Executive Summary

Creping is one of the most important phases in the tissue and towel making process, and has a major impact on the touch and feel of the product for the end user. In addition to the obvious impact on end product feel and quality, unsatisfactory creping also has a negative impact on total production line efficiency including the converting process.

Creping produces strong topographic marking on the surface of the tissue web. Although it carries detailed information about the creping process and tissue properties this structure is not routinely analyzed in the laboratory. On-line methods for this analysis are even more uncommon.

Crepe Structure Measurement presented in this white paper is based on a new, imaging-based sensor to improve visibility into the creping process. By providing constant online characterization of crepe topography structure in cross and machine directions, the sensor provides an unprecedented tool for the user to optimize multiple cross-coupled production factors of creping including doctor blade geometry and pressure, Yankee and hood temperature, crepe aid mix and application, crepe percentage, and blade lifetime to improve production quality and efficiency. In addition, Crepe Structure Measurement delivers valuable real-time information during process development, trial runs, and trouble shooting.

Implementation of online crepe structure measurement in conjunction with the Experion MX QCS platform can result in significant improvements in product quality and production.
# Table of Contents

Crepe application overview......................................................................................................................3

Operating principal of crepe structure measurement..................................................................................4

Introduction to crepe measurement...........................................................................................................5

  Visual comparison of different crepe properties..........................................................................................5

Trial results of measurement response to crepe blade wear and change.......................................................6

  Folds per length............................................................................................................................................6

  Crepe micro................................................................................................................................................7

  Crepe Macro..............................................................................................................................................8

  Impurity....................................................................................................................................................9

Caliper correlation.........................................................................................................................................9

Tissue caliper measurement by analyzing sheet topography structure.........................................................9

Honeywell Experion MX QCS and user interface............................................................................................10

Value of on-line crepe structure measurement............................................................................................11

  Benefits of Online Measurement of Crepe Topography Structure Include................................................4

Benefits of Online Measurement of Crepe Topography Structure Include....................................................11

Conclusion...................................................................................................................................................12
Crepe application overview

Many of the fundamental properties required by high quality tissue and towel products are dependent upon creping. Creping increases sheet bulk and softness and improves sheet absorbance and stretch. It is the single, most important phases in production of tissue paper.

After initial dewatering of diluted slurry of pulped wood fibers, the moist sheet is transformed onto the surface of a hot, rotating cast iron drum called a Yankee dryer. Transformation is done by a pressure roll rotating against the Yankee. The lightweight sheet of fibers moves at high speed rates up to 2200 m/min and gets scraped off the Yankee surface by a creping blade. This transition of mechanical energy breaks the fiber bonds creating micro folds piling up against the Yankee as it rotates. The sheet separates from the Yankee in sequences, as the pile of micro folds gets high enough to allow separating forces to overcome the adhesive forces. As a result the pile falls into a macro fold. The sheet is then wound up on a rotating reel with lower speed compared to the Yankee. The speed difference sustains the folded surface structure of the sheet characteristic to crepe paper.

Crepe doctor blade geometry and loading has significant impact on crepe topography and sheet folding properties. The top of the blade is ground to a certain angle. The angle between Yankee tangent and blade top is called creping angle or angle of attack, and it has significant impact on crepe wave length and distribution of micro and macro folds. The larger the creping angle becomes, the less micro crepes are formed per each macro fold. Likewise in a geometrical arrangement positioning the blade to a lower angle can create and sustain higher structure with more piled-up micro crepes.

In addition, the creping process typically involves usage of a polymeric mixture of adhesive spayed onto the Yankee surface to ensure wear protection of the Yankee, sufficient sheet adhesion during drying, and non-destructive release of the fragile sheet when doctored by the creping blade. Coating mixture application and properties has a major impact on crepe structure as well.

As discussed earlier, uniform crepe performance and quality depends upon a sensitive balance of a multitude of factors affecting the process. Until now, only laboratory offline measurement solutions were available for measuring crepe. A new imaging-based measurement of crepe structure introduced in this white paper characterizes surface crepe properties online. Process parameters such as coating spay temperature, pressure, viscosity and flow, blade geometry, load and wear, Yankee and hood temperature, pressure roll performance and so on, all together determine creping performance. Optimization of these parameters based on real-time feedback for trouble-shooting and process development, results in comprehensive performance and quality improvements including converting efficiency. This is due to uniform and optimized dry end performance on the tissue machine.
Operating Principal of Crepe Structure Measurement

This new modular sensor is based on single-sided gauging and contains a camera, a high-power solid-state illumination unit and dedicated signal processor for real-time image analysis. The sensor module is mounted into a traversing scanner head and produces multiple numeric values characterizing crepe topography structure in both cross (CD) - and machine (MD) directions. In addition, the sensor provides image captures from user-definable cross direction positions for visual analysis and trouble-shooting during each scan.

The sensor operates on the imaging-base principal. It triggers an extremely short, yet highly intensive light pulse length varying from 0.2µs to 4.0µs to immobilize the moving sheet for image capturing. Capturing is executed at rate of 10Hz and light pulse length is adjusted continuously for each image individually based on the machine speed and reflectance properties of the sheet. Every image is analyzed in real-time with proprietary algorithms to perform numeric characterization of the sheet’s crepe topography structure. In addition, the sensor provides an average of all images analyzed during edge to edge scan.

The sensor communicates with the quality control system (QCS) host using redundant ethernet communication. Special real-time protocol is used over ethernet to align sensor data acquisition to a common timeline and spatial domain with the measurements from other sources by means of ethernet asynchronous packet data methodology.

The tissue machine environment presents a challenge for any sensitive mechanics and electronics due to high ambient temperatures and the constant presence of excess fiber dirt. The sensor is able to compensate for dirt build-up onto the gauge window, variations in reflectance and environment illuminations as well as sheet pass line fluctuations. The QCS system provides environmental stabilization for temperature and humidity inside the head that encloses the sensors.

The imaging-based, non-contacting gauging principal is most suitable for fast moving, fragile tissue sheets, but it also sets some fundamental application constraints and requirements. The topography of crepe structure must be visually detectable at the measurement location. Despite advanced algorithms used by the sensor tuned exclusively for crepe structure detection, it is possible that the measurement may be impacted by other more dominant surface markings such as TAD or belt patterns. The sensor has proven to perform without any issues on many applications. However, if other dominant markings are present, measurement feasibility can be easily evaluated by off-line analysis of product samples.
Introduction to crepe measurement

Crepe Structure Measurement provides the following online numeric variables: crepe folds per length unit (centimeter or inch), crepe micro, crepe macro, and crepe impurity as primary measurements. In addition, the sensor provides gray level and passline as auxiliary measurements for internal calculation and compensation. Crepe micro correlates to small scale surface smoothness and roughness, and is defined as image grayscale variance within specific short wavelength range of the spectrum. Crepe macro represents crepe fold magnitude and is defined as image grayscale variance within a longer wavelength range. A crepe fold per length unit defines a dominant folds wavelength and can be expressed in 1/inch or 1/cm units. Crepe impurity indicates dominance of bright or dark areas in the picture. Table 1 indicates measurement ranges and their correlation to the sheet surface topography.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Units</th>
<th>Measurement range</th>
<th>Typical value</th>
<th>Visual Surface Appearance (low value)</th>
<th>Visual Surface Appearance (high value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crepe Micro</td>
<td>-</td>
<td>0-50000</td>
<td>1000-4000</td>
<td>Smooth silky surface</td>
<td>Small scale roughness</td>
</tr>
<tr>
<td>Crepe Macro</td>
<td>-</td>
<td>0-50000</td>
<td>500-2000</td>
<td>Flat surface</td>
<td></td>
</tr>
<tr>
<td>Crepe folds per length</td>
<td>1/inch, 1/cm</td>
<td>1-2000</td>
<td>50-200</td>
<td>Long crepe waves</td>
<td>Short crepe waves</td>
</tr>
<tr>
<td>Crepe Impurity</td>
<td>-</td>
<td>-100 to 100</td>
<td>-5.0 – 5.0</td>
<td>Dark areas dominate</td>
<td>Bright areas dominate</td>
</tr>
<tr>
<td>Image Gray level</td>
<td>-</td>
<td>0 – 255</td>
<td>70-100</td>
<td>Dark image</td>
<td>Bright image</td>
</tr>
<tr>
<td>Sheet passline</td>
<td>mm</td>
<td>0.0 – 10.0</td>
<td>3.0 – 7.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Crepe Structure Measurement also correlates to sheet caliper and stretch with certain applications even thought they are not the primary measurements. Stretch is defined as machine direction scan average value only.

Visual comparison of different crepe properties

Figure 4 shows images of three different crepe samples and gives an example of visual appearance and its relationship to the measurements. The middle sample, for example, has a relatively flat surface and higher folds per length compared to other samples. Correspondingly, the right hand side sample has a more dominant and high magnitude fold structure with longer dominant fold wavelength.

![Figure 4. Images of three different crepe samples](image-url)
Trial results of measurement response to crepe blade wear and change

When the blade pushes against the rotating iron Yankee it wears despite the friction-reducing coating layer. As the blade wears, its geometry and surface pressure properties change causing crepe bias to drift out of from the optimum. Therefore, the blade needs to be replaced frequently. Most commonly used steel blade is typically replaced in every three to eight hours to maintain crepe structure within acceptable limits. A blade change procedure requires a sheet break, resulting in production downtime.

The following graphic shows scan average MD measurement trend during several hour run period. The graphs show periods of several consecutive blade changes in the time domain. Blade change events are identified with red arrows.

**Crepe folds per length**

Measurement in figure 5 shows large step in folds per inch measurement right after each blade change compared to situation with a worn blade. Measurement decreases rapidly during first 5 to 15 minutes. This is an initial blade wear period where the blade angle of attack and contacting area settles. After a rapid initial wear, measurement decay is somewhat linear until a blade change occurs and shows step up again in the measurement.

It is also noticeable that the folds per inch measurement demonstrated very good repeatability. Graph in figure 6 plots seven blade run sequences into a single diagram and the trend plots align quite perfectly. Measurement repeatability is important when considering process target shifts or blade life optimization based on online feedback.
Waterfall graphics in figure 7 shows 50 consecutive crepe folds per inch cross direction profile measurements before and after the blade change where the most recent measurement is shown on the top. Graphics clearly shows significant step right after the blade change. In addition to obvious jump in profile average, the shape of the profile also changes significantly. As the blade reaches its end of life, the profile gets more deviated from its flat optimum as can be seen in the graphics at the middle of the sheet. Like with any other online measurement, it is possible to set specific profile deviation limits within the QCS system to notify operator if any of the crepe structure variables deviates more than accepted. Profile measurement provides a tool for process target shifts or optimization. In addition, crepe profile data carries valuable information about process conditions and helps the user to evaluate possible needs for adjustments and maintenance actions to maintain quality within an acceptable range. Uniform quality of a jumbo roll crepe in cross direction ensures good efficiency and runnability in the post converting process.

**Crepe micro**

Crepe micro measurement behavior in figure 8 is similar to fold per length after a blade change. Identical initial decay can be seen in crepe micro measurement followed by more linear decay. Accordingly, the sheet has finer crepe structure and higher surface softness when running with a new, unworn blade. After running some time blade wear and excess coating build up on the Yankee cylinder surface resulting in coarser crepe structure and decreased surface softness.
Crepe macro

Macro crepe behavior shown in figure 9 is different than crepe micro and folds per length. As the blade wears, the crepe structure becomes more uneven and coarser but the sheet bulk softness also increases. Contrary to folds per length which indicates the frequency of crepe folds in spatial domain, crepe macro represents magnitude (or amplitude) of the folds. Measurement linear increase in the adjacent graph is a result of bulk softness increase caused by a wearing blade. Coarseness and unevenness can be seen in a trend plot as increased deviation and noise at the end of life of a blade prior to replacement.

Trend plot graphics in figure 10 shows a grade change where sheet grammage is increased from 17 gsm to 24 gsm. Transition is identified with red arrows and shows related sensor image captures before and after. Along with grammage increase, the spray boom size dosing is reduced by half during transition. Accordingly, crepe macro changes from 700 to 2200 during grade change and can be seen clearly on related images.

Graph in figure 10 shows a blade change impact on crepe macro with corresponding image captures. Impact of a worn blade and its correlation to crepe macro can be visually observed from the images below. Major drop from 3300 to 1500 in crepe macro can be seen immediately after a blade change. Obvious visual correlation to the measurement can be seen in the images as a new, unworn blade (1500) produces finer, more uniform crepe structure compared to captures prior to (3300) and several hours after a blade change (3000).
Crepe impurity measurement defines the relationship of dark and bright areas in a sample picture. When dark areas dominate, sign of the measurement becomes negative. Correspondingly, sign is positive when bright areas dominate. As discussed earlier, crepe structure will become coarser as the blade wears, which would eventually even cause holes to develop unless blade is replaced. Coarseness increase can be seen in the adjacent impurity trend as increased noise when approaching the end of life of a blade.

When holes start to develop, the impurity indicator will show dropping spikes as the average reflectance of the sheet with hole(s) in it suddenly decreases.

Tissue Caliper Measurement by Analyzing Sheet Topography Structure

The caliper of lightweight tissue sheet is primarily defined by the magnitude of crepe fold structure. Therefore, it is possible to determine caliper of the sheet with restrictions by analyzing its topographic structure. However, it is important to recognize that some grades or later process phases may have an impact on the fold structure and the method sensor applies may not be eligible on every case. Even though caliper is not considered as a primary measurement of the crepe sensor, some very encouraging evidence of good caliper correlation has been found. Trend graphics in figure 13 shows laboratory measurement plotted with online measurement during three day trial period. Coefficient of determination for laboratory and online measurements data in figure 14 shows good laboratory correlation during the test run period. Evidently, the sensor has caliper measurement capability on restricted grades and applications.
Experion MX QCS and User Interface

The new Crepe structure measurement is available on Honeywell’s Experion MX QCS platform. While the sensor is performing the actual measurement and heavy real-time computation required by image analysis, The QCS performs functions such as engineering unit conversions, data mapping and storage, measurement analysis, MES system connectivity, and user interface. It also provides access to sensor maintenance and diagnostic information. Experion MX offers a versatile set of features and tools for comprehensive utilization of the measurement such as configurable trending view, 3D-colormap of profile history, profile measurement stability analysis, CD and MD measurement power spectrum analysis, and more.

Special displays engineered solely for imaging-base measurements have been developed for operator use. Displays present actual image captures from the gauging position in addition to conventional numeric data provided by the sensor.

**Main user display** (figure 15) shows all the crepe MD measurements in numeric, but it also show the main variables graphically in a single polar plot with history and nominal data. Each measurement can be selected into a profile plot view with different spatial and time domain filtration. In addition, image capture best representing the average on a scan is presented.

**Image capture display** (figure 16) is intended for visual analysis and trouble shooting. The Operator can select four locations across the sheet edges from which the sensor reports numeric characterization and delivers real image capture during each scan. Selectable profile plot is shown also on the display.

**Image gallery display** (figure 17) improves operator’s situational awareness showing crepe bias development in a longer timeframe. The display shows the eight most recent reel average images on a ring buffer with grade related nominal reference image in the middle for comparison. It helps operators to detect and respond to slow drifting in crepe bias. Numeric values related to each image can be selected for observation from the pull-down menu.
Value of On-line Crepe Structure Measurement

Profitable tissue making means continuous, stable production with minimal deviations from quality specifications. Creping is one of the fundamental and the single most important phases in tissue and towel making process. It defines major portion of the end product quality but it has significant impact on overall production efficiency as well. The crepe process is in fact in a continuous state of transition due to doctor blade wear. Subsequently repeated blade changes cause frequent upsets to a process. While optimal steady state performance is essential, minimization of downtime, waste, and recovery time due to upsets and transitions such as grade changes or sheet breaks is where the greatest gains can be achieved.

It would not be prudent to consider a modern tissue machine without having a QCS system and at least some basic online measurements. Until now there have been only offline laboratory apparatuses available for analyzing of crepe topography structure. While such devices can be used for routine sample-based production quality monitoring, they are not really suitable for effective process optimization or development. A QCS system equipped with new crepe structure sensor delivers real-time feedback and characterization of crepe online similar to and aligned with other process quality measurement data.

By optimizing and increasing performance of a creping alone, it is possible to achieve major improvements on production quality and total efficiency. Like any optimization - even manual – the foundation is set by the feedback of continuous, reliable measurements. Controlling of complex cross-coupled process like creping with multiple factors defining the output can be challenging by itself, and it is virtually impossible to max out any process to the limit without having true, online visibility into it.

Improved visibility and modern data analysis features provided by Experion MX and crepe structure measurement apply unprecedented toolset for efficient process development, trial runs and troubleshooting.

Benefits of Online Measurement of Crepe Topography Structure

There are many potential targets for utilization of the new measurement of crepe topography structure. The following are major benefits identified based on the sensor test run results and site feedback.

- **Improved, uniform quality** – Constant online process feedback available to enable real-time optimization
- **Increased production** – Enables process target shifts with less downtime
- **Improved efficiency** – Reduced waste and re-setting of converting machines required when steady crepe bias is maintained
- **Extended doctor blade lifetime** - Blade change strategy turn-around from runtime with safety margin to needs based only
- **Optimized coating mix and application** – Yankee adhesion optimization to achieve optimal sheet smoothness and stretch
- **Yankee energy optimization** – Equal or better crepe with less energy
- **Process development and troubleshooting** – Unprecedented tool for agile process development
Conclusions
Creping is a complex yet important process phase where many of the properties required by quality tissue and towel grades are introduced into a final product. In addition, sustaining uniform crepe is important for gaining good runnability and efficiency in post converting operations. This white paper has presented a new imaging-base online sensor for crepe structure measurement. Until now, there have been only a few offline laboratory apparatuses and no online solutions commercially available for crepe measurement. This new sensor delivers characterization of crepe with multiple numeric values as well as real image captures from the fast moving sheet, and it has demonstrated good results in beta testing on various tissue grades.

The sensor is now available in Honeywell’s Experion MX QCS platform and consolidates common Experion architectural features for easy, efficient and flexible data utilization. The new Crepe Structure Measurement applies a unique tool to optimize production quality and efficiency in real time.

For More Information
Learn more about how Honeywell’s Crepe Structure Measurement can improve tissue production, quality and efficiency, visit our website www.honeywellprocess.com or contact your Honeywell account manager.

Honeywell Process Solutions
Honeywell
1250 West Sam Houston Parkway South
Houston, TX 77042

Honeywell House, Arlington Business Park
Bracknell, Berkshire, England RG12 1EB UK

Shanghai City Centre, 100 Zun Yi Road
Shanghai, China 200051

www.honeywellprocess.com