A Practical Guide to Eliminating Wrinkles in Film Extrusion

Resin to Revenue Conference
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The two most common types of quality problems in film manufacturing are gels and wrinkles. This paper deals with the most common causes and solutions to wrinkles formed during the film extrusion process.

Most Common Film Problems

Gels

Concentrate on
- *material*
- *extruder*
- *die*

Wrinkles

Concentrate on
- *material*
- *bubble cooling*
- *collapsing*
- *winding*

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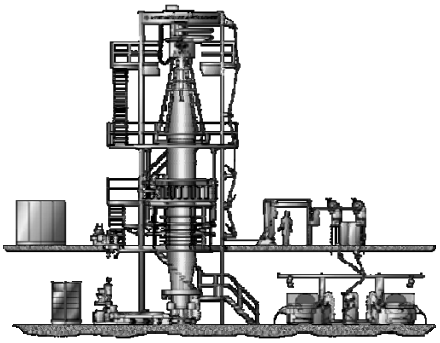
One useful technique to diagnose wrinkling problems is to separate the line into tension zones. A tension zone is the web path between upstream and downstream nips. A nip is defined as any point where two rollers pinch the film.
The most practical technique is to work your way upstream until the wrinkles disappear. This helps you isolate the zone where wrinkles begin to form.
In most cases, different types of wrinkles are formed in different zones, resulting in an overlay of defects.

Compare Wrinkles in Each Tension Zone (between each set of nip rollers)



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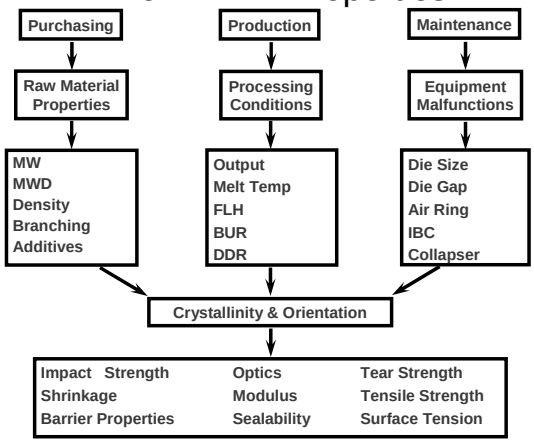
Some of you may have seen this diagram before. The properties that our customers are concerned about are a result of the degree of crystallization and orientation of the molecules within the film matrix. These are affected by the raw material properties, the condition of the equipment and the processing conditions used to manufacture the film. Wrinkles are defects caused by problems in the manufacturing process.

Blown Film Properties



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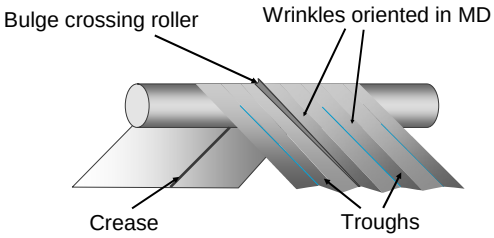
Machine direction wrinkles are caused by compression forces in the transverse direction of the web. This results in creases as well as peaks and troughs in across the web. A common cause is wobbling in the rollers. The maximum deflection in rollers should be less than 0.015% of roller width in order to prevent web tension pulsations across the web which produces MD wrinkles. A common optical illusion occurs when idler rollers are reflecting more light on one side than on the opposite side as they rotate. Try touching the idler roller lightly as it rotates. If you can detect a wobble in the roller, it will result in MD wrinkles.

MD Wrinkles

Compression in the Transverse Direction



Max. roller deflection < 0.015% of roller width

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There are three principle techniques used in winding film: tension, nip pressure and torque. Most operators make the mistake of setting the web tension too high. Winding film is like winding a rubber band. It will deform over time to relieve the built in stresses. This is why rolls that look good just after completion deform over the next few hours. The best approach is to adjust the winding torque, then the nip pressure and the web tension last.

Winding Control Techniques

Tension ⟺ Winding web tension
- controls roll hardness in elastic films

Nip ⇩ Nip of pressure roll or drum
- controls roll hardness by removing boundary air layer

Torque ⟲ From center drive or torque drum
- Controls stress in layers of film

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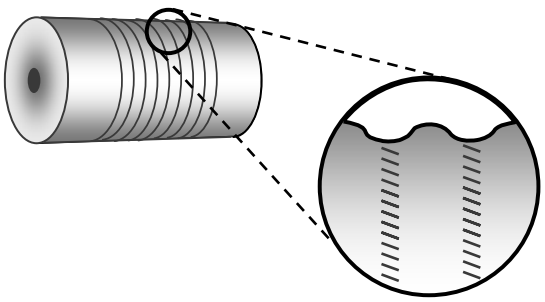
Machine direction wrinkles often form corrugations on the roll surface. This is sometimes referred to as Tin Canning.

“Tin Canning”



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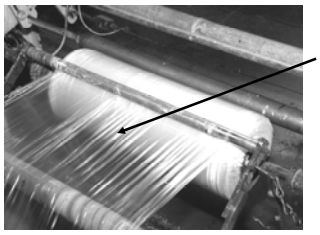
Film Tension Bands

Machine direction wrinkling can often be caused by excessive web tension or too much drag resistance from idler rollers.



May be caused by
- Too much film tension
- MD gauge bands
- Too much drag resistance from idler rollers

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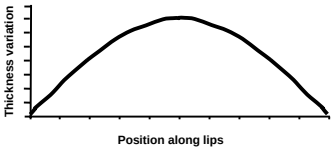
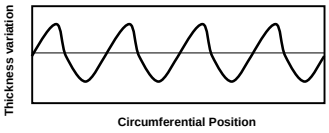
Uneven Material Distribution

Machine direction wrinkles can be caused by excessive flow variation inside the die. Although dies are designed to minimize the variations in melt viscosity, they are not perfect. Randomization techniques include oscillating or rotating dies and nips.





The product has an undesired shape

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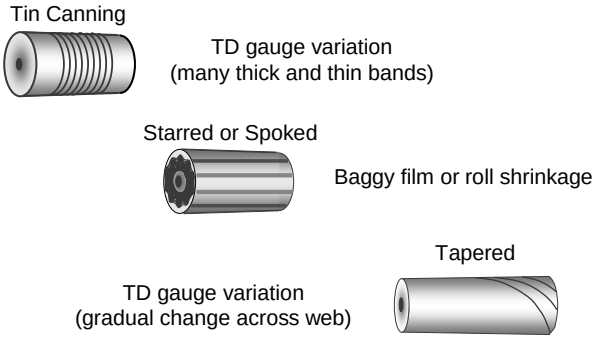
Solutions to MD Wrinkles

Material	Improve mixing inside die
	Increase modulus (density) of film
	Increase film gauge
Process	Reduce film tension
	Reduce film temperature
	Air currants
Equipment	Reduce drag resistance in collapsing frame
	Match rotation speed of rollers to line speed
	Reduce width of spreader roller grooves
	Adjust position of spreader roller
	Reduce idler roller deflection
	Reduce drag resistance across idler rollers

Common wrinkle patterns in rolls are shown on the right. Tin Canning is the most common type of Machine Direction wrinkles.

Common Wrinkle Patterns in Rolls



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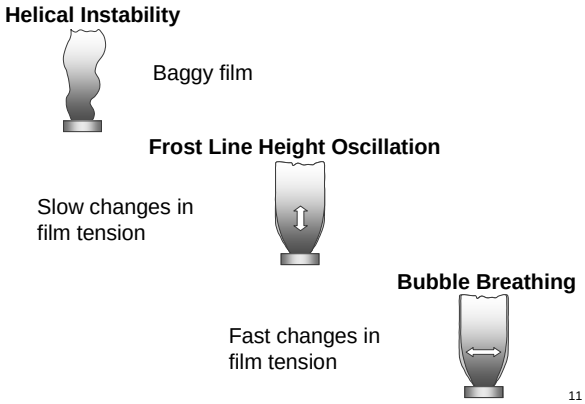
The three types of bubble instability shown on the right can contribute to wrinkles found on rolls. In these cases, the wrinkles will begin to form in the collapsing frame and continue all the way to the winder.

Wrinkles Caused by Bubble Instability



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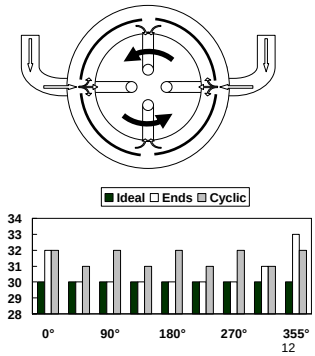
Bubble breathing can occur in IBC systems due to a leakage of air in the IBC plenums. Static pressure will very as the die cycles back and forth.

Uneven Pressure Distribution

- **Uneven pressure distribution in oscillating die air plenums**
- **Static pressure changes either in cyclic pattern or when rotation changes**



Source: D.R. Joseph, Inc.

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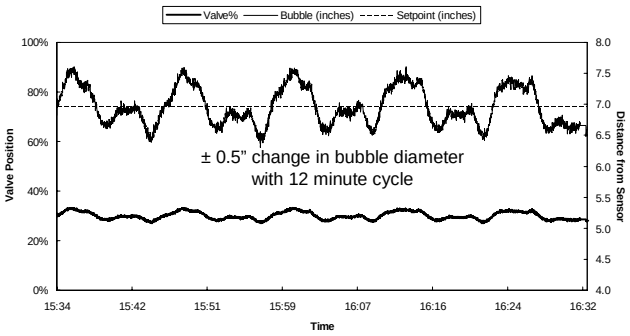
Evidence of Leaking IBC Air Plenums

The result is a regular, sometimes complex layflat width variation as shown on the right.



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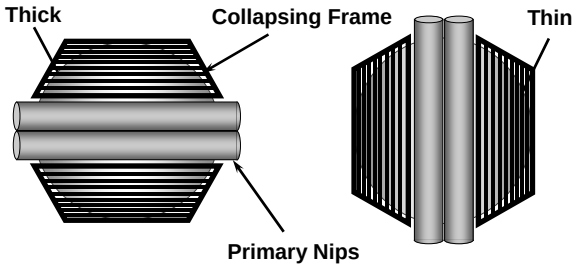
Oscillating Nip Assemblies

Randomize Up to Collapsing Frame

Oscillating nips will randomize Transverse Direction gauge variation only up to the collapsing frames. It cannot compensate for bubble that moves from side to side due to bubble instability.



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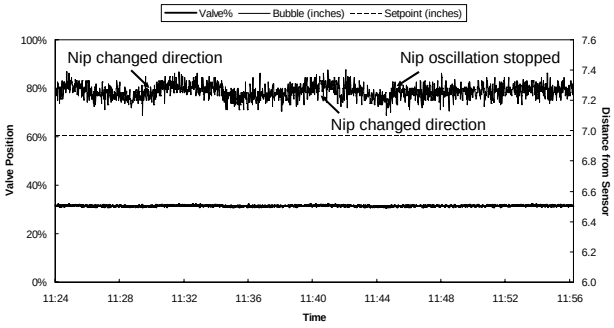
Evidence of Misaligned Collapsing Frame

Even slight misalignments in the collapsing frame will move the bubble away from the centerline, resulting in layflat width variation. An easy way to detect this problem is to stop the oscillation and observe what happens to the edges as the roll builds up.



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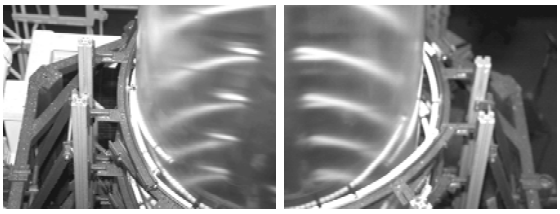
Another useful tool is to watch for a cyclic change in position of the bubble compared to the cage as the nip oscillates. This can be difficult if the cage is in poor condition or if the bubble is wobbling too much.

Bubble Misalignment

Bubble touches cage | Bubble does not touch cage



Moves with oscillating nip?
Yes Realign collapsing frame and side stabilizers
No Problem caused below collapsing frame

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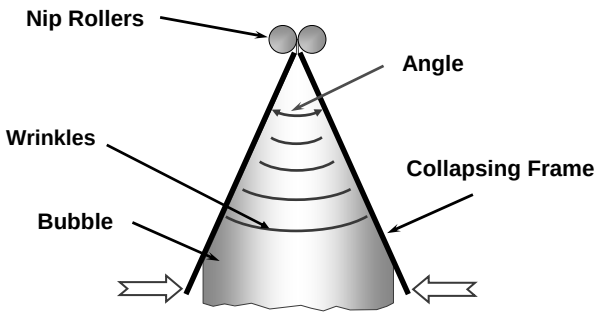
The angle of the collapsing frame can create both Machine Direction gauge variation (too much drag resistance in the center of the collapsing frame) Transverse Direction wrinkles near the edge fold. Since it is not convenient for operators to go to the top of the tower to optimize the angle, adjustments are usually done only if no other solution is effective.

Optimizing Collapsing Angle

Side View



Wrinkles form if Angle is too large

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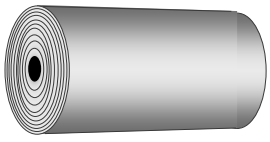
A useful technique to determine where problems are occurring is to inspect the edges of the rolls for patterns as shown to the right.

Edge Variation

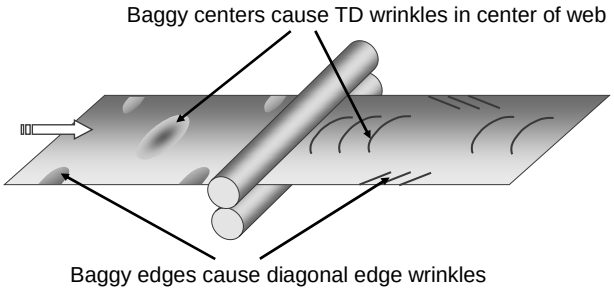


Sawtooth
• slippage in nip
• tension variation at slitters

Oscillation from side to side
• misaligned die, cage, collapsing frame

Baggy film is usually caused by bubble instability, variations in drag resistance inside the collapsing frame or temperature gradients in the upper section of the tower. These changes in tension form pleats or wrinkles when they pass through nips. Watch to see if the pattern moves or remains in the same position over time. Moving patterns are caused by problems below the collapsing frame.

Nips Turn Baggy Film into Wrinkles



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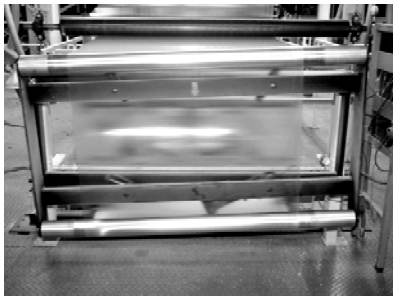
Edge Guide

Edge guides compensate for tension variations in the Transverse Direction and gauge variation that pulls the web to one side as it passes through a nip. It is a useful tool to diagnose web misalignment problems.



Good tool to indicate bubble stability or alignment problems

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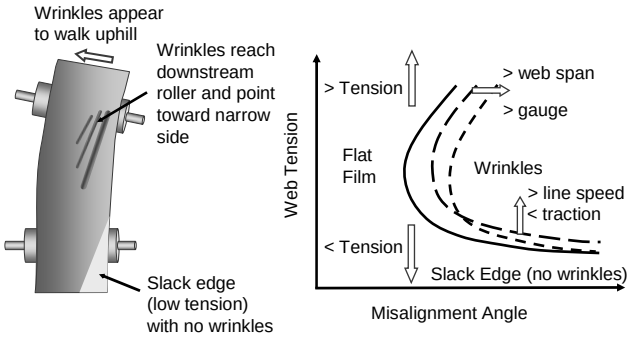
Solutions to Misalignment Wrinkles

Material	Increase modulus (density) of film
	Increase film gauge
Process	Increase film tension (maximum 25% of ultimate tensile strength)
	Decrease film tension (minimum 10% of ultimate tensile strength)
	Increase line speed
Equipment	Align rollers
	(maximum misalignment 0.001”/12” 25 microns/24 cm face width)
	Increase span between rollers
	Decrease friction (traction) on rollers

Roller Misalignment Patterns

Many of the solutions to roller misalignment problems listed on the previous page are shown on the graph to the right. This model was first developed by the 3M company. The amount of misalignment that can be tolerated depends on the web tension. This Flat Film region can also be increased by changing the processing conditions or condition of the rollers.



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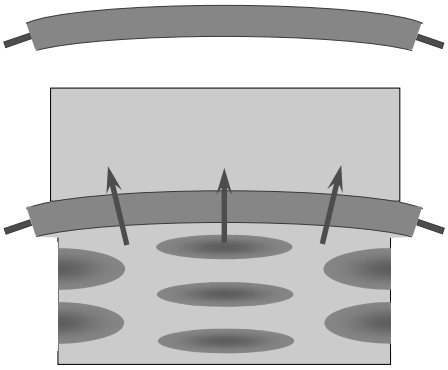
Bowed Spreader Roller

One way to compensate for baggy film is with spreader rollers. Keep in mind that fixed bowed rollers create higher web tension in specific regions across the web. Bowed rollers do not work well when the web movement from side to side is excessive.



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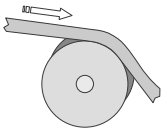
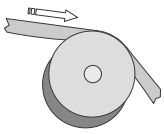
Bowed Spreader Roller

Point bow downstream with 30° wrap

Adjustment of the angle is critical. A minimum 30˚ wrap is required for this to work effectively. Non-driven bowed rollers often create more wrinkles because the drag resistance is too high.



Baggy Centers
Rotate bow into web



Slack Edges
Rotate bow away from web

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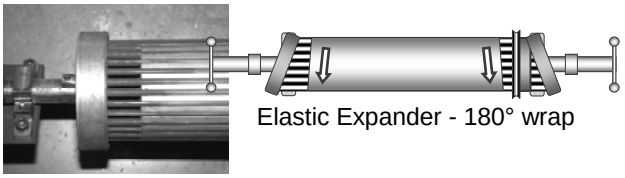
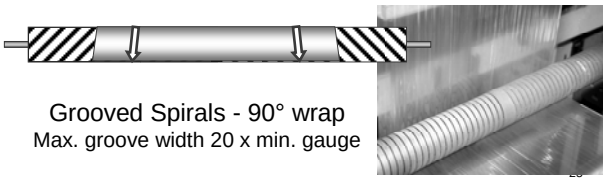
Other Spreader Rollers

Alternative spreader rollers include elastic expander rolls and grooved spirals. Grooves that are too deep or too wide will actually create Machine Direction wrinkles.



Elastic Expander - 180° wrap



Grooved Spirals - 90° wrap
Max. groove width 20 x min. gauge

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Locking Rollers Causes TD Slippage

Locking idler rollers with tape, particularly ones that are wobbling dampen web tension pulsations and allow the web to slide sideways to relieve the stresses that create wrinkles.

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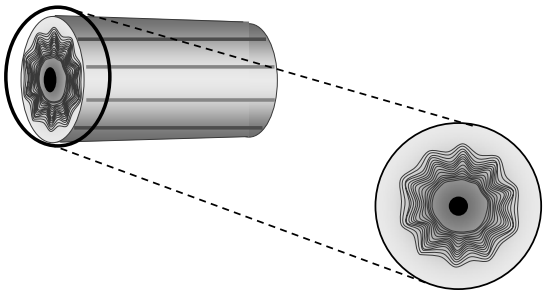
Starred or Spoked Rolls

Starred or spoked rolls are a common Transverse Direction wrinkle pattern. It can be caused by baggy film as well as poor winding control.



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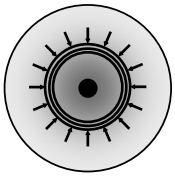
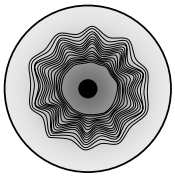
Starred or Spoked Roll Deformation Mechanism

Even flat film can cause deformed rolls if wound under the wrong conditions.



Pressure from outside layers compresses inner layers

Roll deforms into star or spoked pattern because layers buckle when compression is too high



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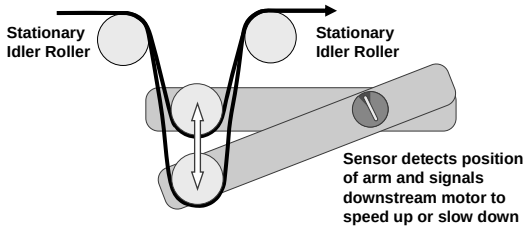
Solutions to Starred or Spoked Rolls

Material	Reduce density difference between layers (co-extruded films) Change layer ratio to avoid curling (co-extruded films)
Process	Adjust melt temp. to bring frost lines closer together (co-extruded films) Reduce film temperature Reduce film tension at winder Reduce lay-on pressure at winder
Equipment	Improve winding tension control (watch movement of dancers)

Dancer Assembly

Another useful tool is to watch the dancer assembly inside winders and secondary nips. If load cells are used in the winder, watch for cyclical changes in web tension on the digital displays.



Unstable idler may be caused by bent idler rollers or worn out sensor

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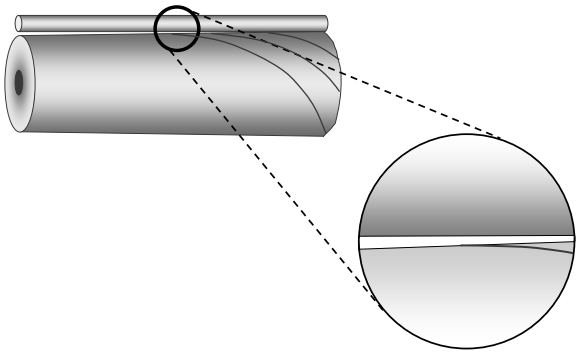
Tapered Rolls

Tapered rolls are usually caused by a tilted frost line or equipment misalignments.



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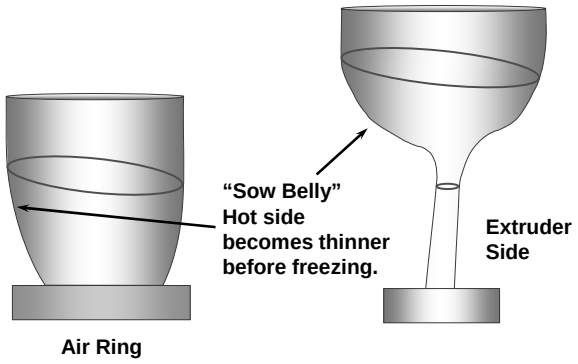
Solutions for Tapered Rolls

Material	Reduce melt temperature variation (melt channeling)
	Eliminate air drafts across bubble
Equipment	Align die
	Align air ring
	Align cage
	Align collapsing frame
	Align haul-off nip

Affect of Melt Channeling

Melt channeling is caused by excessive melt temperature variation from an extruder. If the die cannot randomize large variation in viscosity, it will result in hotter melts on one side of the bubble. Oscillating or rotating dies cannot randomize this problem because the die rotation speed is too slow. The result will be baggy film and Transverse Direction wrinkles.



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Summary

The best way to diagnose and fix wrinkling problems is to look for clues in the rolls and web tension fluctuations that result in changes in reflection of light from the web. Work your way upstream until the changes in tension are no longer significant. This will help you isolate bubble from web transport problems. Keep in mind that several problems are likely to be occurring at the same time.