

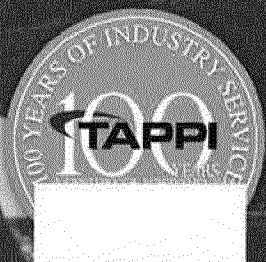
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ALSO:
STRUCTURED TISSUE TECHNOLOGIES
SUPPLIER PROFILE: GAPCON
NEW TISSUE TECHNOLOGY ROUNDUP

FEATURES

SUPPLIER PROFILE

25 Rapid Growth Puts GapCon on Global Tissue Stage

From a components supplier when founded in 2006, company is a key provider of complete systems today

NEW TECHNOLOGY

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Review features new approaches to energy/cost savings, optimization, quality



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Our cover uses an image based on one of nine panels that make up the wood mural at TAPPI headquarters in Atlanta, Georgia, that was a TAPPI fundraising project in the 1980s. Each panel represents a historical milestone in the industry and is a reproduction of an old woodcut, etching or drawing. This one commemorates construction of the first paper machine by Thomas Gilpin in 1817

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feature

Softness vs. Strength

Analysis compares Tissue Processes

Softness, Strength, Fiber, Tissue

BRUCE W. JANDA

Conventional pressed tissue processes are increasingly being supplanted by "structured tissue processes" for increased product performance. Through Air Drying (TAD) is the best known of these structured tissue processes. TAD has experienced a renaissance over the past decade. More than 30 percent of USA tissue capacity is now TAD.¹

More recently, concern about energy costs, difficult retrofitting, and pressure drop due to high ash content recycled furnishes has spurred development of alternative processes to achieve structured tissue.² About 50 percent of new U.S. tissue capacity (recently installed) employed some form of structured process.² TAD and the alternative structured processes tend to share some key characteristics in both the equipment (hardware) and processes (software) for structuring tissue. This remains an area of secrecy with little product data published. However, publicly available patent information can be used to explore the similarities and differences between the TAD process and the known alternatives.

TISSUE PROPERTY TRADEOFFS, OPERATING CURVES

Specific tissue process efficacy in creating desirable product performance can be compared using operating curves that describe inherent physical tradeoffs based on the tissue structure.

Softness versus strength. The best-known operating curve is the tradeoff between softness and strength. Softness measurement is the subject of many papers and controversy. However, the inverse and relatively linear relationship to tissue strength has been demonstrated with both panel and mechanical softness measures. Tissue strength is frequently represented by the geometric mean average of the MD (machine direction) and CD (cross direction) tensile break strength.

Most tissue is creped, which reduces MD tensile strength while increasing texture, free fiber ends, and bulk. Creping also increases MD stretch, resulting in reduced elastic modulus (stiffness). However, experience has shown that the curve can only be shifted with a major change in creping adhesion or blade

angle. Figure 1 illustrates the relative effects of improved formation, fiber, or creping on the strength versus softness relationship based on experience.

Tissue strength/softness optimization is well known and can shift the curve only so far. TAD or structured tissue moves the curve 30 - 50 percent versus conventional dry crepe by creating a network of dense and resulting stronger areas in an otherwise un-compacted web (illustrated in Figure 2). Figure 3, taken from the patent literature, shows a side view of both the un-densified pockets and the surrounding densified network that characterize TAD or structured tissue.

Figure 3, taken from the patent literature, shows a side view of both the un-densified pockets and the surrounding densified network that characterize TAD or structured tissue.

Structuring tissue requires the wet web to be differentially pressed or compacted with a pattern. This creates areas of high strength that surround uncompressed islands. Rush crepe from the forming to molding process tends to further create structure and

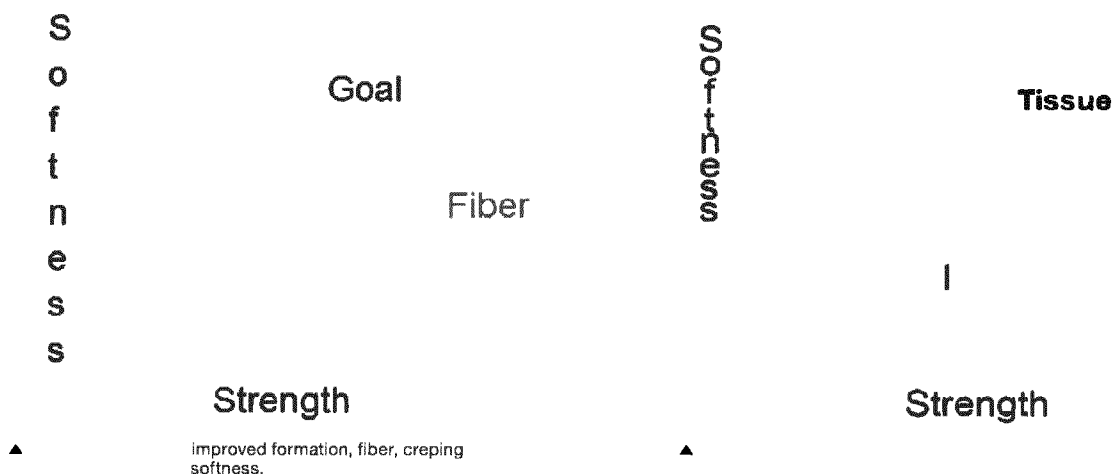


FIG. 1
FABRIC CREPE

B
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k

Structured Tissue

Dry Crepe

FIG. 2
CREPED AND STRETCH

Strength

Typical TAD Configurations

2 TAD Drums

6

20

25

7

21

U.S. Patent

Jan. 6, 2004

Sheet 1 of 14

US 6,672,992 B2

disturb the local fiber distribution of the wet web, reinforcing the compressed areas with more fiber. Good random micro formation has always been seen as a requirement for softness optimization. Counter intuitively, patterned disruption of fiber formation results in improved softness versus strength performance.

This strength network functions like a reinforcing scrim added to the web, while the uncompressed pockets continue to have low strength but retain high flexibility and cushion for softness. The molded areas and fabric crepe provide additional MD stretch beyond dry creping. More importantly, the molded pattern offers an opportunity to increase CD stretch lacking in the conventional pressed and creped tissue process. Values cited in patent literature range from 5 - 20 percent CD stretch.

Bulk versus strength. The inverse relationship between tissue bulk and strength is shown in Figure 4. Conventional tissue has focused on minimizing the pressing step where most of the web bulk is ironed out. Dry embossing is a common method to increase the bulk of tissue, but the bulk created can be ephemeral. Tight roll winding will cause it to become crushed. Emboss definition tends to be lost as the tissue structure and creping relax with time. Most importantly, the dry embossed tissue loses its definition and bulk as soon as it is rewetted.

Structured tissue processes share a common approach of wet embossing before the tissue web is dried. There are other molding

ADT- AIR DRIED TISSUE

Outer Fabric

Transfer Fabric

Drying Section

Reel Fabric

Inner Fabric

Dryer Fabric

Reel

effects, but a simplified analysis shows that the structure pattern is hydrogen bonded as the tissue is dried. This creates a greater resistance to the wet emboss pattern relaxing with time and resistance to bulk collapse when the tissue is wetted in use. The wet structured tissue will show some spring back after compression or "wet resilience." Figure 4 illustrates the effect on the process-operating curve. Structured tissue develops a strength reinforcement network that can be used to reduce the basis weight of tissue fiber required to meet a bulk target for hand feel, stack height, or roll diameter.

HARDWARE REVIEW: STRUCTURED TECHNOLOGIES

The equipment layouts or "hardware" of tissue making technologies are frequently discussed but often considered confidential, resulting in incomplete technical comparisons. This section provides a brief summary of processes based on patent literature, public papers, and sales literature.

TAD. TAD is the dominant structured tissue technology, continuing to evolve after 50 years. Typical one- and two-dryer layouts are shown in Figure 5. Earlier TAD systems used multiple smaller dryers in series. TAD

Observations:

- Conventional Crescent Former
- Shoe Press and Wet Crepe
- TAD like Shaping Fabric

42

70

Patent Application Publication Oct. 4, 2005 Sheet 15 of 20 US 2005/0173141 A1

Patent Application Publication Jun. 28, 2012 Sheet 1 of 17 US 2012/0160434 A1

2

4

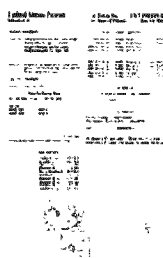
ATMOS technology

Forming:
Wet Molding

Steam Transfer:
only 25% of the

Dryness
0.10% 15% 30% 35%

Voith Paper



Source: Voith Sales Presentation and U.S. Patent

fabrics tend to have low yankee dryer surface sheet contact area that reduces the drying capacity of the yankee. This is why we see so many 18-ft. yankees at the end of TAD runs, with low apparent drying loads.

The wet un-compacted web is dewatered to about 25 - 30 percent solids using very high vacuum boxes with steam showers. This compares with about 38 - 42 percent solids from a conventional pressing process. The pickup and molding step also packs the wet web into the 3D topography of the TAD fabric using rush transfer speeds also called fabric crepe. TAD drying is very efficient but dependent on porosity of the wet web to allow the drying air to pass through. Contaminated recycled products with increased fines and fillers are not friendly to the TAD process due to the reduced porosity of the recycled web.

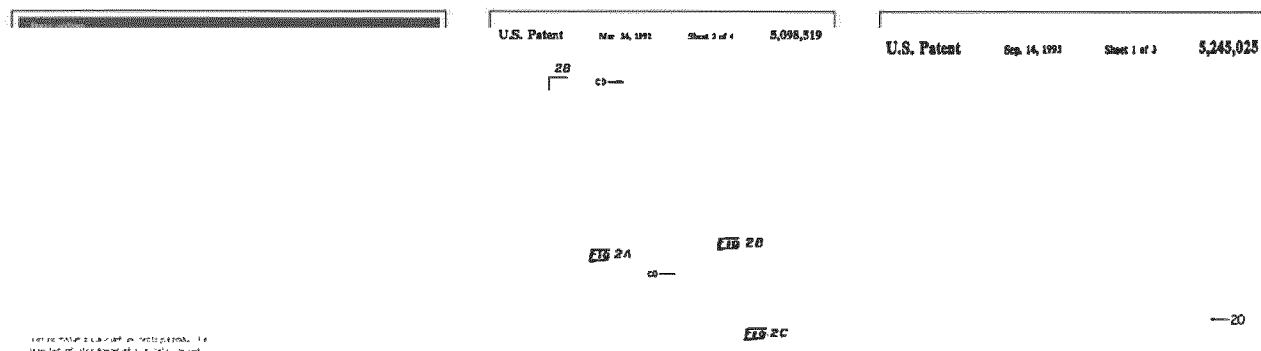
UCTAD. UCTAD is a variant of TAD with "UC" standing for un-creped tissue. This proprietary Kimberly-Clark process is shown in Figure 6. Eliminating the yankee dryer removes TAD fabric pattern design restrictions for yankee surface contact. No creping is a potential weakness for high softness grades. Compensating technologies of fabric crepe, fabric design, and chemistry are employed to boost the softness of the un-creped sheet.

ADT. ADT stands for "air dried tissue," where the sheet is dried by impinging air streams from either side. The air does not travel through the web so porosity of recycled furnishes does not affect the drying rate. Reports indicate it has been successfully added to at least one machine in the past two years. ADT could be conventionally creped on a following yankee dryer or run as an un-creped process such as UCTAD. Figure 7, drawn by Rene Naranjo, is a simplified process diagram. The individual drying units are compact and modular which may make rebuilds easier than TAD systems and big rotary dryers with concerns about CD air distribution.

eTAD. eTAD and/or fTAD are informal names in the news for a proprietary Georgia-Pacific process. The "e" is said to stand for energy efficiency as no actual through air-drying is employed. Figure 8 shows a patent application diagram describing the process. U.S. patent application 2012/0160434 and others document the product advantages.

With eTAD, the wet web is shoe pressed against a small dryer can and then wet creped and/or rush transferred to a TAD type fabric at about 30 - 60 percent solids for molding before it is pressed on the yankee to be dried and creped. Apparently, no air is blown through the web in drying and the solids transferred to the yankee are expected to be correspondingly lower. The patterned structure can be expected to limit yankee dryer contact and drying efficiency in a similar way as TAD. Figure 9 suggests the molded web is significantly redistributed to local high and low basis weight areas. This could be expected in TAD molding processes as well.

ATMOS. ATMOS (Advanced Tissue Molding System) is an alternative structured tissue technology provided by Voith. Figure 10 shows both a patent and sales presentation describing the process. Molding is said to start



at low solids using topography from the structured forming wire. A high-tension permeable belt press is used to dewater the sheet under steam or hot exhaust air showers that are drawn to a vacuum box below the belt. Web solids in this step are from 15 - 35 percent. The dewatered sheet is then molded and rush transferred on a TAD-like shaping fabric, and then transferred to the yankee at about 35 percent solids.

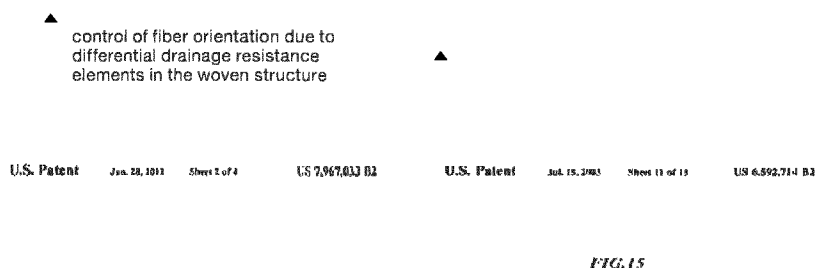
The sheet contact area on the yankee is similar to TAD at about 25 percent, resulting in the claim to not press "75 percent of the sheet for quality." ATMOS avoids the heat and electrical energy issues associated with TAD drum operation. The lower solids to the yankee and the reduced yankee contact area would be expected to reduce production throughput on a given capacity system.

NTT. Valmet is moving forward with the NTT process shown from their sales literature in Figure 11. There appear to be some similarities to the ATMOS process. The key feature noted is the laser engraving on the NTT belt that creates the structure pattern. The laser engraving process offers greater flexibility than a woven TAD fabric to create interesting consumer patterns for desirable properties. NTT claims that initial compaction of the sheet in pressing is avoided to give better results. News reports indicate at least one machine in North America is operating at this time.

SOFTWARE REVIEW: STRUCTURED TECHNOLOGIES

Another way to compare the progress of these processes is to look at the fabric designs and process settings applied to create structured tissue. These could be referred to as the "Process Software."

Forming fabric molding. Molding on the forming fabric is worthy of separate mention. Conventional wisdom is that the papermaking fabric should minimize any disruption of the sheet structure and leave no mark. Yet a patterned forming wire is the most direct process



to create structure through controlled fiber basis weight distribution patterns (as opposed to random "bad formation"). Several examples of shaping forming fabrics are shown below. U.S. Patents 5,098,519 and 5,211,815 show increased bulk, absorbency, and control of fiber orientation from the forming fabric in Figure 12. This is due to differential drainage resistance elements designed in the woven structure.

US Patent 5,245,025 shows a forming fabric with cast on structure used to create a differential continuous higher basis weight network with low basis weight zones caused by differential forming drainage presented in Figure 13. This is also a technology used to create TAD fabric patterns with planar top surface elements that cannot be woven directly. U.S. Patent 7,967,033, shown in Figure 14 is a woven forming fabric with patterned elements on the top surface to create a molded structure.

Shaping fabric molding at specific sheet solids. This review of the published literature suggests that there are optimum web solids regimes for effective wet molding. This could be attributed to the

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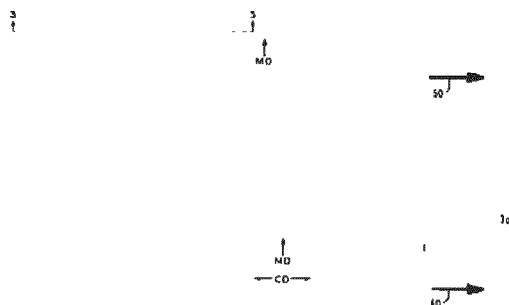
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conformability of the wet web and its ability to hold the shape imparted. TAD molding in a 25 percent solids zone appears to be most common. Molding at high solids (above 35 percent) appears to be more difficult in part due to the potential need for pressing and compaction to remove water before molding. Very high solids molding is expected to be even more difficult and the resultant technology curves should reflect different fiber use efficiencies for each process.

Shaping or TAD fabric design.

Structured tissue depends on engineered shaping fabrics for selective densification and creation of a strength network. This area has been evolving since the early TAD period. TAD fabric designs use woven knuckles to selectively densify the web and partially define un-pressed pockets that preserve initial bulk. Processes that use dry creping must make a minimum yankee surface contact area for creping adhesion. Typical required contact areas range from 18 - 30 percent. This requires significant adjustment to the TAD fabric knuckle surface. Fabric sanding is frequently used to create a surface for increased yankee contact. This has the adverse effect of reduced fabric life when fabric thickness (fabric life) is sanded away before it is installed. Some fabric suppliers use hot calendering to soften and smooth the surface without sanding.

Weaving with flat yarns is another approach.

The molding pocket depth is also limited by the ability to transfer the sheet to the yankee without creating holes or breaks. The optimal size of the pockets is referenced as

proportional to 0.25 to 3 times the fiber length in U.S. Patent 4,528,239. Un-creped processes have a much wider design window. Fabrics that support actual TAD or UCTAD processes must have minimum open areas or porosities to allow good air flow. Non-through air processes do not share this limitation and the

woven fabrics or belts employed can again focus on developing physical properties and decorations.

The strength networks created by most woven fabrics are discontinuous, defined by a series of fabric knuckles. The patent literature suggests that 10 - 20 percent improvement in

system design...

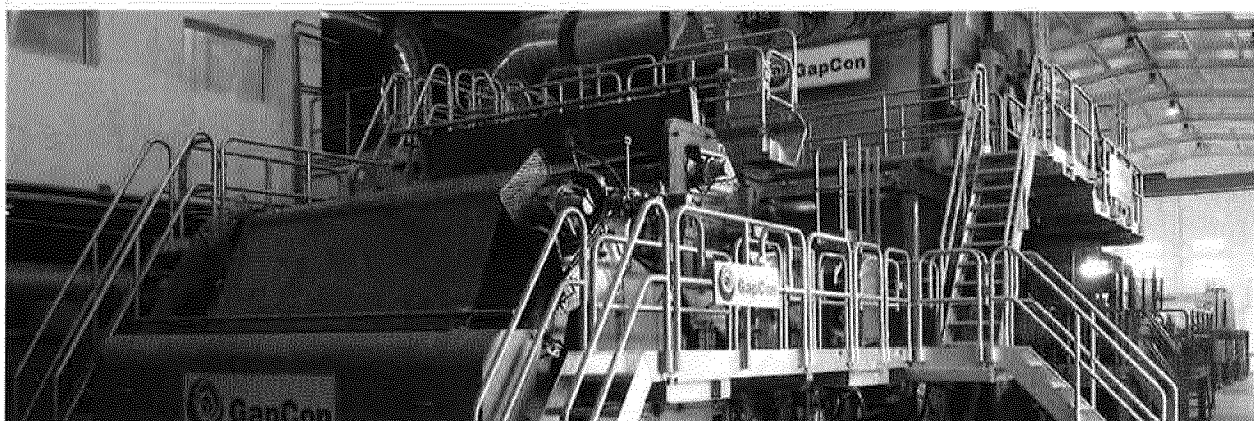
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operating curves for bulk and absorbency can be realized by creating a continuous strength network.³ This is presumably due to improved overall strength by eliminating the weak spots between the dense areas to more completely support loading. Either complex woven patterns or a nonwoven network can accomplish this.

Figure 15 shows woven fabric patterns from U.S. Patents 6,593,714 and 6,649,026 to create a nearly continuous linked strength network. They recommend 20 percent yankee contact area. Pocket depths are referenced at 30 - 60 percent based on yarn diameter ratios

US Patent 4,528,239 provides an alternative to all woven molding fabrics, as shown in Figure 16. A polymer surface is cast on top of a woven structure to create a continuous strength network. This provides increased flexibility in creating optimum shaping and runnability. Open area is controlled from 35 - 85 percent, while free span of opening is 0.25 to 3.0 times the average fiber length.

Fabric rush crepe. Fabric crepe is a key process in developing the sheet structure and is interactive with fabric or pattern design. Synergy can be achieved with subsequent dry creping or it can replace dry creping altogether. The runnability-operating window limits the speed differential and molding pocket depths possible. We can assume that web solids at the point of fabric crepe greatly influence the results from a wet sheet getting more structure to a dryer sheet, resulting in more of a MD dry crepe effect. Figure 17 illustrates the process, showing the trailing edges of the molding pockets grabbing and folding the web.

CONCLUSIONS

Structured tissue processes have common features based on wet web shaping that is dried into place with hydrogen bonding. These processes can provide a range of superior benefits, balancing physical properties that become apparent when comparing operating curves. Softness, bulk, and absorbency are improved at higher strengths. These advantages can be traced to development of a reinforcing strength network around defined pockets or pillows for softness and absorbency.

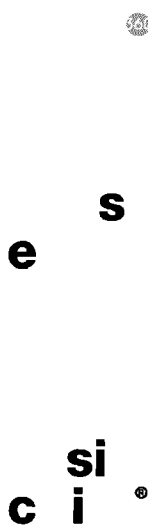
RECOMMENDATIONS

Selection of the appropriate process hardware and software requires an analysis of

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- ¹ Lindssay Gervais, "Increased Capital Spending in North American Tissue Industry Pushes TAD Capacity to 30 Percent," *Tissue360*, Spring/Summer 2013, p. 19
- ² Ken Patrick, "Structured Technologies Continue Evolving, Growing in N.A. Premium Tissue Markets," *Tissue360*, Spring/Summer 2013, p. 9.
- ³ US Patent 4,637,859, p. 22

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