Roll bouncing

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ABSTRACT

The finishing industry does not completely understand the phenomenon of roll throw out or roll bouncing. This paper explains the mechanism of roll bouncing, the most common causes of the phenomenon, and the many known solutions to the problem. It contains a listing to help mill personnel identify causes of vibration to reduce or eliminate them.

Application: *Following a suggested troubleshooting guide, one can identify causes of roll throw out or roll bouncing leading to their elimination.*

CERTAIN PAPER GRADES ALWAYS have roll bouncing. Vellum, sack kraft, and fine paper are common vibrating grades while newsprint is nonvibrating. In the last ten years, the finishing industry began to experience intermittent periods of vibration often ending in throw outs on many grades of paper.

All two-drum winders whatever model or manufacturer experience roll vibration at some time. A mildly vibrating roll might not be a problem. If the vibration lasts for a few seconds, there might be a barely visible ring on the side of a roll. A stronger or longer vibration will leave a heavier ring that is more than a cosmetic defect. If the layers of paper have sufficient displacement, there can be ample interweaving so two adjacent rolls will be difficult or impossible to separate. This causes a serious loss of production. If roll vibration becomes a roll bounce, there can be loss of an entire set and concomitant winder damage.

Most roll throw outs begin with a vibration. The vibration amplifies and often changes into rocking between the drums or from side to side. If the winder is not slowed immediately, one or more rolls come out of the drum pocket and start bouncing around the winding cluster. The amount and degree of damage are proportional to the speed at which the bounce occurred. On properly designed winders, there is practically no danger of rolls flying out of their confinement to hurt any one in their vicinity. There can be internal damage and substantial down time.

Roll vibration and throw out are not new phenomena. They have become larger and more universal problems for many reasons. All new two-drum winders are now shaftless. Winders run faster. Design speeds of all new winders are 2600 m/min (8500 ft/min). Recycling changes certain physical properties of paper grades in sometimes unexpected ways. These potential causes of roll vibration combined with high speeds create serious problems.

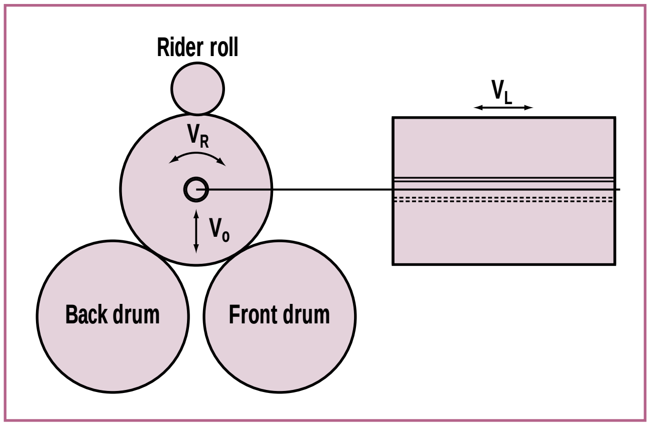
The roll throw out phenomenon is complicated. There are many sources of vibration on every winder. All winders and paper rolls are subject to free vibration due to internal forces within each system. These are the natural frequencies. Simultaneously each roll and each rotating component of a winder produce forced vibrations because of their geometric imperfections and imbalances. Whenever a single roll or the whole set can accidentally have a natural frequency equal to or at least near these forced vibrations, there can be resonance. If the vibration persists, resonance amplifies it further to cause roll bounce.

PURPOSE

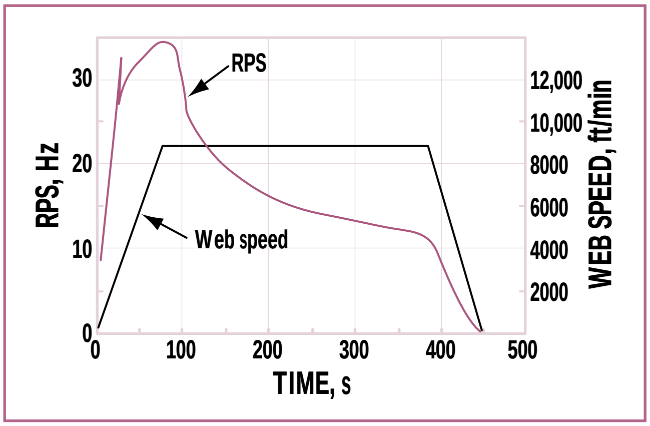
This paper will define roll throw out and roll bounce, explain the many contributing elements, present a strategy for analyzing the root cause, and provide old and new solutions to the problem. There will be a distinction between winder vibration and roll vibration. In this presentation, the author differentiates between them for simplicity. Failure to differentiate between the two phenomena can result in wasted time, effort, and money. There are some simple and inexpensive methods to determine the root cause of vibration—paper rolls or the winder. After passing that hurdle, one can apply the existing body of knowledge using engineering and 30 years of industry experience to resolve roll vibration and throw out problems.

ROLL BOUNCING PHENOMENON

There are many different vibration frequencies present on any winder at a given time. If one or more rolls develop a natural frequency matching the vibration that persists for more than a few seconds, resonance can amplify the vibration and eventually cause a throw out. From this, we can immediately recognize the necessity for two simultaneous phenomena—a source of vibration or a forcing function as engineers call it and a roll of paper with a natural frequency matching the vibration. Stated another way, no vibration present in a winder will have any effect unless there is at least one roll of paper that has a natural frequency equal to it. This leads to another important conclusion. The complexity of the problem of bouncing and of predicting what can and will happen at any moment arises from two sources. The natural frequency of every roll of paper is different from others. In addition, the frequency



1. Three fundamental vibration modes



2. Frequencies created by paper rolls

changes continuously as rolls increase in diameter and their rotating speed in revolutions per second (RPS) changes during the winding process.

Following are some common causes of paper roll vibration and bouncing:

- Accidental throw outs due to web breaks
- Mechanical hardware
- Roll structure
- Physical properties of paper such as layer-to-layer coefficient of friction
- Barring
- Operational problems.

Any cause can throw a roll or a set. Rarely does one of these causes exist alone. There are usually two or more causes working together. This makes precise identification of causes difficult and lengthy. This paper is an attempt to provide a troubleshooter faced with paper roll vibration with a theoretical understanding of the phenomenon. Enough practical information will lead one through the maze of conflicting information to eliminate methodically the incorrect causes and find an acceptable solution.

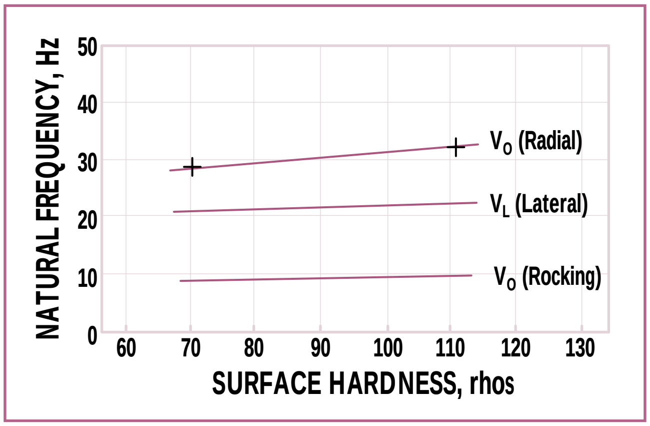
TYPES OF VIBRATIONS

Part of this article uses earlier studies *(1,2)*. The remaining information comes from more recent work to help finishing departments cope with roll vibration. Consider first the fundamentals.

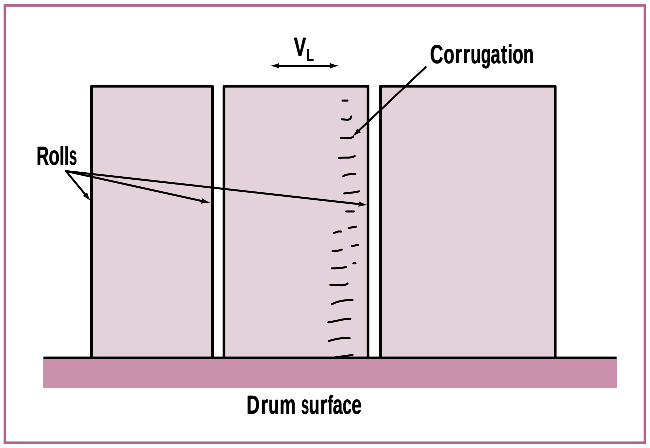
A roll of paper wound on a two-drum winder can vibrate in the three fundamental modes shown in **Fig. 1**: vertical, rocking, and lateral. The rocking mode often occurs on two-drum winders. In this mode, a roll rocks back and forth between drums and twists from right to left pivoting around its vertical center axis. Rolls can vibrate in a single mode or in any combination of the three. Chances of throw out increase dramatically when rolls have more than one mode of vibration. Vibrations present any time in a winder can come from different sources. The winder itself creates some, and the rotating paper rolls and the reel induce others. Some reach the winder through the foundation from various outside sources.

The vibrations created by the winder are those due to eccentricities or imbalances of any carrying rolls or other rotating components. These frequencies are constant except during acceleration, deceleration, or any speed change. The second group of frequencies present on a winder comes from the paper rolls and the expiring reel. This undergoes continuous changes during a winding cycle. The reel starts at a slow speed—4.5 Hz. As the speed of the winder increases and its diameter decreases, the speed accelerates to 20 Hz by the end of the set. The situation reverses in the winding cluster. There the rolls start turning at a very high RPS—35 Hz—by the end of acceleration and then slow to zero at the end of each set. **Figure 2** illustrates the typical frequencies a roll of paper generates as it builds from a 11.5 mm (4.5 in.) core to a 1270 mm (50 in.) diameter roll. In addition, many rotating pieces of equipment in a mill transmit their frequencies to the winder through the foundation. There are therefore many different vibration frequencies present at the winder at any time.

Figure 3 illustrates some specific natural vibration frequencies of an uncalendered bleached kraft roll 1092 mm wide and 1206 mm in diameter (43 in. x 47.5 in.). The figure is a snapshot at a specific time. During winding, the only parameter that remains constant is the width of a roll. Diameter, weight (mass), and spring constant (hard or soft) continuously change as a roll winds under different operating conditions. The natural frequency of each roll in a set is continuously changing. One should also note that primary natural frequencies of paper rolls are in the middle of frequencies nor-



3. Typical natural vibration frequencies of a kraft roll



4. A group of narrow unstable rolls

mally found on winders—5—70 Hz.

The following are some important conclusions about winder vibration:

- Some grades like kraft and vellum vibrate more than others.
- All paper rolls vibrate somewhat, and vibration frequencies change during the winding cycle.
- All rolls can vibrate in the three modes described earlier—vertical, rocking, and lateral.
- One vibration mode intersecting with another amplifies vibration.
- Vibration amplifies further if a driving frequency matches the natural frequency of a roll.

There are some additional conditions that increase the possibility of vibration or throw outs:

- Higher winding speeds
- Narrow rolls
- Uneven cross direction (CD) basis weight or caliper profile especially when low in the center of the winder.

Once a roll becomes unstable in the machine direction (MD), it can easily transfer into one or all three modes.

MECHANISM OF ROLL BOUNCE

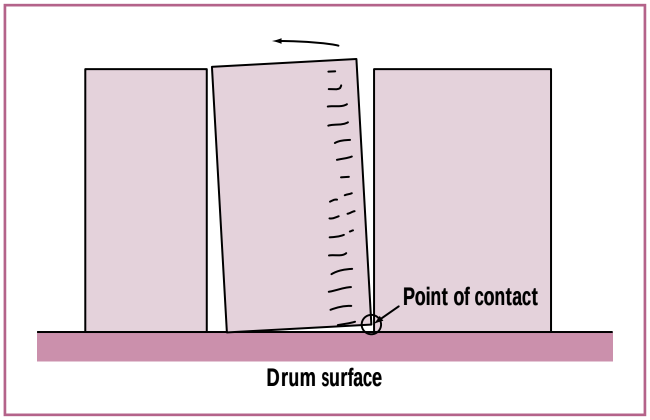
Before going further, one must understand the actual mechanism of roll bounce. **Figures 4, 5, and 6** show the process graphically. The mechanism can throw a roll of any grade out of any winder and has no relation to vibration. Any time a web break occurs, there is a chance that a wad of paper will get under one side of a roll. The bottom of the tilted roll is moving at the same speed as the drum and the web. The rotational speed of the side of the adjacent roll slows as it approaches the core. Then the faster moving edge of the tilted roll touches the slower moving side of the adjacent roll and spirals out of the pocket with great force. There is another way to look at this. When the edge of one roll touches the side of the adjacent roll, its rotational energy instantaneously converts into translational energy. A spiral gouge on the side of an adjacent roll is a certain sign of this type of roll bounce.

VIBRATING VS. NONVIBRATING GRADES

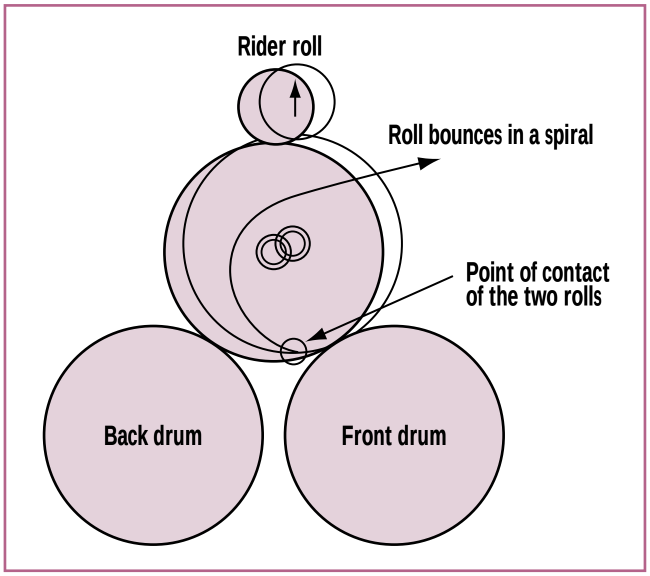
Why are some paper grades more prone to vibrate than others? Daly has explained how roll deformation with high coefficient of friction creates the necessary conditions for making some paper grades more susceptible to vibration than others. Let us review those points. Daly starts by comparing a roll of paper rotating on steel winder drums with an automobile traveling on an unpaved road. Like the surface of an unpaved road, the surface of a paper roll will deform and acquire a surface similar to a washboard. Any imperfection on the surface of the roll causes the first deformation. The rider roll bounces off it and strikes the roll surface to form another depression. During the following revolutions, the two drums and the rider roll will bounce on the depressions and add new ones. This process repeats itself. Eventually, bumps like an unpaved washboard road will cover the entire roll surface as **Figs. 7 and 8** show. The following combination of factors is necessary to generate the washboard effect:

- A deformable surface (the roll of paper)
- A rotating elastic cylinder of known frequency of vibration (the roll of paper)
- Rolling on an inflexible, nondeformable surface (the drum or drums)
- A small disturbance on the deformable surface to cause the roll to start an oscillation.

Figure 8 shows two disturbances generated downstream from the original one. As the roll continues to



5. One roll shown tilting sufficiently to touch the adjacent roll



6. The roll spiraling out of the drum pocket

turn, these disturbances propagate around the surface and form a repeating pattern. Daly stated, "If the wave lengths pitch out to exactly an even number of cycles per revolution, the condition of amplification of the disturbance will be the worst and may amplify enough to cause the roll to be thrown clear of the drum(s); hence 'bounce.'" An even number of deformations are not necessary for a violent vibration.

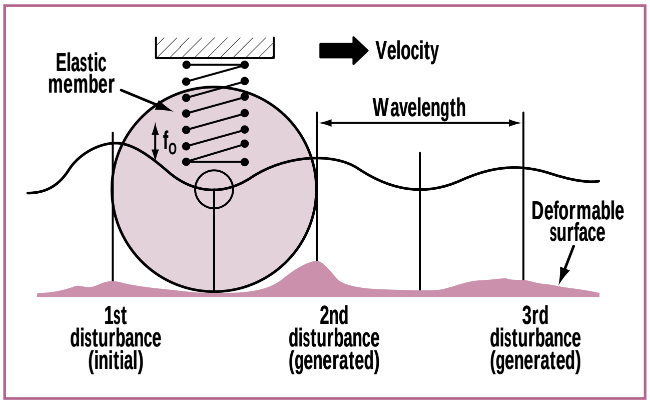
The model above describes the mechanics of throw out but does not explain why some grades of paper vibrate more than others. To understand this, one has to consider another thought also developed by Daly. This second part of the puzzle concerns the capacity of a roll surface to lock the deformations until new ones form. The mechanism here is the friction force that prevents layer-to-layer slippage. Friction force develops from a combination of radial compressive forces created by wound-in tension and the layer-to-layer coefficient of friction of the material. This makes some grades vibrate more than others. On the scale of 0.00 to 1.00 for static coefficient of friction, paper grades divide into vibrating and nonvibrating at approximately 0.5. Above the value, grades tend to vibrate. Below 0.5, they do not. Daly illustrates this phenomenon in **Fig. 9**. A material with a low coefficient of friction like playing cards will immediately spring back to its original shape after being bent. A stack of sheets with a very rough surface will retain deformation longer. The mechanism is a combination of the layer-to-layer coefficient of friction, μ, and the compressive radial force, P_C. Together these items make the friction force, F, that resists layer-to-layer slippage:

$$F = \mu P_C \qquad (1)$$

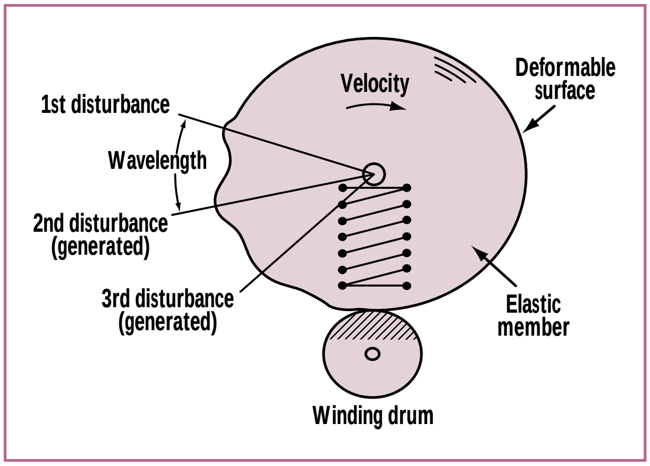
Measurements taken on actual rolls that developed deformations show run outs of 0.2 mm (0.008 in.). The difference between bouncing and nonbouncing grades is in the ability of the roll surface to hold or dissipate the deformations. All rolls of paper deform the same way. If the coefficient of friction is low, the deformations have a chance to dissipate. If the coefficient of friction is high, the deformations cannot dissipate before new ones form. They become permanent, help propagate new ones, and become a source of vibration with a frequency equal to the number of deformations and the surface speed of these rolls.

Consider now the second element of the friction force—P_C. Low coefficient of friction combined with high compressive forces can lock the sheets together and change a grade from nonvibrating to vibrating and vice versa. A grade of paper with a marginally high coefficient of friction with a low wound-in tension will not vibrate at all or vibrate very little. Simultaneously a roll with a very low coefficient of friction but high wound-in tension will vibrate. **Figure 10** shows this relationship as a family of curves for different paper grades as they relate to the coefficient of friction and layer-to-layer pressure. Daly noted the importance of the friction force, μP_C, the force resisting slippage. The value of μP_C depends on both variables. This explains why coated paper despite its low coefficient of friction may vibrate if wound with a high wound-in tension. In marginal cases, any change in either variable can move the paper grade from one extreme to another.

This information gives a grasp of the relationship between the magnitude of μ and vibration. On a scale of 0.00 to 1.00, paper grades with a sta-



7. Washboard effect on an unpaved road



8. Washboard effect on the surface of a roll of paper

tic coefficient of friction over 0.5 are prone to vibrate. As the magnitude of μ increases, so does the tendency to vibrate. After establishing this relationship, it is easier to visualize how a mill can go from a smooth operation to a severe vibration in a matter of hours. If the coefficient of friction is close to the value of 0.5, any minor increase in it or in the P_C caused by increase in wound-in tension will immediately push the set into a vibrating mode. This is another reason why coefficient of friction of paper should be part of a standard battery of tests performed on some regular basis. How can one do anything about vibration if an important variable affecting it is not measured and known?

Let us now look at another scenario. If μ is again close to the 0.5 mark and the set is not vibrating because the rolls are wound with a lower wound-in tension (lower P_C friction force), any change in μP_C caused by changing winder parameters can push the set from the nonvibrating into the vibrating range.

Before formulating prevention and vibration control techniques, we will consider other possible causes of roll vibration. For convenience, the arrangement is in groups by cause—mechanical, control, roll structure, paper properties, and operating characteristics.

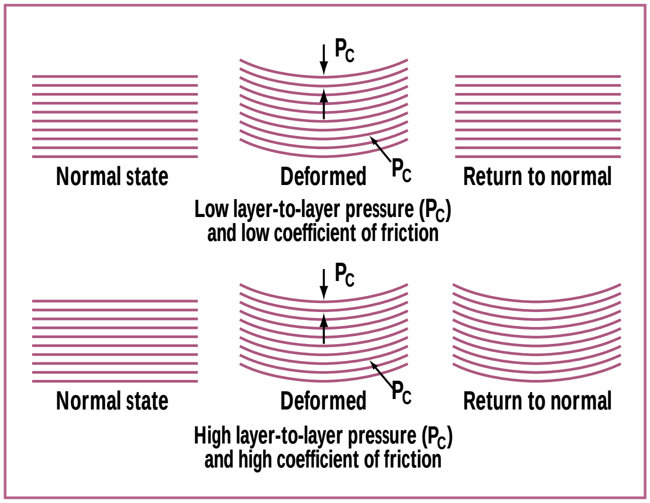
VIBRATION CAUSES AND SUGGESTIONS FOR THEIR REDUCTION OR ELIMINATION

There are many possible and probable causes of roll bouncing. The phenomenon is a way of life on all those grades of paper having a high static coefficient of friction ($\mu > 0.5$). There are also other conditions under which roll bouncing or vibration can occur. The following check list can help eliminate most possible causes of vibration as part of the troubleshooting process described at the end of this paper.

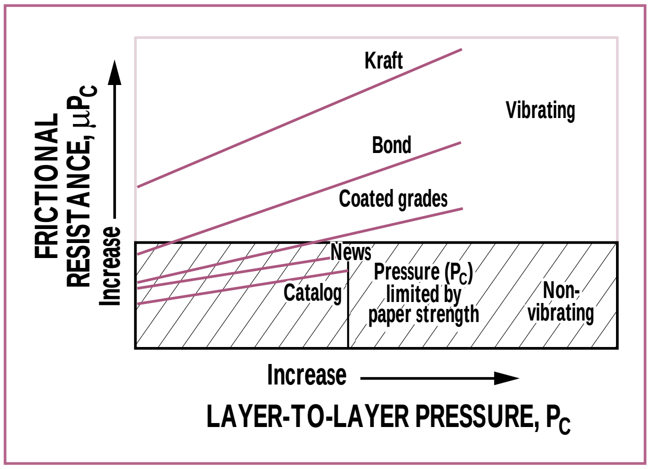
Mechanical

Here is a list of mechanical conditions that have caused a roll throw out. The inclusion of a condition in this list does not mean that every time one has this mechanical condition the rolls will be thrown out. It merely implies that these mechanical problems can induce vibration in any winder and set vibration in place under proper conditions *(3)*.

1. A bad rider roll bearing, a bent rider roll journal, a defective drum bearing, or an eccentric or unbalanced rider roll segment or drum may induce vibration into the winder and the set of paper rolls long before a catastrophic failure occurs. Whenever the driving frequency created by these defective components meets a roll or rolls with a matching natural frequency, the danger of roll vibration and throw out will occur. Winders should have proper maintenance. Immediately investigate any incidents of vibration. Bent or worn journals, bad bearings, and unbalanced rotating members all induce dangerous vibrations and could cause a roll bounce. Keep the winder properly aligned *(4)*. Check alignment of high speed primary paper machine winders at least once or twice per year. Correct any misalignment promptly.
2. Any binding in the ways that can cause a momentary hesitation of the rider roll or core chucks can cause an immediate and violent roll bounce. Rider rolls and core chucks must move up and down freely and smoothly. Check and clean all ways and guides regularly.
3. Check all bolts and nuts and tighten them as required.
4. Replace rider roll chains and sprockets every two years and check torque tube keys for wear and slip. There are some documented cases of roll bouncing traced to worn rider roll chains



9. Bouncing and nonbouncing grades



10. A family of vibrating and nonvibrating grades

and sprockets. Because worn chains have many other adverse effects on roll structure, winder runnability, and safety, change all chains approximately once each year and all chain sprockets every other year.

5. Although they do not prevent roll vibration and throw outs, direct acting rider rolls by the nature of their design are stiffer and provide an additional benefit of viscous dampening. When a bounce does occur, some energy dissipates on displacing the hydraulic fluid in the cylinders. The capability of loading the rider roll cylinders in case of emergency stops provides a further protection from or at least a reduction in damage.

Controls

Certain types of control malfunctions have caused roll vibration or throw outs. This is a list of the well-documented ones.

1. Maintain, calibrate, and tune up winder controls regularly. Depending on age and design, check the controls at least once every three months, although a monthly checkup is preferable.
2. On all shaftless two-drum winders, the rider roll provides a vital function of holding the set of rolls in the pocket between the drums. Under no circumstances should the rider roll be allowed to rise off the rolls while the winder is running. Accidental lifting of a rider roll at high speeds could be and often is a cause of roll throw outs.
3. Excessive core chuck pressure, if applied during a run, can cause a throw out and must be prevented. The best way to resolve this is to modify the core chuck mechanisms to a type that lock when the winder is in the running mode.
4. Violent fluctuation of hydraulic pressure in the rider roll relieving system has caused several documented roll bounces.
5. Extremely high negative or positive torque difference between the front and the back drums at large roll diameters—over 1000 mm or 40 in.—can cause roll bouncing.
6. A sudden drop or increase in rider roll nip caused by changes in hydraulic pressure can deform a set of rolls. At high speeds, this deformation will begin a violent cycle of vibrations that has thrown rolls clear out of the winding cluster.
7. Closed loop nip control systems may become unstable under certain operating conditions. Never allow the rider roll to lift off the surface of the paper rolls.
8. Maintain, calibrate, and tune up the drive with the rest of the winder controls. Check acceleration and deceleration rates. Excessive deceleration rates can be dangerous.
9. Rolls or complete sets may be thrown out of a winder if the front drum decelerates faster than the back drum. This happens when the front drum motor goes into emergency stop while the back drum decelerates under normal control mode. Parking drum brakes can cause the same problem, if they are energized before the winder comes to a complete stop.
10. Rider rolls must decelerate at the same rate as the drums. Rider rolls trying to turn much faster than the rest of the winder add an additional component that can help throw the rolls.
11. Install a vibration sensor on the rider roll beam and interface its output with the drive to slow the winder down immediately, if excessive vibration is sensed. This

will not prevent all roll throw outs. Preventing some of them from happening and reducing the damage from them is worth the effort.

Roll structure

Rolls wound with an improper structure vibrate more than rolls wound correctly.

1. All rolls in the set must have a good start. A good rule is to have the level of wound-in tension near the core 10–20% higher than in the rest of the roll. Rolls must also be round. The best way to assure this is to accelerate immediately to the highest speed possible. In cases requiring slower speed for any reason, 915 m/min (3000 ft/min) is the lowest speed necessary to obtain a round roll at the start.
2. Very hard rolls vibrate more than softer rolls. Excessive torque difference at large diameters makes rolls rock between drums. If negative torque difference (crossover) cannot be used on a specific grade, at least reduce the torque difference to near zero by the end of the set.
3. Keep the level of wound-in tension constant and uniform throughout the roll. Avoid large upsets as localized starring can cause vibration.

Physical properties of paper

The physical properties are usually available for a grade of paper. Studying them can occasionally offer clues.

1. Layer-to-layer coefficient of friction is important for making a grade prone to vibration during winding. Any static μ higher than 0.50 makes a grade a potentially vibrating one. Control coefficient of friction within safe limits by using chemical additives. For marginal cases, one may effect the transition from vibrating to nonvibrating state by changing P_C by winding harder or softer rolls. Knowing what changes the coefficient of friction in either direction can help the mill to control it better and, if necessary, adjust it or the roll structure to avoid or limit vibration.
2. Improve CD basis weight and caliper profiles. Uneven profiles reduce the effectiveness of conventional rider rolls in stabilizing narrow rolls. Conventional rider rolls sit on high spots of the set and do not touch the lower parts (light under the rider roll). A narrow roll with a hard spot is especially unstable in the lateral direction.
3. Barring creates out-of-round and lumpy rolls. Some common causes of barring created on a paper machine are mechanical vibration of press rolls and hydraulic vibration of stock in the delivery systems. These rolls become the sources of vibration frequencies that can begin vibrating themselves or make the adjacent rolls and wider components vibrate *(5)*.

Operating characteristics

Simple operating techniques sometimes contribute to roll bouncing.

1. Cores with out-of-square ends are a common cause of roll bouncing. A two-drum winder requires a small pre-load on the cores at the start of winding. Cores with nonsquare ends under an axial load will defect. They can come out of the pocket or vibrate until some paper builds on them. Later in the winding process, when diameters of adjacent rolls begin to vary because of caliper variations, their rotational speeds differ enough that these edge imperfections can catch on one another to create a perfect mechanism for tilting them. This causes a bounce as Fig. 4 shows. A minimum squareness standard for fiber cores is ± 0.13 mm (0.005 in.) on 100 mm (4.0 in.) diameter cores. For steel cores the tolerances should be even tighter.
2. Steel caps (tips) pressed on at an angle cause the same vibration problem as described in 1 above.
3. Bent cores or cores deformed in any way will cause a bad and out-of-round start and a possible bounce later. Use only straight cores. Any bow or kink in a core will cause the rider roll and drum nips to vary during the critical first turns at the beginning of the wind with the resultant soft start. Reconditioned cores should meet the same new core specifications.
4. Steel caps can be a source of additional problems. If the caps are larger in diameter than the core, a conventional rider roll will sit on top of these caps and will have little or no contact with the body of the core. This results in a soft start and a potential source of vibration. Core OD in the same set should not vary more than 0.13 mm (0.005 in.). The above rule applies to mixed sets with capped and plain fiber cores.
5. A heavy wad of paper under one end of any roll during a web break can cause a roll throw out on any grade.
6. Interlocking cores—cores of either wrong length or cores that were not aligned properly with slits—can cause a roll tumble if caliper variations sufficiently change the size of the adjacent rolls. Always cut cores to size and adjust core chucks to line up with slits.
7. If CD basis weight or caliper variations are such that one can see light under a conventional rider roll, try not to place narrow rolls in that area. Narrow rolls are less

KEYWORDS
Damage, equations, friction factor, hazards, motion, problem solving, trouble shooting, vibration, winding drums, wound rolls.

stable and lighter and therefore more susceptible to excitation and vibration. Any rolls under 635 mm (25 in.) are narrow.

8. When checking fiber cores, make sure that cores are pre-loaded at least 1.5 mm (0.06 in.). Excessive pre-load is not advisable, but loose cores will allow the whole set to move in the CD causing dishing and a possible throw out of a narrow roll.
9. When the diameter at which the rolls begin to vibrate is known—there might be a slight rumble at that spot and a visible ring on the side of the roll—one can use some techniques developed over the years to reduce the vibration, prevent a throw out, or both.

   Decrease the line speed. This is the least satisfactory of the methods but sometimes the only one available. If the winder is running at maximum speed, this might be the only safe thing to do.

   Change the natural frequency of the set momentarily. Since it is not possible to change the mass quickly, change the shearing constant, K, by winding some layers of paper at a changing wound-in tension just before the vibration begins. Do this by reducing or increasing unwind tension, rider roll nip, or torque difference momentarily. After the danger has passed, bring the changed variable back to the original value. This method creates a momentary change in roll structure, but it is a small price to pay in comparison to winder damage that might occur with roll bounce. On winders with computerized tension, nip, and torque (TNT) controls, it is possible to program these changes into the operating program. One must initiate the change just before the onset of vibration. When using this method, remember that it is easier to make a quick transition to a softer roll than it is to make a tighter roll. The ring of paper with less wound-in tension creates a softer roll. This changes its natural frequency to one that is not excited by the existing vibration frequency *(4)*.

   Attempt to accelerate through the dangerous frequency. The principle here is to proceed through the area of vibration as fast as possible instead of running in it for a time. This allows the rolls to become more excited. **Figure 11** shows a technique of doing this. Accelerate the winder to at least 915 m/min (3000 ft/min) to assure a round start. Immediately before the vibration begins, accelerate the winder through the vibration range as fast as possible.

   Change the top speed of the winder continuously as **Fig. 12** shows. Never allow any one frequency to dominate long enough to excite any rolls.
10. Severe vibrations can be transmitted into the winder through the foundation from other mill sources.
11. The winder foundation might be inadequate for the job.

A RATIONAL APPROACH TO ROLL VIBRATION

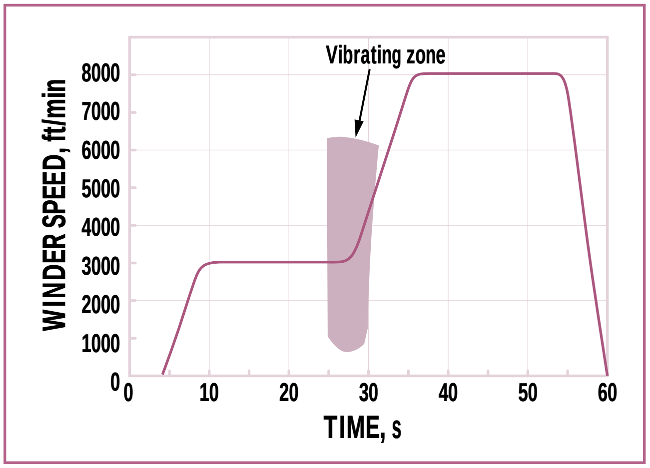
What does one do when confronted with roll vibration and throw outs? Here are some suggestions and a rational, systematic approach to this difficult problem. Finishing operations can use this as a troubleshooting guide.

Establish if the vibration or throw out was an isolated phenomenon. If it was and it occurred during a web break, there is little one can do but fix the damage and continue. If the winder has a chain type rider roll, it is a good idea to consider a direct acting rider roll for a rebuild. When the winder already has a direct acting rider roll, consider loading the rider roll to 2630–3500 N/m (15–20 pli) at any detection of web break. Follow also the lists of possible causes and solutions in this paper to isolate any of the common causes of roll throw outs. These lists are a good place to begin troubleshooting.

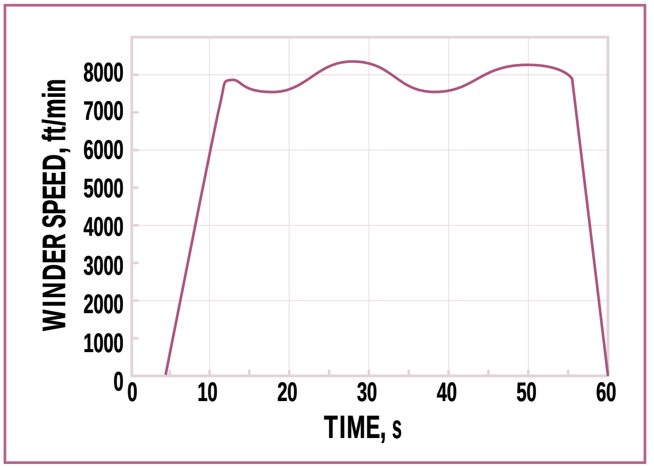
What should one do if vibration persists? Roll vibration does not always result in a bounce. More often there is only a spot—a ring on the diameter of the rolls where the winder vibrates a little. Depending on the intensity of vibration, this can be a minor cosmetic problem or can occasionally cause serious offsets. There is always a reduction in wound-in tension, and interweaving. Now one must establish if the problem is caused by the winder (hardware) or by the vibration of paper rolls in it. It is important to identify this as early as possible since the troubleshooting process and solutions are completely different. This paper concerns itself only with the second type of vibration.

Here are two simple means to differentiate between these sources of problems:

- Run the winder up to full speed without paper and check if it vibrates at any of the speeds. Besides running it up in normal acceleration, it is a good idea to vary the speed slowly over 20 min in manual to give any imbalance time to occur.
- Use another test as a check. If paper rolls are the cause of vibration, one can change the diameter at which they vibrate by any of two available means. Change speed. Run the winder at a differ-



11. A typical winder speed program



12. An additional example of a speed curve

ent speed such as 1000 m/min (3280 ft/min) or change the spring constant of the rolls by making them much softer or much harder. One must be brave here and really change the roll structure to make a difference. The object is not to make good or bad rolls but to change the natural frequency of the rolls so they will vibrate at a different diameter or respond to a different frequency. If the experiment is successful and the ring moved to another position or vibration ceased completely, the cause is paper roll vibration. If changes with speed or roll structure do not move the diameter at which the rolls vibrate, the cause is probably the winder.

After conducting these two tests and analyzing the results, it is necessary to make an important decision. If the problem is the winder hardware, one should obtain vibration analyzing equipment to determine which component of the winder is vibrating and correct the situation. If the paper rolls are vibrating, there is no need to use vibration analysis to confirm this. Merely continue the procedure described below to reduce the intensity of vibration and possibility of roll throw outs.

There are a variety of options. Try the suggestions in the above section, "A rational approach to roll vibration." Soften or harden the rolls. Go all the way and try to change the roll structure enough to make a difference. This procedure changes both the mass and spring constant of the roll significantly to change the natural frequencies. The idea is to change them enough so the prevailing vibration frequencies cannot excite them. Pushing the vibration ring high enough up the diameter often vibrates rolls less violently and causes no operational problems.

Many mills running difficult vibrating grades like vellum and some bond papers successfully use speed programs similar to that shown in Figs. 11 and 12. Instead of tampering with natural frequencies of the rolls, change the frequencies that might excite them. Accelerating quickly through the critical range reduces any possibility of initiating the problem. **TJ**

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