

Wound roll density analysis for supercalenders

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Analysis of wound roll density is an excellent tool for diagnosing machine-direction roll-structure problems.

Roll quality off the winder is commonly evaluated by measuring the radial (machine direction) density of the roll as it is wound at the reel. Density of the wound roll is measured using a wound roll density (WRD) analyzer, which calculates the average wound-in caliper of the web as the roll is building. With a known basis weight, a density profile of the roll is easily developed. The WRD profile provides information about wound-in tension and internal roll pressure. Information such as this can be used to monitor and optimize any winding operation.

The first practical, computerized WRD analyzer was developed at the Swedish Newsprint Research Center, headed by Eriksson (1). Similar analyzers have been developed by machinery builders as well as paper companies. Roisum (2) compiled a list of developers in 1989. The machinery manufacturers that have developed WRD analyzers include ASEA (3), Beloit (4, 5), General Electric (6), Jagenberg, Voith, and Valmet (1, 7-9). The paper companies listed by Roisum include Abitibi-Price (10), Champion International, Norpac, and Tasman Pulp & Paper (11).

Most of the cited literature describes the theory and operation of WRD analyzers (1, 4, 7-13). Although the principles are the same, the quality of the analyzers varies depending on the software, computer, encoders (sensors capable of transmitting thousands of pulses per revolution), and the way the sensors are mounted.

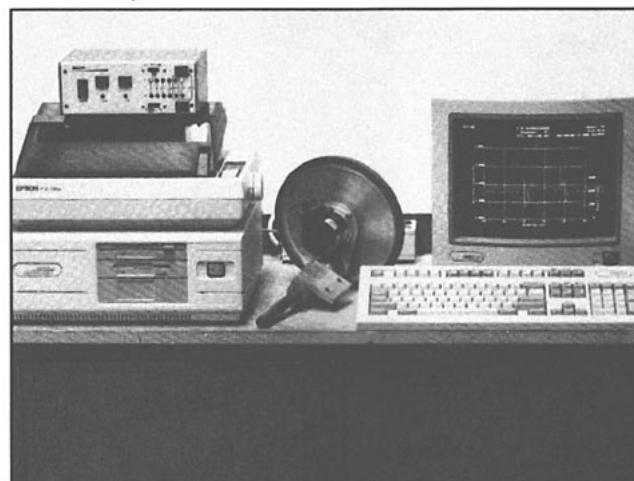
Wound roll density analysis

Equipment

Figure 1 shows our WRD analyzer, which is described by the diagram in Fig. 2. The photo eye records one pulse per revolution of the paper roll. An encoder—or an encoder/wheel arrangement—is placed on a web-bearing roll and records multiple (typically thousands of) pulses per revolution. The web must have good contact with this roll to prevent slippage and erroneous data.

Appropriate data-acquisition hardware, software, and a personal computer are required to process these pulses,

1. WRD analyzer



which are used to calculate and plot density vs. paper roll diameter. The graphs and the tabulated data are stored in the computer, where they can be used immediately or saved for subsequent manipulation.

Calculation of wound roll density

Our WRD analyzer produces a nearly real-time plot of density (lb/in.³) vs. diameter as the paper roll is building. Density is calculated based on the simple equations that follow (Eqs. 1-6). The actual calculations and software are more complicated, since the WRD analyzer counts the pulses from the encoder and the photo eye. Detailed descriptions are available in the literature (1, 2, 4).

The circumference of the paper roll is calculated from the length of the paper that is wrapped around the roll in n revolutions of the reel. The photo eye on the paper reel counts n wraps. The length of web, L , that travels over the web-bearing roll during n wraps is calculated from the encoder pulses and the diameter of that roll, d , connected to the encoder.

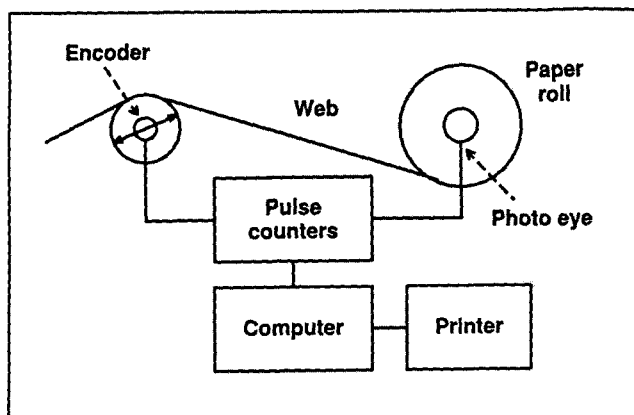
$$L = \pi d(p/p') \quad (1)$$

where

p = encoder pulses during n wraps

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2. WRD analyzer



p' = pulses per encoder revolution

The term p/p' gives the number of revolutions of the web-bearing roll, n , and πd is the circumference of the roll. Thus the average circumference is the length divided by the number of wraps.

$$C = L/n \quad (2)$$

Accordingly, the average roll diameter, D , is calculated as shown in Eq. 3.

$$D = C/\pi = L/(n\pi) \quad (3)$$

Next, the WRD analyzer calculates a new average diameter for the next set of wraps in the same way. The change in average diameter, ΔD , can be related to the change in caliper of the individual wraps of the wound roll. For each additional wrap, the roll diameter increases by twice the web caliper or thickness, t , since one thickness of paper is on both sides of the roll.

$$\Delta D = 2nt \quad (4)$$

So the average caliper can be calculated from the change in diameter and the number of wraps, as seen in Eq. 5.

$$t = \Delta D/2n \quad (5)$$

Density, ρ , is simply the basis weight, b , divided by caliper.

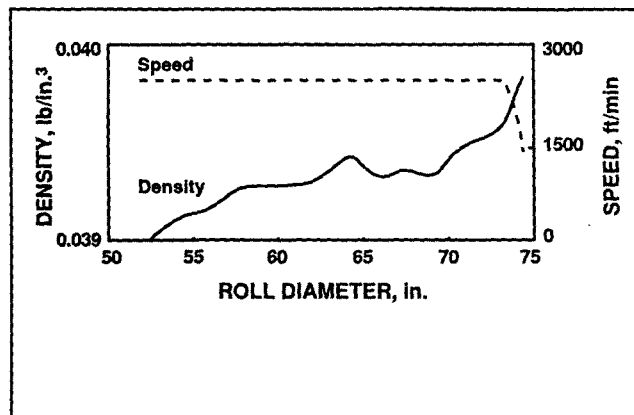
$$\rho = b/t \quad (6)$$

Use of wound roll density

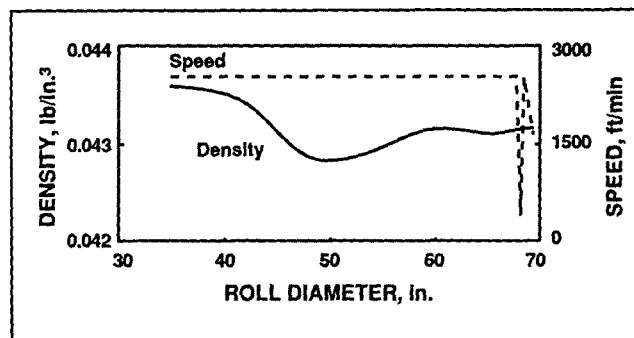
The WRD analyzer is an excellent tool for diagnosing machine-direction roll-structure problems (2). Its resolution is sufficient to pick up operating problems, and the analyzer can be used during production. Web speed also is measured precisely and accurately. WRD is compared favorably with other diagnostic tools by Larsson (13).

WRD analysis can be used on any process where a web is wound into a roll. This includes paper machines, reelers, coaters, supercalenders, and winders. Diagnosis

3. Density profile for roll from supercalender A showing undesirable increasing density



4. Density profile for roll from supercalender A after recalibrating computer-controlled settings



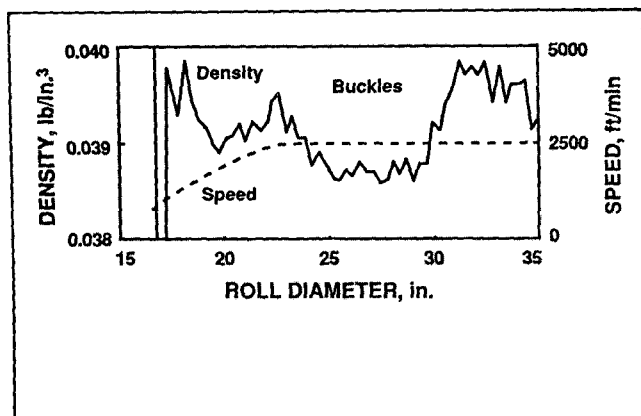
is carried out by isolating the effects of winding and processing variables on WRD. Several studies have been reported, although most of them have been on paper machine winders (1-3, 7, 8, 10-13). Variables studied include web tension, rider-roll pressure, current differential (for two-drum winders), winding speed, torque, nip, wrap sample size, roll hardness, wound-off density, calendering and caliper, acceleration, and splices.

Supercalender studies

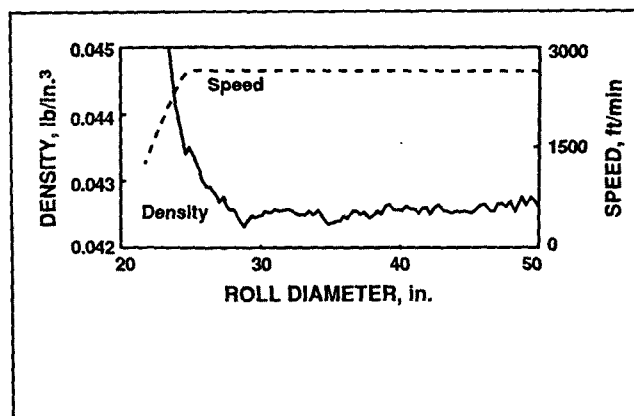
Buckles in the paper roll occur when the paper is packed with increasing density as the roll is building. The ideal roll density profile is one that starts high enough at the mandrel to prevent slippage and then stays level or decreases slightly towards the outside of the roll. This profile varies somewhat with the capabilities of the winder system.

The buckle patterns can appear in different forms. The most severe form of buckles is when the entire roll buckles or stars. This is caused by packing outer layers too tightly (too densely) compared with the interior layers. Buckles also can be formed in small wavy patterns at different locations. These wavy patterns are formed when small, isolated areas of lower-density paper in the roll are followed by higher-density paper. This type of buckling typically occurs when the paper at the beginning of the roll is not tightened properly. When tension is lost on the

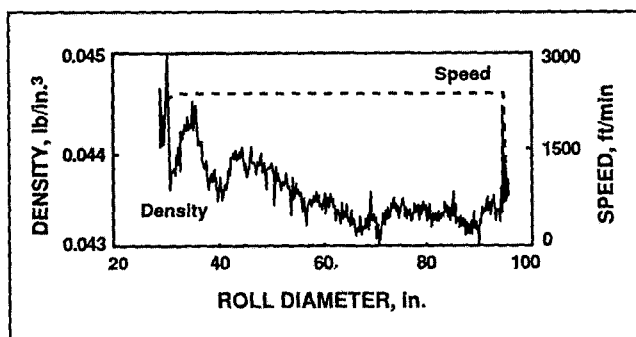
5. Density profile for roll from supercalender A showing density fluctuations that caused buckles at the start of the roll



6. Density profile for roll from supercalender A showing no density fluctuation after computer-controlled settings were recalibrated. Buckles at the start of the roll were eliminated.



7. Desirable, tapered density profile for roll from supercalender B



machine, such as a web break, buckles can be formed if the tension is reset too high when the machine is restarted.

Some buckle patterns cannot be evaluated with the WRD analyzer, such as when buckles are located on one side of the roll. These buckles relate to cross-machine-direction (CD) problems such as caliper variation, secondary-arm pressures, or bent mandrels.

Case history 1

Supercalender A was a 10-roll supercalender with a windup system consisting of a surface drum with centerwind assist. Roll density was influenced by:

- Total tension (pot setting)
- Taper tension control
- Current differential (ratio of surface-drum amps and centerwind-assist amps)
 - Start and finish pot settings
 - Start and finish calibration settings
- Secondary-arm pressures
- Web caliper.

The objective of our study was to determine the cause of buckles in rolls of paper at the supercalender. Some of the rolls buckled or starred completely, while others consistently formed wavy buckles around the mandrel.

Figure 3 shows the density increasing toward the end of the roll. Adjustment of the start and finish pot settings

had no effect on the upward trend in density. The next step was to inspect the computer-controlled calibration settings, which revealed that the calibration percent settings for start and finish were adjusted incorrectly. Figure 4 shows an improved density profile after recalibrating the computer-controlled settings. Standard operating procedures, which previously had been ineffective because of the incorrect computer settings, now worked fine.

Figure 5 shows the density profile of a roll that had buckles around the mandrel. The undesirable drop in density, which caused the buckles, was brought about by the incorrect operating procedures that had evolved as the operators attempted to compensate for the improperly adjusted computer controls. The operators had been increasing the total tension and the secondary-arm pressures during the first 10 in. of roll build. The density dropped when the pressure of the secondary arm decreased. The computer controls then adjusted themselves back to normal running conditions. The resultant increase in density caused the buckle pattern around the mandrel.

Trials were run after recalibration of the computer settings. During these trials, the total tension setting and the secondary-arm controls were fixed. This simple change was enough to eliminate the buckles at the mandrel, as seen in Fig. 6.

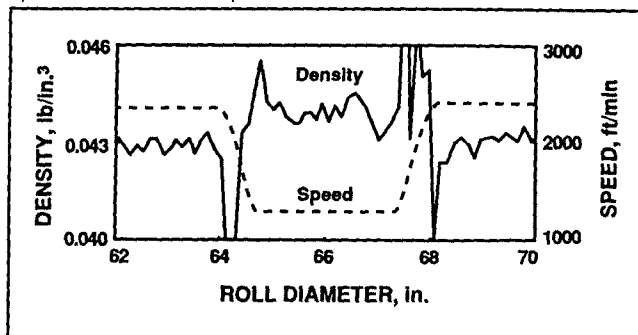
Case history 2

Supercalender B was a nine-roll supercalender with a windup system consisting of a centerwind with a rider roll. Roll density was influenced by:

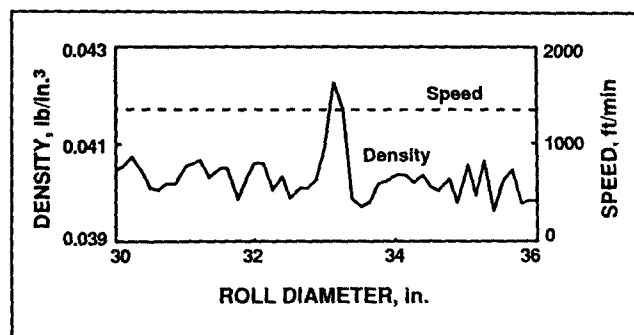
- Total tension
- Taper tension
- Rider roll pressure
- Web caliper.

The WRD profile had a slightly decreasing taper from start to finish, as shown in Fig. 7. This taper showed that the centerwind and rider roll system was working properly and needed no changes. However, during this evaluation the supercalender speed was decreased to accommodate a problem with cracked edges. Figure 8 shows that

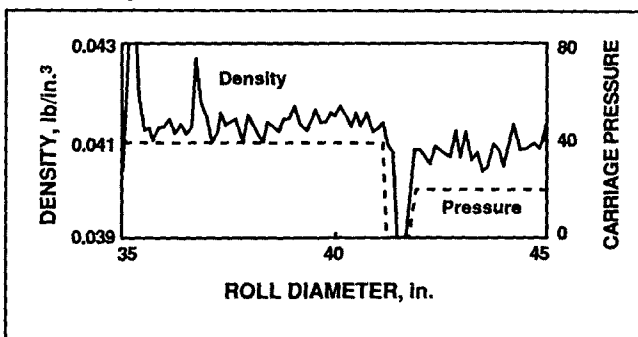
8. Density of roll from supercalender B increased when supercalender speed was dropped to accommodate cracked edges in the web. Density dropped to its previous level when supercalender resumed operation at its normal speed.



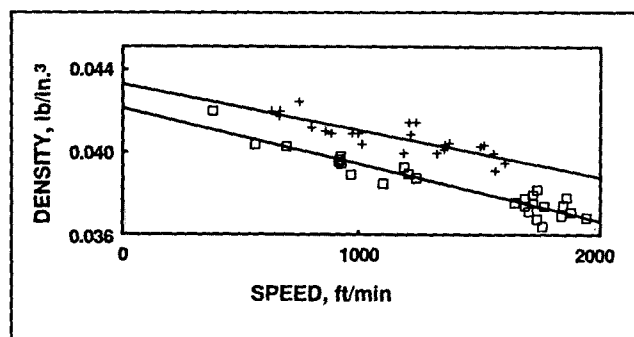
9. Density peak at 33 in. in roll from supercalender C



10. Density in roll from supercalender C at various pressure settings for the carriage arms



11. Density as a function of speed for supercalenders C and D



density increased when the speed decreased and then decreased to normal levels when the machine resumed operation at running speed. Such changes in density would normally cause wavy buckles around the defect. In this case, however, the roll did not buckle.

It was determined that this density change was due to changes in web densification rather than wound-in tension. Lowering the supercalender speed led to a decrease in web caliper, so roll density increased. Changes in densification also can cause other paper properties to change. Since consistency of paper properties is important, the speed of the supercalender should not be changed unless necessary.

Case history 3

Supercalender C was a nine-roll supercalender with a surface-drum-driven windup system. Roll density was influenced by:

- Total tension
- Carriage pressure
- Web caliper.

The WRD profile in Fig. 9 shows an increase in density at 33 in. This profile was typical of every roll that was processed. The supercalender was equipped with carriages that held each end of the mandrel. The carriages sat atop the rails and moved down the rail as the log increased in size. These carriages were attached to arms that were equipped with pressure adjustments. The higher the pressure on the carriage, the greater is the nip

pressure. Higher nip pressure created higher WRD. With the increase in density repeating itself at the same location in every roll, the problem was diagnosed to be in the carriage system.

During this evaluation, one roll was being run at shift change. When the second operator took over, the carriage pressure was decreased from a setting of 40 to 0 before being reset at 20. Figure 10 shows the result. The WRD dropped drastically when the adjustment was made to 0. When the setting was adjusted to 20, the density increased to a level lower than that obtained at a setting of 40. More information is needed to determine which of these carriage pressures would be ideal.

There were many changes in speed while running rolls on supercalender C and the supercalender running next to it (supercalender D). Different speeds produced different WRDs. Figure 11 shows that density increased when running speed decreased. As already noted, supercalender speed should not be changed unnecessarily, since this can affect other paper properties.

Caliper-corrected density

Our studies, as well as studies by others (2, 4, 7), show that changes in web caliper can confound the interpretation of WRD and wound-in tension. Basis weight and caliper are assumed to be constant throughout the machine direction for each paper roll. While these assumptions may be appropriate for paper rolls from paper machines, rereelers, and coaters, they may not be true for paper rolls

from the supercalender, where caliper can fluctuate because of changes in supercalender speed, loading, or temperature.

Figures 8 and 11 show that density increased as supercalender speed decreased. Web caliper probably decreased, with a consequent increase in web density, because of the longer nip-residence time. Wound-in tension may not have changed much, since no roll-structure defects were seen at this area.

It would be useful to have a method of correcting the density to reflect the changes in wound-in tension rather than changes in web caliper. This can be done by continuously measuring web caliper after the supercalender. In this case, basis weight is no longer assumed to be constant. Instead, web density is assumed to be constant, and basis weight, b , is calculated from web density, ρ' , and web caliper, t' .

$$b = \rho' t' \quad (7)$$

The caliper-corrected density provides a better representation of wound-in tension than does regular density.

Variation in web caliper can be used to predict print quality variation. For example, if web caliper to the supercalender is constant, then variation in web caliper out of the supercalender should correlate with print quality parameters such as roughness and gloss. Lower caliper will correlate with lower roughness and higher gloss. Uncorrected density also can be used to predict print quality, although with less confidence. Neither approach eliminates the need for on-line gloss and roughness gauges.

Permanently installed WRD analyzers

Many winder manufacturers have the option of installing a permanent WRD analyzer on their equipment. With a WRD analyzer in place, the operator can monitor the quality of every roll of paper processed through the winder. According to McDonald, on-line density monitoring is used on 32% of all Canadian newsprint winders (14).

WRD analyzers also can be installed on supercalenders. Lehtonen lists advantages for supercalender winding and paper roll structure using WRD analysis (9). With a permanently installed system, the operator can continuously monitor the supercalender operation and the quality of the emerging roll. Caliper-corrected density should be considered for supercalenders, since variation in web caliper out of the supercalender confuses the interpretation of regular WRD.

Conclusion

The wound-roll-density (WRD) analyzer is a useful tool for diagnosing machine-direction (radial) problems in any winding operation. Analysis of wound-roll density can help establish standard operating procedures and detect inconsistencies in supercalender operations.

Recommendations

Supercalender operation

- Determine the factors controlling WRD (tension controls, arm pressures, taper tension control).

- Develop standard operating procedures for all controls.
- Install permanent WRD analyzers so that operators can observe and adjust density.

Operation of WRD equipment

- Calculate footage using an encoder mounted in line with the roll shaft instead of using an encoder/wheel arrangement. Unfortunately, this is often impractical. In such cases, the encoder is mounted to a wheel, and the wheel is brought into contact with the roll with C-clamps and mounting brackets.
- Check mounting brackets frequently, since they can be loosened by vibration.
- Develop an easier, more reliable method for reading the rotations of the mandrel, possibly with lasers. The current system has little margin for error.
- Modify the WRD analyzer to monitor both unwind and windup density.
- Modify the analyzer to measure caliper-corrected density for applications such as supercalendering, where web caliper is subject to change.□

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