$60\,g\,m^{-2}$ to compensate for their lack of wet handling strength. Corrugating medium is also produced with a high machine-direction fiber alignment to enhance compression resistance in the direction of fluting.

Manufacturing Corrugated Containerboard

Producing corrugated containerboard requires converting machinery that combines separate rolls of linerboard and medium into a glued structure. The simplest structure is one sheet of linerboard glued to single sheet of corrugated medium and is known as single faced corrugated. Gluing an additional sheet of linerboard to the corrugated side of single face produces a single wall corrugated board. Gluing either two or three single faced corrugations together with a final linerboard face produces a double wall or triple wall corrugated board respectively.

During the production of single face corrugated, linerboard is unrolled and preheated to a temperature of 160–190°C in a unit known as a 'single facer.' In this unit, medium is also unrolled and preheated, but is passed over a corrugating roll to form the flutes or corrugations. During this operation, the medium must be held securely by either pressure or vacuum in the fluting roll to maintain the shape of the flutes. Glue, generally starch, is applied to one side of the flute tips, and then pressed firmly to the underside of the linerboard instantaneously bonding them together. The bond line formed by the glued tips is observable through the linerboard, and is preferably used as the inside surface of corrugated boxes. Single face is flexible, bending easily at the glue lines. As a material by itself, single face is used as a packing material due to its ability to wrap around items such as bottles providing them with excellent crush protection during shipping.

Single wall corrugated boards are produced in a converting machine where the single facer unit is coupled with a 'double facer' or 'double backer' unit. In this unit, the single face material is again preheated and glued to the remaining unbonded flute tips. The prepared single face is then pressed to another preheated linerboard sheet, which produces the rigid containerboard. Less pressure is applied in the double facer than in the single facer to avoid crushing the corrugations. However, because of the reduced pressure the linerboard glued in this manner does not have the same observable glue line as the single face material, and is more suitable for use as the printable outside surface of a containerboard box. Once the single wall board is produced, further heating to set the glue must take place over hot plates in order to convey the board flat through slitters and scorers before being cut into the final board sheet. Converting machines capable of producing double and triple wall container board operate in a similar manner to that just described with the exception that flutes on the corrugation side of a single face board can be glued to the linerboard side of a second single face board to form the final multilayer construction. Final boxes are manufactured using similar die-cutting, creasing, and printing techniques as described above for boxboard.

See also: **Packaging, Recycling and Printing**: Packaging Grades; Paper Recycling Science and Technology; Printing. **Papermaking**: Paper Raw Materials and Technology; World Paper Industry Overview. **Pulping**: Bleaching of Pulp; Physical Properties.

Further Reading

Attwood B and Morre G (1995) *An Introduction to the Theory and Practice of Multiply Forming*. Leatherhead, UK: Pira International.

Biermann CJ (1993) *Essentials of Pulping and Papermaking*. New York: Academic Press.

Cakebread D (ed.) (1993) *Paper-Based Packaging*. Leatherhead, UK: Pira International.

Hunter D (1947) *Papermaking: The History and Technique of an Ancient Craft*. New York: Knopf.

ISO (1998) *ISO Standards Handbook: Paper, Board and Pulps*. Geneva: International Organization for Standardization.

Kouris M (ed.) (1990) *Pulp and Paper Manufacture: Coating, Converting, and Specialty Processes*. Atlanta, GA: Joint Textbook Committee of the Paper Industry.

Paulapuro H (ed.) (1998) *Papermaking Science and Technology: Paper and Board Grades*. Helsinki: Fapet Oy.

Paulapuro H (ed.) (2000) *Papermaking Science and Technology: Papermaking,* Part 1, *Stock Preparation and Wet End*. Helsinki: Fapet Oy.

Savolainen A (ed.) (1998) *Papermaking Science and Technology: Paper and Paperboard Converting*. Helsinki: Fapet Oy.

Smook GA (1992) *Handbook for Pulp and Paper Technologists*. Vancouver, BC: Angus Wilde.

Tissue Grades

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Introduction

'Tissue' is a generic name for a variety of light-weight paper products. In normal use, the word refers to the hygienic or sanitary grades which collectively encompass products commonly known as bath or toilet tissue, facial tissue, napkin, and toweling. Other products in the tissue category include condenser paper, wrapping paper, and tea bags. The focus of this discussion will be on the sanitary grades, which account for the vast bulk of the production of tissue papers; the latter products will be discussed only briefly. In the remainder of this article, the word 'tissue' will refer to hygienic grades unless explicitly indicated otherwise.

Tissue use is very much driven by economic development. North America, western Europe, and Japan exhibit very high per capita consumption of tissue, while other regions have per capita consumptions that are small (**Figure 1**).

Growth rate data suggest that the North American market is close to saturation, as tissue growth is about the same as the population growth. Major tissue growth is expected in other regions (**Figure 2**).

Tissue production is dominated by two very large manufacturers (Kimberly-Clark and Georgia-Pacific), two medium-sized manufacturers (Procter & Gamble and SCA) and a host of smaller companies. Consolidation will continue to occur, as the four large companies have about 80% of the market in North America, 50% in western Europe, and 40% or less in other regions.

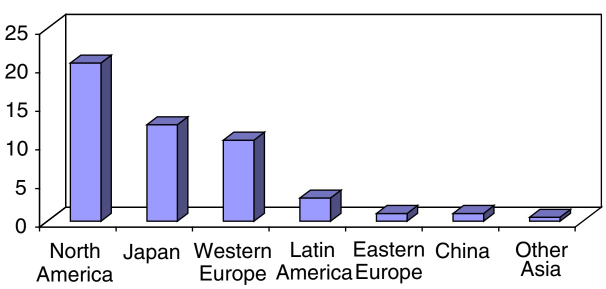

Figure 1 Per capita consumption of tissue products.

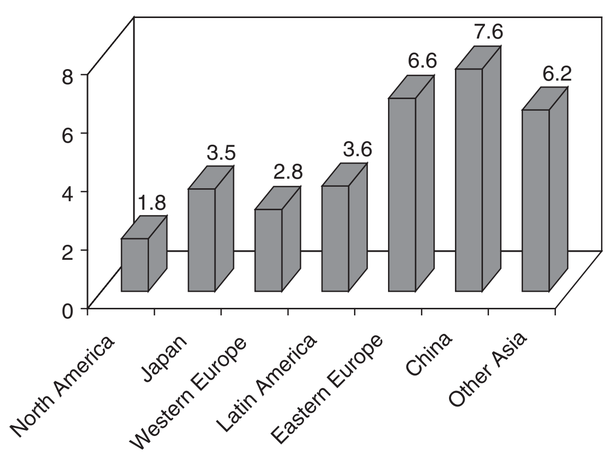

Figure 2 Forecast percentage per capita tissue growth (1994–2005).

In addition to categorization by use, the tissue market is often divided into two large distribution channel categories. Consumer tissue is that destined to the home user and brand-name recognition is critical to marketing success. Unlike most other paper products, manufacturers in the consumer tissue market channel product under their own names and do considerable marketing focused on brand-name recognition. The leading manufacturers (Georgia-Pacific, Kimberly-Clark, and Procter & Gamble) devote considerable resources to developing and protecting their brands (e.g., Brawny from Georgia-Pacific, Kleenex from Kimberly-Clark, or Charmin from Procter & Gamble.) The leading manufacturers, as well as the smaller producers, also supply products for private-label or 'house' brands. This latter market is growing substantially, especially in North America. While the consumer market is price-sensitive, product performance is paramount. The market can be segmented by performance/price expectations of the consumer as premium, value, or economy.

The away-from-home (AFH) channel distributes many of the same products as in the consumer channel, as well as some products made specifically for this distribution category. As indicated in the name, this category is for products not used in the home, and includes products distributed to hotels, food-service operations, health care, lodging, office, manufacturing, and institutions. Dispensing systems for product delivery with portion control and labor savings are an important factor. Specialty products in this channel include heavy-duty industrial wipes, heavy-duty napkins, and other specially treated products. This is a major channel for products made from recycled paper, as cost, rather than performance, may be the major selling characteristic. Performance is still important, but business owners who make the selection to service their business judge it. Tissue is generally a necessary cost and not a profit item for AFH.

Performance Characteristics

Performance of tissue products, in either the consumer or AFH segments, is critical. There are three major performance areas – softness, absorbency, and strength – that are common to virtually all tissue products. Visual appearance is an important characteristic, especially in the consumer channel. These four characteristics drive much of the manufacturing process. While the visual appearance can often be manipulated without affecting the other three to a significant extent, there are significant trade-offs in the other properties. Bulk is a key factor in product design as it signals to the user if there is enough product to do the job. Another key point is the bulk or absorbency per unit weight of fiber – getting the job done more efficiently.

Softness

Softness is a quality that is perceived by the user and, to date, has defied quantification. It is a critical property, especially for toilet and facial tissue in the consumer markets. It is becoming a more important characteristic for some toweling and for products in the AFH market where image is important. Softness has been studied extensively by the tissue manufacturers and they have drawn heavily on studies done in the fabric industry. There appear to be two components to softness as perceived by humans. A surface softness refers to the texture felt when the product is rubbed lightly across the skin (or vice versa). This characteristic appears to be related to the frequency, variability, and flexibility of the fiber ends that stick up from the surface of the tissue sheet. All three components are important. If there is no variability, then the user may perceive the product to be flat or smooth, but not soft. Similarly, if the flexibility is too low, then the product is rough. And if the frequency is too low, the product may be perceived as rough, even though the ends that stick up are very flexible. There is extensive work being done in this area, but to date the research work has not yielded quantitative models of human touch.

The other component of softness is bulk softness. This quality is related to the overall bulk and flexibility of the sheet and appears to be related to the tensile strength and modulus, tensile energy absorption (TEA), and thickness of the sheet. 'Hand' or 'drape' are similar terms from the fabric industry and the tissue industry has attempted to modify, with very limited success, test methods from the fabric industry. In general terms, bulk softness increases with the apparent thickness of the sheet and decreases with increasing tensile strength. Thus, manufacturers attempt to increase the thickness, or bulk, of the sheet while simultaneously decreasing the strength. Adding more fibers per unit area (that is, increasing the basis weight) will increase the bulk. Unless other steps are taken, however, this will also increase strength, as well as increasing cost. The goal, then, is to increase the bulk and decrease the strength at constant-basis weight. As fiber becomes more expensive, the goal becomes to reduce the basis weight without affecting other properties – a major challenge in the tissue industry.

Fiber type also plays a role in softness. Hardwood fibers tend to be short, thin, and flexible, contributing to a higher surface softness. Hardwoods also have a high number of fibers per unit weight, which contributes to a more uniform visual appearance. Softwood fibers tend to be long, bulkier, and somewhat less flexible, thus contributing more to the bulk softness component. Recycled fibers tend to be stiff, thus decreasing surface softness. However, their stiffness allows them to make a bulkier sheet, increasing the perception of bulk softness. The actual impact of recycled fibers on the tissue properties will depend upon their original source (e.g., high-yield pulp, bleached chemical pulp).

For the tissue industry, there are no agreed-upon, standardized tests for softness. Tissue manufacturers rely on human panels to measure softness and, while not truly quantitative, such tests do give relative rankings of products. Such tests can support advertising claims, but are not suitable for direct control of the process. A surrogate test that was rapid, accurate, and cheap would allow a tissue producer the ability to improve quality control of the process and lead to a competitive advantage. Such surrogate tests are under development by the major producers and hints of such work can be seen in the patent literature.

Absorbency

Absorbency is the ability of the product to absorb, or imbibe, a fluid. For most tissue products, the fluid of interest is water, and absorbency is normally measured with distilled or tap water. However, some products are required to absorb other fluids. Tampons, for example, must absorb catamenial fluids, while industrial wipes may need to absorb oils. Normal cellulose-based tissue products may need to be specially treated to meet these challenges.

For many products, the rate of absorption is of equal importance to the amount of absorption. The rate of absorption is, in general, related to the size and number of the surface pores. Relatively small pores give a high rate of absorption due to the high surface tension driving forces. Larger pores can hold more liquid. Multi-ply products attempt to deliver an optimal combination of both characteristics. The base paper of each ply can contain small pores to enhance the rate of absorption, while the space between the plies offers volume to hold the imbibed liquid.

Pore size is not directly controllable (or measured) by the tissue-maker. It is a function of the fiber type and how they bond to each other in the papermaking process. In general, low-basis-weight paper will have larger pores due to the larger spacing between the fibers, while higher-basis-weight paper, with more densely packed fibers, will have smaller pores. Increasing the basis weight to increase absorbency also increases cost.

As with softness, there is no standardized test for absorbency. Absorbency rate is usually measured by dipping a vertical strip of the product in water and observing how fast the liquid interface rises up the strip. Another option is to put a drop of water on the product and time the disappearance of the drop. Most tissue products are sufficiently absorbent so that this test is very inaccurate.

Total absorption is usually measured by placing a weighed piece of the product in water, waiting a fixed amount of time, and then extracting and weighing the test piece.

Fiber type and fiber processing are also important for absorbency. Cellulose fibers are hygroscopic and thus absorption of water into the fiber pores and on to the fiber surface are important components of the total absorption process. For most products, the bulk of the absorption is due to the physical spaces between the fibers, not absorption into the fiber pores. Absorption on to and into the fiber are probably significant components of the rate of absorption, but there is little work in this area. Virgin fibers have a much higher rate of absorption than recycled fibers due primarily to the hornification of the recycled fiber during repeated drying. Recycled fibers must be extensively treated, usually by refining, to make their absorption properties similar to that of virgin fibers. Unless recycled fibers are specially treated, products made from them will have relatively low rates of absorption. The total amount of water taken up may be equivalent to that of products made from virgin fibers as the total amount is related to the overall structure of the sheet, but they will require significantly more time to reach this final amount.

Strength

The importance of sheet strength depends upon the product. Bath tissue can be relatively weak, whereas toweling and napkin must be relatively strong. Sheet strength is primarily governed by the fiber-to-fiber bonding characteristics of the sheet. The more bonds that exist, the stronger the sheet. However, as indicated above, increasing the sheet strength generally leads to a stiffer, less soft sheet. The tissue manufacturer must balance the need for strength with the consumer's desire for softness.

Sheet strength is primarily controlled by the hydrogen bonds between the fibers. Fiber entanglement contributes in a minor way to sheet strength. As a result, when the sheet absorbs water, the hydrogen bonds are broken and sheet strength deteriorates rapidly. For bath tissue, this is not a serious problem, as it is generally used in the dry state and water absorption is not a major issue. For toweling and napkin, and facial tissue to a lesser extent, strength while wet is an important, consumer-driven property. Chemicals are added to the sheet during the manufacturing process to improve wet strength. These are normally long-chain polymers that bridge or cross-link between fibers during the drying process. Thus they impart additional dry strength as well as providing wet strength. Because they have significant wet strength, towel and napkin products are difficult to recycle as they will not break apart upon contact with water.

Visual Appearance

The visual appearance of the product, both in its roll form and as individual sheets, is an important marketing tool. This is especially true for the consumer distribution channel, but is playing an increasingly important role in the AFH distribution channel as well. The visual appearance can be affected in a number of ways. Until recently, the primary way was to treat the product during the converting process to impart a distinctive pattern on each sheet. Embossing, passing the sheet through a nip in which the opposing rolls contain a pattern, is a conventional way to impart a pattern on the sheet. This embossing could also be used to increase the bulk and absorbency of the sheet. Recently, manufacturers have developed ways to put patterns directly on the fabric used in the forming and/or drying processes.

Tissue products can also be printed to provide a distinctive visual appearance as well. Since the products are designed to absorb water (and other materials), high-resolution printing is difficult, as the ink tends to spread on the surface and creped tissue is not flat, thus destroying a crisp print pattern. Printed products tend to be slightly higher in price and are used primarily for special occasions.

Manufacture

The forming of a tissue sheet is very similar to that of other paper products. Fiber stock is prepared much like all other paper products. Virgin fiber is lightly refined to increase fibrillation; recycled fiber is more heavily refined to obtain the necessary fiber properties. The stock is cleaned, screened, and diluted to 0.5–1.0% consistency before being deposited on to a forming wire by the headbox. Both Fourdrinier and twin-wire formers are used. Modern machines are generally of the twin-wire type as they permit much higher speeds due to the two-sided drainage of the sheet. One unique modification for tissue manufacture is the crescent-former. This is a twin-wire-type machine, but the bottom 'wire' is not a true wire, but is a felt, similar to that used in dryer sections of other machines. The advantage of the crescent former is that the light-weight sheet can be carried from the headbox to the dryer without transferring the sheet. This is a significant advantage, given the light weight and low strength of tissue sheets. The combination of light-weight sheets, high drainage, and continuous sheet support allow tissue machines to reach high running speeds. Typical light-weight tissue machines will operate in the 5000–6000 ft min^{-1} (25.4–30.5 m s^{-1}) range and it is speculated that tissue machines will approach 8000 ft min^{-1} (40.6 m s^{-1}) in the not too distant future.

While the forming sections of tissue machines are very similar to that of other paper grades, it is in the pressing and drying sections that these machines differ dramatically from the other paper grades. For most tissue grades, there is no press section. One of the goals of the tissue manufacturer is to have a high-bulk, relatively low-strength product, so it is desirable to prevent the sheet consolidation and bonding that occur in pressing. Sheets are conveyed directly from the forming section at 20–45% fiber content, depending upon the forming method, to a drying section.

There are two types of drying systems in use: the Yankee dryer and the through-air dryer (TAD). The Yankee dryer is normally combined with a creping system to impart the desired properties. The TAD can be used alone or in conjunction with some form of Yankee dryer and creping.

Yankee Dryer and Creping

The in-line Yankee creping dryer was first pioneered by the Scott Paper Company in the early part of the twentieth century. Prior to their work, drying and creping were two distinct operations. The Yankee dryer removes moisture from the sheet, while creping breaks bonds and imparts bulk and softness to the sheet.

The Yankee dryer (**Figure 3**) is a large, cast-iron, steam-heated cylinder. Typical diameter is 16 or 18 ft (4.88 or 5.89 m) and the wall thickness is around 2 in. (0.051 m) to contain the pressure of the steam. The cylinder is the full width of the machine, sometimes exceeding 20 ft (6.096 m) in width, so these are massive items of construction. Steam (100–150 psia) is condensed on the inside of the cylinder and hot air (700°F (644 K)) is blown against the surface of the sheet to remove evaporated water as well as provide additional drying energy. The sheet is

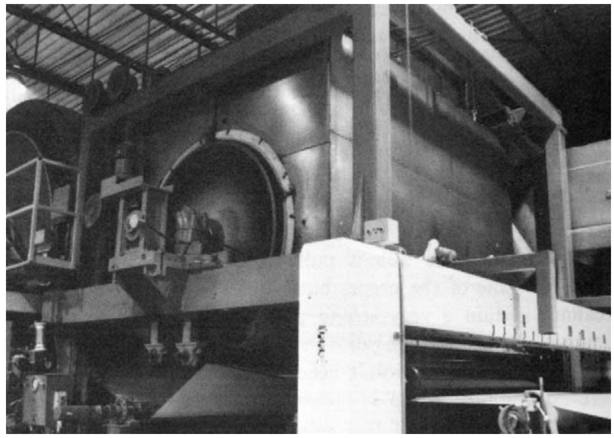

Figure 3 Yankee dryer. From *Pulp and Paper* (1978).

pressed against the Yankee surface and some water is removed in this light pressing operation. The sheet leaving the press nip is typically about 40% fiber. The sheet is then dried to around 95–98% fiber in the roughly 0.5 s that it takes to travel from this press nip to the crepe blade.

It is imperative that this drying process be as efficient as possible. As the sheet dries, it tends to lose contact with the drying surface, thus decreasing the ability of the Yankee to transfer drying energy to the sheet. To aid in heat transfer, as well as assist the creping operation, a small amount of an adhesive-type material is normally sprayed on to the surface of the Yankee just prior to the sheet nip. Manufacturers, both tissue and supplier companies, devote considerable resources to developing new and improved adhesives. A wide variety of materials have been patented, including polyvinyl alcohol, poly methyl methacrylate, and several types of poly amino amides. Exact formulation and application levels are protected by patents or kept as trade secrets. Application levels are small and the patent literature reveals application rates in the 0.5–1.0 lb (0.25–0.5 kg) of adhesive per ton of fiber.

The dried sheet is then creped off from the Yankee. The crepe blade is a thin steel blade that is pressed against the Yankee dryer and it 'scrapes' the sheet from the dryer. In effect, the sheet, traveling at about 60 miles per hour (26.82 m s^{-1}) impacts a solid-steel wall in the form of the crepe blade. The sheet buckles and fiber–fiber bonds break, imparting both surface softness and bulk to the sheet. This process is not well understood, but micrographs of a creped sheet show a large number of fiber ends, indicating broken bonds. Surface photographs show a large number of 'corrugations' or crepe bars. These run in the cross-machine direction and are up to a half-inch (0.013 m) in length. On a well-creped sheet, there will be 50–100 crepe bars per inch (1970–3940 crepe bars per meter) in the machine direction. While there is no proven theory for crepe bar formation, it is generally believed that the bars result from sheet buckling at the crepe blade. Thus the crepe process can be envisioned as repeated buckling of the sheet as it impacts the crepe blade. These crepe bars impart bulk to the sheet and affect surface softness in at least two ways. They provide some of the variability the sense of touch registers and they also provide hills and valleys for the free fiber ends to stick up and provide a component of surface softness.

Control of the creping process is critical to machine efficiency as well as producing the correct sheet attributes. If the sheet adheres too tightly to the Yankee, then it will not crepe cleanly and there will be holes in the sheet (which is a problem for later converting processes) or the sheet will tear altogether, resulting in machine downtime. If the sheet is not adhered strongly enough, then it will tend to float off the crepe blade and not provide the desired properties. At present, there is no automatic way of determining the quality of the crepe, although there are several laser-based instruments that have been tried. The current control is one of manual operation, with the machine operator judging both the sheet characteristics and the operability of the machine.

The crepe blade also plays an important role in the creping process. The crepe blade is pressed against the Yankee with a small level of force (about 10 lb (44.5 N) force per lineal inch or pli). It is believed that the crepe adhesive provides a very thin coat of organic material on the dryer and that the crepe blade cuts through part of this coating and rides on the remainder of the coating, thus protecting the Yankee surface. Thus, the crepe blade does not actually ride on the metal surface of the dryer. A new crepe blade has a very sharp corner that cuts into this adhesive layer, as shown in **Figure 4a**. As time passes, the corner is worn away and the blade starts to conform to the Yankee surface, as shown in **Figure 4b**. As this corner wears away, the surface contact area increases and the pressure applied drops, as the force pressing the blade to the surface remains constant. At some point, the pressure is insufficient to cut through the adhesive coating and the blade (at a localized point across the width of the machine) no longer crepes the sheet. This leads to holes in the sheet and indicates that the blade must be replaced. Also, as the blade wears, the crepe quality decreases. Changing the blade causes machine downtime, so blade life is a trade-off between machine efficiency and product quality. Typical blade life is in the 4–8-hour range, depending upon product type and product quality demands.

The angle the crepe blade makes with the dryer is an important part of the machine set-up, as it is difficult to adjust this angle. The set-up angle (α in **Figure 5**) is typically between 12 and 22°, resulting in a crepe angle (δ in **Figure 5**) of between 88 and 78°. The face of the crepe blade can also be beveled to adjust the crepe angle. Current belief is that the crepe angle is the critical angle for the process, not the set-up or take-off (θ in **Figure 5**) angles.

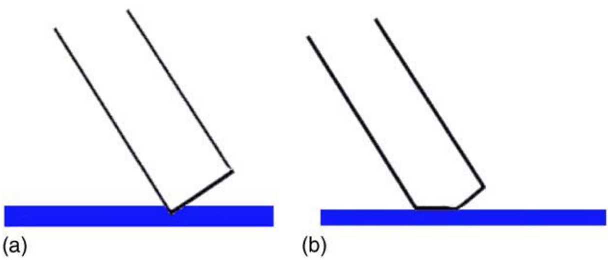

Figure 4 Crepe blades. (a) New blade; (b) worn blade.

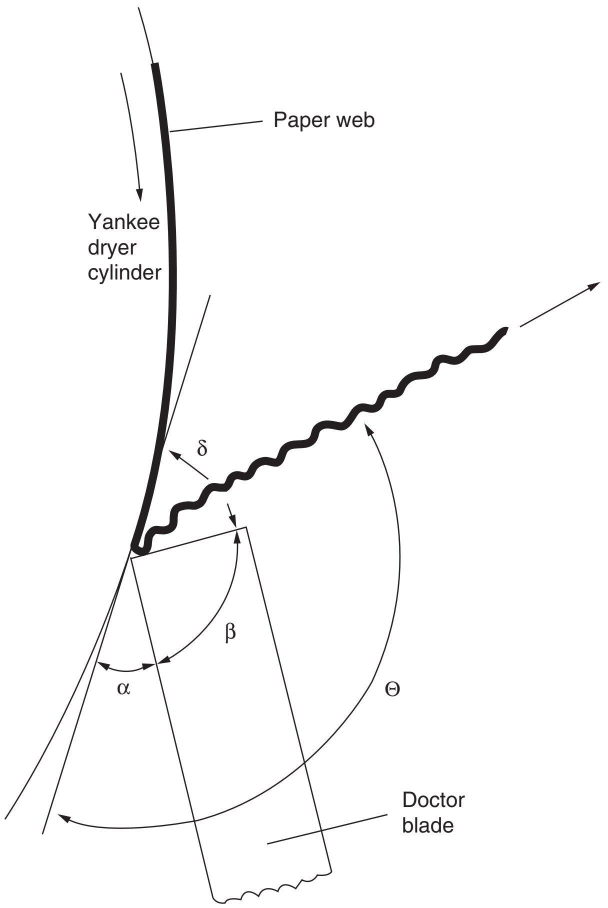

Figure 5 Crepe blade geometry. Reproduced with permission from Smook GA (1992) *Handbook for Pulp and Paper Technologists*, Angus Wilde, Vancouver.

Through-Air Drying and Uncreped Sheets

The Yankee dryer requires that the sheet be pressed against the dryer surface to assure good heat transfer for drying. The creping process is difficult to control and requires some downtime to change crepe blades. To overcome these issues and to provide a sheet with improved properties, the through-air-dried process was developed. This has recently led to a version in which the sheet is only through-air-dried (TAD) and is not creped.

The TAD is a large, open-type cylinder which is the full width of the machine. Hot air (400–500°F (477–533 K)) is blown through the sheet to dry it. Air can be blown from either the inside, with the sheet held against the TAD by a wire of some form, or it can be blown from the outside. This leads to two versions of TAD, commonly referred to as inside-out and outside-in. The main advantage of the TAD over the conventional creped Yankee dryer is that most, or all, of the water can be removed from the sheet by pressing the sheet. This leads to a bulkier sheet, as there is no press-related sheet consolidation.

In the early version of the TAD, the sheet was not completely dried on the TAD. Rather, it was taken to some intermediate dryness (around 60–70% solids) and drying was finished on a small, conventional-type Yankee dryer. The pressing necessary to adhere the sheet to the Yankee in this configuration was not damaging as the sheet was dry enough that the pressing did not consolidate the sheet. It did require a more complex machine, however, as now two drying cylinders (TAD and Yankee) were required and there was a need to transfer the sheet from the TAD to the Yankee. In addition to the drying, the Yankee was also needed to crepe the sheet to provide the desired surface characteristics.

A significant advance for the TAD process was the development of specialized forming and TAD fabrics. Conventional forming and early TAD fabrics were quite smooth, as the papermaking fabrics were designed to minimize the impression of the fabric design in the sheet itself. With TAD, it became possible, and even desirable, to leave some fabric impression in the sheet. These impressions can replace the crepe bars imparted by creping and contribute to desired bulk and surface characteristics. Operating the TAD at a slower speed than the forming section, called negative draw, can impart increased fabric impression in the sheet giving a surface with a visual texture similar to creping. This is commonly called fabric crepe and the negative draw may range from 3 to 15%. With the proper TAD fabric design, it is possible to eliminate the Yankee dryer altogether and impart surface characteristics with the fabric pattern, making full use of fabric crepe. This type of tissue making is called uncreped TAD.

While the uncreped TAD process eliminates the crepe dryer and the drawbacks associated with creping, it is not without some disadvantages. As currently practiced, it requires several fabrics and usually two TAD cylinders. This means that there are several sheet transfers, which increase the risk of sheet breakage. The additional wires are also an additional operating cost. The actual design and operation of an uncreped TAD machine is a closely held trade secret, as well as being protected by multiple patents.

See also: **Papermaking**: Overview; Paper Grades; The History of Paper and Papermaking; World Paper Industry Overview.

Further Reading

Adanur S (1997) *Paper Machine Clothing*. Lancaster, PA: Technomic.

Ampulski R, Spendel W, Sawdai A, and Weinstein B (1991) Methods for the measurement of the mechanical properties of tissue paper. In: *Tappi International Paper Physics Conference*. Kona, HI.

Biermann C (1996) *Handbook of Pulping and Papermaking*, 2nd edn. New York: Academic Press.

Carstens J (1981) US Patent 4,300,981. *Layered Paper Having a Soft and Smooth Velutinous Surface and Method of Making Such Paper.*

Costello P and Alberts C (1998) US Patent 5,753,076. *Method of Creping Tissue*.

Farrington T, Bahlman J, Burazin M, *et al*. (1999) US Patent 5,932,068. *Soft Tissue*.

Oliver JF (1980) Dry-creping of tissue paper – a review of basic factors. *Tappi* 63(2): 91–95.

Smook GA (1992) *Handbook for Pulp and Paper Technologists*, 2nd edn. Vancouver, Canada: Angus Wilde.

Coating

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Introduction

Coatings are applied to paper and paperboard for two essential reasons: to create a uniform surface for printing or to impart certain functional properties to the surface such as, grease resistance, water resistance, etc. Paper contains a series of holes formed by the overlaying of the fibers during the papermaking process. Coatings are applied to fill these holes and smooth the surface (**Figure 1**). Smoothing the surface enables the image carrier of the printing process to