre moisture (WRV) Sheet structural changes may be undesirable (density, porosity) Available refining capacity Increased energy cost
Increased wet pressing	Mechanical limitations may not allow an increase (sheet crushing etc) Sheet structural changes may be undesirable (density, porosity)
Machine upgrade	Capital cost Production opportunity cost Risk the upgrade does not deliver the desired result.

Changes in raw materials are generally restricted by cost and availability while unit operations enhancements for dry strength development such as refining and wet pressing are limited by current assets at a given mill and changes imparted to the sheet structure. Both raw material choices and changes in papermaking unit operations can have a detrimental impact on a mill's economic efficiency. Keeping raw material costs low and production rates at a maximum are the paramount concerns; therefore balancing the demand for stronger and/or lighter paper comes with some difficulty.

Clearly there is a need for a multifunctional approach that would allow increased dry strength while mitigating or eliminating detrimental impacts currently experienced when trying to meet final sheet specifications. Dry strength resins offer the best opportunity to improve paper strength while also giving the papermaker a tool to increase operational efficiency (light-weighting, reduced refining, etc.). Cationic starches have historically been the dry strength of choice and can reasonably deliver improved strength. However, lower quality of furnish characteristics (due to mill water system closure and increased use of recycled material) have led to a limited the ability of starch to further improve dry strength. Additionally, some containerboard mills do not have the built in capacity to cook starch for wet end addition. The use of synthetic dry strength resins (DSR) can provide an additional avenue to improve dry strength properties while expanding the mill's opportunity to increase operational efficiency.

Polyacrylamide based DSRs have also been used to deliver improved dry strength. They provide good strength performance at considerably lower dosages than starch and, generally, require minimal or no make down equipment when supplied in liquid form. Modified versions of polyacrylamide have experienced a renaissance in the past decade because they can be designed to deliver superior dry strength as well as improved production efficiency via a press dewatering mechanism. The use of modified polyacrylamides for strength and productivity gains has led to a greater interest in other chemistries that deliver both dry strength and the opportunity for improved operational efficiency. This paper will focus on the development of new multifunctional DSRs and their use in board and packing paper mills.

RESULTS AND DISCUSSION

This work investigated the impact of changes in polymer formulation and manufacturing processes on the activity of multifunctional DSRs. A variety of polymers were synthesized and screened in the lab. Early in the development process a viable candidate was identified. Several versions of this polymer were generated in which the formulation was modified in an attempt to design a polymer that:

1. Delivers good dry strength and
2. Delivers some multifunctional advantage that can improve operational efficiency in some manner.

Laboratory Development and Screening

Figures 1-4 show data collected throughout the development phase. All of the experimental DSRs shown are the same chemistry with various modifications to the formulation and/or synthesis process. These polymers were benchmarked against a commercially available DSR. This commercial DSR was chosen because of its long demonstrated ability to generate good strength improvement in both the laboratory and board and packaging mills.

Two types of furnishes were used in the lab screening and development. Initial studies were carried out in a laboratory prepared recycled furnish made from unused corrugated shipping boxes. This furnish was chosen for screening because it is both representative and can be controlled for consistent thin stock properties from experiment to experiment. In addition, several 100% recycled fibre furnishes were collected from mills in the midwest United States and screened for polymer performance.

The ability to deliver dry strength improvement is the primary objective of this work. Figure 1 shows tensile index results from a handsheet study using the laboratory recycled furnish.

The commercial DSR (benchmark) performed well showing ~15% increase in tensile index. All experimental DSRs showed slightly better to equivalent performance when compared to the benchmark DSR. This result, along with many experiments that are not shown, encouraged further development and evaluation of the experimental polymers with respect to different kinds of activity that could be used to enhance paper machine operational efficiency.

Several types of experiments were also conducted to screen for retention and drainage activity. Figure 2 shows the turbidity reduction in filtrate collected from a dynamic drainage jar on laboratory prepared furnish using different commercial single component polymer programs.

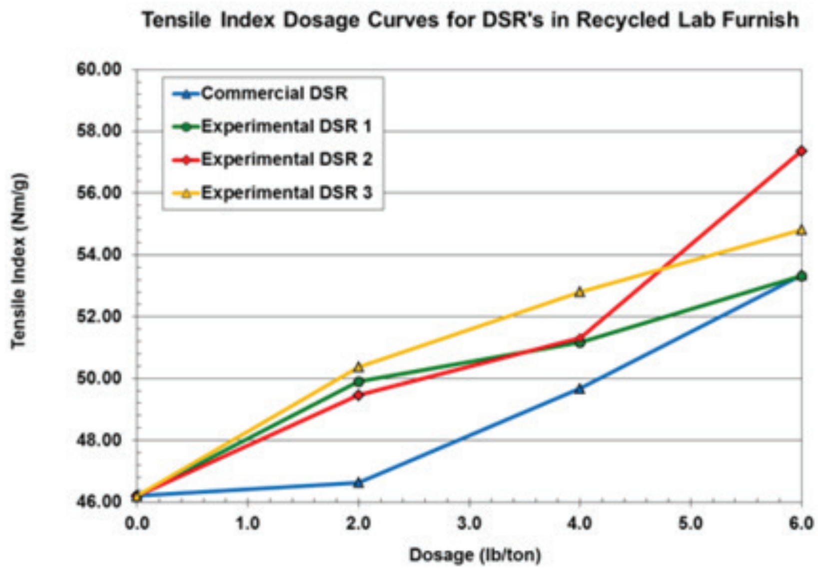

Figure 1. Tensile index results from a handsheet study using 100% lab recycled OCC.

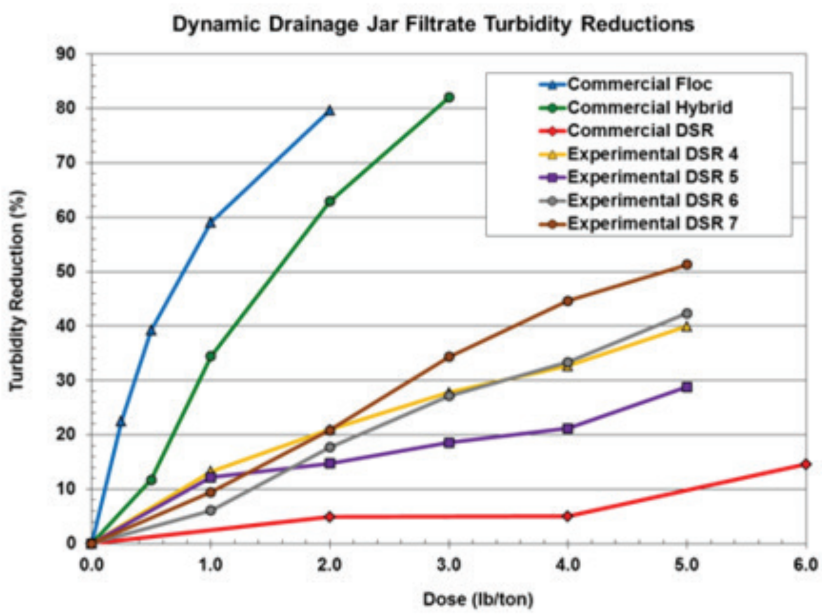

Figure 2. Turbidity reductions in the filtrate of the dynamic drainage jar using 100% lab recycled OCC.

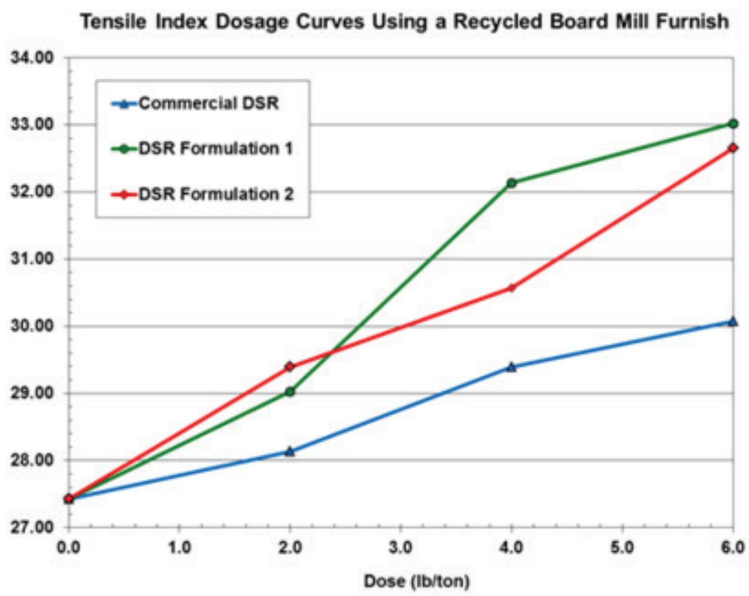

Figure 3. Tensile index results from a handsheet study using a recycled mill furnish.

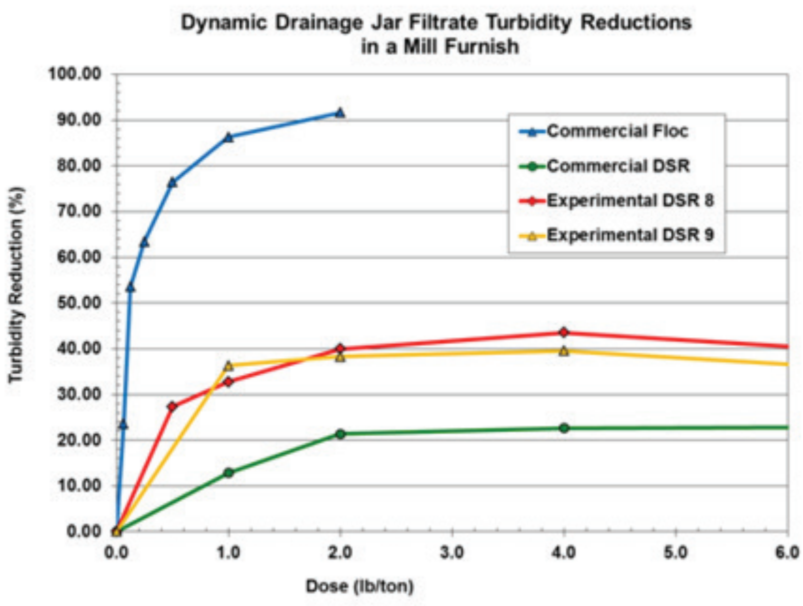

Figure 4. Turbidity reductions in the filtrate of the dynamic drainage jar using a recycled mill furnish.

The graph shows typical levels of turbidity reduction. Flocculants and hybrid type polymers do extremely well, while the commercial DSR has very little activity with respect to retention. This agrees with observations in board and packaging mills. The experimental DSRs, however, show an intermediate response compared to the commercial polymers leading to an expectation that a potential exists for retention and/or drainage in addition to dry strength.

Further screening was completed in mill furnishes. The dry strength response was relatively good (Figure 3), albeit slightly lower than the laboratory furnish.

A reduction in overall strength is not unexpected when one considers the contaminants (stickies, anionic trash, fillers, etc.) often present in a mill recycled furnish. Figure 4 shows turbidity reductions similar to those seen in the laboratory furnish.

Mill Trial Results

During the development phase, the experimental DSR formulation was modified to improve its activity and enhance ease of use. Two experimental DSR formulations were scaled up to commercial quantities and trialled in several board and packaging grades. Results from two mill trials are included.

A mill producing a Tube and Core from 100% recycled old corrugated containers (OCC) on a single ply Fourdrinier machine was selected as an alpha trial site for the experimental DSR. The mill was interested in increasing machine direction tensile to determine the feasibility of producing a new high strength grade. During the trial, refining and machine speed were held constant. Figure 5 shows a tensile increase of ~22%.

The mill also reported improved retention and sizing performance, which allowed for significant reductions in the use of flocculant and size additive.
A second mill producing corrugated medium was selected as a beta site. The paper machine, a traditional Fourdrinier with an average daily production of 425 tons per day, utilizes a furnish mix of 50% neutral sulphite

semi-chemical (NSSC) and 50% double lined Kraft (DLK). Both formulations of experimental DSR were successfully trialled at this mill. Table 2 shows results obtained during a trial on 33 lb/1000 ft2 corrugated medium.

The paper machine speed is limited by steam available to dry the sheet, which is dependent on the amount of refining required to meet the compressive strength (STFI) specification; therefore, the mill desired to use gains in strength to improve production rate. During the trial, an increase in STFI allowed the machine to speed up through a reduction in refining energy per ton of pulp. Over the course of the trial, the experimental DSR was used to increase production rate 9.3% representing an extra 40 tons/day of paper produced.

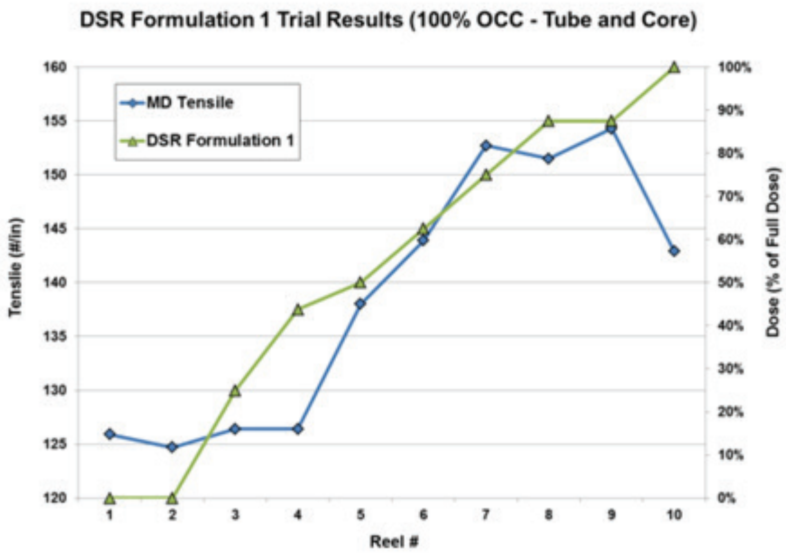

Figure 5. Results from a mill trial producing Tube and Core in a 100% recycled OCC mill.

CONCLUSIONS

Dry strength is often used to increase operational efficiency and produce useable paper products. A new DSR was developed to offer papermakers good dry strength performance and multifunctional activity to increase paper machine performance. Formulations were evaluated in laboratory experiments and modified to enhance activity in mill furnishes. Trial results indicate substantial dry strength and improved production rates can be achieved.

Table 2 – Results from a mill trial producing corrugating medium with furnish composed of 50% NSSC and 50% OCC.

33# CM – Raw Averages	6-hrs pre-trial	DSR Formulation 1 Trial (~ 9 hrs)	6-hrs Post Trial
STFI (lb-f/in)	17.2	17.3	17.2
Total Refining (HPD/Ton)	15.2	14.4	15.1
AVG Production Rate (Ton/day)	430	470	430
Reel Speed (FPM) – avg/min/max)	1420/ 1419/ 1422	1420/ 1480/ 1532	1397/ 1393/ 1433

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