

World Class Yankee Coatings – Combining the Latest Chemistry and Monitoring Techniques

By Gary Furman, Sam Archer, and William Von Drasek,
NALCO Water Company, Naperville, IL

ABSTRACT

Yankee coating chemistry has evolved over the past decade away from standard, high crosslink density PAE chemistries, toward sophisticated multi-component systems, some of which contain uniquely different base chemical platforms. The non-PAE Tulip™ platform, offered by Nalco Water, is currently at the forefront of this coating evolution. The logical next step in coating program development and sophistication is to combine the latest chemistry with new automation tools to improve application control and creping performance, thus providing a truly world class program. This paper examines efforts to couple Tulip coating chemistry with both on-line and off-line automation tools to improve process efficiency and product quality. The first tool (EWCD or Early Warning Chatter Detection) is utilized on-line to monitor crepe blade vibration and provide early warning of the onset of conditions leading to the occurrence of chatter. The second tool (NCAT or Nalco Water Crepe Analysis Toolbox) is an off-line method to monitor the crepe structure of tissue sheets. This standardized, user-friendly tool provides quantitative information to understand and optimize the creping transformation.

INTRODUCTION

As is well known, synthetic adhesives sprayed onto the Yankee dryer are predominantly of the polyaminoamide-epichlorohydrin type, also known as "PAE's" in industry jargon. If one reviews the patent literature, the evolution from solely natural based coatings, originating from hemicelluloses in the process water, to sprayed on synthetics, started in the 1970's. Synthetic sprayed on coatings were quickly accepted by the industry due to quick response times, ease of control, and more efficient use of chemicals.

The focus on PAE chemistry seems likely due to the observation of positive coating benefits when wet strength agents (also PAE-based) were being used in the wet end.

Today, the PAE-based products used in the industry can be classified into two main types, crosslinking and non-crosslinking¹. Crosslinking PAE's retain an active functional group (azetidinium ion) which can further crosslink during use. For non-crosslinking PAE's, the active functional group has been fully reacted during the manufacturing process and no further crosslinking occurs during use. The cross linking PAE's can build additional molecular weight as the active groups react under the influence of heat, pH, and concentration. These polymers are classified as thermosetting resins due to their change with heating. On the other hand, non-crosslinking PAE's do not change in molecular weight upon heating and are non-thermosetting.

The predominance of PAE's notwithstanding, other adhesives are either currently used or have been used over the past years. A short list, but certainly not an exhaustive one, includes polyamines, polyamides, polyvinyl alcohols, polyvinylacetate and copolymers, polyethers, polyacrylic acid and copolymers, animal glues, starches, and cellulose derivatives². Blends of polymers have also been used to good effect in order to obtain a set of coating properties not possible from either polymer used alone. A good example is the combination of PAE and PVOH polymers, which have been used successfully in both light dry crepe (LDC) and creped through air dry (CTAD) applications (e.g. see references 3 and 4). A second example is the blending of different PAE chemistries to provide desired levels of adhesion and durability⁵. Of course, the Yankee coatings that develop on dryers are not just composed of the adhesive, but can also include natural furnish components^{1,6}, modifiers⁷, and release agents.

Demands for improved product quality and reduced manufacturing costs continue to be at the forefront of manufacturer's objectives. Since the creping unit operation is at the heart of the tissue making process, the demands for improvement require continuous upgrading of Yankee coating chemistries as well. Manufacturer's wish lists run the gamut from low to high moisture creping. Lower moisture

creping is utilized for improved softness and bulk, while higher moisture creping is desired for energy, runnability, and speed gains, but only if softness can be maintained. These needs put stress on today's coating platforms to perform and result in the need for new and improved offerings.

Improvements are also needed from the monitoring and control aspect. Due to the complexity of the creping process, the harsh environment in which it takes place, and limited space availability, development of on-line sensors to monitor the process seem to be lagging. Likewise due to the low basis weight, minimal strength, high bulk, and compressibility compared to other paper grades, on-line sensors to monitor tissue sheet properties have also been slow to develop. While this situation may have been acceptable during past times of higher industry profits and less competition, today's competitive and profit margin squeezed environment demands progress. Tissue products must be produced at the highest possible quality levels, in a consistent manner, and with the highest possible raw material and machine efficiency. Since the creping unit operation has an overwhelming influence on both, product quality parameters and machine efficiency, development of sensors, and strategies to keep the process in control are paramount for making significant improvements in the tissue-making operation.

DISCUSSION

Tulip Coating Platform -The Tulip™ adhesive platform has been described previously^{8,9}. Tulip products are based on proprietary vinyl polymer chemistries, which can be further modified to alter the viscoelastic and adhesive properties of the resultant Yankee coating. The polymers are non-thermosetting and provided in aqueous form having solids in the range of 10-20%. Bulk product viscosities tend to be higher than PAE products and are in the 100-1000 cps range at 25°C. Product pH is near neutral.

From a regulatory and environmental perspective, the Tulip products offer a number of key benefits. Unlike PAE-based products, Tulip offerings do not contain any organic chlorides. Likewise, no VOC is present. The products are registered under major regulatory listings including EINECS/REACH, TSCA, and IECSC. Furthermore, they are approved for indirect food contact under the BfR and FDA codes.

Depending on the details of the application, Tulip products can provide greater adhesion than PAE's, which can be used by tissue makers to improve tissue softness. Furthermore, this strong adhesion is evidenced over a wide moisture range, and in practice, the Tulip coatings show excellent tolerance of CD moisture variation. This results in coatings having a very uniform appearance on the dryer surface. Tulip adhesives can be modified to provide the coating softness or viscoelastic properties desired for a particular application. Finally, the Tulip coatings show excellent durability, in conjunction with superior rewettability. This combination is somewhat unique and contributes to a wide window of operation.

Since commercial introduction two years ago, the Tulip based coatings have met with good acceptance in the tissue industry. Their versatility has led to a wide range of commercial applications, the scope of which is summarized in Table 2. In short Tulip has performed successfully with all major grades, machine types, virgin or recycle fiber, cast iron or metallized Yankees and with steel or ceramic creping blades. The Tulip adhesive can be paired with different releases and modifiers depending on the customer's product quality and machine runnability requirements. The range of creping moistures and machine speeds over which Tulip functions is quite wide.

Table 1 - Brief summary of major Yankee adhesive characteristics according to adhesive type.

Property	Adhesive Type		
	X-PAE	X-PAE	Tulip
Thermosetting	Yes	No	No
Adhesion	Low to moderate	High	High to very high
Film Softness (modulus)	Hard	Soft	Soft
Rewettability	Low	High	High
Durability in use	High	Moderate	High

Table 2 - Breadth of Tulip Commercial Applications.

Parameter	Range
Grades	Bath, facial, towel, napkin
Machine types	Crescent, TWF, fourdrinier, breast roll, CTAD
Yankee surface	Cast iron and metallized
Blade type	Blue steel and ceramic
Machine speed	750 - 2000 m/min
Furnish	Virgin, recycle and mixed
Creping moisture	1-10 %
Release types	Both oil and surfactant- based
Compatible with modifiers	Yes

MONITORING TOOLS

In order to assist tissue makers in improving and controlling the creping process, Nalco is engaged in an ongoing effort to develop sensor and automation tools appropriate for this task. These tools enable tissue manufacturers to consistently produce high-quality creped products while at the same time optimizing machine efficiencies. The tools are designed to be utilized with Nalco's coating chemistries, thus providing customers with timely and objective information to control the creping process. The first two of these sensor and automation tools to be introduced commercially will be discussed here. They are crepe blade vibration monitoring and crepe structure analysis.

Vibration Monitoring - Machine health monitoring using vibration analysis has become a routine maintenance practice in the industry¹⁰. The continuous monitoring of pumps, screens, motors, and roll bearings all involve measurement of low-frequency vibrations. Monitoring the high-frequency vibrations of creping blades, however, is not a standard practice. This type of monitoring has been utilized

for diagnostic and research purposes for some time, but is not a routine part of machine monitoring. Importantly, such monitoring can be used to detect increasing vibration levels that may eventually lead to blade chatter and marking of the Yankee dryer (see for example reference 11). Chatter has become an increasingly common occurrence in the industry as tissue makers strive for increased quality and productivity¹².

Nalco, in conjunction with development partner SKF, has been engaged in crepe blade vibration monitoring for several years. SKF brings a wide knowledge of asset management, maintenance, and condition monitoring, along with related hardware and software products. This naturally complements Nalco's offering and expertise in Yankee coating chemistries and process management. The resulting benefit to the customer is a platform for crepe blade vibration monitoring based on detailed experience with both condition monitoring and the Yankee coating itself. A basic system diagram showing the setup and components for blade vibration monitoring is provided in Figure 1. A typical installation will include 2-4 vibration sensors, most commonly, piezoelectric-based accelerometers that are mounted on the crepe blade holder. These are connected by shielded cables to a junction box adjacent to the machine. Also connected to the junction box is a tachometer the input from which allows synchronous data collection. From the junction box, a multicore cable is used to connect the sensors and tachometer to a monitoring unit which performs the data acquisition, signal monitoring, and conditioning functions. Ideally, this piece of hardware is located in the machine control room. A computer and software used to trend, analyze, and provide alarming functions completes the system. These systems are being deployed to provide asset protection on machines that have concerns with chatter. Their use enables an early warning of intensifying blade vibrations that could lead to chatter. A case study detailing the use of this system is provided later in the paper.

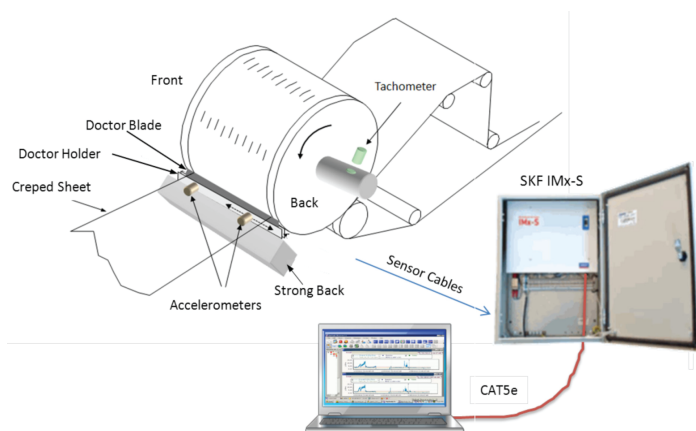


Figure 1 - Basic system diagram showing setup for crepe blade vibration monitoring system.

Crepe Structure Analysis - Nalco's NCAT crepe analysis technology was introduced a year ago at the Tissue World Americas 2010 Conference¹³. NCAT stands for Nalco Crepe Analysis Toolbox. In its current form, NCAT is an off-line sensor that provides automated analyses of crepe structure, which are reported as crepe size distributions, along with descriptive statistics of the distributions. Additionally a crepe count or frequency is calculated, and the crepe sizes are categorized in terms of fine, medium coarse, and very coarse structures. A photograph of the NCAT system is provided in Figure 2. The system comprises the sensor or imaging head, shown on the right of the photo, which is connected to a lap

top computer by a USB cable. The image obtained by the sensor head is processed by proprietary software to obtain and report the crepe structure information. Additional detail is provided in reference 13.

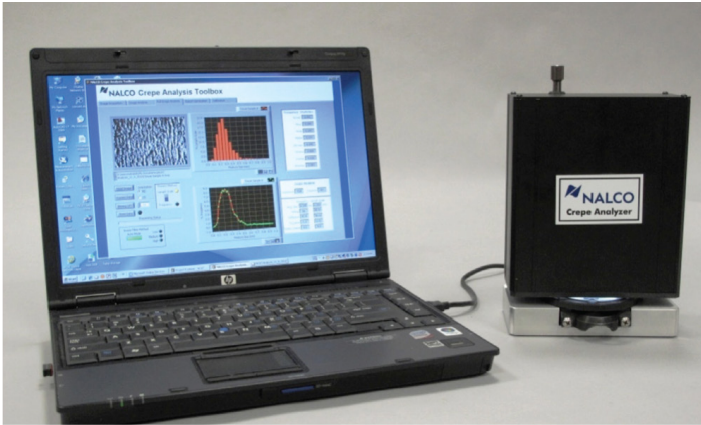


Figure 2 - NCAT system sensor head on right and lap top computer and software on left.

The NCAT technology has met with enthusiastic reception from tissue producers who find the portability of the instrument, along with fast, quantitative crepe structure analysis useful for on-site monitoring, optimization and troubleshooting of the creping process. Examples of NCAT's use with the Tulip™ coating package are provided later in the paper.

World Class Yankee Coatings

The combination of leading coating platforms like Tulip with the latest monitoring tools for the creping process can result in truly world class coating programs. In the following discussion, examples of using Tulip combined with both vibration monitoring and NCAT crepe analysis are provided. The combinations give customers additional assurance, backed by quantitative data, that the coating program is providing the desired crepe structure attributes in the sheet and asset protection of the Yankee.

Tulip and Vibration Monitoring - A European tissue producer was experiencing chatter in the Yankee coating and tissue sheet when producing a premium, high-softness grade of bath tissue. This high-softness grade, manufactured on a crescent former, required the use of wet-end softeners and ceramic creping blades to produce and maintain the desired sheet quality attributes. The incumbent coating, a cross linking PAE, was used with an oil-based release. The chatter became severe enough that the metallized Yankee surface was marked and had to be reground in order to repair the damage. Based on this experience, the mill wanted a coating that would protect the Yankee dryer and reduce chatter potential, while at the same time still deliver the high

adhesion required for fine creping and high sheet softness. In addition, the mill wanted to be more proactive in monitoring for and reacting to conditions that could lead to chatter.

For other value grades made on this machine the crosslinking PAE coating caused hard edge buildups that eventually resulted in sheet breaks and runnability issues. Felt filling was also a problem with the high add-ons of the crosslinking PAE coating. For these grades, the mill required a Yankee coating with a wide operating window that would improve the profitability of their value-based products.

Based on the mill's needs, Nalco designed a coating program consisting of the Tulip adhesive paired with both surfactant and oil-based releases. The choice of release depended on whether premium or value grades were being produced. In addition, a crepe blade vibration monitoring system was designed and deployed, similar to that shown in Figure 1. This system provided real-time monitoring and alarming of blade vibrations that could lead to harmful chatter events. For this machine, four accelerometers were installed on the crepe blade holder.

Implementation of the program provided a more uniform coating, delivering superior protection of the Yankee dryer. With the surfactant-based release, Tulip delivered high adhesion that provided the high softness required of the premium bath grade. When combined with an oil-based release, the hard edge deposits were eliminated resulting in fewer sheet breaks and improved machine efficiency for the value tissue. Good crepe results were obtained while maintaining quality parameters over the entire life of the creping blades. Additional results from the changeover to the Tulip program are briefly summarized in Table 3. The ability to reduce adhesive add-ons while increasing crepe moistures and maintaining sheet quality parameters, is especially noteworthy.

Most importantly, the combination of the Tulip coating and vibration monitoring system has prevented a recurrence of harmful chatter on the dryer. The primary purpose of the monitoring system is to serve as an early warning system to alert operators to possible beginnings of chatter, but it also provides useful information related to day-to-day operation and troubleshooting of the machine.

Examples of this usefulness are shown in Figures 3-5. Blade changes have a significant effect on vibration intensity. When in a stable condition, the normal behavior is for the vibration intensity to build to a constant level. This is reflective of the coating thickness build on the Yankee dryer. As shown in Figure 3, changing the creping blade reduces the vibration intensity, which gradually increases to a new constant level as the coating rebuilds. Similar behavior is observed for

Table 3 - Summary of Tulip coating results by grade and release type.

Program	Tulip/Surfactant-based Release	Tulip/Oil-based Release
Grade	Premium bath	Value tissue, towel and hankies
Adhesive add on	!20%	/ 40%
Reel speed	+ 100mpm	same
Creping moisture	+ 0.3-0.4 %	+0.9%
Wet end softener	+ 22%	not applicable
Felt life	same	improved

cleaning blade changes. Figure 4 provides an example where the cleaning blade is loaded for a short time. The vibration intensity is immediately reduced when the cleaning blade is loaded. Once unloaded, the RMS levels start to climb as the coating becomes thicker again.

Figure 5 provides a troubleshooting example. Here, the vibration sensor located on the front side middle of the blade holder showed a different RMS trend than the other three. Upon noticing the deviating trend of this sensor, the machine operators made a further inspection of the Yankee and coating spray boom. They discovered that one of the spray boom nozzles, located near this sensor, was plugged. The plugged nozzle was resulting in non-uniform coating in this CD position on the Yankee. After replacing the nozzle, the vibration RMS intensity returned to a normal value, similar to the other three sensors. Thus, the utility of the vibration sensors in providing early warning of impending problems including chatter was aptly demonstrated.

Tulip and NCAT Analysis - The high adhesion of Tulip™ has been found to be especially beneficial for improving

the crepe structure and surface softness of tissue grades. By utilizing the NCAT technology to monitor Tulip applications during the trial phase, and after conversion, it is straightforward to document the improvements in crepe structure. Two examples from North American mills follow.

In the first example, the customer's objectives were to improve blade life and reduce program cost while maintaining or improving sheet quality of their 2-ply bath tissue made from recycled fiber. Doctor life aver aged 8-12 hours using ceramic blades, and the sheet became "pinny" after approximately 6 hours into the blade life, using the incumbent (or baseline) PAE crosslinking coating.

Changeover to the Tulip coating and an oil-based release resulted in an immediate improvement in coating uniformity and crepe structure. Figure 6 shows the improvement in crepe structures versus blade life from four different perspectives. This figure also serves to highlight some of the capabilities of NCAT to quantify crepe structure and provide meaningful and quantitative data totissue makers.

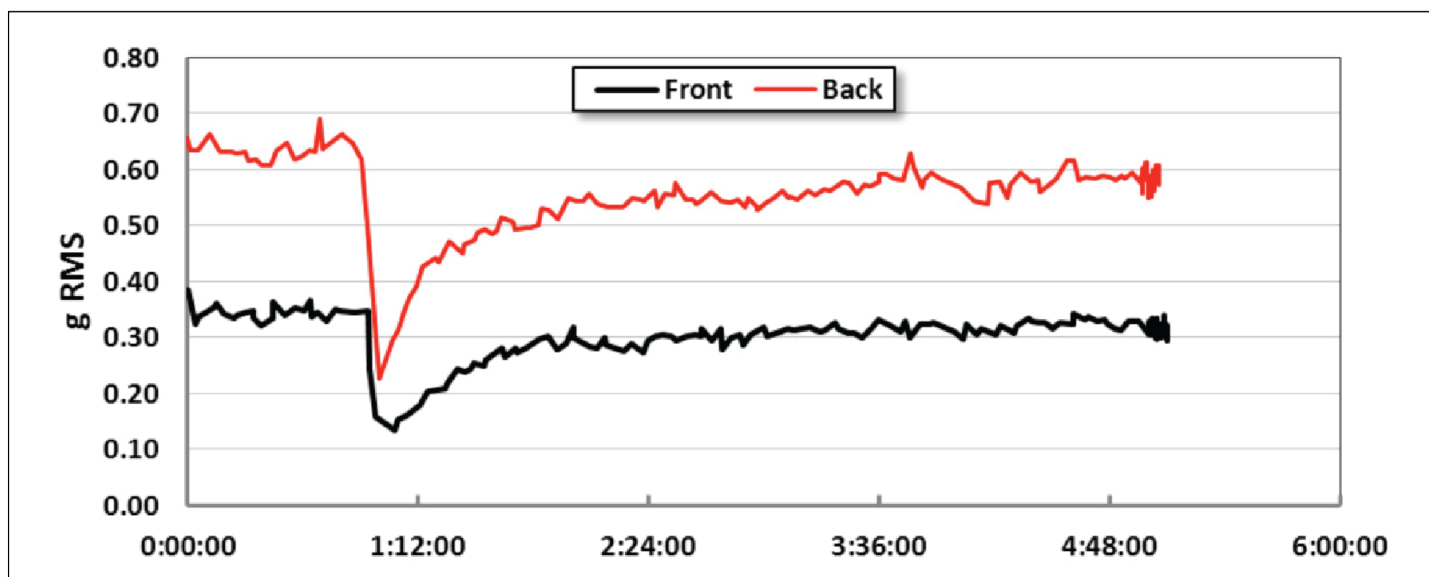


Figure 3 - Vibration intensity level (RMS) versus time showing the effect of a crepe blade change. Note for clarity only the front and back sensor vibration signals are shown.

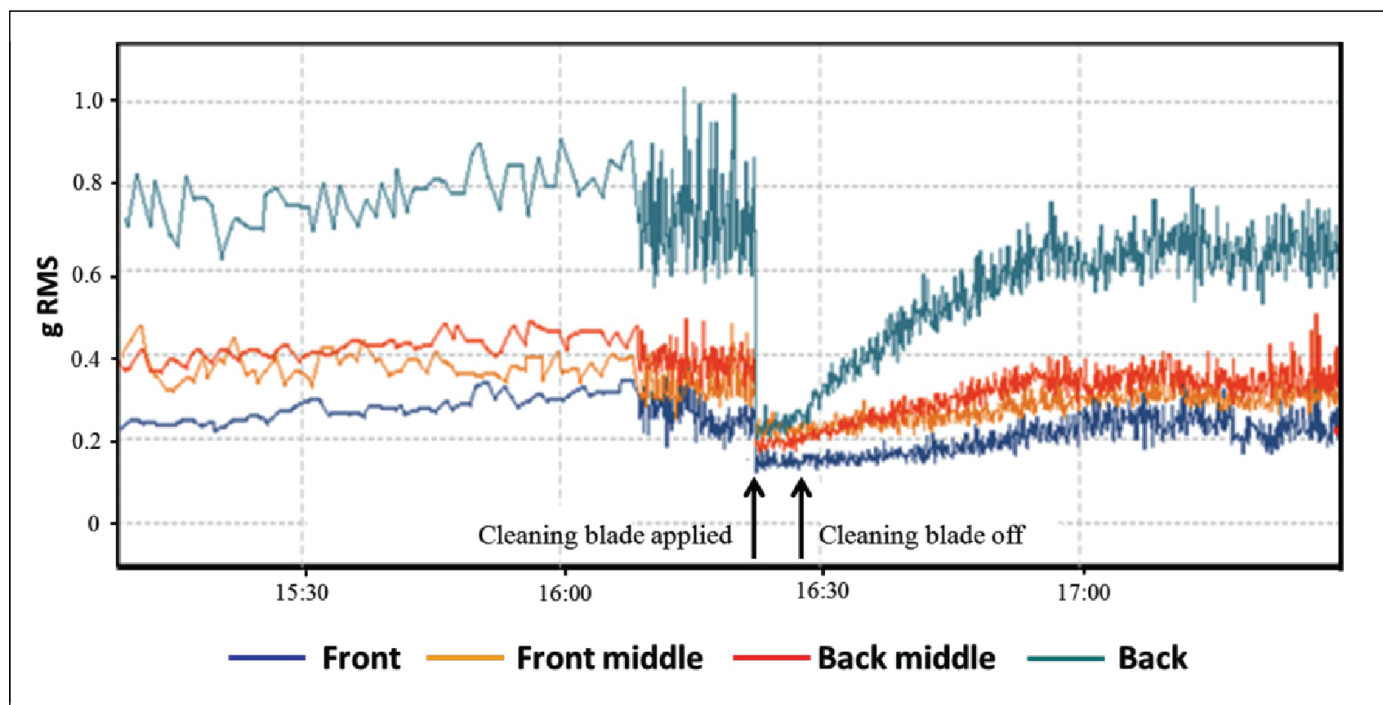


Figure 4 - Vibration intensity level (RMS) versus time showing the effect of loading the cleaning blade for a 15 minute time period. For this example data is shown for all four sensors.

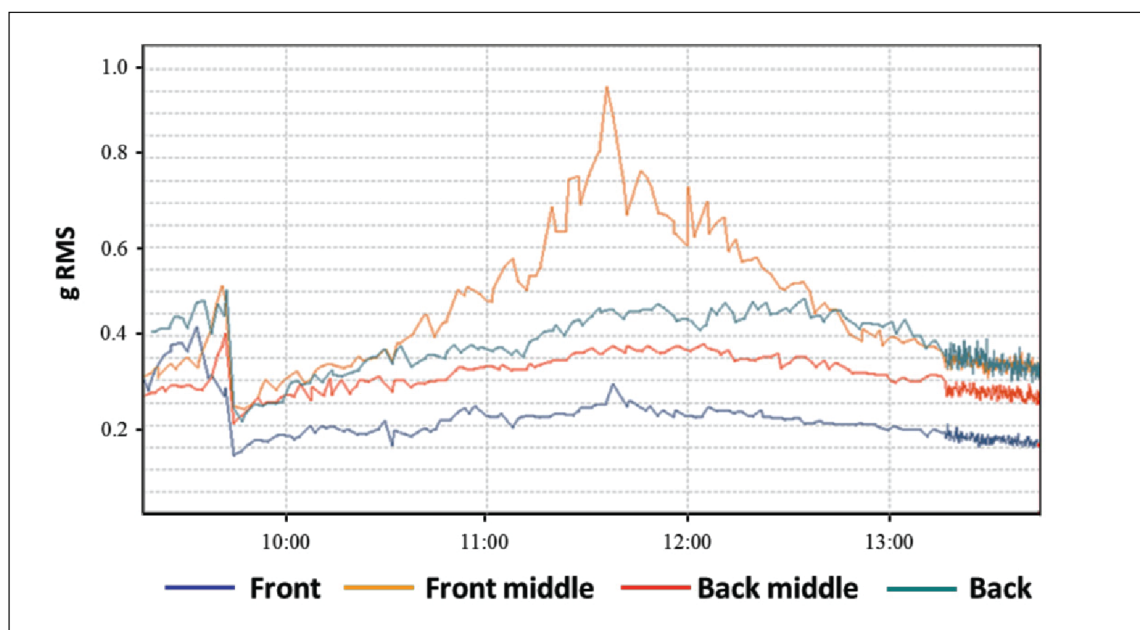


Figure 5 - Vibration intensity levels (RMS) versus time for four measurement sensors. The higher intensity top (orange) trace was linked to a plugged spray nozzle causing non-uniform coating adjacent to this sensor.

Panels 6A and 6B provide the total crepe structures for the Yankee and air (or hood) sides of the sheet. Images of the crepe structure representative of panel 6A are provided in Figure 7 (panels C and D). Tulip™ provides a clear improvement over the PAE coating that increases with blade age. Likewise, Tulip maintains sheet softness characteristics as the blade ages compared to the PAE coating. Panels 6C and 6D provide additional detail regarding the specific size classifications of the crepe structures. Tulip maintains an

edge in fine structures(< 0.25 mm) throughout the blade life. The increase in coarse structures(> 0.5 mm) as the blade ages is especially problematic for the PAE coating, as these structures are likely to hurt surface hand feel the most. Coarse structures are maintained at a low level with the Tulip coating during the second half of the blade's lifetime.

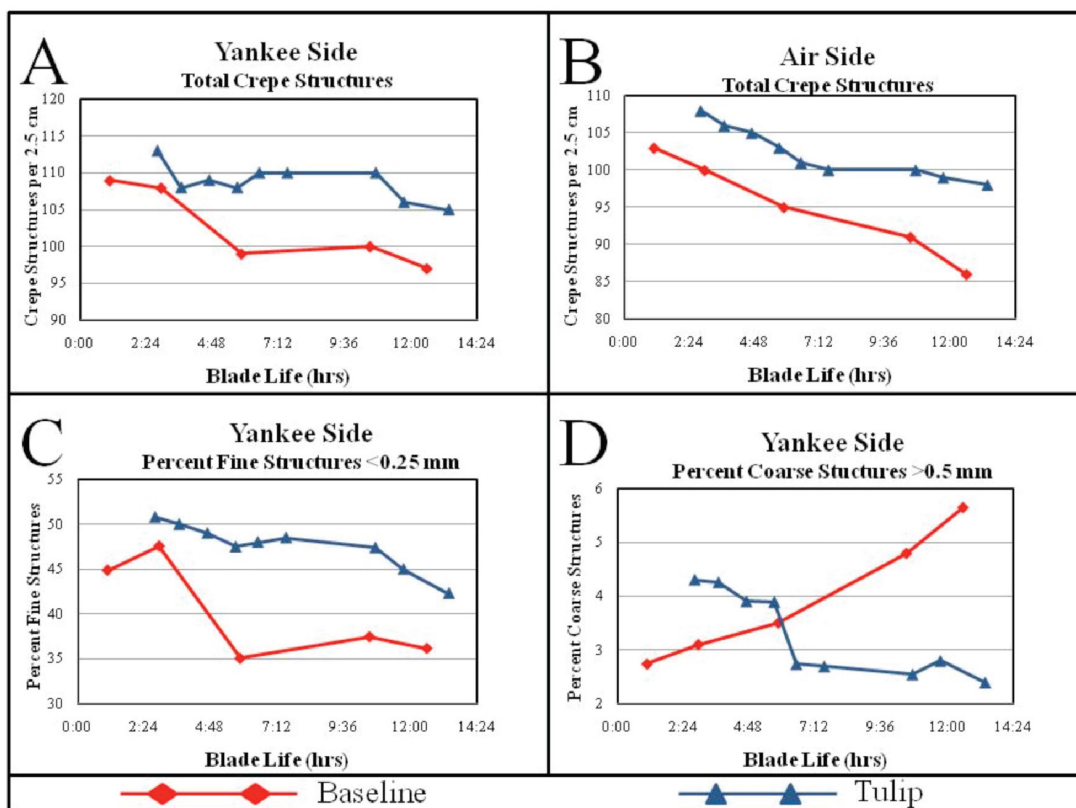


Figure 6 - NCAT analyses of tissue crepe structures versus blade life for Tulip and PAE (baseline) coatings.

Another significant benefit from the Tulip™ coating was a more uniform sheet with a large reduction in pin holes. Figure 7 shows photomicrographs of the air side of the sheets made with the baseline PAE coating compared to the Tulip coating. Panels 7A and 7B visually depict the reduction in pin holes. With this reduction, a significant increase in sheet strength was observed. This allowed a decrease in dry strength additive from 9 to 2.3 kg/MT and refining by 55%. Panels 7C and 7D depict the crepe structures for these samples. The improved crepe frequency and greater amount of fine structures for the Tulip coating was quantified by the NCAT analysis given in Figure 6. Finally, blade life showed a dramatic improvement to an average of 36 hours.

In the second example shown in Figure 8, the customer wanted to improve productivity by decreasing the number of breaks on the machine while at the same time increasing softness. The operating window with the incumbent PAE coating was extremely small for this value category bath tissue. Cross direction moisture variability on the machine led to sheet uniformity issues. In turn, converting line speeds were limited due to these paper quality problems.

Implementation of a Tulip coating in place of the incumbent PAE coating improved coating uniformity in spite of the variable cross direction moisture. Reel build in the cross-direction became uniform compared to the corrugated appearance with the PAE coating. As is typical with Tulip

programs, coating add-on was reduced by 40%. Production was increased due to fewer sheet breaks and doctor blade changes.

As shown in Figure 8, the crepe structure of the sheet was improved leading to a perceived softness improvement. The crepe structures/inch are shown during the initial trial period for the changeover from PAE coating to Tulip coating. The creping doctor blade was not changed during this 12-hour trial segment. Crepe structures/inch improved once the Tulip coating was established on the Yankee, even though the blade was already six hours old. Also the ability of the Tulip coating to provide a stable crepe frequency with blade aging is evident versus the declining crepe frequency of the PAE coating. Due to the improved sheet quality, converting line efficiency was greatly increased, resulting in a line speed improvement of 120 m/min.

CONCLUSIONS

1. Tulip™ adhesives possess a desirable range of coating properties that have led to quick acceptance by the industry. These include high adhesion, soft films, and good rewettability while maintaining high durability. Tulip has performed successfully on all major grades and machine types over a wide range of creping moistures.
2. Crepe blade vibration monitoring is straightforward to implement and provides useful benefits. A vibration monitoring system can be utilized for providing an early warning of intensifying blade vibration that leads to damaging chatter. Vibration monitoring also provides another window to the creping process regarding the Yankee coating and its application to the dryer.
3. Crepe structure analysis has been automated for off-line applications, and provided in a portable easy to use form called NCAT. The quantitative crepe structure information that NCAT provides allows tissue makers a new ability to monitor, optimize, and troubleshoot the creping process.
4. Combining the Tulipcoating technology with automation and monitoring tools like NCAT and crepe blade vibration measurement offers tissue makers additional assurance, backed by quantitative data, that the coating program is providing desired sheet attributes and protection of the Yankee.

REFERENCES

1. Grigoriev, V., Furman, G., Archer, A., Su, W., Kaley, C., and Frette, G., "Wet-end Impacts on the Creping Transformation," PTS Tissue Symposium 2008, March 3-4, 2008, Munich, Germany.
2. G.S. Furman and W. Su; Nordic Pulp and Paper J., 1993, Vol. 8, No. 1, pp. 217-222.
3. U.S. Patent 4,501,640. Soerens, D. A. (assigned to Kimberly-Clark Corporation), "Creping Adhesives Containing Polyvinyl Alcohol and Cationic Polyamide Resins." February 26, 1985.
4. U.S. Patent 6,187,138. Neal, C. W., Forde-Kohler, L. J. and Salsman, D. A. (assigned to The Procter & Gamble Company), "Method for Creping Paper." February 13, 2001.
5. U.S. Patent 6,277,242. Archer, S. L., Dristas, R. E. and Gray R. T. (assigned to Calgon Corporation), "Creping Adhesive Containing an Admixture of PAE Resins." August 21, 2001.
6. G. Furman, R. Phillips, and S. Archer, "Wet End Impacts on Creping, Part I - The Effect of Retention and Drainage Aids

on Yankee Coating," Tissue World 2007, Nice, France, March 2007.

7. G. Furman, V. Grigoriev, W. Su and C. Kaley; "Effects of Modifying Agents on Adhesive Film Properties - Findings Toward Improved Yankee Coatings," Tissue World Americas 2004 Conference, September 21-23, 2004, Miami Beach, Florida.
8. Grigoriev, V. A., Furman, G. S., and Frette, G., "New High Adhesion Creping Technology for Improved Sheet Properties and Energy Savings," Tissue World 2009 Conference, Nice, France, March 23-26, 2009.
9. Furman, G., Archer, S. and Zha, H., "New High Adhesion Creping Technology for Improved Sheet Properties and Machine Productivity," Tissue World Asia 2010 Technical Conference, Shanghai, China, November 17-19, 2010.
10. Swansen, D., "Paper mill gains from condition monitoring," Evolution, ed. 3/00, Sept. 16, 2000, pp. 26-30. <http://evolution.skf.com>
11. Alessandrini, A. and Pagani, P., "Chatter Marks: Origin, Evolution and Influence of the Creping Doctors," Tissue World 2003, Nice, France, March 2003.
12. Archer, S., Grigoriev, V., Furman, G., Bonday, L. and Su, W., "Chatter and Soft Tissue Production: Process Driven Mechanisms," Tissue World Americas Conference, March 11-14, 2008, Miami Beach, Florida.
13. Archer, S., Furman, G., and Von Drasek, W., "Image Analysis to Quantify Crepe Structure," Tissue World Americas 2010 Conference, March 24-26, 2010, Miami Beach, Florida.

ACKNOWLEDGEMENTS

The authors would like to thank Tom McClymont, Alberto de Martino and Larry Bonday from Nalco, and Ed Bondoc from SKF for their contributions to portions of the work described in this paper.