Reading a roll

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ABSTRACT

Web or winder defects often leave a visible record in a wound roll that read much like the rings of a tree. Varying strains in each layer as it is wound will cause changes in geometry observable visually or with simple tools. These cylindricity deviations are a fingerprint of the cause of the defect. This paper shows how to read a roll's history by diametral variations across its width, radial variances around the periphery, and variations in width or cross direction position. It also discusses the winding mechanics that produced the cylindricity deviations. Defects covered include corrugations, dishing, ridges, starring, and telescoping.

Application: *Visual examination of a wound roll can usually show that it is free of defects.*

WOUND ROLLS RECORD A history of the raw materials that produced them and the machine that made them. If we know how to read the record, we can troubleshoot the web and winding process. Reading a roll is like reading the seasons from annular growth rings on a tree, the success of a species from fossils frozen in a sedimentary stratum, or the habits of people from an archeological dig of an ancient city. Any person can read the history given sufficient sensitivity and training.

THE WOUND ROLL AS A RECORD

While archaeologists, paleontologists, and winder technologists all have specialized tools, visual inspection remains most important. Most roll defects are visible so that no special instrumentation is necessary *(1)*. Visual inspection can usually resolve defects better than most roll structure measurements *(2)*. A visual inspection also outperforms most process sensors and laboratory test measurements *(3)*. Measurements therefore support rather than supplant visual inspection. Researchers are working to replace the operator's inspection and disposition of a wound roll condition with less subjective mathematical modeling or measurement techniques. Manual inspection nevertheless remains the fastest and most certain way to detect many wound roll troubles.

Some wound roll defects are so obvious that they are visible at a glance from across the room. Vivid defects include telescoping and starring. Other wound roll defects are so subtle that one must look quite closely. Subtle defects include crepe wrinkle and slitter edge cracks. These may need a magnifying glass for clear observation. Straightedges and tape measures can easily resolve some defects.

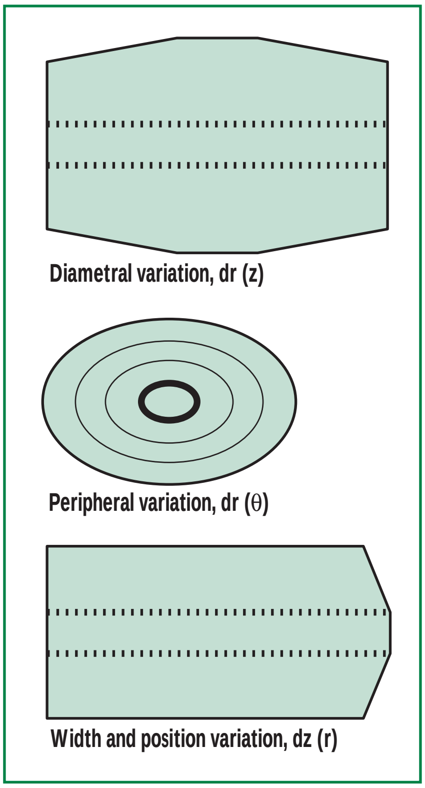
When troubleshooting winding difficulties, knowing that defects form at different parts of the wound roll's life cycle is important. For example, crepe wrinkles and bursts form within seconds of winding. Flat spots and other out-of-round troubles happen during the first minute of handling and storage. Blocking, core bursts, and telescoping occur or become apparent only upon unwinding. A single inspection therefore may not always detect an incipient defect. A roll must look good before, during, and after winding before declaring it trouble free.

ROLL SHAPE MEASUREMENT

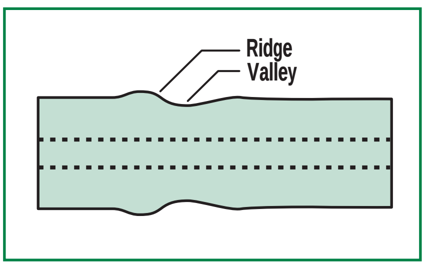
Many wound roll defects are a deviation from a perfect cylinder or, more precisely, a coil. We could classify these geometrical deviations as variations in diameter, periphery (out-of-round), or width (roll edge condition) as **Fig. 1** shows. While some roll defects are readily visible without aid, simple tools or instruments give better results with others. Measurements are also necessary to quantify roll deviations for serious quality control and trouble- shooting efforts.

Measurements of variations of diameter across the width, dr(z), are possible in many ways. The simplest technique is to place a straightedge along the top of the roll so that caliper ridges and valleys are more obvious. This is not quantitative and will not detect the conical portion of roll cylindricity error. A better approach is to measure a mean diameter using a flat tape around the roll's circumference. While this is accurate, it can be time consuming and unwieldy. The roll may require upending or suspending by the core so the tape will fit around the outside. While other instruments do exist for profiling diameter across the width, they are cumbersome *(4)*.

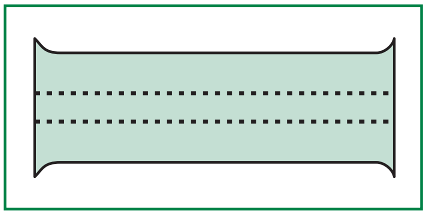
Some roll structure measurements can also infer deviations across the width because large diameter portions of the wound roll are harder or tighter. Measurements that profile across the width include all the impact hardness devices such as the Backtender's friend *(5)*, billy club, Paro Roll Tester, Rhometer *(6, 7)*, and Schmidt Hammer *(8)*. Interlayer pressure transducers, the



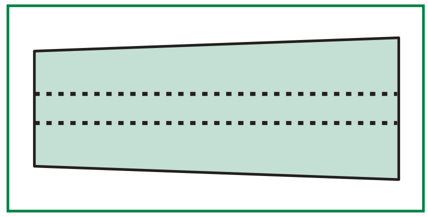
1. Examples of roll shape variations



2. Caliper ridge and valley



3. Raised edges due to slitting



4. A cone-shaped roll

Cameron gap test *(9)*, and other methods might also profile tightness across the width. Unfortunately, small ridges and valleys are often spaced too closely for many roll hardness instruments. Fine features are usually more visible by tracing the outside of the roll with a flat crayon pad.

Variations in periphery, dr(θ), due to out-of-roundness are less commonly measured. A simple means of measure is to use a flat tape from the inside diameter of the core to the outer diameter of the roll at various radials. A better documented approach is to make a polar graph of the radial runout with the Radiavarius chucked into the cores *(10)*. A more involved method is to turn a wound roll in concentric chucks and measure total indicated runout (TIR) with a dial indicator. Besides measurement difficulties, the periphery changes shape more than diameter or width because it can be easily distorted during any handling or storage process step.

Variations in width or axial position are easy to see but are very hard to measure. For example, a single layer offset the thickness of a human hair and bulging only a millimeter is readily visible against an otherwise straight roll edge. Measuring that defect mechanically without deforming it would be difficult. The simplest way to measure gentle changes in roll edge shape such as dishing or width expansion is by ruler between the roll edge and a straightedge. An indirect but automated means of measuring variations in axial position is to use an edge sensor immediately upstream of the roll during winding or unwinding.

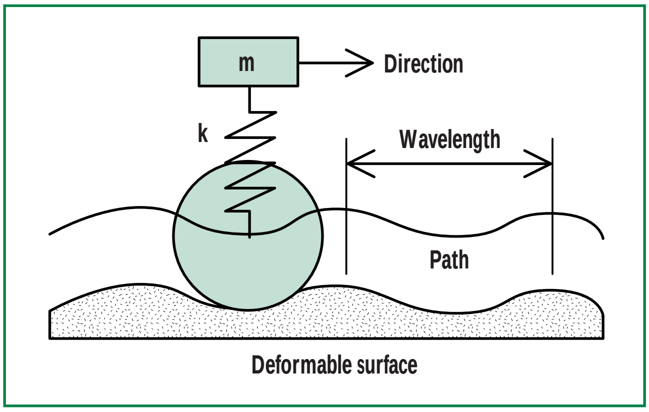
DIAMETRAL VARIATIONS

Figure 2 shows diametral variations that include the ridge and the valley. While ridges are most often areas of high caliper, they can also be long or baggy. In the first case, the roll is larger there because it contains more material. In the second case, it is larger because it contains more material, and it is more loose. If a ridge is within a few centimeters of a valley, a corrugation—rope or chain marks—may form. Beware that the size of the caliper variation that can generate a corrugation might be too small to measure with online or laboratory tests. The spacing of the caliper variation may be too close for resolution by typical measurement methods or control by typical profile actuators.

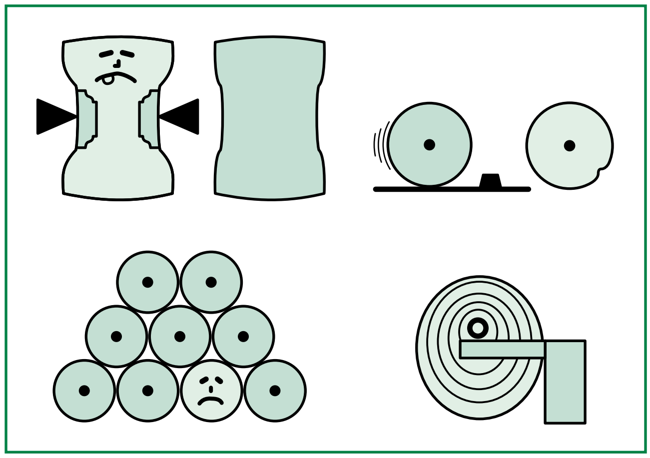
What is interesting is that the wound roll is far more sensitive to caliper than most online or laboratory instrumentation. A caliper gauge missing a ridge or valley does not mean it is not there or that it does not alter the wound roll. For example, we can easily measure a diameter or circumference difference of 1 part in 1000. Conversely, caliper measurements have difficulty resolving even 1 part in 100 or sometimes even 1 part in 10 on very thin materials. Note that caliper errors do not stack up proportionately because thick spots that would cause a larger diameter are also wound more tightly. This moderates the diametral variation. While incompressible materials may stack to diameters nearly indicated by their caliper, wound rolls of spongy materials may show diametral variations across the width due more to machine direction (MD) tension variations than to caliper variations.

Figure 3 shows raised edges due to slitting. This is a common difficulty with film slitting despite the method used. What differentiates this from a caliper ridge caused by the maker is that it occurs wherever a slitter drops into the web. Sometimes the web, roll, or slitters require oscillation to prevent this defect from growing unstably on light film. Similar diameter variations can occur from other converting processes such as coating, gluing, printing, folding, etc.

Figure 4 shows a cone-shaped roll. This shape may have resulted from a linearly varying caliper from



5. Washboard road analogy for roll vibration



6. Some roll deformation causes

the maker. The winder can produce this shape from uniform material, if a nip roller is not parallel to the wound roll's axis. This will cause building of the roll small on the high pressure, closed side and large on the low pressure, open side.

Caliper variations may be much more detrimental in winding than in end use. The caliper variations that result in rejected wound rolls may not comprise the base sheet itself before winding. Winding difficulties include excessive local nip pressures, bagginess, wrinkles, and sheet steering as follows:

- Areas of high caliper take a disproportionately large share of the nip pressure. This may damage some delicate materials.
- Diametral variations can cause an uneven stretching of the web around the roll so that bagginess might result.
- A web moves to the high diameters of rolls in traction. A thin web may therefore gather on a tiny bulge that feeds on itself unstably.
- A diametral variation causes the web to steer toward the larger side.

PROBLEMS ON THE PERIPHERY

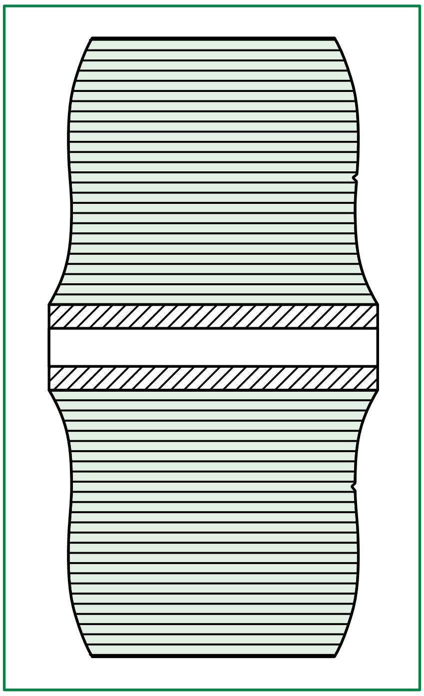
Out-of-round rolls can cause difficulties with the supplier and their customers since the rolls may not wind or unwind smoothly. If the winder or unwind is purely center driven, the web run will bounce with tension oscillations. If the winder or unwind has a nip, wound roll vibration will result—an exceptionally difficult problem to solve *(11, 12)*. In either case, excessive roll run out may require slowing the machine to avoid web damage or even web breaks.

Rolls may become out-of-round during the winding process. This will cause troublesome or even dangerous levels of vibration. While this can result from a winding machine design or operation deficiency, it is often the result of an instability of the web material itself. Grades prone to this type of vibration often include those that are bulky, have high web to web friction coefficients, or exhibit both. Examples of these grades include book, carbon less, tissue, and perhaps similar papers such as lightweight coated (LWC) or news. As **Fig. 5** shows, bouncing grades will deform and retain the deformation of any disturbance of the nip. This deformation provides a bump for the next revolution. The problem therefore builds. The roll run out that causes noticeable vibration may be only a hair's breadth in amplitude when winding stiff materials at high speeds. In more severe cases, rolls of softer materials with eccentricities more than one inch can be wound and unwound but at slow speed.

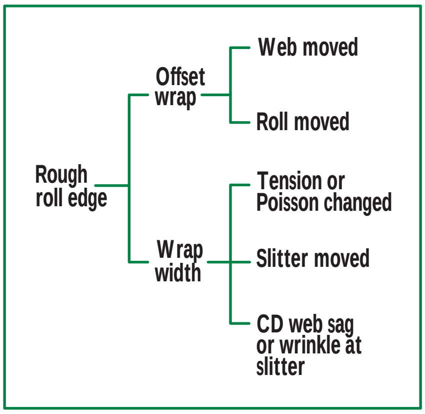
Often a wound roll becomes deformed during storage and han dling. Some storage methods such as using the belly sling or slowly rotating the roll during core support provide the greatest resistance to distortion. Setting the roll on the floor is the worst situation. Certain handling methods such as the clamp truck are notorious for leaving a pair of flat spots *(13)*. This has led to minimal clamp force designs *(14, 15)*. Although the prong truck can be less damaging, it has weight and width limitations. Conveyor stops and kickers can leave a dent in the roll. **Figure 6** illustrates some common roll distortion mechanisms.

Diagnosing the cause of the problem is often easy because the shape of the deformation is a fingerprint of the machine component that made it. Knowing the component makes the solution easy. For example, clamp pressures can be reduced or intelligent clamps can be employed. If a roll stop is the culprit, the rolling velocity can be decreased or the stroke of the stop increased. Note that one should work more aggressively to reduce the force than to decrease the time of force application. In these problems, the residual distortion approximately varies with the logarithm of time. Setting a roll down for an hour may distort it only a little more than setting it down for a moment.

Another approach to keeping rolls round is to wind them as tightly as the web, roll, or machine will allow. This is because winding tightness causes interlayer pressure that



7. Roll width growth due to Poisson expansion



8. Roll edge disturbance troubleshooting

9. Sawtooth edges due to nip friction

increases the friction between layers. Friction is important because it is the "glue" that holds the roll together. A reduction of handling distortion as much as half when changing tightness from the minimum to the maximum of a practical range is possible.

ROLL EDGE TROUBLESHOOTING

A wound roll ideally should have edges that look like they were cut by a laser. A high quality edge means that it is flat and smooth. The physics of the wound roll will cause width to swell as **Fig. 7** shows. In the figure, radial or interlayer and tangential or MD compressions cause a smoothly varying width increase due to the Poisson response. The roll is narrowest at the top because the interlayer pressure is lowest and the MD tension highest and vice versa deep in the roll.

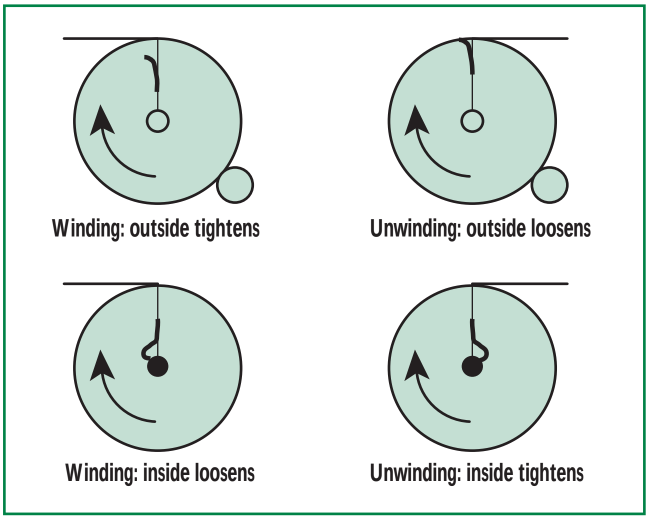
In most materials, the width changes are very small and present no difficulty. This width change can be profound and permanent on materials such as nonwovens. The material then remembers something of its previous position of varying width as it was stored in the wound roll. The width increase can also cause interior rolls to push the centers of outer rolls outward into a dished or telescoped shape. This problem is worse on wide machines cutting many rolls. It manifests itself as symmetrical and progressively increasing outward dishing for rolls further from the center of the machine. The only way to reduce the width increase is to change the material's properties or wind more loosely. (Symmetrical and progressive outward dishing can also result from causes other than width growth.)

Superposed on the nominal roll shape are subtle edge variations that result if the slit width, winding tension, or web path vary. One can read these edge disturbances much like the growth rings of a tree. **Figure 8** shows a troubleshooting diagram that first separates an edge disturbance into a width variation or an offset. Although the wide and offset wrap may look similar on one side, there is almost nothing common to their causes. The easiest way to separate the type of edge disturbance is to peel the roll down to the layer in question. A layer with two "outsies" is wide where an "outsie" is on one side and an "insie" is on the other. This is obviously an offset wrap. This basic diagnostic technique will suit almost any winding situation. This technique may also help in the troubleshooting of registration problems.

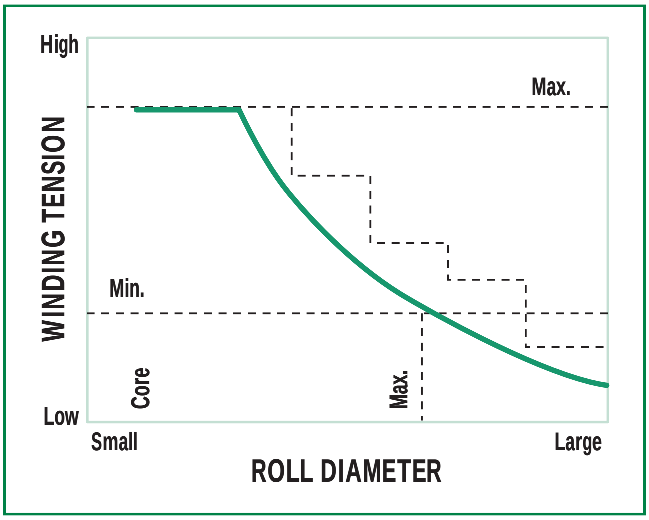
The width change may result from variations of web tension through the slitter section. Width changes can also occur if the slitter blade moves, For example, a bottom slitter band that wobbles will cause the edge to be cut into a scallop with a wavelength nearly equal to the circumference of the band. This scalloped slit edge will wind up into interference patterns on the edge of the roll. These patterns yield a bull's eye appearance with "slitter ring" diameters corresponding to integral numbers of bottom blade diameter *(16)*. Any web sag, flutter, wrinkle, or other out-of-plane feature through the slitter section will result in a wider cut width.

Roll width variations will also result whenever the wound-in-tension (WIT) of the roll changes due to variations in the tension, nip, and torque (TNT) of the roll. For example, if the web tension is momentarily tighter as it enters the windup, it will be narrower on those layers due to Poisson contraction. Another example is the stick-slick phenomenon of excessive nip control system friction that can cause a sawtooth appearance of the roll in **Fig. 9**. Changing speeds on a surface winder will also cause inertial tension upsets since few winders compensate for this effect. Machine vibration will cause the roll edge to adopt a fuzzy or sometimes corrugated appearance.

An offset wrap will result if either the web or roll moves sideways during winding. To improve the tracking of the web, the web and machine should be very uniform. Shortening the spans between the winder and the maker or slitter as much as possible is also important. This gives the web less chance to wander sideways.



10. J-line slippage cases for bulky materials



11. Tension program to minimize telescoping on a pure center winder

The roll can also move sideways in a variety of ways. Perhaps the most common is due to poor maintenance of the winding machine that allows axial play in the shaft or core system. Other causes include axial thrust loading on surface winders that can swage the ends of cores up onto the core chucks and even deform the winder frame. This axial thrust can be in either direction and can be as large as the friction coefficient times the nip load.

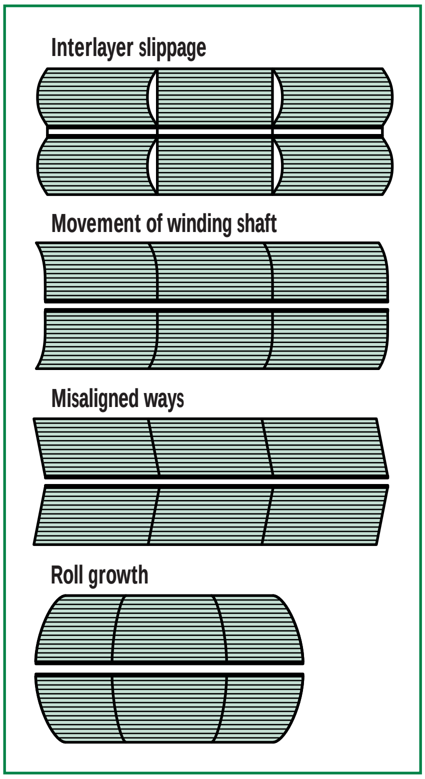
Interlayer slippage inside the roll during winding or unwinding can allow both MD and sideways movement. A J-line drawn on the side of the roll is the best detection for interlayer slippage *(17, 18)*. An initially straight line will bend into an arc as layers shift under the rolling nip as **Fig. 10** shows. Note that the rolling nip can be internal due to core support or external as in surface winding. The direction of movement is different for winding and unwinding or for bulky and stiff materials. Although the details of this interlayer slippage under a rolling internal or external nip are very complex, the effects are very common. This interlayer slippage causes many winding defects including burst, core burst, corrugation, crepe wrinkle, and telescoping *(19)*.

The telescope occurs where the layers broke free first in the MD that then allows a possible sideways shift. Although the tension induced torque could be a factor in the MD slippage, another means is the rolling internal nip of the weight of the core- supported roll. The winding roll can teach us how to program the tension curves to avoid telescoping of the core supported roll. As **Fig. 11** shows, the winding tension begins at the highest value the web or machine can sustain. The tension level remains until the roll begins to J-line near the core. When the J-line shifts, the winding tension is decreased until it freezes again and so on in a step-wise fashion. One makes a program that clears the undersides of the steps. Note that the maximum roll diameter to which any particular grade can be wound is the intersection of this winding tension curve with the minimum tension the grade or winder can sustain. Also note that the resulting ideal tension program to avoid the telescope is far different from the constant tension, taper tension, or constant torque curve in common use.

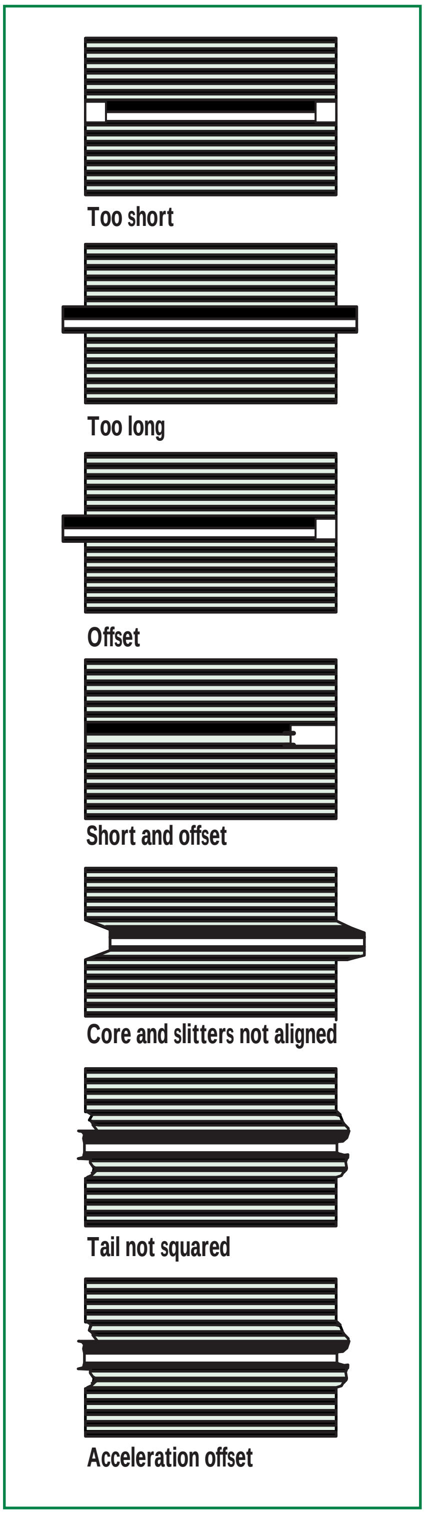
Dishing during winding can also happen if the cores move during winding. This may happen due to slippage on a core shaft or axial play in the shaft or chuck system. If the winding arms or ways are misaligned, the rolls will build into cones. Dishing can also happen due to the roll growth or Poisson effect discussed earlier that yields a progressive outward dish. **Figure 12** summarizes some types of dishing during winding.

Figure 13 indicates other common roll edge conditions one may encounter. For a proper start, the cores must be aligned so each lane will track after slitting. If a lane is forced from its desired path when taped to the roll, it will return there after a dozen or so web widths have run. The operators must also make certain the lanes are evenly taut through the machine and squared with the core before taping. A problem here is not pulling enough web through during thread up.

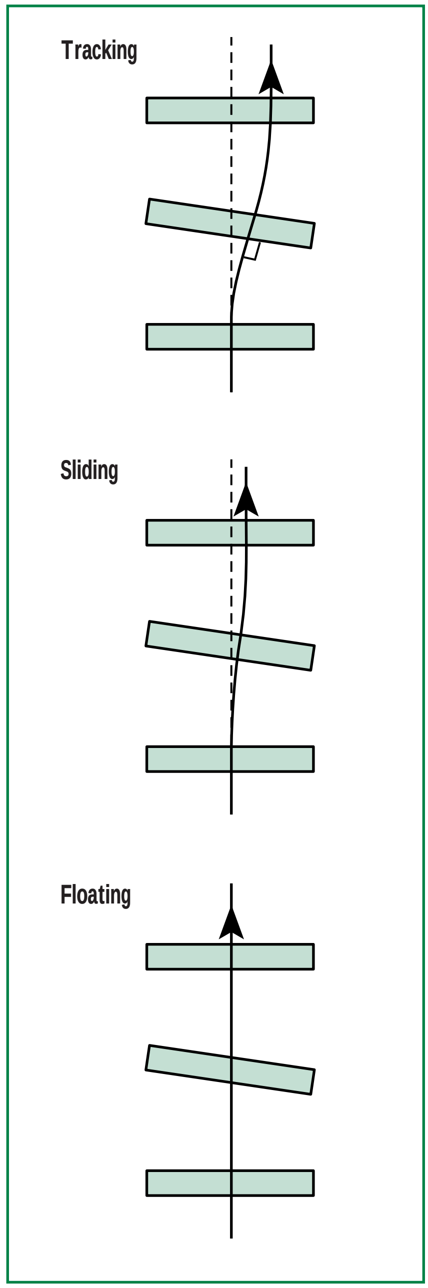
Sometimes the roll edge will show an edge disturbance corresponding to the top and bottom of speed changes. This disturbance could be wide, narrow, offset, or a combination. Although this disturbance is commonly known as an acceleration offset, it is a drive system problem where tensions are not held properly during the challenging dynamics of speed changes *(20)*. As **Fig. 14** shows, a web that changes its state of traction—due to a tension upset—will change its path through a machine at a misaligned roller.



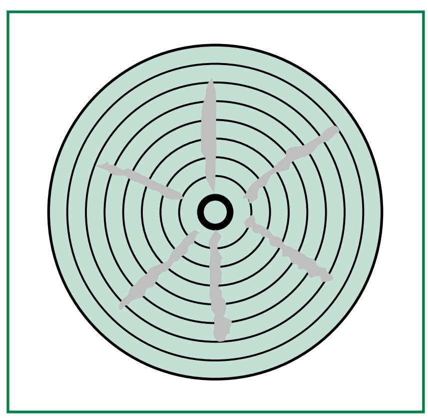
12. Dishing examples



13. Edge disturbances near the core



14. Offsets due to changes in traction



15. Starring

The starring or spoking in **Fig. 15** indicates poor roll structure or abusive handling of the rolls. Avoiding starring is usually possible by making certain that the foundation of the wind is solid—no core crush—and continuous—no core key ways. The roll must also have the proper structure with a tight start, looser finish, and bump less curve.

SUMMARY

We need not have excess concern whether our rolls are well wound and free of defect. If they look good upon close inspection, they probably are satisfactory. All we need for tools are our own eyes—sometimes supplemented with a tape measure, straightedge, and pencil. Although modeling and measurement have and will continue to provide insight and understanding, these techniques do not have wide use. They are more complex and not as discriminating as simple visual inspection.

Most defects are readily visible from the exterior. Only some such as

KEYWORDS
Defects, dishing, perception, starred rolls, telescoped rolls, trouble shooting, vision, winding, wound rolls.

blocking, bursts, and certain wrinkles are hidden from view in the interior of the roll. These avoid detection until unwinding. Rarely do defects require instrumentation to detect such as caliper loss due to interlayer pressure.

The fact that visual inspection works so well is not surprising. It is because winding is nothing more than a packaging operation. As a package, the roll only needs to hold its cylindricity sufficiently to avoid most defects. TJ

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