RECYCLED STRUCTURAL PAPERS: NEW APPROACHES FOR MATERIAL PROPERTY IMPROVEMENT

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ABSTRACT

Recycling of fiber into structural papers for the corrugated container industry, paper tubes, cartonboard or other paperboard with structural performance needs may require enhancement of properties through changes in the papermaking process. The loss of bonding capability, coupled with a degree of fiber shortening and fiber inflexibility, reduces the utility of recycled fiber and thus their competitiveness with their virgin counterparts, Traditional means for enhancing performance includes addition of starches or other binders, mechanical beating, or heat treatments. Other means for achieving heightened performances are reviewed which include alternative drying technologies, optimal placement of fibers within the paper sheet and forming technologies that provide structural enhancement.

KEYWORDS: Fibers, fractionation, swelling, drying methods, fiber bonding, fiber alignment, pulp molding

INTRODUCTION

This country has been blessed with an abundance of natural resources yet changes must occur to address the future concerns of the recyclability of fibers and the landfill problems. The US currently generates 180 million tons of municipal solid waste (MSW) annually, with more than 130 million tons going to landfills. Wastepaper and wood wastes represents more than 44 percent of the total MSW. In 1988, the paper and wood wastes comprised an amount equivalent to over three times the annual timber harvest from the National Forest System. About 78.5 million tons of paper and wood wastes (6.5 million tons wood waste) were generated of which about 18.4 million tons were recovered and 59.9 million tons were disposed of mainly through landfilling. In the next 15 years, 75 percent of all our landfills will be closed, and by the year 2000 we will have a massive shortage of disposal capacity (1).

While the collection rates and use of recyclable fiber is increasing. more work needs to be done to enhance its performance and to increase its use and acceptance in a wider variety of paper and paperboard products. However, the loss of bonding capability, coupled with a degree of fiber shortening and fiber inflexibility, reduces the utility of recycled fiber and thus their competitiveness with virgin counterparts. This paper reviews some of the traditional and some new approaches that could be used to enhance the performance and use of recyclable fiber.

IMPROVEMENT OF FIBER-TO-FIBER BONDING

One of the most challenging aspects of recycling is understanding and decreasing the loss in potential fiber bonding, which in turn impairs strength and stiffness, that occurs when fiber is dried. Fiber-based composites and structural products from fiber will never utilize the full strength or stiffness potential of cellulose fibers. That is, fiber products will always be bond limited. Therefore, a key to maximizing the potential for recycled fibers is to develop new ways to chemically, biologically, or mechanically increase their potential for forming interfiber bonds.

Caustics are an easy first choice to treat recycled fibers for enhanced bonding. For cellulose fibers, caustic is primarily a swelling agent. It also has several other beneficial affects on recycled fiber. In the hydropulper the caustic is used to break apart the inter-fiber bonds of the paper and soften the fibers.

DEWATERING/DRYING PROCESSES

The forming, pressing, and drying sections each have very important roles in influencing the use and performance of recycled fiber. One of the affects of recycling is a loss of pulp freeness (a measure of the rate at which water drains from a pulp suspension). The affect is a slower draining furnish resulting in slower machine speeds. Chemical drainage aids are used to increase flow through the sheet. An emerging technology is the use of enzymatic drainage aids to replace chemical use in the paper mill. It has been shown that a mixture of low concentrations of extracellular microbial enzymes can markedly increase the freeness of recycled fibers. As the consistency of the pulp increases, freeness becomes more important in order to maintain efficiency and throughput.

High Intensity Pressing-

Recycled fiber is stiffer (less flexible) than virgin pulp it thus forms a bulkier wet mat. To obtain high-strength paper or paperboard from recycled recycled it is necessary to consolidate the fiber mat to increase the number of inter-fiber bond sites. To compound the situation further, recycled fiber does not have the same inter-fiber bonding capabilities as virgin fiber. One solution to increase performance is to increase the consolidation pressure to increase inter-fiber contact hence potential bonding sites. The use of high pressure wet presses called high-intensity presses have shown a noticeable increase in the strength properties with their use. Without such consolidation action a recycled mat will be performance limited.

Impulse Dewatering-

The performance from the high-intensity press can be further improved with heat. By increasing the temperature, the fibers are more flexible and conformable and the water is less viscous. The results being that the fiber sheet can be consolidated more and the water flows out the with less resistance and thus increasing the dryness of the sheet before it enters the drying section. Higher dryness in the sheet relates to increased savings in drying energy required to evaporate the water out of the sheet. Carry this idea a little farther such that the temperature in the press is sufficiently high to transfer enough energy into the water in the sheet and to be able to convert it to steam. The rapid expansion or impulse of the steam can then "push" some of the remaining water out of the sheet. Experiments with this technology have shown that it works well with sheets of low basis weight but as basis weight increases the impulse begins to have a tendency to disrupt the sheet and lowers the performance.

High-Effect Press Drying-

In a conventional drying section the fiber sheet is allowed to shrink as it dries. In doing so the inter-fiber contacts made in the previous wet-press sections are partially disrupted and will lower the performance of the sheet. If the inter-fiber contacts are held until the fibers are bonded, significant performance improvement can obtained. This is called high-effect press drying. The holding of the fibers is accomplished by continuous Z-direction pressure with heat. Another benefit of this process is increased drying rates. With the increase Z-direction pressure in heat there is better energy transfer into the sheet to evaporate the water. Experiments have shown that recycled fiber press dried have shown significant improvements in performance and approach if not equal the performance of virgin fiber dried in the conventional process.

OPTIMAL PLACEMENT OF FIBER IN THE SHEET

Fractionation-

Fiber sorting is one possible method for enhancing performance of paper and paperboard through optimal placement of fibers in the structure. The premise for fractionation is that, at some level of waste paper collection sorting of paper becomes impractical if not impossible. At that point, the strategy must shift to the sorting and selection of fibers from within a heterogeneous fiber source. The source could be expected to include bleached, unbleached, and dyed fibers, chemically and mechanically pulped fibers, long and short fibers, and contaminants. As in paper sorting, the primary goal is uniformity and consistency of recovered material and economic feasibility of the recovery system. Consistent high quality fiber recovered from a heterogeneous mixture will have many times the market value of the source.

Once the fibers have been sorted into classes of more "homogeneous" mixtures, specific fiber treatments can then be tailored for that specific class for a specific end use. By tailoring the treatment for only one specific class of fibers you can then maximize the performance of those fibers as well as increasing the efficiency of the process.

Fiber recovery from wastepaper is not the sole reason for development of efficient fiber sorting means. With the development of multilayer formation technology, there is no reason to think that fiber must be homogeneously distributed through the thickness of the sheet. If a furnish can be economically fractionated, it is more likely that fibers will be distributed in core and surface layers in the way that best pairs fiber attributes with desired performance characteristics of the paper product. There are numerous sorting systems that are primarily based on size or density differentiation of the sorted material by employing screens or centrifugal separation.

Fiber Alignment (MD/CD Ratio)-

The fiber alignment in a sheet of paper has a significant influence on the properties. The strength, stiffness, and dimensional stability properties increase in the direction of alignment and decrease in the cross direction. Typically in machine made paper and paperboard the fibers primarily align themselves in the machine direction (MD). This is due to the differential velocity between the forming screen and the pulp flowing from the forming box, It also occurs when the sheet stretches in the press section as well as from MD tension exerted from drying stresses and from the sheet tension necessary for winding. By controlling these factors the product's properties can be controlled to maximize the desired product performance. For some products a "Square" sheet or equal MD and CD properties is desired and for others it may be desired to increase strengths in one particular direction. If fiber direction can be controlled then performance can be controlled.

Multi-Ply Forming-

The development of the multi-ply forming box has changed the way the fiber sheet can be structured. With a multi-ply forming box different types of fibers can be selectively placed through the thickness of the sheet to engineer the sheet's performance. For example, a "I-beam" type structure could be formed by placing high-quality high-strength fibers on the outer surface and recycled fibers in the core. In the same way, if a "contaminant free" white surface is important then bleached virgin fibers could be formed just on the surface and the deinked recycled fiber in the core. These two examples show that with selective placement the amount of high quality virgin fiber can be reduced while at the same time reducing the expense needed to bring recycled fiber up to the same quality of virgin pulp.

With recycled fiber also comes the fiber-fines that are generated during the process. These fines add very little to the strength of the sheet but are primarily undesirable because they reduce the sheet's freeness or are washed through the screen and end up in the sludge for disposal. A possible use for these fines could be to supplant the need for clay coatings. With the use of a multi-ply head box, fines could be formed just on the surface of the sheet to smooth out the surface roughness.

NOVEL FORMING APPROACHES TO STRUCTURAL PAPER PRODUCTS

The future direction for structural products from fibers will require new approaches to selectively place fibers in the structure to enhance performance as well as new approaches in processing the fibers to maximize inter-fiber interaction to maximize performance needs. Two forming methods developed by the FPL take a step toward improved placement of fibers in a three-dimensional structural product and improved processing of the structural fiber mat to enhance inter-fiber bonding.

One forming method is similar to forming a flat web on a fourdrinier or cylinder machine, where the fibers are deposited on a screen while the water flows through. The difference in the new forming method is that an array of silicone rubber pads are attached to the screen. The array of rubber pads differentiates itself from conventional pulp molding molds in that the rubber pads serve three purposes. The first purpose is to serve as the initial 3-D form that the fibers will flow around. The second purpose is to allow the fibers to flow around and between the pads without resistance. The third purpose is to deform while under pressure to provide a 3-D densification force to the fiber mat during pressing and drying.

The second forming method requires a slightly more complex forming apparatus than the first but many of the forming, pressing, and drying principles are the same. The basic concept in forming is to use an array of retractable porous mandrel that serve as the initial fiber form. Covers are placed over the mandrel to force the forming down to the bottom and then as the covers are removed the forming follows up the mandrel. , After the basic mat has been formed pressure is applied to the top of the mat and as pressure is applied the mandrels are retracted. This vertical retraction is used primarily to compress the fibers that formed between the mandrels. The pre-densified mat is removed from the mandrels and deformable rubber blocks are inserted into the cavities of the mat. The mat and the rubber block package is then pressed and dried. The rubber blocks serve to provide a 3-D densification force in the same manner for the first forming method.

With these two forming methods we seek to enhance the properties of recycled fibers in a similar manner as discussed above for paper and paperboard. We do this through; 1. selective placement of fibers in the third dimension similar to multi-ply sheet forming, 2. increased densification from deformabel molds or retractable mandrels similar to high intensity pressing, and 3. continuous pressure during drying from deformable molds similar to full restraint press-drying .

SUMMARY

The non-traditional methods for imparting improved structural performance have been reviewed here to supplement the information presented in previous chapters on fiber bond strength restoration, structural changes in the pulp and molecular transformations due to papermaking processes. Improvements in fiber bonding due to the use of z-directional pressing of the wet web in press-drying yields a denser sheet and water-resistant fiber-to-fiber bonds. Placement of fibers for optimal performance in a sheet can be effected through a variety of methods including fractionation or fiber sorting, changes in the fiber alignment ratios, multi-ply forming. and control of fines losses. Two novel approaches to improved performance are reviewed which combine the benefits of press drying and optimal fiber placement.