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Calender Gauge Control Tips

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Calender Gauge Control Tips

This paper briefly discusses calender control issues that affect the ability to properly control rubber gauge or to produce a consistent rubber sheet. There are two principal sources of variations in calendered gauge or thickness. These are:

- Mechanical induced variations
- Force induced variations

These two sources of variations are closely related. For purposes of this discussion, mechanically induced variations will be classified as those that are present at ambient condition with the calender not operating under load. Force induced variations will be classified as those that are induced by the way the calender is operated or by the proceeding process steps.

Mechanically Induced Variations

Mechanically induced variations relate directly to the calendars mechanical condition and are thus basically a maintenance issue. While there are many maintenance issues that affect calender performance, the following are the main items that directly effect calendered gauge:

- Calender Roll grind profile
- Calender Roll eccentricity or run out at ambient temperature
- Bearing condition
- Roll water passage condition
- Roll end actuator condition

Calender Roll Grind Profile

The calender rolls must be ground periodically to establish the proper profile. The profile is selected so that the roll separating forces, which cause the rolls to bow apart in the center, are partially compensated for by grinding the center to a larger diameter. The specific profile selected is based on the range of rubber compound hardness, type of center compensation such as cross-axis or roll bending, and roll width. If the grind profile is incorrect it will be difficult or even impossible to achieve a flat-calendered rubber profile.

Calender Roll Eccentricity

Calender rolls must be round and free of run-out at ambient temperature. Any run-out of the individual calender rolls will be amplified as the high spots and low spots periodically match up between the roll pairs. This is relatively easy to check with dial indicators when the calender is running without rubber and with a slight gap between the rolls.

Bearing Condition

Calender roll bearings may also have excessive run-out. The result is the same as, and will appear as calender roll surface run-out. Excessive bearing clearance will result in the roll shifting during operation as roll separating forces vary. These conditions will adversely affect the ability to control calendered gauge.

Roll Water Passage Condition

Most modern calender rolls are the drilled type. This means that water passages are drilled across the roll face under the surface. This effectively forms a radiator-like heat exchanger around the periphery of the roll. If these passages become plugged, then non-uniform heat transfer will occur and this results in a thermal 'out-of-round' condition for the roll or rolls. This has the same effect as if the rolls were machined 'out-of-round'. To avoid this condition only treated water should be used and the rolls should be periodically flushed. Comparing the roll run-out at ambient temperature with that at normal operating temperatures can check this condition.

Roll End Actuator Condition

Electric screw actuators are the most common type of calender roll end positioning system. The screw and nut operate under very high loads and thus experience significant wear even with proper lubrication. As the actuators wear, backlash develops. As the back lash increases, the response to small changes or corrections deteriorates. Also with increased backlash the number of corrections required would increase, which in turn causes increased wear.

Most calenders still have fixed speed electric motors with mechanical brakes. These require periodic maintenance, particularly the brakes. Sticky brakes will adversely affect gauge control results.

General

Proper maintenance of all the above systems is crucial to calendar performance.

Force Induced Variations

Force induced variations result from the way the calender is operated and from previous process steps such as feed mill operation and compound consistency from mixing.

The separating forces generated during calendering are quite high; typically 160,000 lbs to 300,000 lbs at each actuator for a 66 inch active roll face producing a 60-inch wide rubber sheet. Those forces literally stretch the calender frame. Variations in these forces will therefore vary the amount of frame stretch and thus vary roll position and calendered gauge.

Force Induced Variations – The key points

1. Keep the calender running – stops cause the rolls to become egg shaped and introduce significant gauge thickness variation.
2. Keep the calender running during warm-up and cool-down.
3. Increase the temperature by 20 to 40 degrees F when the rolls are stopped to maintain a more uniform roll surface temperature.
4. Limit the temperature rate of change at all times to a maximum of 3 degrees per minute F. Faster rates can damage or warp the rolls.
5. Minimize speed changes.
6. Mill management - be consistent
7. Cord Spacing Effects on Calendered Gauge - Cord spacing has a significant impact on overall sheet gauge and quality.

1. ***Keep the calender running – stops cause the rolls to become egg shaped and introduce significant gauge thickness variation.***

When the calender is stopped, roll heat loss is not uniform around the roll. Heat loss along the circumference near adjacent rolls is minimal while heat loss in other areas is much higher. This leads to different temperatures and therefore different degrees of roll expansion. A few degrees on a 24" to 30" diameter will result in measurable "out-of-roundness" of each roll. This is true when the calender is empty but even more so when there is a hot bank of rubber between the rolls. The longer the calender is stopped the worse the condition.

Since the rolls run at different speeds, periodically the high spots match up resulting in thin gauge spots. When the low spots match up a thick spot results. This results in an effective doubling of any roll "out-of-round" or run-out error.

Typical short-term thermal out-of-round gauge variations are plus or minus .5 mils (.0005") to 2 mils (.002"). Thermal run-out is gradually reduced as the calender runs, but takes 15 to 25 minutes to be eliminated. To minimize "thermal run-out" the following procedures are recommended:

- Keep the calender running during warm up
- Minimize calender stops
- When the calender is being stopped for more than a very brief time, remove the rubber from the banks. This is considered good practice anyway for the rubber compound.
- On gum calendars always keep the calender running when there is no rubber on it
- On textile calendars or on any calender when leader is going thru the calender, dropping off tension and allowing the uncoated fabric (advance the calender 18" if necessary) or leader to go slack will permit running the calender during delays and personnel breaks. This will dramatically reduce thermal run-out.

2. Keep the calender running during warm-up and cool-down.

Severe thermal run-out can be introduced during warm-up of the calender if it is not kept running. Also remember that the calender gap will be reduced as the rolls grow (get larger) as their temperature increases. Good practice is to open the calender at least 100 mils (0.10") before starting to increase the roll temperature above ambient. Keeping the calender rolls turning during warm-up and cool down also eliminates the possibility of warping the rolls.

3. Increase the temperature by 20 to 40 degrees F when the rolls are stopped to maintain a more uniform roll surface temperature.

The TCU (Temperature Control Unit) controls the temperature of the <u>water</u> exiting the calender <u>not</u> the roll <u>surface</u> temperature. This is an important distinction.

When the calender is not actively processing rubber, i.e. during warm-up and when the calender is stopped, the roll surface is <u>losing</u> heat to the ambient and thus the TCU is actively heating the water loop. In this condition the roll surface temperature is between 10 degrees to 20 degrees F <u>below</u> the water temperature.

When the calender is running and actively processing rubber, heat is being generated so the TCU is actively cooling the water loop. In this condition the roll surface temperature is between 10 to 30 degrees F <u>above</u> the water temperature.

From this description it becomes apparent that for a constant water loop temperature, the roll surface temperature changes as much as 50 degrees F between the calender normal running condition and when the calender is stopped. This difference in roll surface temperature means that the rubber processed is being processed under substantially different conditions. Shrinkage and other properties will therefore be different.

To minimize the difference in processing conditions, the roll temperatures should be increased 30 degrees F whenever the calender stops. The temperature increase should be gradual and the specific amount should be experimentally determined by comparing roll surface temperatures in normal operation and after the calender has been stopped for 20 minutes. This function is available as a standard option as part of the ***FACTS*** TCC 1600 calender control systems.

4. Limit the temperature rate of change at all times to a maximum of 3 degrees per minute F. Faster rates can damage or warp the rolls.

The control system on the TCU should limit the rate of temperature change for each roll water loop to 3 degrees per minute. Faster rates of change do not allow for equalization of mechanical expansion throughout the rolls, bearings, and calender frames. Differential expansion can stress various components and in severe cases actually crack or warp the rolls, or even damage the bearings.

Heating usually is limited by the available heating capacity but the cooling system frequently has the capacity to rapidly cool the rolls and therefore also has the potential to cause damage if not limited to 3 degrees per minute.

Again, it is important to keep the calender running during warm-up <u>and</u> during cool down. Stopping the calender and turning off the TCU circulation pumps before the calender reaches ambient is not considered good practice. If the temperature control system has rate of change limits properly set, cool down is simple, since all the operator must do is to lower the temperature set points to ambient and then 60 to 90 minutes later return to turn off the TCU.

5. Speed Changes

Changes in the calender speed result in gum wall gauge thickness changes that are undesirable.

When the calender is running there are forces generated that try to separate the rolls. These separating forces are proportional to calender speed, although the relationship is not linear. The hardness of the rubber stock and bank temperature determines the magnitude of separating forces. The thickness of the gum wall being calendered also affects the separating force, with thinner gum walls generating larger separating forces.

These separating forces are large, as much as 160,000 to 300,000 lbs., at each actuator. The calender frame literally stretches from these forces. When the forces vary, the amount of stretch varies, resulting in the roll gap varying and this causes the gum wall gauge to vary.

From the previous discussion it is obvious that speed changes should be avoided to the extent practical. A speed reduction from 50 ypm (yards per minute) to 10 ypm can result in a gauge decrease of 2 mils (.002”). Likewise a speed increase of 40 ypm from 10 or 20 ypm to 50 or 60 ypm can result in a gauge increase of 2 mils. Different calendars have different degrees of frame stiffness so the magnitude of the gauge change for a given speed change will vary accordingly.

6. Mill Management

A consistent feed to the calender will substantially reduce gauge variations. Consistent, uniform, dwell times on the break down and feed mills, as well as consistent bank size, will result in consistent stock temperatures, work history, and reduced variations in roll separating forces. The stock temperatures, bank sizes, and work history all directly influence roll-separating forces. Minimizing variations in these 3 important process parameters will minimize variations in roll separating forces, and this in turn will minimize gauge variations. Good mill and bank control practice also results in improved uniformity for other final calendered gum and/or fabric properties.

The feed to the calender must also assure that the rubber bank does not have areas that stagnate. If rubber remains in the bank on the calender for an excessive amount of time it will partially cure and become much harder. Edge trim that returns to the bank and stagnates is a common source of this problem. These areas will introduce gauge variations as well as negatively influence other properties of the calendered material. In extreme cases, burned lumps will appear in the calendered gum.

Bands of hard stock also make it hard to properly penetrate the cord and may cause cord disturbance and improper cord distribution in these areas. In such cases the cushion force causes lateral movement in the nip and this results in cord displacement that is visible. Paired cords are often the first indicator. The thickness will be heavy and there will be cord displacement and irregularities but the weight of test samples will not be significantly affected.

7. Calendered Fabric Issues

The following relates to fabric calenders, both textile and steel cord, whereas the previous discussion is applicable to any calender.

Localized cord disturbance in cord distribution does not usually affect fabric weight, whereas redistribution of the cord does. Overall cord distribution problems can affect fabric weight. For example, incorrect cord distribution that reduces the average EPI in the center of the fabric and increases the EPI on the outer edges will affect fabric weight <u>and</u> thickness. In this example, the weight of the center would be light, while the outer edges would be heavy. Visible cord displacement and cord pairing after the cushion nip would also be expected in the areas where the cord EPI count was excessive.

Cord Spacing Effects on Calendered Gauge - Cord spacing has a significant impact on overall sheet gauge and quality, but consider the following:

- Weight samples alone do not distinguish between cord & gum
- Thickness samples alone do not distinguish between cord & gum
- Thickness & weight still do not distinguish between cord & gum
- Cord count must always be considered

The above are the reasons a scanner is an excellent tool for the operator but is not necessarily recommended for control.

Many 4 Roll Calenders have space limitations that have prevented the use of on-calender gauges on the top gum wall. Historically this has necessitated the use of on-calender gauges on the lower gum wall and an overall scanner with math derivation of the top gum profile. This has lead to many calenders producing off spec material that had a flat weight & thickness profile. Cords tend to bunch on the outer edges and have reduced EPI (Ends Per Inch) in the center. The scanner cannot distinguish cord from gum & hence adjusts C/A (Cross Axis) or R/S (Roll Straightening) and fills in the center with rubber at the expenses of the outer edge zones. The result is a final fabric profile with edges that have high EPI count and low rubber insulation and centers that are the reverse, i.e. low EPI and heavy rubber gauge. Yet the scanner profile will indicate all is well. Even though the scanner may indicate an overall profile that is within spec, the edges may be out of spec, with excessive cord EPI distribution, and low rubber insulation thickness, while the center is out of spec with low EPI and heavy rubber gauge.

Technology is available to solve this problem. The small size and high accuracy of modern on-calender gauges permits using 3 gauges on the top and bottom gum walls, 6 total, to assure a flat sheet. Since both top and bottom gum walls are now precisely controlled and assured to be flat and on spec, the scanner will provide a more accurate representation of the profile. Heavy edges for example, would indicate cord distribution problems.

In conclusion, good calender gauge control requires both proper maintenance of the calender and good operational practices. Educating the operational personnel in the effects related to these issues can go a long way towards achieving improved gauge control.

8. Sampling Techniques When Checking Calendered Gauge

Proper sampling techniques are essential in accurately determining actual calendered gauge distribution.

The principal considerations in sampling are:

- *The calender must be running in a steady state and stable condition*
  - Running at a fixed speed
  - Running without extended stop time (less than 15 seconds) for previous 15 minutes to assure rolls are thermally round
- *The proper sampling tape must be used in order to stabilize the sample*
  - Prevent sample stretch
  - Prevent sample shrinkage
- *Check for long term and short term variations*
- *Check cross direction and machine direction*

Sampling should be done after the calender has been running long enough that any thermally induced run out is gone. It can take 15 minutes, or even longer in some cases, for the roll temperature to even out and stabilize after an extended stop. Since speed changes cause gauge changes, it is important that the samples not be taken near a speed change. Remember that it may take a few yards for the system to correct and recover after a speed change.

The recommended sampling tape is 3M251 or the newer 3M254 in a 4" wide roll. The purpose of the tape is to stabilize the sample to prevent stretch or shrinkage. Each new roll of tape should be checked for thickness and weight. This may be done by carefully folding five layers of 5" length together. Die out the standard sample and weigh it to determine the tape weight. Measure the 5-layer sample thickness at several spots to determine the thickness. Remember to divide the results by 5! Use these values to correct all samples taken with that roll of tape.

For finished fabric samples, tape across the full width at the end of each roll. Only one side needs to be taped. Label the roll number and identify the water side and drive side with a pen on the tape. Cut the full width strip and carefully move it to where the samples will be died out for weight and thickness checks. The died out samples can be stacked together. Remember to identify each sample across the width by position and sample/roll number. Five samples are typically taken for routine testing, with 15 samples across the web for detail testing. When taking 5 samples, avoid the outer 2" on each edge.

The above technique is also appropriate for taking gum wall samples on the calender roll. The calender should be running in a stable condition and the emergency stop used to stop the calender for sample taking. The sample should be taken as far from the roll nip as possible to avoid the areas where the speed was changing. Normal stop will have a long deceleration time and the samples would therefore be taken during a speed change and thus be unrepresentative. When access is limited it may not be practical to take a full width sample. In this case a 6" long piece of sample tape should be used in 3 or 5 locations across the roll face. Cut out around the sample and remove it from the roll.

Using a computer spreadsheet (such as Excel) is the best way to analyze the data. The optimum method incorporates an electronic weight scale and electronic thickness gauge to directly enter the sample weights and thickness into the spreadsheet.

Long term and short- term analysis of machine direction, MD, and cross direction, CD, variations are required. The sampling methodology is different for each.

Long-term analysis can be accomplished by taking full width 5 samples set at the end of each roll. The data should be separated by fabric code. Both MD and CD long-term analysis can be performed utilizing this data. Cord count should be checked and recorded on all five samples for at least 1 roll of each fabric code. All samples should be visually inspected for any unusual cord spacing conditions.

For short-term analysis samples must be taken at 10" intervals in the machine direction along a length equal to 6-10 roll circumferences in 3 to 5 positions across the web. This means the total length is between 450" and 880". This short term testing is time consuming and need only be done when establishing a base line and when checking calender condition. Typically this should be done at least once per year or when problems are suspected.

Short-term sampling is typically accomplished by winding up a full width piece of calendered material of suitable length in a liner and then moving it to a location where the samples can be taped and cut. On steel cord and textile fabric, it is usually not practical to do short term tests on the gum walls, only on the final fabric. These short term samples should all be weighed and have their thickness measured. Cord count should be examined for any unusual conditions. Actual cord count should be checked at 5 locations across the web and at 2 or 3 locations along the length of the sample.

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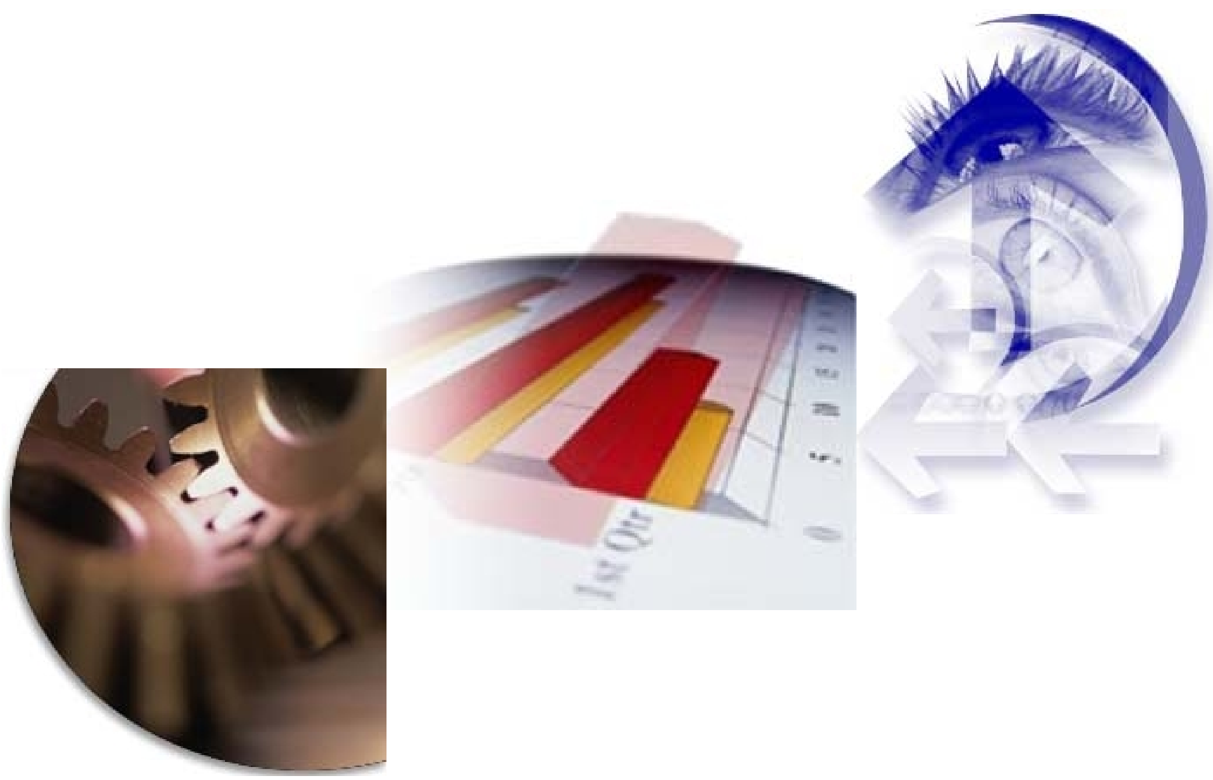

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