Advanced Yankee Surface Management

Ian Padley, BTG Eclépens SA

INTRODUCTION:
Management of the Yankee surface, or more specifically, the organic coating on the Yankee surface has a great impact on the operations and maintenance of the tissue machine. Tissue quality and machine productivity are both highly influenced by the composition and also adhesive and rheological properties of this surface. For example, a hard coating will make achievement of the bulk target difficult. Likewise, a lack of adhesion (also a by-product of hard coating in some cases) will give a drop in handfeel or softness. Hard coating at the Yankee edges can give rise to edge tears and web breaks, and a hard coating with poor release response makes achievement of a low crepe ratio difficult. Finally, we have the dreaded specter of chattermarks, blade-vibration induced CD scoring of the Yankee surface, causing sheet defects, slow running and ultimately a costly regrind or metallization of the Yankee surface. So clearly, correct management of this thin organic layer is of paramount importance to the majority of tissue makers who use light dry crepe technology.

MEASUREMENT OF THE COATING LAYER
It is an axiom of control technology that ‘if you don’t measure it, how can you control it?’ So, how to measure such a thin and largely unobservable but also dynamic phenomenon as a Yankee coating? Subjective measurements such as visual observation and even listening to the coating are a good starting point. Some classifications are possible, for example:

<table>
<thead>
<tr>
<th>Observation</th>
<th>Status of Yankee surface</th>
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<tr>
<td>Even, translucent grey. Quiet. Sheet tight</td>
<td>Good soft coating coverage, adequate adhesion</td>
</tr>
<tr>
<td>White but even coating, noisier, sheet tight</td>
<td>Some fibre/fines contamination of coating, but OK</td>
</tr>
<tr>
<td>White and dusty, distinct noise, often with sheet flying</td>
<td>Highly contaminated coating</td>
</tr>
<tr>
<td>Streaky white coating, high pitch noise</td>
<td>Contaminated coating and poor moisture profile</td>
</tr>
<tr>
<td>Shiny Yankee, high pitch noise</td>
<td>No or little coating, wet sheet or cool Yankee</td>
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Many process engineers and operators will have their own classification, and with practice this can be quite discriminating, especially in combination with other less subjective methods.

An objective measure to add to this is to measure the amount of coating sprayed onto the Yankee. This is extremely useful, but still requires the engineer to make some assumptions. Typically, we start with a flow rate of the various chemicals, which can include a base coating, release, sometimes a modifier and sometimes phosphate additive. Best practice is to define this flow rate as a total solids add-on per unit area, normally expressed in mg/m² of coating. This requires knowledge of the concentration of the chemicals, their specific gravity and of course sprayed width and Yankee speed. However, this can only measure the chemicals as dispensed; what attaches to the Yankee will be somewhat lower due to misting of the applied spray, boundary air layer effects and so on. Eighty percent (80%) chemical stick-on versus dispensed chemical is a good rule of thumb for a correctly designed spraybar operating at 3-4 bar pressure. Whilst a very useful benchmark, add-on calculation does not take into affect coating rheology or adhesion (this requires some knowledge about the
proprietary features of the chemistry) nor does it take into account so-called natural coating, which we deal with in a later section.

Direct measurement of the coating thickness has some promise, but is not widely applied yet. Amongst the techniques proposed is a subtractive measurement using first an eddy current probe to determine the distance onto the metallic surface in tandem with a reflective EMR measurement to determine distance to the organic layer. Thus we can have total coating thickness including natural coating, but still not adhesive or rheological information.

Crepe blade vibration measurement is very commonly used across the tissue industry now, initially to alarm for high vibration and protect the Yankee from chattermark damage. However, a more detailed examination of vibration trends and spectra can reveal much about the Yankee surface and coating.

Working on the assumption that vibration can be caused by hard coating, and that a blade change will refresh the coating layer and allow softer coating to predominate, we can easily see this effect in Figure 1 below.

![Vibration trend from crepe blade showing blade change response](image)

Figure 1: Vibration trend from crepe blade showing blade change response

Looking at the vibration spectra shows a similar impact, but now we can start to discriminate at which frequency the hard coating (assumed to be stripped away after blade change) cause vibration:
So for this machine, illustrated in Figure 2 above, we can see the hard coating pre-blade change induces a high frequency vibration at around 19kHz. Taking this forward is extremely useful troubleshooting information.

It’s ultimate expression is to map various frequencies to known and observed Yankee surface phenomenae, as per this example in Figure 3 below.

In this case, the edge build up and chatter associated with it gives a lower frequency of vibration. This is determined by measuring actual Yankee marks on a shutdown and comparing them with the spectrum. Thus, in the future, we know that a high vibration at 6 kHz is likely caused by Yankee edge contamination. Higher frequency vibration is generally harder coating in the sheeted area, and consequently may have quality or crepe ratio implications.

In summary, the skilled process engineer will use a range of techniques to make judgments about the quality of their Yankee coating. The next question, having measured it, often is ‘why is my coating hard’, which we address.
IMPACT OF TISSUE MACHINE WET END UPON COATING LAYER

The applied Yankee coating chemicals are only part of the story on our Yankee surface. Practically everything else in the tissue machine stock and process water system has the potential to end up on the Yankee surface. Some researchers put the applied coating add on at less than 1% of the total Yankee organic layer. The contaminants can include cellulose short fibre and fines, hemicellulose, lignins, starch, other polymeric dry strength additive, wet strength resin and others, such as inorganic ash. The influence of chemical parameters such as pH, ionic charge demand, temperature, water hardness and system conductivity, as well as Yankee heat flux and other operational parameters can all impact how these behave on the Yankee surface. In this section we will focus on the fines, fibre and ash.

Short fibre, such as eucalyptus or inappropriately refined fibre can be easily incorporated into the catonic Yankee coating. Fines and ash may be added to the tissue process at various points, and in some cases (e.g. inappropriately refining) they will be created in the system. In addition, the short and long water loops will continuously recycle these materials. A stable equilibrium is eventually reached on the tissue machine system. Thus, the net addition of fines plus fines generated must equal what is incorporated in the sheet exiting the machine system plus losses to sewer and sludge disposal; or what ends up on the Yankee, causing the issues described earlier.

The fines circulation loops can be depicted using a Sankey Diagram as shown in figure 5:

![Sankey Diagram of fines recirculation on a tissue machine](image-url)
The Sankey diagram allows us to visualise the quantity of fines, ash and short fibre as they circulate around the system. One key point for us to understand in the context of this article is how much of this material ends up in the silo loop. This is important as any material here ends up diluting the forward flow of thickstock and will be present in the wet sheet as it is transferred from the press felt to the Yankee. Any anionic material here is pressed into a hot, cationic polymer plasma on the Yankee and thus the anionic material, if unfixed and mobile, readily transfers into the coating.

We need to be aware of a secondary factor as well, the Dreshfield effect. This describes how particulate matter in the wet sheet matrix will migrate to the sheet surfaces when it is heated. This further exacerbates the fines and ash incorporation into the coating film.

Realising that the Sankey diagram can visualise this equilibrium, the next step is to quantify it by making suitable measurements. Depending upon the time available, various techniques can be used from a simple total solids through to lab instruments for accurate fines determination of the various samples. The relative merits of the different techniques have been described elsewhere, now let us turn to how we use these measurements.

One approach, shown here in Figure 6, is to develop some generic indices which we can use to benchmark one system against another.

The 4 indices described in this study are as follows:

- Calculated net solids addition to system as percent of production
- Solids in clarified water shower, kg/hr/m
- Percent trash in short loop
- Percent silo fines in coating

![Figure 6: Typical tissue machine fines and ash audit](image)
Please note that these are arbitrary indices, not necessarily absolute values to be interpreted rigidly per machine. However, the indices do allow machine to machine comparison, and thus some patterns start to emerge.

This study was carried out over a 12 month period in the EMEA area. The results are summarized in Table 2 below.

Table 2: Comparison of fines audit KPI's over 5 European tissue machines

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Values highlighted in red may be considered out of range. In the context of this article, machines exhibiting a high percent silo fines in coating, what we may term as a ‘Yankee Coating Contamination Factor’ or YCCF had poor runnability, characterised by high crepe ratio or low crepe efficiency plus in some cases chatter.

The relationship between hard coating and crepe blade vibration was explored in a study, over a 4 month period for the ‘North EU economy and luxury’ producing machine, second from left in the above table. What became apparent when we transformed the YCCF data via cusum calculation is that an upward change in YCCF correlated well with increases in crepe blade vibration, Figure 7 below. We speculate, that as the Yankee/Coating/blade dynamic may be in a stable equilibrium until a change in coating hardness triggers an increase in coating friction, this making the blade unstable and vibrating. As is well known, unmitigated blade vibration will propagate both in extent and amplitude until chatter occurs, as was the case for this reference.

Figure 7: crepe blade vibration trend compared with YCCF cusum
CONTROL

So far we have established that a number of techniques can be used to characterise the organic coating layer on a Yankee, but amongst these, vibration can be a useful guide to the coating rheology. Moreover, with a knowledge of the add-on and the fines recirculation in the system and other parameters, an index for the contamination factor of the coating can be determined, which correlates well to vibration. Thus, the process engineer could determine the potential for an issue and some of the causes. But what may be done to control them?

One obvious solution, and a good one, is to better control the tissue machine wet end. Having determined the problems points with the kind of audit shown above, repeated over different grades and times, we can propose solutions. These may include:

- **Selection of low fines furnish**
- **Correct refiner plate design and refining strategy to avoid excessive fibre-cutting SEL**
- **Good polymer treatment for any DAF unit**
- **Appropriate disposal or reuse of DAF sludge**
- **Consideration of fines impact of polydic recovered fibre usage**
- **Awareness of fine equilibrium consequences of water closure**
- **Use of controlled short loop retention aid or better fines fixative.**

The latter solution has worked particularly well when there have been other system constraints, fibre yield and water closure for example.

However, some trash will nearly always end up on the Yankee, so let us turn our attention to the much neglected cleaning blade. This is a potentially very powerful aid for the tissue maker in the field of Yankee surface management.

Any doctor blade will wear against the Yankee surface, faster for a steel doctor, slower for a high performance (normally ceramic) version. However, once the sliding surface wear area reaches say 200µm, the specific pressure (force per unit area) exerted by the blade is substantially lower then when the new blade was loaded, and thus coating refreshment, which depends upon the removal of the older hard coating, becomes less effective. This explains the exponential increase in vibration at the end of a blade life on a hard-coated machine. Thus, a frequently changed cleaning blade will help keep the coating fresh, with all its attendant benefits.

However, there is an argument against the steel cleaning blade.

1) On a metallized Yankee surface there is the possibility of adhesive blade-Yankee wear if the coating is in any way compromised.  

2) On any Yankee surface, the steel cleaner will wear first against the hardest coating, and with wear rates of over (sometimes much over) 50µm/100km of machine travel, the steel cleaner soon has too great a sliding surface in localised spots for effective cleaning. The blade with the smallest sliding surface against the Yankee will of course do most of the cleaning work, thus with a high performance creper and steel cleaner, it is often the creper doing most of the work on the Yankee, compromising its lifetime and quality output.

Good results have been obtained by using a high performance cleaning blade, with a design optimised for the cleaning position.
In this case, the machine runs a 80° high performance crepe blade. In Figure 8 above, on the left is the FFT spectrum with the intermittent steel cleaner and on the right with a continuous ceramic cleaning blade. Over an extended period, overall vibration was reduced by 47% and the machine was able to break free of a two (2) month regind cycle.

In a second case, after an extended trial, these benefits were confirmed for a modern high speed tissue machine using both state-of the art wet end fines control and high performance ceramic cleaning blades:

- Consistent shut-to-shut Yankee surface roughness: no adhesive wear
- 50% crepe blade vibration reduction
- 30% longer crepe blade life (changed for quality)
- Better bulk consistency
- Fewer cleaning blade changes, a safety benefit

CONCLUSION

Attention to Yankee Surface Management as an holistic concept will repay the tissue machine process engineer with improved quality, more production and enhanced asset protection. The key steps are:

1) Implement an objective way to measure and track the organic Yankee surface condition, including classified visual observation, add-on measurement, vibration measurement and the more novel techniques as they come of age.

2) Understand and mitigate the wet end and natural coating influences on the Yankee surface.

3) Implement active control measures to suit the circumstances
   a. A wet end management system
   b. Use of a high performnce cleaning blade strategy

REFERENCES:

A Methodology for Quality, Productivity and Asset Protection
Overview: The Yankee Surface

Creping: critical operation
- Quality - softness and bulk
- Productivity - crepe ratio and web breaks
- Asset protection - adhesive and abrasive wear and blade vibration

Understanding Yankee surface behavior is key to improved performance
3 Steps to a good Yankee surface

1. Objectively measure Yankee coating parameters
2. Understand influences on coating
3. Implement control measures
1. Measurement

Some common ways to ‘measure’ the coating

**Add-on:**
Chemical flow or more accurately mg/m² of chemical coverage. A guide, but does not take account of wet end additives and contaminants.

**Thickness:**
Promising techniques using laser/eddy current/other EMR. When reliable, good to know the thickness. Adhesive/ rheology properties not measured.

**Vibration (Crepe blade):**
Doesn’t directly measure the amount of coating but gives a great guide to its rheology and Yankee surface protection. Widely used across the industry.
Blade Vibration trend measurement

Blade change strips away hard coating: Reduces vibration

Impact of blade change

Vibration Strength

Time
Vibration Spectrum Measurement

Before Blade change
Vibration Spectrum Measurement

After Blade change
Map FFT frequency events to specific Yankee

Yankee damage matched to Vibration FFT spectrum by BTG Experts
Tissue machine blade vibration monitoring system example

- Live FFT Spectrum
- Blade life indication
- Frequency-defined damage level indication
- Damage level accumulation
2. Understanding Coating Composition

What’s in your coating?

In fact as little as 0.5 to 1.0% of the coating is the applied polymer and release (Boudreau, 2009).

Control of this is critical, but what about the other components?
Tissue machine first pass retention is 50-85%. Many unretained fines will be in the water phase at the suction press.

The fines-rich water is in direct contact with the Yankee coating. The anionic fines will have a natural affinity for the cationic Yankee coating.
Dreshfield Effect

- This is the name given to the effect which happens when the wet sheet is dried on the hot Yankee.
- The small fines, ash, and other particles move to the surfaces of the sheet to make hard and dusty coating.
- Most of these particles are anionic and easily combine with cationic Yankee coating.

Need to understand fines loops
How: multipoint fines audit of whole system

Date: Survey Average Grade: 0

Fresh Water 4.3 m³/T

Superclear Shower Contamination 2.83 Kg/Hr/m

Machine Production Rate 494.25 ºC

Machine Production Rate 494.25 ºC

Dilution 5.625 Bar

Superclear Water

BD gsm 12.9

Machine Chest Input Tonnes 4.1 T/hr

Trash in Short Loop of Paper Production 92%

Sludge recycled 123 kg/hr

Effluent Solids to Sewer 19 kg/hr

Sludge to Waste: 0 kg/hr

Fines in Coating % Silo Fines ALL coating 87%

Drum Hood

Yankee Dryer

Crepes Blade

Pressurizing Roll

Spray Nozzle

Flume 1160 mg/L

WW1/Silo 1090 mg/L

FPR 48.1%

Yankees Speed: 1975 m/min

Crepe Ratio: 16.8%

Crepe Efficiency: 66%

Production Statistics

Production: 3.67 T/Hr

Calculated BD Yield: 83%

Yankee Speed: 1975 m/min

Crepe Ratio: 16.8%

Crepe Efficiency: 66%

Coating Add-Ons

Base: 1.8 mg/m²

Release: 3.8 mg/m²

MAP: 0.4 mg/m²

Fines in Coating % Silo Fines ALL coating 87%

50% 60% 70% 80% 90% 100%

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key indices determined...

Clear shower water contamination 2.83 kg/h/m

Silo Fines in coating 87%

Trash in short loop 92% of production

Net solids to system 19.9% of production
Comparative audits using these indices

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![Graph showing comparisons](image)
Comparative audits using these indices

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Multiple issues across these machines: chatter, observed hard coating, low crepe efficiency are all own coating contamination issues corresponding with a high contamination index.
Vibration versus coating contamination

CUSUM plot of % silo fines in Yankee coating index
3. What are my control measures?

High vibration can indicate compromised coating.

Use of controlled wet end
kative/retention technology

Use of high performance
leaning blade

Archer, Furman, Van Dresek:

Tissue World Nice, March 2011

Evilliers, Padley:

Tissue Expo, March 2011
Cleaning blade to control coating

To better **control coating** and stabilize machine runability when process is compromised (poor moisture profile, hard coating due fines contamination)

To **improve creping** blade performance, especially when lifetime and/or tissue quality is the issue (softness, bulk).

**Reduce blade vibrations** and chatter risks
Why should we use a ceramic cleaner?

To avoid **adhesive wear** on metallized surfaces

To avoid localised rapid wear which happened with steel to give non uniform coating in 15 minutes in some cases.

→ Steel cleaning blades will only adapt to local wear conditions across the Yankee and not clean the surface

→ The real cleaning is done by the creping blade, hence compromising tissue quality and blade life
Case history 1: East Europe

High Performance Ceramic Crepe, HP Ceramic cleaning blade loaded and aged randomly

Outcomes:
- 47% less CR vibrations, mostly correlated with hard coating (friction)
- Lower grinding frequency (every 2 months → ???)

80° High Performance Ceramic crepe, HP Ceramic cleaning blade in use continuously
Benefits: Modern EU Tissue Mill case 2

With high performance ceramic cleaner usage and wet end fines control:

- Improved Yankee surface condition (consistent roughness, no adhesive wear)
- 50% creping blade vibrations
- +30% creping blade life

Consistent tissue quality (bulk)

Less cleaning blade changes (Safety)
Summary: Yankee Surface Management

- Measure
- Control
- Understand