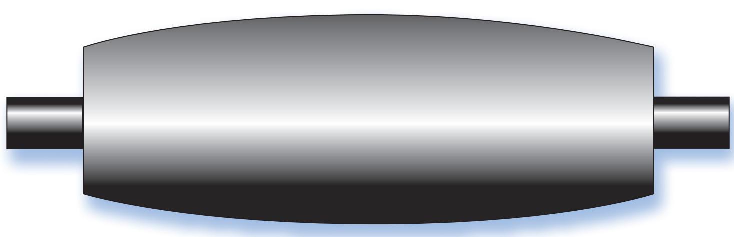
The Basic Theory of Crowning Industrial Rollers

Written by
Matthew Menges &
Javier Carreon



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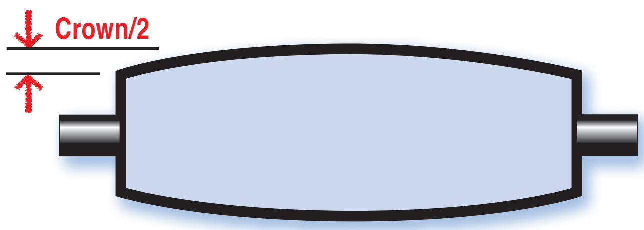
The Basic Theory of Crowning Industrial Rollers

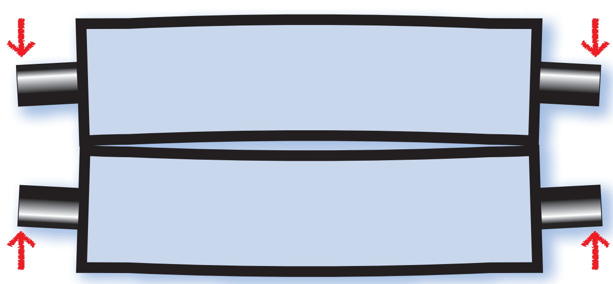
Rollers that are crowned are utilized by many industrial manufacturers. These companies are in the paper, film and foil converting industry. As a roller manufacturer, specifying a crown on a roller has to be taken with caution. Failure to do so may lead to problems and costly errors. Let us first establish the definition of a crown with respect to the roller industry. *A crown is a shape or diameter profile necessary to compensate for deflection in order to obtain a uniform nip pressure distribution.* (See Figure 1).

FIGURE 1



Roll crowning is intended to ensure proper web alignment and mainly to counter the effects of deflection. In a simple nip system, roller deflection is one of the main reasons for nip variations across the width of the roll face. This is primarily evident in all end loaded rollers. The roll will deflect or bend away from the nip, which causes pinching at the ends as seen in Figure 2.

FIGURE 2



Roller deflection *is bending due to its dimensions, material, and the load being applied to the roll in its particular application*. Therefore, roll crowning is one common method of reducing the nip variation caused by roller deflection. The other benefit of crowning a roll is that it will yield improved product quality. And more importantly crowning helps the roll covering last longer, increases the rubber life and helps reduce machine down time.

As discussed earlier, specifying a crown on a roller has to be taken with caution. This is especially true when grinding or cutting an accurate crown. It is such a difficult

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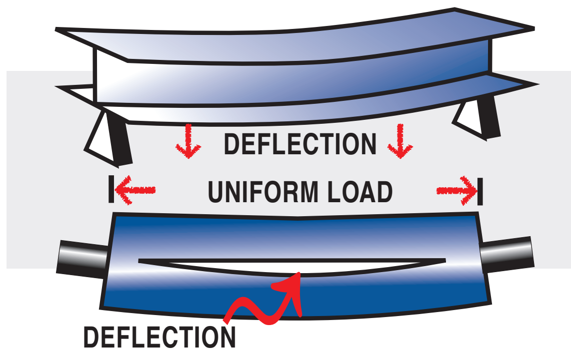
process that if one compromises the shape/profile, it will cause more problems than not crowning at all. The amount of crown needed is usually very small and within a magnitude of a few mils (.001"). The amount of crown (barrel shape) is calculated from beam deflection formulas. The shape of a crown is nominally the shape of a beam deflected under a uniformly distributed load as shown below in Figure 3.

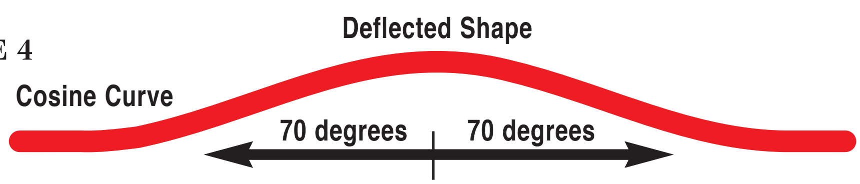
FIGURE 3



Utilizing the basic beam principle, roller specifications, and end user operating load requirements, a roller manufacturer can recommend a crown requirement for a roll. This process is achieved through modern computerized grinding machines. A program takes the deflection formula or tabulated values to produce the correct shape.

The most commonly used crown angle is a 70 deg cosine angle. The reason behind this is that 70 degrees on each side of a cosine curve shows a close approximation to the deflection shape of a uniformly loaded simple beam (refer to Figure 4). The second most widely used crown angle is the 90 deg cosine angle. This specification is used for heavily loaded rollers with great lengths or unique header designs.

FIGURE 4



A theoretical crown will equalize the nip pressure but the results should be checked. First, the actual diameter as measured by a Pi-tape or other means should be checked in at least 10 to 20 evenly spaced stations (in the cross machine direction). What is being measured is the target crown shape and magnitude across the width of the roll face. Second, the nip profile can be checked using nip impression paper and other techniques that are available. Nip impression paper behaves like carbon (or carbonless) paper which turns color when enough pressure has been applied to it.

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

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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

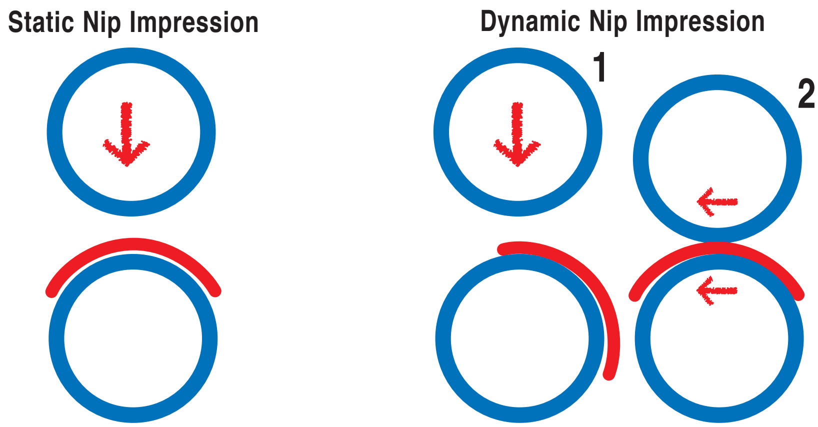
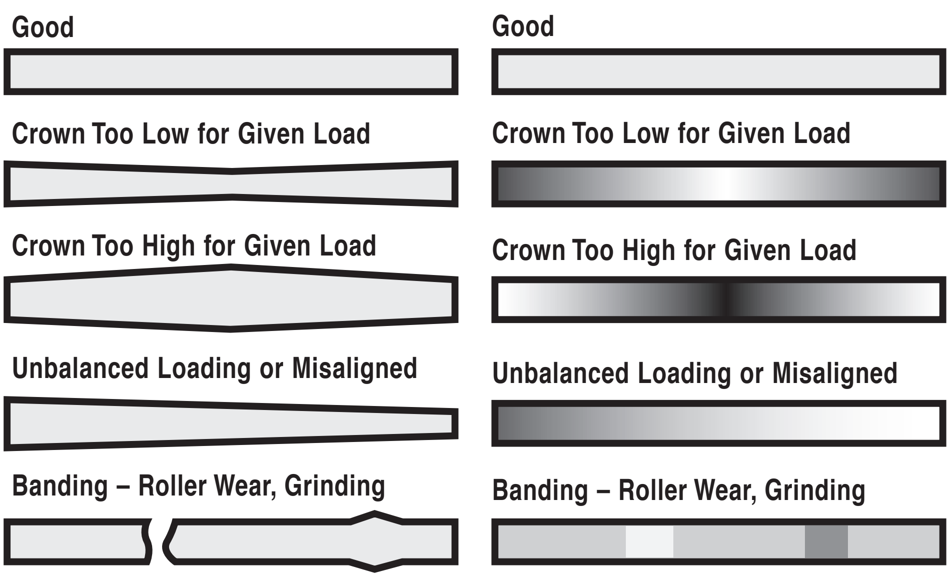


FIGURE 6



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There are other methods of checking nip impressions. One is using embossed foil, which is evaluated by reading the embossing elements flattened in the closed nip. This method of test is helpful when testing heated nip rolls. The embossed foil eliminates worrying about ink running, bleeding, or blotting that results in using carbon paper. Another popular form of crown evaluation is an electronic nip reader. This device converts the nip loading and variances into real time data. Its benefit is that one can quickly read and adjust roll alignment or loading at the start-up or at maintenance shut down. In summary, this electronic device in terms of crown adjustment has no real advantage over a static or dynamic nip impression test. This is due to the fact that crown correction is done outside the production machine or more precisely at a grinding shop.

In review, the crown amount and profile can be determined or confirmed by utilizing the useful techniques that were covered above. The results from testing will confirm the following:

- The need for a crown (on un-crowned rolls)
- Crown accuracy (for crowned rolls)
- Roll alignment quality
- Actual nip width

And as previously discussed determining the crown amount can be calculated using engineering equations following the basic beam principle. One can also use methods like Finite Element Analysis (F.E.A) or other engineering type software. The bottom line is that because of simplicity and cost effectiveness the nip impression paper technique will help determine whether the crown is correct. For a static nip impression test or embossed foil kit, the following formula can be used to determine the required crown.

$$C = \frac{(We^2 - Wc^2)(D_1 + D_2)}{2 x D_1 D_2}$$

Where....

C = Diametric crown deficiency (positive if too little crown, negative if too much crown)

We = Nip width on the roll ends

Wc = Nip width at the roll center

D1 = Diameter of roller 1

D2 = Diameter of roller 2

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A good amount of information has been covered so far in respect to roll crowning. But one very important fact has to be mentioned in regards to the nip load vs. crown.

In Figure 2, there is an externally applied force at the ends of one of the rolls which actually provides the nip load. Therefore, the amount of deflection and as a result the crown amount is determined by the nominal nip load. There is a load (x) which determines the required crown (y), and thus a given crown (y) matches only the value of load (x). Any other load than the match load above will not provide uniform nip loading across the width. Consequently the problem in a simple nip system is that one can not change the nip load without negatively affecting the uniformity of the nip.

This poses a big challenge when there are a number of different grades or products that must be run. But fortunately there are solutions to this problem and that would be deflection compensation techniques. These techniques include using a small roller on a large roller nip system, roller skewing, and using a specialty roller like a controlled crown roller. The end result is that these techniques are weak and provide only a limited range of adjustment. As a result, one will usually crown one of the rolls to the lightest load and use the above deflection techniques to achieve higher operating loads.

Below is an example of a crown report offered by Menges Roller Company.

Roll Crown Specifications

Input Crown Amount:
0.030

For a 70º Cosine Crown Only!

Inspection Station	70º Cam Angle Multiplier	Target Shape
0	00.000	0.0000
1	0.0112	0.0003
2	0.0451	0.0014
3	0.1009	0.0030
4	0.1778	0.0053
5	0.2748	0.0082
6	0.3904	0.0117
7	0.5226	0.0157
8	0.6699	0.0201
9	0.8298	0.0249
10	1.0000	0.0300

Specifications needed to inspect crown:

1. Crown amount - thousandths of inches of diameter
2. Measured crown face - inches
3. Cam angle - degrees
4. Taper dubs - (if applicable) length x depth
5. Centerline of crown should be centerline of roll
6. Station Spacing = Measured crown face /20 spaces

Commonly asked questions and answers.

Web is not tracking properly and/or moves back and forth - Usually caused by uneven nip pressure or a wider nip area in one area of the web. The larger nip area pulls the substrate at a differing rate than the smaller area during nip lead in or nip lead out which causes the web to move back and forth.

Excessive wrinkling or fold overs of the web or sheet – This is the same case as above. An uneven nip pressure causes an unbalanced pull because of an unequal dwell time of the substrate in the nip. This wrinkling can be made worse by downstream pull rollers actually pulling the web as the uneven nip is holding the substrate which creates wrinkles into the sheet.

Uneven coating weight or laminating films are baggy in the center or the edges - Because the nip is uneven across the face, coatings are immediately affected lighter in the middle. This problem usually gets worse as operators add pressure to the ends of the rolls which cause deflection or bowing of the rolls. In laminating, the low center causes poor laminating film penetration which can be a cause of wrinkles pulled into the sheet as the deflection causes greater and greater nip pressure irregularities. Laminating is an art form. The nip pressure can be perfect but other factors like humidity can drive operators crazy. The point is that laminating will not tolerate uneven nip values.

Tracking or steering is the issue - Crowns can be used to align or steer. If you can picture a band saw, the blade runs between to large wheels with a steep crown. The blade stays perfectly centered on top of a steep crown. For example, steel mills utilize crowns to steer the difficult web of steel which is stretched tight as a piano wire through coil lines as long as a football field.

I crowned my rollers and I still have problems - A crown is a tool in your tool box. Used correctly it will solve problems. However it will not rectify a poor design or bad machine alignment. Crowns should be used in the design of rollers and equipment and not because of it. For example, a paper machine roll 25" in diameter 40' in length can only be designed to work with crowning as an absolute preconceived notion from the start. Paper machine engineers don't design their rollers to find out that they have uneven nip pressures and then go back to the drawing board.

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REFERENCES

Mechanics of Rollers by David Roisum TAPPI 1996

Rubber Roller Group, technical paper by John Slotten

Roll Crown Specifications and Definitions, technical paper, TAPPI 1975

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