Reprint R-1104

Yankee Coating Systems - The Functional Interface

By Sam Archer and Gary Furman, Nalco an Ecolab Company
1601 West Diehl Road, Naperville, IL 60563, USA,

ABSTRACT

At the interface between the Yankee dryer surface and the tissue web resides a thin film comprising an agglomeration of materials we call a Yankee coating. The Yankee coating is composed of chemical additives applied to facilitate development of specific film properties (e.g. adhesion and release) and "natural" components from the wet end, process water along with cellulosic material from the sheet. For a coating to provide "Best Practice" results it must be able to protect the Yankee surface and be optimized to deliver the proper level of uniform adhesion for commercial creping operations.

In order to properly manage the creping unit operation, it is important to understand the different types of Yankee coating materials (e.g. adhesives, releases, modifiers) and how they work together to provide a functional film. In building this understanding a mechanistic view of coating systems will be reviewed along with interactions of various components on the Yankee surface. A general applications guideline will be presented highlighting process specific differences with reference to desired coating system characteristics. Further discussion will review coating system "watch outs" and potential corrective measures. A case study will be presented to illustrate the impact of different Yankee coating systems on the tissue manufacturing process.

INTRODUCTION

Every day tissue makers manufacture thousands of tons of products by creping tissue from the surface of a rotating Yankee dryer. The general process relies on attachment of a light weight sheet of fibers to the surface of the Yankee dryer at the pressure roll nip, drying the sheet to a desired product moisture level and mechanically removing this sheet from the Yankee dryer with a creping doctor blade. The commercial process is supported by having a receptive, adhesive coating on the Yankee surface prior to the pressure roll to facilitate efficient sheet transfer and adequate adhesion at the creping doctor blade to support the development of desired sheet properties.

As the coating is critical to the overall function of the tissue making process, it is important to understand more about this thin layer that is resident on the surface of the Yankee dryer. Understanding the important performance criteria of the coating, how the coating forms on the Yankee surface, and how to change performance attributes provides essential knowledge to optimize the creping transformation and ultimately the tissue making process.

There are three critically important performance functions that any Yankee coating must provide in both the machine and cross directions.

1. The coating must facilitate protection of the Yankee surface – both from mechanical and chemical induced defects.
2. The coating must provide adequate adhesion between the sheet and the Yankee to support:
   a. Development of product attributes at the creping doctor blade tip.
   b. Adequate sheet control from the doctor blade to the reel to support desired speed.
3. The coating must be:
   a. Soft enough to allow doctor blade tip penetration below the sheet - coating interface throughout the life of the creping doctor blade.
   b. Hard enough to prevent complete blade tip penetration to avoid metal to metal contact.

Figure 1 shows an even "gray" in appearance functional coating on a Yankee dryer surface after the spray boom and prior to the pressure roll nip. In this best case scenario the coating appears even and gray to white in appearance. It is very difficult to determine if all the critical functions of the coating are being met but the coating is extremely uniform. Figure 2 shows an uneven coating with a high degree of variation. In this image the variation that is present would indicate that some of the critical performance functions are probably compromised.

Printed with permission of UBM Asia Trade Fairs Ptd., Ltd. Presented at Tissue World 2013, March 18-21, 2013, Barcelona, Spain

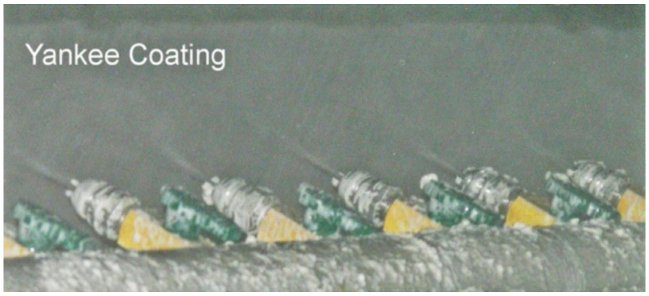


Figure 1 – *Photograph showing a functional coating on a Yankee dryer that is uniform.*

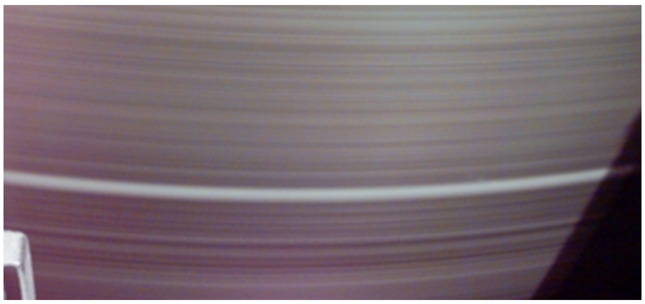


Figure 2 – *Photograph showing a functional coating on a Yankee dryer that is streaky and non-uniform.*

In most cases the critical performance functions of the coating are supported by the presence of a uniform thin layer of material on the surface of the dryer. This thin layer protects the Yankee surface by providing a functional layer between two surfaces having high mechanical energy - the tip of the doctor blade and the surface of the Yankee dryer. By developing a Yankee coating with appropriate durability and hardness characteristics, the tip of the doctor blade can penetrate into the coating, below the sheet of paper, and still be above the metallic surface of the Yankee dryer during the creping process. Figure 3 conceptually illustrates the impact of three different coating hardness conditions that can develop on the surface of the Yankee dryer. Figure 3a depicts a coating that has the correct hardness. Here the coating allows the tip of the creping doctor blade to penetrate into the coating and stay under the sheet, but does not allow the tip to go all the way through the coating and ride on the metal surface of the Yankee dryer. Figure 3b illustrates what can happen if the coating that develops on the Yankee dryer gets too hard for the tip of the blade to enter. Here the doctor blade can start to vibrate due to a phenomenon known as "stick slip". When this occurs the tip of the doctor blade moves away from the Yankee surface and back into the Yankee coating on each cycle. If this phenomenon is left uncorrected, the doctor blade tip will cause loss of process integrity and potentially will damage the surface of the Yankee dryer (Archer 2011). Figure 3c illustrates what can happen if the coating is too soft to properly support the doctor blade tip. In this condition the tip of the doctor blade slices down and through the coating and begins to ride on the metal surface of the Yankee. The doctor blade tip will get extremely hot and will wear due to high levels of metal to metal friction (Paczkowski, 2009). Mechanical erosion and erosion/corrosion mechanisms can develop with continued heat and the high temperatures at the tip of the doctor blade ultimately leading to damage of the Yankee surface.

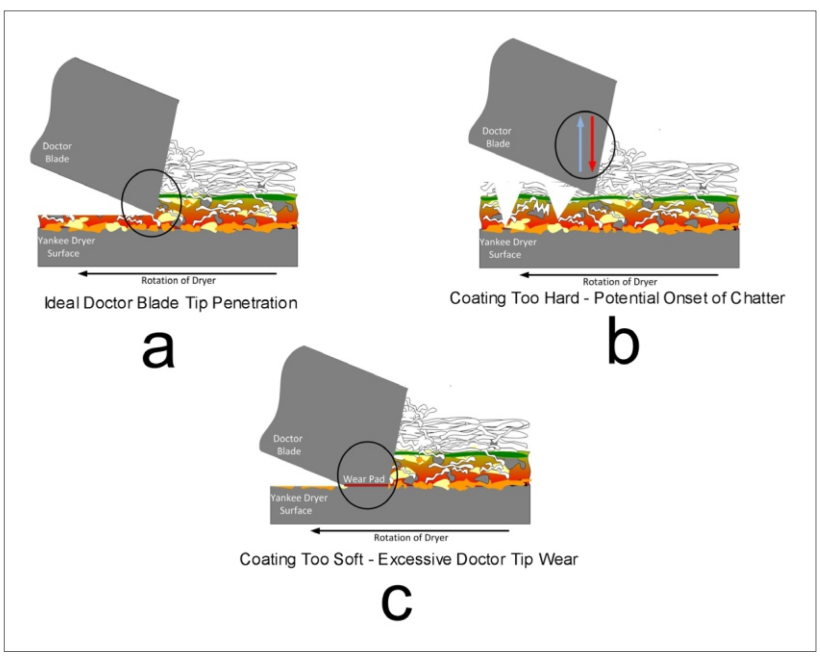


Figure 3 – *These illustrations show what can happen when a functional coating has the correct hardness, is too soft, or too hard.*

FUNCTIONAL YANKEE COATING

Characteristics of a Functional Yankee Coating – as described by "Coating Space"

The coating that develops on the Yankee dryer is a complex agglomeration that is composed of not only adhesive and release materials applied at the spray boom, but also fibers and fines from the sheet, ash and wet end chemistries from the furnish, and minerals from the process water. It is also affected by machine operations and creping conditions. A practical way to understand the characteristics of Yankee dryer coatings is to use a model known as "Coating Space" (Figure 4), (Archer, 2005). This model describes critical coating properties that facilitate sheet transfer at the pressure roll, creping and ultimately protection of the Yankee dryer surface.

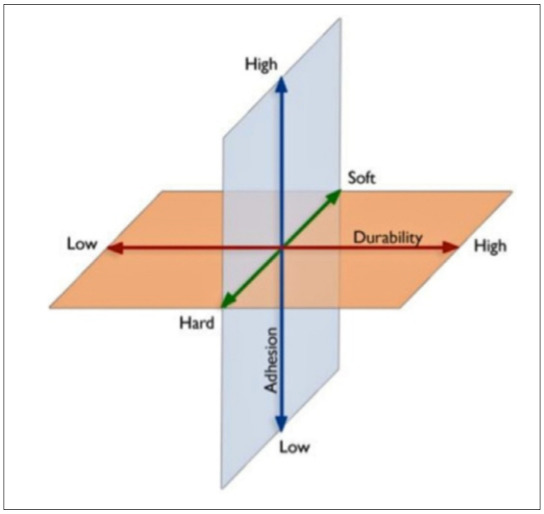


Figure 4 – *Depicts the three axes defining film properties within the domain of Coating Space™*

Coating Space is a three-dimensional domain defined by the axes of:

- **Adhesion** – Ability to quickly adhere and transfer a moist web at a pressure roll nip and develop useful levels of sheet to Yankee adhesion at the creping doctor.
- **Durability** – Stability in high moisture environments. To be useful the coating must be resident on the Yankee surface through all phases of drying and creping.
- **Softness (Hardness)** – Ability to allow intimate contact of the sheet with the coating at the pressure roll nip and the appropriate level of doctor tip penetration to protect the Yankee dryer and allow continuous production.

When adjusting coating properties and working with the Coating Space model, it is important to remember that, changing a coating property along one axis will normally result in concurrent movement along one or both of the other axes. As Yankee coating properties change due to, for example, use of chemical additives or process changes, it would be expected that adhesion, film softness and durability may all change. By careful observation of the coating and creping operation it is possible to characterize the changes such that they are defined by the axes used in the Coating Space model. The axes displayed represent normal characteristics that most operators work with and manage every day.

How a Functional Yankee Coating Forms

As stated earlier the gray to white material observed on the Yankee dryer surface during normal operation is a complex agglomeration of materials. A conceptual depiction of a Yankee coating is shown in Figure 5.

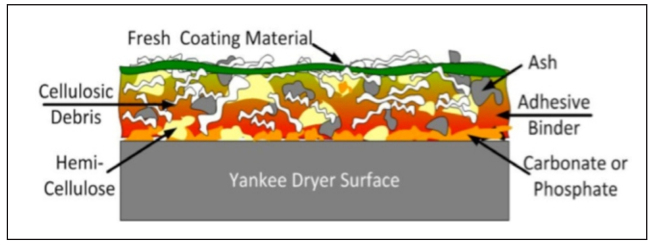


Figure 5 – *This depiction shows the composition and z-directional nature of materials found in a functional Yankee coating.*

Normally this coating builds over time as the system comes into operational equilibrium.

When the functional Yankee coating is broken down into its components, they can be grouped according to process specific drivers. Some of these drivers are chemical in nature and others are part of the process design. As shown in Figure 6, these drivers and process specific components can be defined by four general categories,

1. ***Cellulosic materials and ash*** – These are the dominant materials found in a Yankee coating and are driven by furnish selected to produce a specific type of product. When secondary fiber is used in place of virgin fibers as the source of the product furnish, the amount of inorganic ash in the coating will be higher, but is always far less than the cellulosic component.
2. ***Wet end additives*** – This group of materials is driven by desired finished sheet attributes. They can have significant impact on a Yankee coating.
3. ***Operating conditions*** – How the machine is designed and operated defines the environmental constraints for the development of a Yankee coating. Operating conditions such as pH, creping moisture, creping geometry and how the preceding unit operations are managed can all have great impact on coating development.

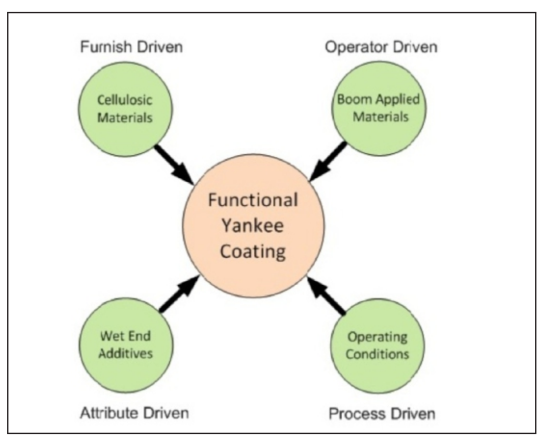


Figure 6 – *Illustrates the process specific components and tissue making drivers that come together to form the functional Yankee coating.*

4. ***Boom applied materials*** – The actual amount of material applied through the boom and found in the Yankee coating on the dryer is relatively low, but the impact is huge. It is the only process control point where materials are added with the express purpose of optimizing the creping process. The materials applied through the spray boom are designed to be very aggressive, as their concentrations are very low, but with the expectation that small changes will have significant impact. Adhesive materials act as binders and releases/modifiers are designed to allow control of the adhesion and coating thickness, as well as mitigate hard coating development and the detrimental issues that can follow.

Carbohydrates and Ash

All tissue products are made from cellulosic fibers, but the source and type of these fibers varies greatly. The type of furnish utilized in tissue manufacture is determined by the products that are being produced, the cost of manufacture and fiber availability. Globally, approximately 50% of the fiber used in tissue is based on virgin materials while the other 50% is produced from recycled fiber. There are major differences within the entire furnish category stretching from relatively clean virgin fibers to recycled grades that can contain a significant amount of ash and other extraneous materials. It should also be remembered that all furnishes contain a fines fraction, defined classically as the portion of furnish passing through a 76 micron screen, or as measured by modern classifying instruments, as that portion of the furnish less than 0.2 mm (length weighted average). The higher the fines content in the furnish, the higher the cellulosic component in the coating is likely to be. Typically northern bleached softwood kraft market pulps will have fines contents between 3% and 4.5% of the total furnish while northern bleached hardwood kraft market pulps will have fines contents between 4.8 and 14.9% (Nanko, 2005). Eucalyptus market pulps will have fines contents between 4.2% and 8.3% and recycled fiber furnishes will have fines contents in the upper end of the hardwood range (Nanko, 2005). These fines are more easily pulled from the sheet as it is dried on the Yankee and incorporated into the coating. Recycled fiber represents a wide range of quality alternatives but generally has fibers that have been dried multiple times along with a potpourri of inorganic and organic extraneous materials that contribute to and influence the development of functional coating on the Yankee dryer.

Previous technical work has demonstrated that as more fibers, fines, fibrils and inorganic materials are included in the coating, the adhesive agglomerate that forms gets harder and adhesion goes down (Archer, 2011). This seems to follow a reinforcement mechanism provided by the insoluble cellulosic or inorganic physical elements. The practical observation is that as the coating becomes harder and more durable there is a significant loss of adhesion.

Wet End Additives and Water Chemistry

Since the tissue maker produces different products from a given set of furnishes, it is often necessary to add an array of functional and process chemistries to the wet end of the paper machine. These chemistries are used to help manage functional properties such as strength, absorbency and softness, and process issues such as foam generation, stickies, microbial control and felt hygiene, and to improve overall fiber and chemical retention. Some of these chemicals also find their way to the Yankee surface as free floating chemistries, or attached to high surface area fines and colloidal materials. The mechanism that describes the migration of materials through a sheet during drying is known as the Dreshfield Effect (see Figures 7 and 8) (Dreshfield, 1956).

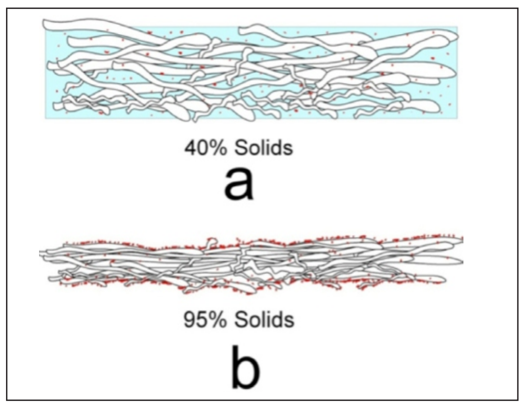


Figure 7 – *Illustrations demonstrating the Dreshfield effect. (7a) As the sheet leaves the pressure roll nip at 40% solids, some chemicals along with fines and colloidal materials are dispersed in the free water between the fibers. (7b) As the sheet dries, the smaller materials concentrate as they move to the surfaces of the sheet.*

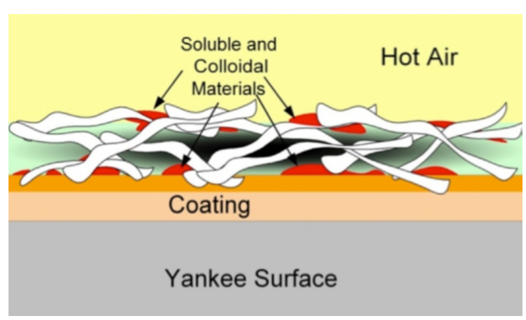


Figure 8 – *Illustration showing that ultimately some of the materials on the surface of the fibers become part of the coating and affect its characteristics*

These materials often impact the the functional coating that develops on the surface of the Yankee dryer and can result in loss of productivity and negatively impact product quality. Understanding how different wet end components influence the characteristics of the functional Yankee coating allows for corrective and timely process interventions (see Table 1).

Operating Conditions

Many of the operating conditions on the tissue machine are determined by the product properties that are desired in the finished products. Away from home or commercial tissue will be produced differently than at home or consumer tissue. Even within a commercial market segment there will be significant differences in the manufacturing set up of one machine compared to another. The creping unit operation shows some of the most significant differences between grades of tissue. The way the creping process is set-up will have significant effects on the development of the functional Yankee coating as shown in Table 2.

Boom Applied Materials

When a Yankee coating is collected from the dryer surface and analyzed, the majority of material that will be identified will be carbohydrates and ash. Although these materials dominate coating composition, they normally cannot be changed by the operator to affect the coating hardness, adhesion or durability. Typically creping specific materials are added to the Yankee surface through the spray boom (see Figure 9) to influence critical creping characteristics of the coating.

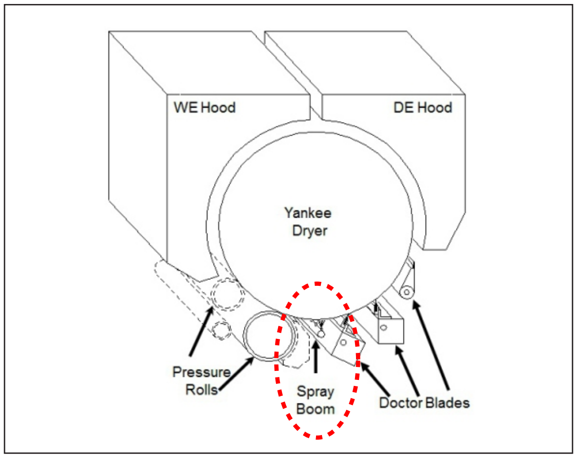
A recent study (Boudreau, 2009) showed only approximately 0.5-1.5% of the coating scraped from the dryer was due to the adhesives applied through the spray boom. Even though the percentage of spray-applied materials is low, the impact of the adhesives and releases cannot be understated. The thickness and robust characteristics of the coating that develop on the Yankee dryer can be a direct result of the materials that the operator added through the spray boom. Some of these materials act as powerful adhesive binding materials and coating modifiers. With a proper choice of adhesive, release or

Table 1 – *Typical impacts of wet end components on functional coating properties. The base coating material on the Yankee dryer is assumed to be a non-crosslinking PAE creped at 4-5% moisture. Expected interactions are with the wet end component listed. (Symbols: ↑ = Increase, ↓= decrease, ↔ = variable, increasing number of arrows = increased effect)*

Wet End Component	Impact on Coating Hardness	Impact on Coating Adhesion	Impact on Coating Durability	Impact on Coating Thickness
Wet Strength Additives	↑↑	↑↑	↑↑	↑↑
Dry Strength Additives	↔	↔↑	↔↑	↑↑
Debonder and Spray on Softener	↓↓	↓↑	↓↓	↓↓
Hemi-cellulose	↑↑	↓	↑↑	↑↑
Fines	↑↑	↓↓	↑↑	↑↑
Calcium Carbonate	↑↑	↔	↑↑	↑↑
Defoamer (Oil based)	↓↓	↓↓	↓↓	↓↓
Retention Aid	↑↑	↔	↑↑	↑↑

Table 2 – *Summarizes some of the general differences in operating conditions and the impacts on building a functional Yankee Coating. The base coating material on the Yankee dryer is assumed to be a non-crosslinking PAE creped at 4-5% moisture. (Symbols: ↑ = Increase, ↓ = decrease, ↔ = variable, increasing number of arrows = increased effect)*

Operating Condition	Impact on Coating Hardness	Impact on Coating Adhesion	Impact on Coating Durability	Impact on Coating Thickness
Lower Moisture Creping (<3%)	↑↑	↔	↑↑	↑↑↑
Higher Moisture Creping (5.5 to 8%)	↓↓	↑ ↔	↓↓	↑↑
Increased Pocket Angle	↑↑	↔	↔	↓↓
Decrease Pocket Angle	↑↑	↑↑	↔	↑↑
Closed Water System	↑↑	↓↓	↔	↔
Higher pH	↑↑	↓↔	↑↑	↑↑
Lower pH	↓↓	↔	↓↓	↔
Higher Add-ons	↑↑	↑↑	↑↑	↑↑



– Indicates the location of the spray boom utilized to apply unique coating materials to the Yankee dryer.

modifier the entire functional coating that builds on the dryer can be adjusted to deliver a wide spectrum of adhesive, durability and hardness properties.

Adhesive Applied Through the Spray Boom: There are a number of different types of water soluble adhesives available for the tissue machine operator to use to provide needed sheet adhesion to the Yankee dryer. The materials are categorized into several general types as listed in Table 3. Each type of adhesive can be further broken down into chemical and structural variants that have been designed to deliver specific adhesion, durability and hardness characteristics in its pure state. When these materials are applied to the Yankee surface through the spray boom, the resulting coating conglomerate will take on some of the characteristics of the pure material, but also be influenced by the carbohydrates, ash and wet end chemistries that are present.

For many years, the most common Yankee adhesives have remained those based on polyaminoamide-epi chlorhydrin, or PAE chemistry. Different molecular weights, crosslink densities and modification technologies have been used to extend the levels of adhesion, durability and hardness that can be provided on the Yankee dryer. PAE-based adhesives are typically grouped into two types, crosslinking and non-crosslinking PAE resins. A key difference between these two groups is the effective molecular weight that can be achieved on the Yankee surface. Crosslinking PAE adhesives can develop higher molecular weights in use, resulting in coatings that are significantly more durable and which tend to be harder. The durability is ideal for tissue manufacturing where moisture variation is very high, or where the process is designed to crepe at high moisture (for example wet crepe). With non-crosslinking PAE adhesives, the molecular weight is controlled during manufacture. The lower effective molecular weight in use results in an adhesive with a greater affinity for moisture (rewet), lower durability, softer film characteristics and generally provides good adhesion characteristics.

Table 3 – *This simple table lists categories of adhesive chemistries. The described Coating Space properties are for nominal creping moisture of 4-5%.*

Chemical Classification	Adhesion Level	Durability	Hardness/ Softness
Crosslinking PAE	Variable	High	Hard
Non-crosslinking PAE	Higher	Medium	Medium
PVOH(partially hydrolyzed; moderate MW)	Variable	Low	Hard
Polyamine	Low	Low	Soft
Polyacrylamide	Variable	High	Hard

Other chemistries, including polyamines, polyvinyl alcohols, polyvinyl acetates, polyacrylamides and polyethyleneimines have also been used in creping applications. Some of the newer proprietary vinyl monomer based polymers promise and deliver shifts in improved performance and productivity to the tissue maker.

Release and Modifier Materials Applied Through the Spray Boom: Release materials are typically used to help manage the level of sheet adhesion to the Yankee dryer. There are three general classes of chemicals normally used to accomplish this goal.

1. The dominant materials used in the industry today remain oil-based. These releases utilize different types of base oil materials that are formulated with proprietary surfactants to assure emulsification and uniform application. They generally interfere with adhesion between the sheet and the Yankee coating by preventing good wetting of the sheet by the adhesive and intimate contact between the sheet and the Yankee coating at the pressure roll nip.

2. A second class of chemistries is non-ionic surfactants.These materials tend to modify adhesion through softening of the entire coating. The coatings that are formed are generally uniform in appearance. The release characteristics are generally mild.

3. The third class of chemistries is cationic surfactants. These materials are aggressive softening agents and provide a medium level of release between the sheet and the coating.

Nalco has studied the effects of release and modifying materials on film uniformity (Furman, 2004; Grigoriev, 2005) The four atomic force microscopy, AFM, height images in Figure 10 show what can happen to surface uniformity when an oil release and two different modifying materials are added to a film produced

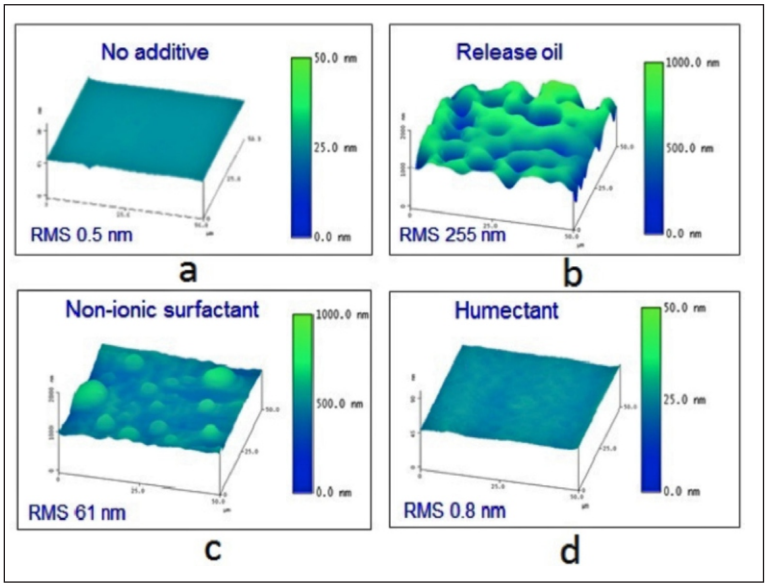


Figure 10a to d – *Shows the effect of different release and modifiers on the film uniformity of a non-crosslinking PAE.*

with a non-crosslinking PAE adhesive. The magnitude of the variation in surface topography is captured in the RMS value, the higher the RMS the less uniform the surface. It is suspected that the loss in adhesion of the sheet to the Yankee coating when oil release and surfactant modifiers are used is due to the general loss in surface uniformity which compromises the amount of wetting of the sheet by the adhesive layer and prevents intimate contact of the sheet to the adhesive in these non-uniform areas. In effect a weaker boundary layer is created.

As mentioned above, different releases influence sheet adhesion to the Yankee dryer. Table 4 illustrates the impact of different classes of releases and release/modifiers on sheet properties. Table 5 lists a few common modifiers that are not normally used to release the sheet from the dryer.

Use of Adhesive, Release and Modifier Tables: The previous discussion illustrates that there are numerous types of adhesive, release and modifier materials that can be combined to change the basic characteristics of a Yankee coating. In today's tissue manufacturing facilities it is common to find two and three components being added to the spray boom to achieve desired Yankee coating characteristics. The complexity of a four-component system has limited usefulness, since developing algorithms for optimization are difficult. By using the visual Coating Space model and the tables above, we can see how different combinations of spray boom chemistries can lead to different characteristics in the Yankee coating. A change in chemistry, like an adhesive, will most often result in changes in both durability and hardness of the coating. In reality there may be more than one combination that results in the desired

Table 4 – *Demonstrates the effect of different release and release/modifiers on Yankee coating and creped sheet characteristics.*

	Chemical Classification	Coating Compatibility	Release Strength	Impact on Stretch	Impact on Crepe Structure	Impact on Coating Development
Release	Various Oils	Separates from coating when dried	Moderate to strong	Increases	Fewer and larger	Coating streaky and variable.
Release/ Modifier	Nonionic Surfactant	Some phase separation.	Weak release	Variable	Can improve crepe structure.	Coating more uniform; softer.
Release/ Modifier	Cationic Surfactant	Some phase separation.	Medium strength	Stretch tends to go down.	Can improve crepe structure.	At low dosages coating is even. At higher dosages coating is streaky.

Table 5 – *Further classification of modifiers that are applied through the spray boom. Note the distinction between release/modifier and modifier/release is the dosage. Low doses fall under the classification of modifier/release.*

Modifier	Chemical Classification	Coating Compatibility	Adhesion	Durability	Hardness/ Softness
Modifier/ Release	Nonionic Surfactant	Minor phase separation	Variable	Durability goes down	Film becomes softer
Modifier/ Release	Cationic Surfactant	Minor phase separation adhesion goes down.	At low doses adhesion can increase. At higher dosages down	Durability of coating goes	Film becomes softer
Modifier	Humectant	Complete miscibility	At low doses adhesion can increase. At higher dosages adhesion goes down.	Durability of coating goes down	Film becomes softer.
Modifier	Phosphate	Homogenous Integration in film when dried (at low dose)	Adhesion tends to go up at lower dosages.	Durability goes up.	Film becomes harder.

Yankee coating outcome. Table 6 may help illustrate how different adhesive, release and modifier materials can be combined to arrive at similar coatings on the Yankee surface. In addition, Table 7 categorizes some common Yankee coating problems along with potential issues and solutions. Used in combination, the tables provide a starting point for making coating adjustments.

Application of Coating Space Concepts and Functional Yankee Coating Drivers

Use of Coating Space concepts and Functional Yankee Coating Drivers can lead to sustainable solutions to creping issues. Creping problems can be caused by a number of process issues, but by utilizing a systematic problem solving approach, the basic issues can be understood and solutions can be commercially implemented. A simple problem solving process is composed of six basic steps, as shown in Figure 11.

1. Problem definition – Clearly define the issues and sheet defects that are occurring at the creping doctor blade. The more definitive the problem statement the easier it will be to understand and correct the problem.
2. Audit the process – Collect appropriate data around the creping transformation. Include historical and current information about grade structure, operating conditions, blade geometries and process efficiencies. This type of data will help define when a problem started and how it has developed.
3. Develop a model that fits observations – After a thorough audit is complete, use the data to construct the general problem statement to define how the problem is occurring.
4. Develop a coating optimization plan – Use Tables 2-8 to assist in developing an action plan to resolve the operational issues.
5. Conduct confirmation trials to define the effectiveness of the solution.
6. Evaluate results – If different issues occur due to changes in other functional Yankee coating characteristics, return to step 1 and restart the problem solving exercise.

Case Study – Tissue Machine Efficiency, Quality and Productivity

Issues that develop around the functional Yankee coating and creping transformation often appear to be very difficult to define and resolve. This is usually due to the fact that efficient creping is driven by many inputs. A good way to visualize how the various tools, models, tables and problem solving processes come together to improve the overall tissue making process is to work through a case study. In the following example tissue machine productivity has been compromised due to sheet defects and frequent creping doctor blade changes. The problem solving procedure outlined above will be used to understand

Table 6 – *General actions to achieve desired Coating Space properties.*

Increased Adhesion	Improved Durability	Harder Coating
↑ Total add on	↑Total add on	↑Adhesive
↑ Adhesive/Release Ratio ↑Adhesive ↓Release	↓Release	◊ Change to adhesive with higher potential to crosslink in use
↑ Coating Softness ◊ Add humectant modifier	◊ Change to less aggressive release	◊ Decrease creping moisture
◊ Decrease creping moisture	◊ Add phosphate modifier	◊ Add higher level of phosphate modifier

Table 7 – *General Yankee coating troubleshooting guidelines – for potential solutions refer back to Table 6 for additional further detail.*

	Problem Type			
	High Blade Wear	Pinny Sheet with Random Picks	Chatter in coating or sheet	Non-uniform, streaky coating
Potential Issues	◊ Thin coating ◊ Moisture streaks	◊ Thin coating ◊ Coating is too hard and thin	◊ Coating too thick and hard	◊ Thin coating ◊ Poor felt CD profile
Potential Solutions	↑ Durability	↑ Total add on ↓ Hardness ↓ Total add on	↑ Total add on ↓ Hardness	↑ Total add on ↑ Durability

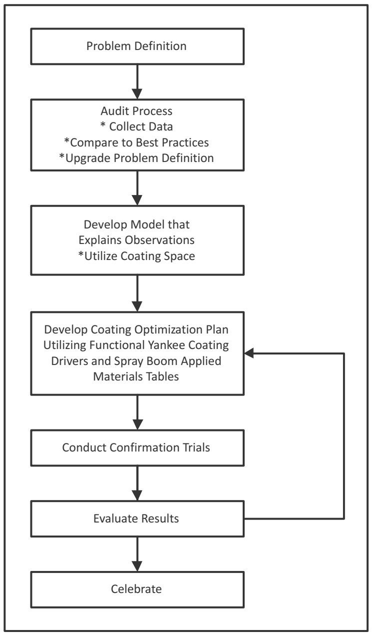


Figure 11 – *Illustrates a simple problem solving approach to Yankee coating issues.*

what the productivity issue is and what corrective actions should be taken.

Tissue Machine: Crescent Former, LDC, 1850 m/min

Grade – Premium Bath Tissue, 16 gsm

Creping doctor blades made from blue steel

Problem Definition: Current doctor blade life is 2 hours. Historical blade life was 10 hours.

Edge cracks, picks, and pin holes in sheet.

Based on audit findings the current problem identified as excessive creping doctor blade wear.

Audit: Abrasive blade wear is present (see Figure 12)

- Blade wear is excessive with an average of 0.41 mm/hr. Range in wear rate from 0.10 mm/hour to 0.70 mm/hr occurring in CD bands.

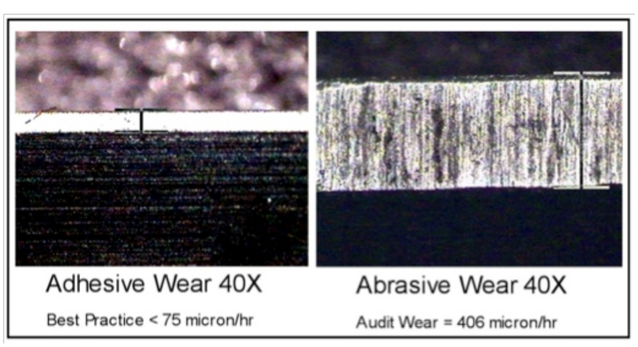


Figure 12 – *Images taken during audit show abrasive wear that was present across the entire width of the doctor blade.*

- Visual appearance of the coating on Yankee dryer surface is uneven with pronounced CD bands.
- Pin holes present in bands that correspond to variable thickness of coating.
- Excessive wear at the edge of the doctor blade near the deckle edges of the sheet.
- There has been a major shift in the grade structure on the machine just prior to onset of the problem. Historically the production was 22 gsm facial; currently production is 16 gsm bath tissue.
- Permanent wet strength usage has been eliminated. Facial had utilized 2 kg/ton.
- Creping moisture target was raised from 3.5% to 5.2%.

Model

- The creping doctor blade wear rate has increased when compared to historical levels. This is due to metal to metal contact between the tip of the doctor blade and the Yankee surface.
- The high abrasive wear rate blade is due to changes in the grade structure. Wet strength has been removed as an additive. The wet end additives table indicates that, when strength materials are removed from the process, there would be a loss in durability and hardness.
- Additionally there has been an increase in creping moisture from 3.5% to 5.2%. This increase in moisture also tends to soften the coating. The combination of these two moves resulted in a coating that was too soft to support the load at the tip of the creping doctor blade.
- With the increased changing of doctor blades to alleviate the pin holes, and picks, there was an increased removal of coating from the Yankee surface. The increased removal of coating further limited coating thickness build and ultimately the protection of the Yankee. Doctor blade wear rate increased leading to faster doctor blade change cycles and increased lost time.
- When the creping doctor tip wears it can no longer efficiently remove the sheet from the Yankee surface. Pockets of higher adhesion can develop due to differences in Yankee surface metallurgy and topography. These pockets tend to hold the fiber bundles tightly to the Yankee surface. These tightly held fiber bundles can cause small holes and picks in the sheet. Some of the small holes catch on the leading edge of the doctor blade causing larger pick holes and breaks. Loss of tensile strength, caliper, and stretch can occur.

Optimization Plan – Once a basic understanding is developed which describes the issues that are occurring on the tissue machine, the model must be tested. Given that the basic model is excessive blade wear, the following trials should be designed and tested to see if the issues are resolved by changes in the functional Yankee coating.

- Increase total Yankee coating add-on in 20% increments until either blade wear rate decreases to acceptable levels, or other detrimental operational issues develop.
- Increase adhesive to release ratio and total add-on until either blade wear rate decreases or other operational issues develop.
- Change Yankee adhesive to a more robust cross-linking material. Increase add-on as necessary and monitor creping doctor blade wear rates.

Note 1 - Watch for adhesion levels that are too high leading to pin or pick holes.

Note 2 - Watch for a coating that gets too hard leading to coating, or Yankee chatter. Soften coating if this occurs.

Evaluate the Effectiveness of Changes Made to the Functional Yankee Coating -

After changes have been made to the Functional Yankee Coating, the system should be allowed to stabilize. During this period of time the process should be monitored to insure that issues and problems are improving and that other problematic issues are not developing. If the problems are improving, additional moves to improve the system can and probably should be made. If the issues are not getting better and/or other issues are developing that are causing different operational issues, the problem solving process should be re-examined again for additional or different solutions. This process is iterative and may need to be re-run until an adequate solution to the issues are defined and commercialized.

SUMMARY

Understanding how a Yankee coating develops on the dryer surface is complex, but very important to optimizing the tissue making process. All unit operations and chemistries utilized in the tissue making process contribute to the formation of a functional Yankee coating. The materials that contribute most to the characteristics of the Yankee coating are delivered through the spray boom. By utilizing the concepts presented in this paper including the Coating Space model, functional Yankee coating drivers and general knowledge of boom applied creping chemistries, it is possible to understand complex creping issues and optimize the creping transformation in a way that assures highly efficient manufacture of tissue and towel products for the market place.

REFERENCES

Archer, S., Furman, G. and Von Drasek, W. "Yankee Surface Chatter – Mechanics, Monitoring and Methods to Minimize Impact," Tissue World, Nice, France, March 28-31, 2011.

Dreshfield, A. C. A Study of Transverse Moisture Distribution and Movement During Hot-Surface Drying of Paper. Ph.D. Thesis, The Institute of Paper Chemistry (1956).

Furman, G., Grigoriev, V., Su, W. and Kaley, C. "Effects of Modifying Agents on Adhesive Film Properties," Tissue World Americas Conference, Miami Beach, Florida, September 2004.

Grigoriev, V., Cloud, R., Furman, G. and Su, W. "Development of New Methods to Characterize Yankee Coatings," 13th Fundamental Research Symposium, Cambridge, UK, September 2005.

Nanko, H., Button, A. and Hillman, D. The World of Market Pulp; Appleton, WI: WOMP, LLC, 2005.

Paczkowski, M. "Material Interactions and the Effect of Doctor Blades on the Yankee Surface," Tissue World 2009 Conference, Nice, France, March 23-26, 2009.

NALCO Water, an Ecolab Company

North America: 1601 West Diehl Road • Naperville, Illinois 60563 • USA
Europe: Richtistrasse 7 • 8304 Wallisellen • Switzerland
Asia Pacific: 2 International Business Park • #02-20 The Strategy Tower 2 • Singapore 609930
Latin America: Av. das Nações Unidas 17.891 • 6° andar • São Paulo • SP • Brazil • CEP 04795-100

nalco.ecolab.com