PAPER MAKING 101

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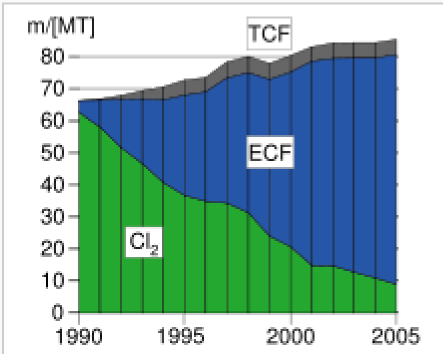
Paper making is an ancient art form, dating to 105 AD, which history records as the point in time when “paper” materials were first formed from a slurry of fibers in water by a Chinese Eunuch named T’sai Lun. Paper was then formed one sheet at a time for nearly two millennia. It wasn’t until about 1800 that mechanized paper webs were formed, thanks in part to an English patent issued to John Gamble, and funded by the Fourdrinier brothers. Today the Fourdrinier machine is by far the most common in the paper making industry.

Much of the paper in the developed world is manufactured from trees harvested from farms or managed forests and/or from sawmill by-products. Other sources are sugar cane, kenaf and bamboo. There are several methods for recovering individual fibers from the wood (pulping), mechanical or chemical, with all providing different physical properties.

From Trees to Individual Fibers

Most methods involve removing limbs, leaves and bark from the logs. Pulp for newsprint operations is generally produced by mechanically scraping the fibers from the log – leaving all of the lignen in place, yielding brownish yellow colored fibers. Pulps for most other commercial and industrial applications are produced by “cooking” chipped wood under high pressure with chemicals that break down the lignen (adhesive that holds the fibers together in the tree) and allow it to be removed. The most common pulping process in the world utilizes sodium sulfate and sodium sulfide as the active chemicals, creating a product known as “Kraft” pulp. The pulping process yields many by-products including turpentine and news headlines with the recent review of the impact of “Black Liquor Credits” on some US based corporate financial results.

The brown fibers that these processes yield need to be bleached to achieve any semblance of whiteness. Non-elemental chlorine or total chlorine-free systems are used today due to environmental concerns related to elemental chlorine bleaching systems and the by-product chemical contaminants they produce. See Fig. 1.



World wide pulp production by type of bleaching used: Chlorine (CL2), Elementary Chlorine Free (ECF) and Total Chlorine Free (TCF).

Fig. 1. “Bleaching of Wood Pulp”, Wikipedia.com

Pulp is either consumed on-site at an integrated paper mill, feeding directly to a paper machine or formed into thick, dry mats and shipped to paper mills. Those mills specify pulp based upon numerous factors, but primarily, wood species. Hardwoods (deciduous trees) have short, weaker fibers, which are used to make soft or very smooth, uniform papers. Softwoods (evergreen trees) have long, strong fibers that entangle well and create rougher, stronger papers. See Fig. 2, 3.

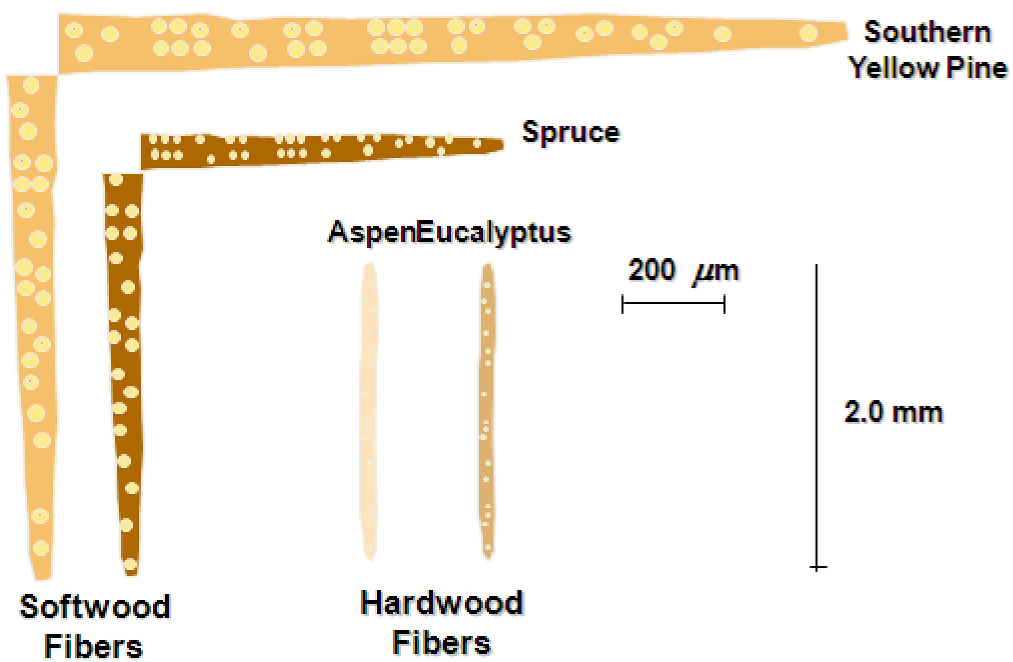


Fig. 2. Neenah Paper, Inc.

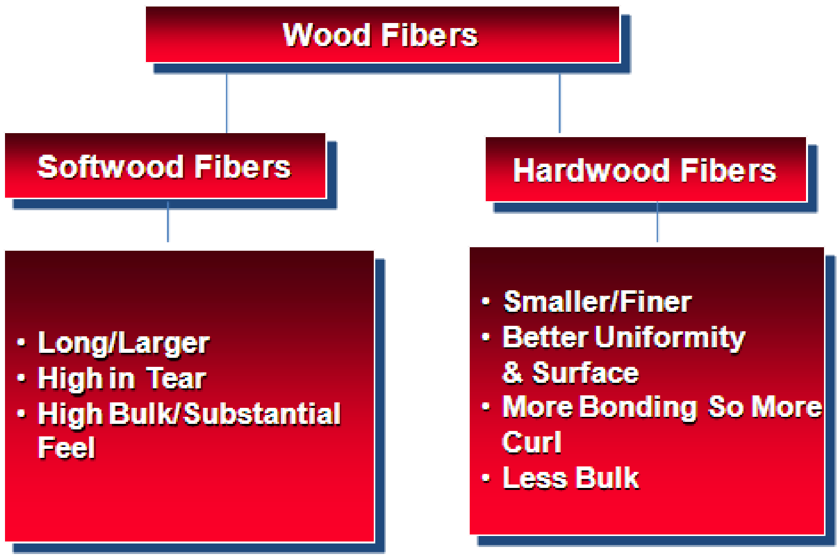


Fig. 3. Neenah Paper, Inc.

Non-cellulose fibers are utilized in papermaking processes when additional strength or dimensional stability is required in the end-use application. Typically they range from 1.0 – 3.0 denier and 3 – 25 mm in length. Polyester is more prevalent, though nylon is used when less stiffness is desired. See Fig. 4. Tests have shown that hydroexpansion is significantly less in 85% Kraft/15% PET papers vs 100% Kraft papers and strength, as measured by an initiated tear test, is nearly double. See Fig. 5.

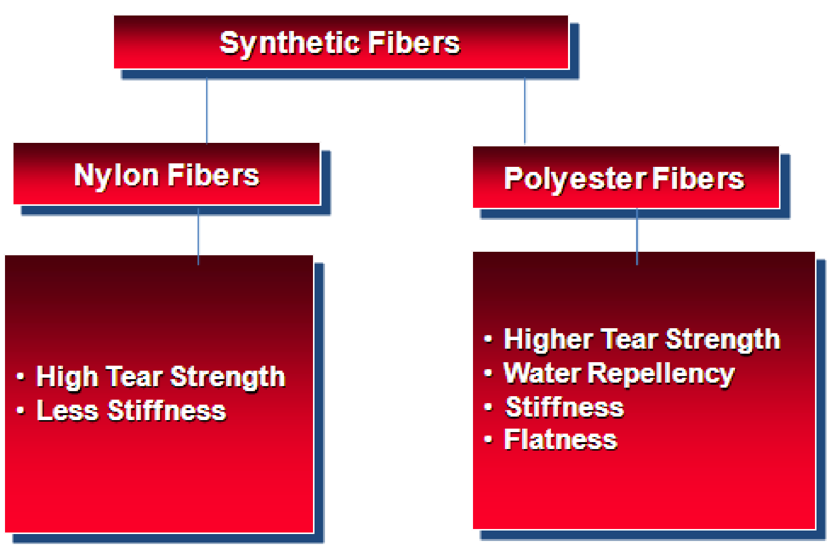


Fig. 4. Neenah Paper, Inc.

Synthetic Fiber

Benefit: Dimensional Stability

	15% Polyester 85% Softwood Kraft	100% Softwood Kraft
Hydroexpansion	0.5%	2.0%

Benefit: Tear Strength

		15% Nylon 85% Softwood Kraft	100% Softwood Kraft
Elmendorf Tear	MD	780	495
g/16 shts	CD	1000	580

Fig. 5. Neenah Paper, Inc.

As covered previously, the fibers (furnish) of a paper determine many of the final parameters.Treatment of those fibers further influences performance. These preparatory treatments allow the fibers to be separated and abraded or cut to enhance fiber-to-fiber (hydrogen) bonding or uniform sheet formation. Refining equipment comes in many forms, but in all cases, mechanical action is used to change the physical form of the fiber, creating “fibrils” which increase the surface area of the fiber, providing more sites for inter-fiber hydrogen bonding. Thus, the tensile strength of a paper can be increased with increased refining – to a point. The tear strength of a piece of paper is generally diminished by refining and too much processing will break down fibers to the point where they lose integrity. Papermaking is all about managing the balance of properties. See fibrillation in Fig. 6.

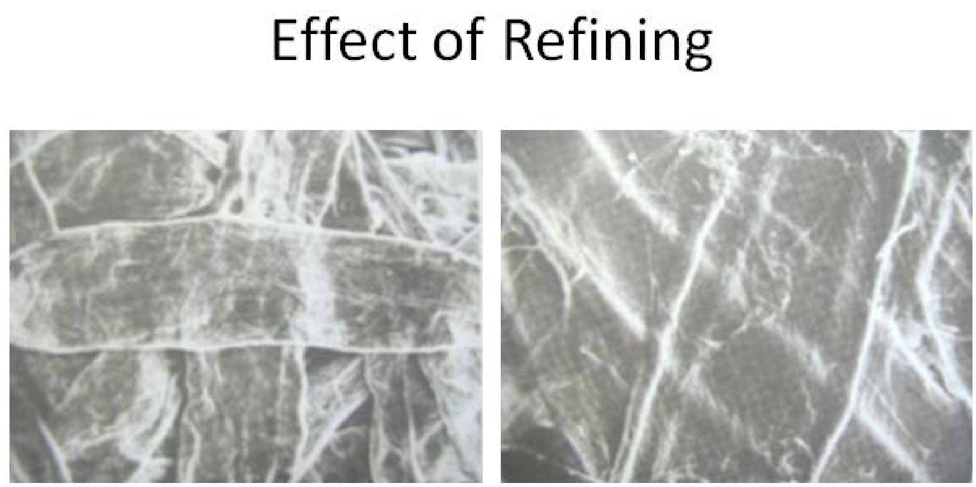


Fig. 6. Neenah Paper, Inc.

The paper industry takes advantage of density differences between most contaminants and fiber (which has a density equal to water) and uses a system of centrifugal cleaners and screens to separate the two. The resultant fiber slurry is diluted to a level of 0.5% or less and pumped to the paper machine. Given this need to produce paper with extremely dilute pulp, paper companies are almost always located on large bodies of water.

From Individual Fibers to a Web

The manufacture of paper is simple – put a lot of water in and then take it back out again. On a Fourdrinier, the low consistency slurry is agitated in a large, pressure controlled, highly agitated "headbox" and then distributed evenly across a wide, fast moving drainage fabric called the "Wire". Water is removed via vacuum-assisted gravity as the Wire travels down the machine. Ultimately, additional work is required to remove water and a Felt covered press section is then employed to remove the remaining "free water" from the web of sponge-like cellulosic fibers. Hence, the "Felt" and "Wire" sides of paper are created.

It is important to note that the orientation of the individual fibers in the web can be controlled while the slurry is traveling down the machine and the degree of orientation influences the physical properties of the final web. The difference between the velocity of the slurry coming out of the headbox and the velocity of the moving wire is the greatest point of impact. A scenario where the wire is moving faster than the slurry will increase the current that pulls the individual fibers parallel to the direction of motion, aligning them in the "Machine Direction" (MD). The width of the web is then called the "Cross

Direction" (CD or XD). The degree of fiber alignment in the web will greatly influence the strength properties of the paper.

It is after the press section where a crepe pattern can be introduced into papers. The process is simple, but parts of it have become proprietary to manufacturers. In a nutshell, the paper is caused to adhere to a very large, driven dryer can and then "scraped" off the can before moving into the remainder of the dryer section. It is important that the paper be constrained during much of the drying process in order to remain flat and pucker-free.

Saturation

To this point, we've discussed how the base fiber web can be manipulated to build strength into a sheet of paper. Strength and durability, whether that is related to tensile, delamination or temperature resistance can then be enhanced in papers by impregnating (saturating) them with natural or synthetic polymers and other chemicals. As with the paper web, balancing properties is key when determining the mix of chemicals used in the saturants. It is important to note that delamination problems can occur with papers when complete penetration of the polymer into the paper is not achieved. Further drying is required after this saturation step and this can occur in a constrained or non-constrained dryer section.

Coating

Papers used for manufacturing tape products generally require a release treatment on one surface and often times benefit by a "tie-coating" which can improve the anchorage of the pressure-sensitive adhesive to the other side of the paper. These coatings can be applied on the paper machine or on a separate, precision coater. The materials used in these treatments are often proprietary to the paper manufacturer and will vary depending upon the degree of release desired for the product and the composition of the adhesive applied by the converter.

Paper manufacturers have many levers that can be pulled to produce the performance that is needed for your tape application. From choice of furnish to type and amount of latex, and type and amount of coatings – custom products are a way of life for the specialty paper company.

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