TIN-CANNING DEFECTS IN THIN FILM WINDING

By

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INTRODUCTION

In winding thin films, especially at larger diameters and higher speeds, rolls may form uniform width machine direction buckles. Commonly referred to as tin-canning defects, they may form across the entire width of the roll (appearing much like a corrugated soup can) or in local widthwise bands. Tin-canning defects may also vary in intensity or breadth by location around the roll circumference or, upon observation of unwinding rolls, by radial position in the roll. Tin-canning defects are common in films, but can also appear in thin foils and papers, both coated and uncoated.

Though this defect is widely known, there is a scarcity of published information about its causes and remedies.

In this study of nipped center winding, we explored the formation of tin-canning defects as a function of tension, nip load, nip roller design, and pre-wind spreading, judging the defect both immediately after winding and 24-hours after winding.

NOMENCLATURE

R = Radius, mm or inches
t = Web thickness, mm or inches
λ = Wavelength of machine direction buckling, mm or inches

BACKGROUND

Though tin-canning defects are common in thin film products, there is a scarcity of published information about its occurrence, diagnosis, and remedy.

In 1991, John Shelton [1] presented an overview of lateral buckling phenomena. This paper and presentation mostly covered causes of buckling in spans between rollers and during web-roller contact, but also included a brief discussion of buckling of cylindrical thin shells, noting these machine direction in-roll buckles would form uniformly and have a wavelength as a function of web thickness and cylinder radius.

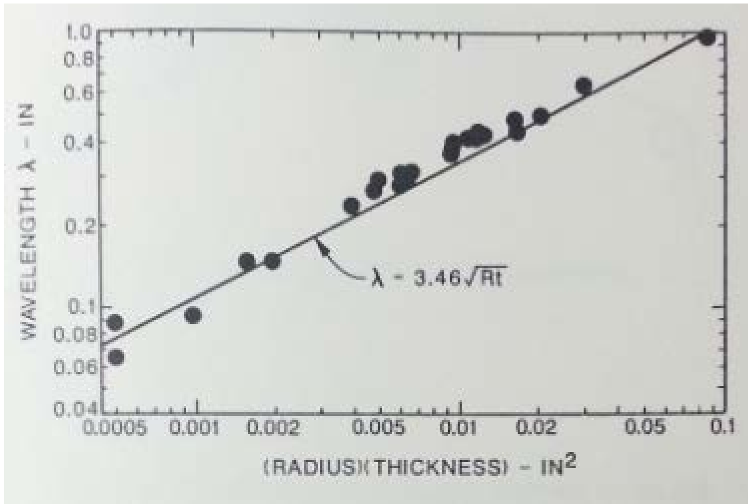

Figure 1 – Wavelength of Machine Direction Buckling vs. Radius and Thickness[1]

In 2003, William Hawkins [2] wrote about machine direction buckling in rolls, including both theories of their formation and novel equipment designs to eliminate them, though his book did not include any supporting images or empirical data. Hawkins' theories described tin-canning formation as dependent on: 1) two prominent gauge bands and a winding nip roller, 2) occurring in atmosphere or vacuum, but air can temporarily postpone the defect formation, 3) occurring less with more surface roughness, as smoother webs are less able to absorb gauge bands, 4) promoted by very soft rubber coverings, as rubber will stretch the web laterally over the gauge bands, exacerbating the formation of tin-canning.

Hawkins included advice on remedies for tin-canning, including 1) minimum winding nip Durometer of 45A, 2) gauge band oscillation ¾ of distance between bands (1/2 distance has minimal help), at 1.5 in/min up to 1100 fpm, 3) winding tension taper of 20-30%, 4) spreading with a bowed roller immediately before winding, even using the bowed roller as the winding nip, and 5) larger core and short roll length.

In their landmark book on winding, Good and Roisum [3] referred to tin-canning defects in two chapters, mostly to describe the defect and theory of their formation. They include the following observations on tin-canning: 1) have the appearance of a soup can or corrugated pipe, 2) common in thin film, rare in heavier grades, 3) appearance is similar to gauge bands, but spacing is reasonably uniform and not aligned one-to-one with thickness profile features, 4) ridge spacing is determined by gauge of material, rather than modulus, diameter, tension, or other factors, with thinner material having closer ridge spaces, 5) tin-canning can get more severe with time, due to shrinkage of material, especially air, and 6) sag of wide rolls supported at the ends (top of roll only).

Good and Roisum's discussion of tin-canning formation starts with the "mechanics are complicated" and continues with the following points: 1) begins with tight layers on the outside of the roll, 2) the layers compress radially, 3) combined Z (thickness direction) and MD compression translates into transverse direction (TD) expansion, 4) underlying layers are held back by layers beneath, and 5) instead of moving axially, the layers buckle, forming upward ridges.

Originally published in 2007 and updated in 2013, Roisum and Hadlock [4] include two pages on tin-canning in their chapter of roll defects. Their description of the defect is similar to Good and Roisum. Their list of potential remedies includes: 1) reduce the wound-in-tension of the roll via more taper on the winding tension and lower transport tension, 2) reduce tensioning from rollers by driving transport rollers or using free-turning idler roller bearings and lighter-weight idler rollers, 3) allow more air into the roll to reduce lateral restriction from traction, 4) reduce or taper the lay-on roll pressure to allow more air into the roll so the web can slide on itself as a result of internal layer expansion, 5) use a lay-on roller with a positive crown to hold the center of the winding roll while allowing more air into the roll so the film layers can slide axially, 6) use a lay-on roller with a relieved surface area (diamond pattern) to allow more air to be wound into the winding roll allowing the layers to slide axially, 7) reduce the COF of the film by adding slip or anti-block agent or by dusting the film before winding to allow the film to slide axially, and 8) increase web TD tension just before contact winding of roll to offset symptoms of axial instability within the winding roll.

Some of the remedies listed in the TAPPI book seem to be counter to the formation theories. Allowing more air into the roll to reduce traction is counter to the mechanism where loss of air within the roll leads to the MD tension loss and TD width recovering that causes the buckling.

The goal of this paper was to empirically explore these theories and seek process conditions to minimize or eliminate the formation of tin-canning defects. Potentially even more challenging, we hoped to transform rolls wound with tin-canning defects into defect-free rolls.

SUMMARY OF EXPERIMENTS

Experimental Plan

Our experimental plan was designed to simulate production on a pilot rewinder. Winding experiments of this type are limited in their ability to simulate production, but the hope is that smaller scale experiments that do not interrupt production can help to understand and justify changes to the production process at minimal cost and risk.

The limits of our experimental plan included equipment, input material, and time constraints. Production winding of PET films are at widths of over 3m on turret winders were rolls are started at full speed. Our pilot rewinder was limited to 1.2m width and required starting rolls at zero speed and accelerating them to target winding speed. Due to these differences, our pilot winding had much less nip roller or core deflection from the nipping load and our core starts were relatively wrinkle-free, which isn't always the case for at-speed roll starts.

The scale of our experiment was limited by both time and material. We had roughly one 40 hour week to complete our experiment and two long input rolls (26km, 900mm diameter). Based on feedback from production of this product, we determined a minimum of about 3x buildup to 0.48m rolls of 6.5km was required to have a strong likelihood of tin-canning defects. From this, we decided to wind four 6.5km length rolls from each of the two input rolls, allowing to wind eight experimental rolls. To increase the number of variables we could study, we decided each of these rolls would be rewound a second time, allowing a total of 16 winding conditions in our experiment.

The variables we chose to study were: winding tension, winding nip load, with and without pre-winding spreading, and comparison of a standard single Durometer nip roller to a specialized dual Durometer nip roller [5]. Each of these variables was studied at two conditions, creating a 4^2 designed experiment. For convenience, we did not randomize the experimental order.

The choice for high and low conditions of winding tension and nip load were chosen based on production conditions. Our choice for low conditions were similar to production values with our high values chosen as roughly 50% above the low conditions.

The single Durometer nip roller was chosen as the default roller used on the pilot winder. This roller was a 100mm light-weight composite shell with 12.5mm of 47A Durometer rubber for an outer diameter of 125mm. The dual Durometer roller had a 132mm steel shell with 16.4mm of 15-20A Durometer soft inner covering and 1.5mm of 60-90A Durometer hard outer covering, for a total outer diameter of 168mm.

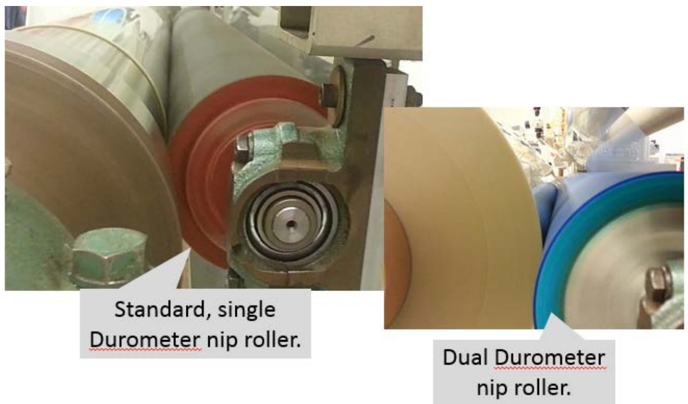

Figure 2 – Standard Single and Dual Durometer Winding Nip Rollers

Regarding pre-winding spreading, an adjustable bowed roller was placed as the last roller prior to wrapping the winding nip roller. In the cases without the bowed roller, a standard anodized aluminum idler was inserted as the last roller before the winding nip roller in a way that bypassed the bowed roller, but did create more wrap angle on the nip roller. We ensured no wrinkles entered the winding roll in either condition.

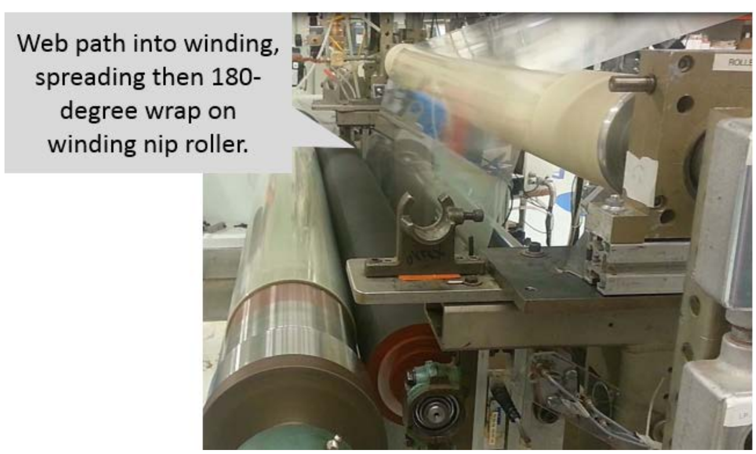

Figure 3 – Experimental Web Path with Pre-Wind Bowed Spreader Roller

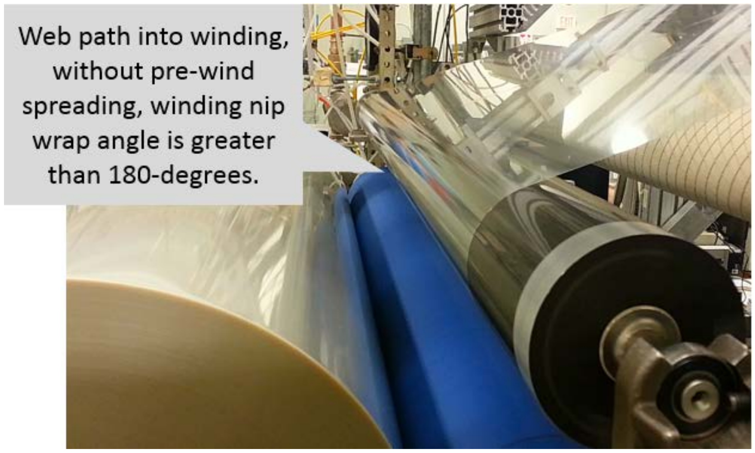

Figure 4 – Experimental Web Path without Pre-Wind Spreader Roller

Experimental Results

We graded the sixteen experiment wound rolls on roll hardness measured by a Schmidt hammer and qualitative judgment of tin-canning defects. The following table summarized these results. The tin canning rating varied from 0 (none) to 3 (severe).

Trial #	Tension	Nip Load	Pre-Spreading	Nip Type	Average Hardness	Tin-Canning Level
1	High	High	No	Dual	29.3	3
2	High	Low	No	Dual	32.8	3
3	Low	High	No	Dual	13.0	1
4	Low	Low	No	Dual	14.9	1
5	High	High	Yes	Dual	32.0	1
6	High	Low	Yes	Dual	32.4	2
7	Low	High	Yes	Dual	14.0	1
8	Low	Low	Yes	Dual	17.6	1
9	High	High	No	Standard	36.3	0
10	High	Low	No	Standard	35.1	0
11	Low	High	No	Standard	45.6	0
12	Low	Low	No	Standard	45.4	0
13	High	High	Yes	Standard	47.4	0
14	High	Low	Yes	Standard	45.3	0
15	Low	High	Yes	Standard	38.4	0
16	Low	Low	Yes	Standard	34.9	0

Figure 5 – Summary of Experimental Condition and Results

We did plan to rate tin-canning at both immediately after winding and again after 24-hrs, but based on the first two days of winding and seeing no 24-hrs difference, we did not continue this storage time and delayed observation on all rolls. We observed enough rolls from a variety of conditions to feel there was not a 24-hr difference in tin-canning.

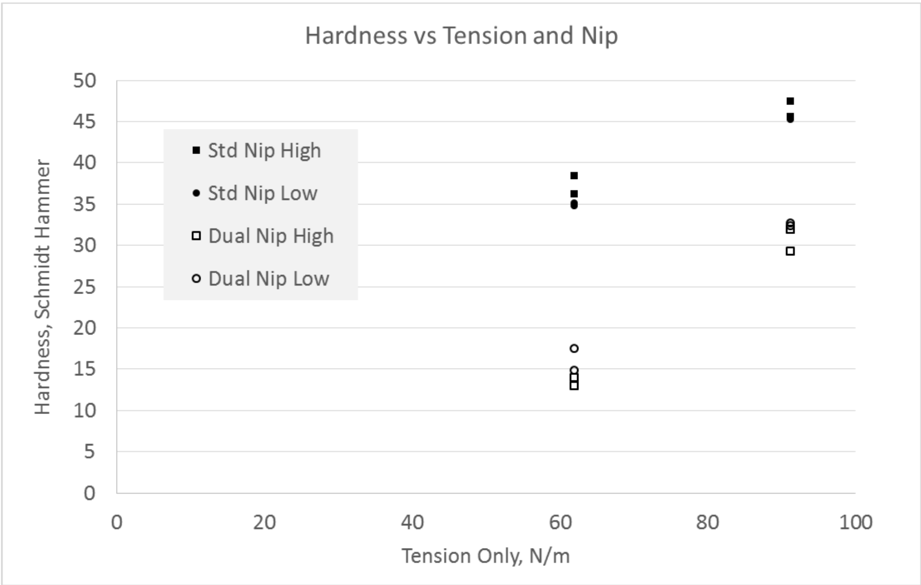

Figure 6 – Schmidt Hammer Hardness vs. Winding Conditions

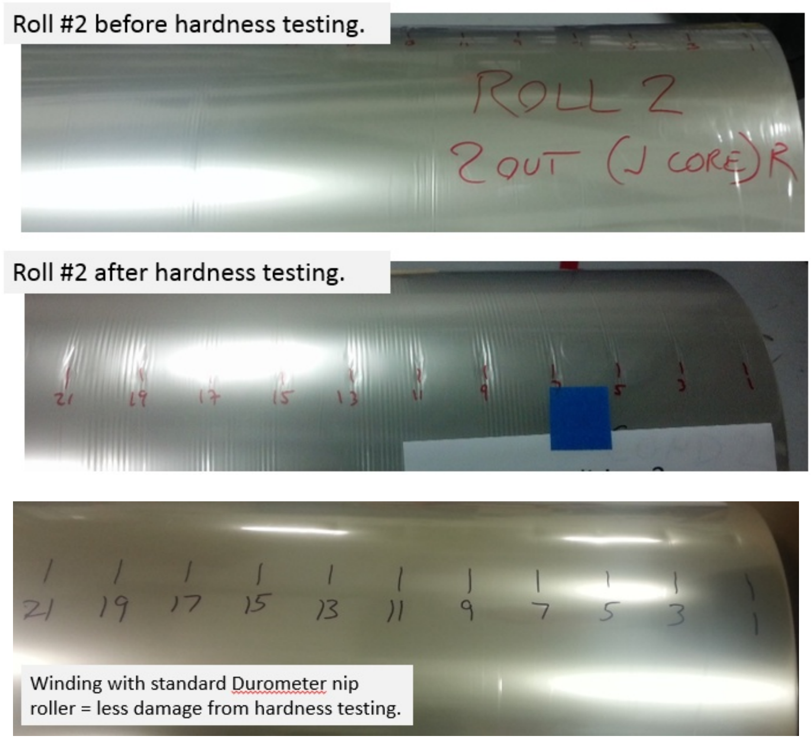

Figure 7 – Tin-Canning Induced by Schmidt Hammer Measurement

CONCLUSIONS

The rolls of our experiment were measure by a Schmidt hammer for hardness and visually compared for tin-canning defects.

Regarding roll hardness:

1. Roll hardness increased greatly for rolls wound using the standard single Durometer roller compared to winding with the dual Durometer roller.
2. Increasing tension from center torque by 48% increased roll hardness by 56%.
3. Increasing nip load had a weak effect on roll hardness. A 44% increase in standard nip roller load increased hardness only 5%. The same nip load increase with the dual Durometer roller decreased hardness by 10%.

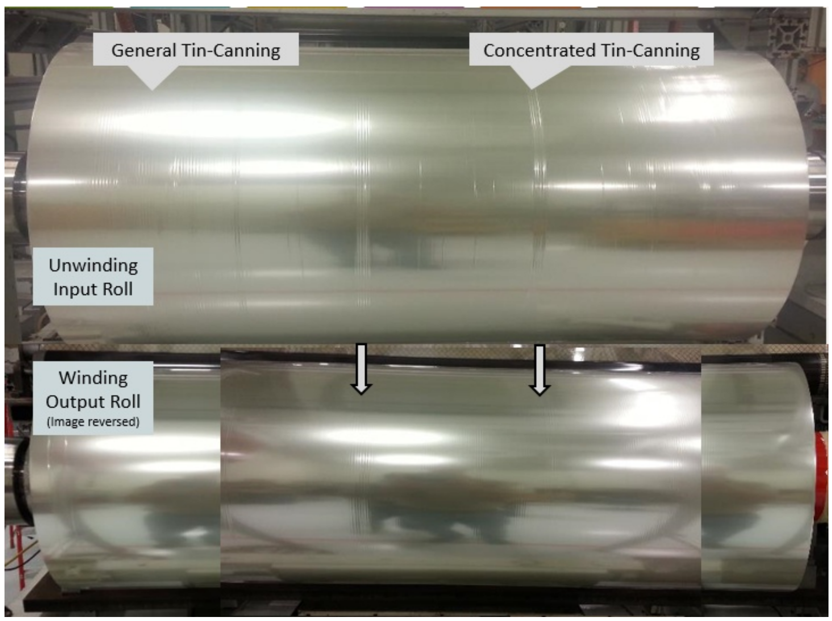

Figure 8 – Tin-Canning Defect Position of Input and Rewound Rolls

Regarding tin-canning:

4. A standard, single Durometer covered rollers was clearly able to eliminate tin-canning defects under process conditions that the dual Durometer roller was not.
5. In rewinding rolls with tin-canning defects, there is a strong propensity for tin-canning to reform in the same lateral positions.
6. The dual Durometer roller slightly increased general tin-canning with higher nip load.
7. Pre-wind spreading slightly decreased general tin-canning in the dual Durometer winding conditions.
8. The single Durometer roller allowed minor tin-canning to form when core chucking eccentricity lead to nip roller bouncing, allowing more air into the winding roll.

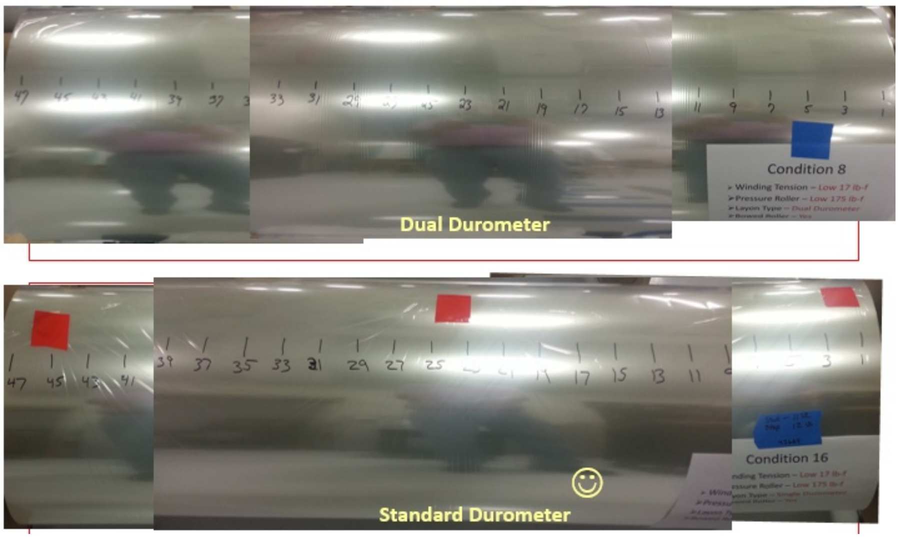

Figure 9 – Tin-Canning of Rolls Wound with Dual Durometer vs Standard Nip Roller

Tin-canning forms under many conditions that point to the contribution of entrained air. In our experiments, factors that increase entrained air increase tin-canning, including: low nip load, lower in-nip pressure (dual vs. single Durometer), and nip roller bouncing. In the experience of literature and the authors, tin-canning increases with additional air-related indicators, including: wider winding with greater core or nip roller deflection, higher speeds, larger diameters, smoother products, roll start wrinkling, and formation or increase in severity over time.

Clearly, tin-canning defects are best avoided by use of standard single Durometer covered nip roller over the specialized dual Durometer nip covering, with modest additional benefits of pre-wind spreading.

ACKNOWLEDGMENTS

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REFERENCES

1. Shelton, J., “Buckling of Webs from Lateral Compressive Forces,” Proceedings of the Second International Conference on Web Handling, 1993, p. 303, 315.
2. Hawkins, W., The Plastic Film and Foil Web Handling Guide, CRC Press, 2003, pp. 152-154.
3. Good, J. K., and Roisum, D. R., Winding: Machines, Mechanics, and Measurements, TAPPI Press, 2008, pp. 58-59, 274-275.
4. Smith, R. D., “The Ultimate Roll and Web Defect Guide,” TAPPI Press, 2013, pp. 87-88.
5. Cole, K. A., “Measurement of Web Feed Rates in Rubber Covered Nip Roller Applications and the Impact on Wrinkle Formation,” Proceedings of the Eleventh International Conference on Web Handling, 2011, pp 407-425.