Solving Common Web Problems by Implementing
Parabolic Crowns on Process Rollers

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Crowns

A crown is the diameter difference between a rolls midpoint and its ends.

The types of crowns are as follows:

1. Convex
2. Concave
3. Straight Taper
4. Trapezoidal
5. Compound

There are many web handling problems that can be eliminated by using crowns, such as proper web control or “tracking” of the web; “Product Profile,” that is “infeed” operations such as paper or corrugated; Proper deflection correction for a given nip load value, where the load is deflecting or bending the roll making the nip footprint greater on the ends then the midpoint; Working with dwell time in the Nip, while the nip performs its function. Machine vibration can be caused from a multitude of things but “roll deflection” can be one of the causes. Additionally, crowning can be required for hydraulic stability caused by hydraulic action of fluids placing pressure between rolls, and finally, this is a function of the infeed scenario, the crown can be used for centering of conveyor belts on conveyor rolls.

We want to focus today on the crowning issue that to me as a roller engineer confuses or lies outside of the plant engineers, maintenance supervisor or machine operators’ understanding. Most problems occur what the Plant Manager calls, “Hey our rolls are low in the middle, and we tried everything, but we can see light through the nip,” or “The substrate we are handling is wrinkling,” or some other problem like poor tracking or winding and many other conditions.

Now, for some reason the answer to nip related problems always seems to try to be solved by adding pressure. Adding pressure is usually the cause of the problem or it solves the problem until the pressure adds to deflection or bending of the roll core. Then what solved the problem, until the load becomes too great, starts making the problem a lot worse. Adding more pressure makes the problem worse by bowing the rolls further and further unbalancing the nip area.
Let’s step back again and see what further could be causing the problem and then we can get to testing and solutions. In my twenty-seven (27) years as a roller engineer, I’ve seen that roll design is usually the issue. Now we have a design department full of engineers that ask the right questions to design rolls, just like many of today’s OEM (original equipment manufacturer) roll designers. However, this doesn’t seem to be the problem.

Today’s industries and substrates are constantly changing. Your plant may be running something for years for a P&G (Proctor and Gamble) product and the product dies and the line needs to run something else. The new product may change the PLI on the rolls. I’ve seen plants buy a section to a line from an unrelated plant and tear it apart and make use of rolls and drives, etc… that weren’t perfectly designed for the product being run. The textile industry was really known for this: using textile equipment and rolls and the like which were bought torn apart and put back into production.

The number one cause in most cases that is not recognized is excessive roll deflection which causes web handling issues. “Roll Deflection” is the bending or bowing of a roll under its own weight and would then be amplified by web tension and or nip load. Now, different substrates react differently to deflection so a universal rule of thumb is not applicable. For instance, using thin film, our foil would not react the same as a heavy non-woven or a textile. Table 1 represents guidelines for Roll Deflection:

Table 1

<table>
<thead>
<tr>
<th>CLASS</th>
<th>DEFLECTION</th>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>&lt; .00004 x Face Width</td>
<td>optically flat or other unusual applications</td>
</tr>
<tr>
<td>A</td>
<td>&lt; .00008 x Face Width</td>
<td>precision or nipped applications</td>
</tr>
<tr>
<td>B</td>
<td>&lt; .00015 x Face Width</td>
<td>most rolls</td>
</tr>
<tr>
<td>C</td>
<td>&lt; .00030 x Face Width</td>
<td>flexible roll materials such as tissue, nonwovens, textiles, and some machine forming elements such as belts, felts, and wires, as well as for web materials over 10 mil thick</td>
</tr>
<tr>
<td>D</td>
<td>&lt; .00060 x Face Width</td>
<td>stiff webs on conveyor belt rolls, spreaders, wind/unwind shafts, cores and other high deflection applications where roller cost dominates design</td>
</tr>
<tr>
<td>E</td>
<td>&lt; .00120 x Face Width</td>
<td>flexible webs on conveyor belt rolls, spreaders, wind/unwind shafts, cores and other high deflection application where roller cost dominates design</td>
</tr>
</tbody>
</table>
Now, thus far we have talked about web handling problems and formulas for allowable deflection. The aforementioned is to get us to identifying the problem and solving it. The simplest way to get to the results you want can be done in ten (10) minutes, and identifies the problem so that you can solve it. The same test can be done when rolls are installed to be sure everything is set properly and head off a costly production slow down. We understand that you can’t design every roll installation using brand new rolls. Plants today have spare rolls all over the place. Working with your competent roll supplier, existing miss-designed rolls and spare rolls that were not originally designed for the product can be engineered to run in some cases. Because of weight etc, crowning techniques can be utilized to eliminate critical nip dimensions so webs can be handled efficiently.

Testing

Practical testing is, “What is happening at the nip or where the Rubber meets the road!”

There are two methods for nip testing. Each testing method is easy and quick to do and considered safe. The easiest and considered safest is the “static nip Impression” as the machine is off and rolls are not rotating. Results are solved using a basic equation or simple software. These carbon paper kits do have a shelf life as the carbon dries out and doesn’t make the results easy to read. So, be sure you have active carbon paper. The test requires using carbon paper and a backing paper to place between the nip, closing the nip to allow the carbon to make a resultant mark on the backing paper and interpreting the result.

For troublesome nips, where a static nip impression has been taken and determined to be within specifications, a dynamic impression can be performed using Fuji film which requires the Fuji Film reader to interpret results. To take a dynamic nip impression Film is attached to the substrate or substituted up stream of the nip being tested the machine is active usually at controlled speeds but can be done at full speed. The film travels through the nip and the full 360 degree rotation comes in contact with the nip. The film is then read to determine the integrity of the nip.

Reading Nip Impressions

First Nip Impression can be performed on compliant (Rubber Covered) or Non-Compliant rolls (Steel, Aluminum, Bronze, or Composites) Note that compliant Rubber covered rolls will provide some variance in load flexibility. Non-compliant rolls have no flexibility beyond design load and will not be tolerant of variance. Also it should be noted that each calculation is only designed for 1 specific load. Meaning for running different substrates or nip pressure testing will have to be repeated and results acted on.
Determining crown amount is done by using basic engineering equations following the design principal or by using sophisticated devices such as finite element analysis, and other engineering type software. Static nip impression paper which is easy to use can be your solution to many nip profile issues and can be eye opening to shedding light on an improperly designed or operating nip.

The following is the formula for determining the crown required

\[
c = \frac{(NE - NC)(DT + DB)}{2(DT \times DB)}
\]

where C= Crown required,
NC= Nip width at center at roll,
NE=Nip Width 2” in from roll end,
DT= Diameter of Top Roll, and
DB =Diameter of bottom Roll.

The static nip impression test is one of the easiest and safest methods that can be performed. The procedure for this test is to cut paper the width of the machine and about 4-12” wide. Center the paper under the nip and flatten against the smooth roller. Then, load nip to operating values and hold for a minute. Finally, unload the nip and remove the paper to examine the impression. Figure 5 & 6 shows how a static nip test is applied as well as how to interpret your results from the actual impression taken at the nip.

In a dynamic nip impression test the impression paper is applied similarly to the static test. The main difference is that the paper is applied just upstream of the nip. The nip is then loaded to the operating/test conditions and while loaded, the machine is briefly engaged at a controlled speed until the paper is completely pulled through the nip. Please see Figure 5 & 6 for the procedure and interpretation of the impression taken.
FIGURE 5

Static Nip Impression

Dynamic Nip Impression

FIGURE 6

Good

Too Low for Given Load

Too High for Given Load

Unbalanced Loading

Banding, Roller Wear, Grinding
Grinding Crowns in Rolls

Grinding roll crowns has taken many roads, today complex crowns are now programmed into CNC type controls and the face of the roll is centered or offset depending upon the desired end result and the control is programmed resulting in a perfect crown ground onto the roll.

Frequently Asked Questions: (FAQ)

Does my roll need a crown?

Yes, if under a nip load with a force that can bend the roll body.

Can a roll require too much crown?

Yes, a roll with a thin shell or wrongly specified length to diameter ratio or simple overload in machine design or location could require a crown beyond what is functional or even safe for a roll. In this case, review the engineering data. If no data exists on used rolls, you should perform non-destructive ultrasonic, or x-ray tests to reverse engineer the core data for safety reasons. Additionally, no roll diameter design should require a crown amount beyond .05% of the core diameter to 16” O.D. Never design rolls over 16” O.D. to require a crown over .025 of core dia. Roll design should always make every effort to keep the rolls as rigid as possible to require little or no crown.

Can I have a crowned roll provide nip for multi load settings, perhaps even on different substrates?

Yes, but only within reason. Non Compliant (steel) rolls do not have loading flexibility, whereas compliant (rubber) rolls do have some minimal flexibility. Many end users find they can get satisfactory results within 10-20% of a designed load setting, especially if a roll crown’s original design is for the mid-point load pressure. Another solution is adding a third roll to the nip section, called a backup roll and have this capable to be offset and skewed.

Is there a downside to a crowned roll?

Yes. If a nip location requires a crown, and the web path had product in contact with the crowned roll face for part of the rotation of that roll. A major issue then arises: “unequal surface feet of product feeding into the nip.” However, if the web path only comes directly into a correctly crowned nip with no additional wrap angle, this will not be an issue. Redirecting the web path can be the solution; by adding an idler roll for straight-in straight out web introduction to the nip. Additionally, crowning the non-wrapped nip roll can be a great solution as well.
In a double compliant nip location (two rubber covered rolls nipped to each other), that requires crowning, do I crown one or both rolls?

The best solution is crowning both rolls. However, in nipped locations with hard and difficult to access rolls many end users chose to crown only one. I highly recommend crowning both rolls because rubber dynamics, elastic nip flow, and wear will be minimized and enhanced with each roll crowned. In addition, many times rolls and extra spares are all interchangeable if done in the same fashion.

Will my crown last or wear out?

A crown designed properly for a given nip load should wear very evenly. If it does not, retesting the nip is required as crown specification is off.

If I run a non-compliant (steel roll) with a compliant roll (rubber) in a nip, do I crown my steel roll?

You can crown the steel roll, however, most end users choose not to. Each regrind on steel reduces its overall life, whereas, a rubber roll covering can always be recovered. Additionally, rubber is usually less costly to grind and crown then steel, rubber can always be recovered and rubber can be ground faster and have forgiveness because it is more compliant.

Can I have an over-crowned roll?

Yes. If a nip impression shows greater nip flat in the middle of the nip impression than the ends, it requires less crown. The roll was simply over-crowned or was specified for a crown utilizing a higher PLI loading than expected.

Does every crowned roll need to be balanced?

Yes especially if the crown is offset on the overall length of the roll.

Does rubber thickness play a part in crown performance?

Yes sometimes, the elastic flow of rubber under load can play a part to change slightly when comparing a thin cover to a thick cover. Additionally, dynamics in the nip can change as well. Thicker covers generally have a greater nip bulge potential. Nip bulge in itself can cause nip dynamic type failure of a crown. Whenever possible, and safe, check nip impression flats at the operating temperature of the roll. Troublesome nips utilizing a thick crowned rubber roll covering should be evaluated by a roller professional for proper rubber thickness. The solution might be thinner rubber reducing nip bulge.. not simply a crowning change.
Summary

In summary, roll crowning is used in the design of rolls but also in the roll's application long after the design is complete. We are in an age where the production line is static, but the substrate is in a constant state of change. Your company needs the product to run. Keep roll crowning as a tool in your tool box for solutions to web handling challenges. Remember to use Nip Impression Paper to test your nip to see if it's straight and true, Nip Impressions are both fast and simple and can shed light on the problem quickly and cost effectively and anyone can do it.
References


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