New Developments in Stretch Film Winding to Improve Productivity

BY
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Abstract
This paper outlines the evolution of stretch wrap production on both cast and blown film lines. Technology improvements have allowed producing thinner films having the same or improved physical properties as previous heavier gauge products. Productivity and pricing demands have forced the production of thinner stretch films at wider widths and higher line speeds. It discusses the demands on the winder operation to meet the current market needs and the new developments for stretch film winders to meet the future demands for improved productivity and profitability of the production of stretch film.

Introduction
Stretch film has become a commodity product that has guided successful producers towards significantly increased production rates and reduced scrap in order to maintain acceptable profit levels in this market. Industry trends in the production of stretch films are for higher line speeds of wider and thinner webs. Recent developments in cast stretch film process technology, polymers and forming equipment have enabled increased production of stretch film to twice the production rates and twice the finished roll widths over what was achievable in the 1980s. In addition, stretch wrap improvements in film properties has allowed the film thickness to be reduced by 40%. This paper discusses the challenging demands have put on the winding operation and the recent developments to meet the productivity and profitability requirements for the production of stretch film.

Evolution of Cast Stretch Film Lines
Maximum production speeds of cast film stretch film lines in the 1980s were in the neighborhood of 300 mpm (1000 fpm). These lines had winders that typically slit into four (4) 500mm (20”) wide rolls of stretch film and wound these into 1500 to 2500 meter (5000 to 8000 ft.) rolls for use on automatic stretch wrap machines. These rolls were commonly referred to as Machine Wrap rolls.

A common cast stretch line in the early 90’s would cast 20 microns (0.8 mil) of thick film of sufficient width to be able to produce five (5) – 500 mm (20”) Machine Wrap rolls after taking about 25 mm (1”) of bleed trim. Bleed trim is a narrow width of film that is trimmed out between adjacent slit rolls on the shaft to allow a small amount of core to extend out from the edge of the rolls. This bleed trim was pulled away using vacuum trim removal systems and usually granulated and fed back into the extruders as reclaim fluff. These machines that were able to produce 2 meter (80”) and 2.5 meter (100”) finished web widths where commonly referred to as “4 & 5 UP machine widths”. They would wind these Machine Wrap rolls on 76 mm (3”) inside diameter (I.D.) fiber cores.

Many of the winders supplied on these cast stretch film lines would have the capacity to wind larger length rolls that were commonly referred to as Parent Rolls. These parent rolls were then taken to a slitter and rewinder operation and slit and wound down to small diameter rolls that could be easily unwound by hand. These smaller rolls are commonly referred to as Hand Wrap rolls. Hand Wrap rolls were typically 300 to 450 meter (1000 to 1500 ft.) and about 100 to 135 mm (4” to 5.5”) in diameter.

As the stretch film markets grew in the 2000s, the production rates grew by increasing the speed and widths of the new lines which were brought into production during these times. Production speeds on cast stretch film lines have doubled in the last 25 years. Stretch Film casting lines went from 300 mpm at their maximum production speeds to 600 mpm (2000 fpm) production rates.

The width of cast stretch film lines also grew during this time. Lines went from producing 4 & 5 UP Machine Wrap rolls (2 to 2.5 meter finished width) to machine...
widths able to produce 6 UP finished rolls and then to lines able to produce 8 & 9 UP or 4-4.5 meter (160”-180”) finished widths.

Blown film line speeds, with the use of orientation equipment and more efficient air rings, are now producing stretch film at speeds up to 400 mpm (1300 fpm).

Improvement in the properties of stretch film resins and formulations has allowed the thickness of the film to be reduced from 20 micron (80 gauge) to 12 micron (47 gauge) while still maintaining similar physical film strength properties.

**Future Stretch Wrap Film Market Trends:**

**Faster – Wider –Thinner**

Stretch Wrap market trends are for even higher line speeds of wider and thinner webs. Recent developments in cast stretch film process technology, polymers and forming equipment, have production speeds of stretch film increasing by another 10% in the near future. That means that stretch wrap film will soon be produced at speeds of 700 mpm (2200 fpm). 730 mpm (2400 fpm) production speeds are not too far over the horizon. Stretch wrap grades will continue to decrease in thickness with a target goal of 8 microns (32 gauge).

These current production speeds, widths and the production rates that are in the foreseeable future have made the winding operation for these new lines the limiting production factor. Also, in order to lower product, labor and scrap costs in the production of Hand Wrap rolls, these small diameter rolls need to be produced directly on the film casting lines. To compound this challenge, the emerging demand is for these Hand Wrap rolls to be wound on 50mm (2”) cores. The slitting and winding of these small diameter rolls at these speeds and widths is a major challenge to the winding, roll removal and recoring operations.

**Winder Requirements to meet Today’s and Future Production Requirements**

These increases in production speeds and widths of modern cast stretch film lines have put challenging demands on the winder operation. The challenges on faster and wider winders include:

- Winding Shaft Stability
- Roll Removal and Recoring Operation Cycle Times
- Tail Scrap Reduction

The current trend for stretch wrap manufactured on blown film lines is to pre-stretch the film to reduce the force required to wrap a pallet. To accomplish this, blown film stretch wrap lines now use a Machine Direction Orientation system, known as an MDO unit. The machine direction orientation process produces thinner film at a much higher production rate. In this application a nominal 25 micron film is presented to the MDO at 175 mpm or more and the MDO unit stretches the material to 10 microns and winds at about 375 mpm. The great majorities of blown film winders are not designed for these line speeds and faster roll changes. Therefore, the demands on blown stretch winders are challenging most existing designs.

**Shaft Stability- Critical Speed and Deflection**

Shaft stability is extremely important on wider and faster winders. The stiffness of the shaft affects the critical speed of that shaft. The critical speed defines the speed at which will resonate or vibrate violently. Winder shafts are typically sized to run at a maximum of 80% of their first critical speed. Critical speed is a function of the square root of the shaft’s natural unloaded deflection. The first critical speed ($N_c$) in Revolutions Per Minute (RPM) is approximated by the equation:

$$N_c = \frac{212}{\sqrt{f}}$$

Where $f$ = the shaft’s natural deflection

The stiffness of the shaft also has a major effect on the winder’s ability to wind straight sided rolls and the ability to wind at high speeds without vibration. Increasing the speed of the stretch film operation, increases the amount of air that follows the winding roll’s and incoming web’s surface into the winding operation. To keep this air from entering the winding roll, a higher nip load is required. Higher nip loading increased the shaft’s deflection; which produces a non-uniform nip across the shaft which resulting in the production of non-uniform rolls of stretch wrap.

The challenge for wide, high speed winders is to reduce the shaft deflection to be able to run the higher speeds without critical speed, deflection and vibration issues.
The easiest way to do this is to increase the core’s inside diameter (I.D.). Unfortunately, stretch film wrapping machines are designed to run on 76 mm (3”) I.D. cores. Hand Wrap rolls want to run with cores as small and thin as possible to keep the core costs down and shipping density up (more film per pallet). Some Customers want rolls to be wound on 2” cores; which makes the task of winding these rolls without deflection issues even more challenging!

Using ultra high modulus carbon fiber shafts increases the natural deflection and therefore increases the shaft’s critical speed. However, the speed and width requirements exceed that of only using expensive carbon fiber shafts. The solution to these issues has been within the shaft’s mounting, the use of a center support on a longer single core shaft or utilizing two side by side winders each with shorter core shafts configured into one unitized frame or as two complete free standing winders.

**Shaft Deflection with Increasing Widths**

As the width of stretch film lines increased, winding shaft deflection caused roll vibration and other winding issues. The shaft deflection increases by the cube of the shaft width.

**Winder Shaft Mounting**

The shaft mounting on winders is typically considered to be simply supported where the shaft is supported in chucks on both ends. This is typical on a winder where the shaft is removed from the winder for roll removal and recoring.

An improvement to this is to mount the shaft rigidly on one end and to pivot the shaft out for roll removal and recoring. (See Figure #1)

A further improvement for shaft mounting is to provide rigid shaft mounting on both ends of the shaft. This also requires that the support be removed for roll removal and recoring and then put back in place for the winding operation.

The shaft mounting system where on one end the shaft rigidly has 2.4 times less deflection than the simply supported system and rigid mounting on both ends has 5 times less deflection than the simply supported system. (See Figure #2).

**Winding with Shaft Supports**

The use of supports to support the winding shafts greatly increases the shaft stiffness and therefore greatly increases the shaft’s critical speed and reduces the shaft’s deflection. (See Figure #3)

The natural deflection of a shaft on a center support winder is approximately 8 times stiffer that a shaft without a center support. This greatly increases the shaft’s critical speed and greatly reduces the loaded deflection. Chart #1 shows the winding speed limitations for winders with and with out center supported shafts. This chart shows that stretch film lines wider than 4 UP (2 meter finished widths) can not use unsupported single shaft winders to operate at the speeds required for competitively producing stretch wrap film. Wider machines need to use either coreshaft support winders or dual winding systems to profitably produce stretch wrap films.

The downside of winding with coreshaft supports is that the web needs to be slit in the area of the support and the width of the support must be trimmed out of the web and sent to be reclaimed. The engineering challenge on coreshaft support winders is having the ability to supply support bearings that can take the radial loads of the shaft and winding roll’s weight. The size of these bearings is very limited as the core’s I.D. must slide over the O.D. of the bearings.

**Dual Winding Systems**

As the speeds and widths of cast stretch film lines keep increasing, the solution to the speed and deflection limitations of the shafts has been to provide side by side dual winders for the winding operation on a single line. (See Figure #4).

Dual Winder configurations are essentially two independent winders with offset turrets which can be configured to wind an odd number of slit rolls. The dual turrets allow winding without the requirement of a wider bleed trim for a center support.

Coreshaft Supports or Dual Winding type systems are currently required for lines capable of winding stretch wrap at overall film widths of over 3 meters wide as shown in Chart #1.
Roll Removal and Recoring Operation Cycle Times

Even with center support and dual winder configurations, the actual winding speed when winding the smaller diameter Hand Wrap rolls has been limited by the roll removal and recoring operation cycle times.

The two basic types of winders used for the winding of slit rolls are either surface type drum winders or center type turret winders. Surface winders have the advantage of little to no waste at the end of the finished roll sets. However, this type of winder has the inherent difficulties with fast roll changes, roll removal and recoring cycle times. Turret type winders have the advantage of much faster cycle times. They have been designed with either a signal or dual pivoting shafts for fast and efficient roll removal and recoring. Pivoting shaft designs have achieved turreting and roll change cycle times of 1.2 seconds and total winding cycle times including roll removal and recoring of 45 seconds.

Even with a 45 second total winding cycle time, the maximum production speed of 300 meter (1000 feet) Hand Wrap rolls limits the line speed to 400 mpm (1310 fpm).

In order to meet the market needs to produce Hand Wrap rolls at production rates of at least 600 mpm (2000 fpm), the total winding operation, including the roll removal and operation cycles, has to be 30 second or less.

Outer Wrap (Tail) Scrap Reduction

Scrap reduction is a very important component in maximizing the productivity and profitability of a stretch film operation. During the roll change process, the web is typically distorted due to tension upsets on the outer wraps of the wound rolls. This is commonly referred to as Tail Scrap. Tail scrap increases as the speed of the production line increases. Tail scrap reduction needs to be incorporated into the roll changer design to enable the wound rolls to be shipped directly off the production line, without the labor to remove this scrap and the cost of the scrap material eating into the cycle time and production costs. The cost of collecting and reclaiming bleed trim also cuts into the profitability of the stretch film operation.

New Winder Design to Meet Future Stretch Wrap Market Needs

Future stretch wrap market needs are for production speeds of up to 730 mpm (2400 fpm) and finished roll widths up to 3.2 meters (128”). In order to meet these requirements, new winders must be designed to have a total cycle time of 25 seconds for winding 300 meter length rolls at full production rates. Plus, the tail scrap needs to be minimized to a level that allows the wound rolls to be shipped directly off the cast film line.

A new winder has been designed and is currently in production that meets the stretch wrap market’s current and near future requirements. This new winder incorporates design features that enable the production of 300 meter (1000 feet) rolls at the full production speed of 730 mpm (2400 fpm). See Figure #5.

This winder makes 1.2 sec adhesiveless roll changes. The four spindle (S4) design separates the roll unloading cycle time from the recoring operation cycle time. The S4’s short draw indexing system allows minimal indexing time and distance which minimizes tail scrap.

The winder incorporates rigid shaft mounting on both ends. It also uses a high intensity intermediate clamping system at the 1/2 or 1/3 points on the winding shaft. These features combine to provide optimum shaft stability. The fully automatic roll removal system provides quick and reliable finished set removal. The separate recoring operation is also fully automatic, complete with a large capacity core bin system.

All of these features allow for the achievement of the required minimum cycle time of 25 seconds for winding Hand Wrap rolls at full production speeds.

The optional bleed trimless system eliminates the requirement of taking bleed trims which allows for up to an additional 6- 8% increase in efficiency and power consumption.

The results of these features allows for the production of smaller diameter rolls of Hand Wrap stretch wrap film directly on the production winder at full operation speed. Dependent on the upstream capacity and with a conservative 80% line uptime, this new winder has the potential ability to produce up to 2,700 roll sets or 21,600 rolls of stretch wrap per day off an 8 up operation.
The ability to wind shippable quality rolls directly off the production line eliminates the off-machine rewinding operation for these rolls.

This provides the following benefits:
- Shortens Production Cycles
- Decreases Scrap
- Lowers Manufacturing Costs
- Increases Profitability

These are critical components to ensure the success of your stretch film operation to meet the current and future needs of this demanding market.

**Conclusion**

The Market for stretch wrap film is driving machine development. The continued evolution of process technology is leading to higher production rates through wider widths of film being produced at higher production speeds. The winding operation in combination with the roll removal and recoring operation has become the limiting operation in the profitable production of stretch wrap films. Newly designed winders are now available that will meet and exceed the productivity demands of this commodity product. Carefully consider your future requirements and position your plant properly for the productivity and profitability needs to meet your profit objectives when producing stretch wrap films.

**References**

2. Smith, R. Duane, *“The Challenges of Winding Flexible Packaging Film”*, Society of Plastic Engineer’s ANTEC Conference, Moscone Convention Center, San Francisco, CA, May 2002
### Finished Product Width

<table>
<thead>
<tr>
<th>Typical Maximum Speed (mpm/fpm) for 76mm (3’’) coreshafts unsupported</th>
<th>Typical Maximum Speed (mpm/fpm) for 76mm (3’’) coreshafts supported</th>
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<tbody>
<tr>
<td>600 / 2000*</td>
<td>430 / 1450**</td>
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<td>430 / 1450*</td>
<td>600 / 2000**</td>
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*Speed Limit based to 80% of Winding Shaft Critical Speed  
** Speed Limit due to shaft deflection from Lay-on Roll Nip Force

**Chart #1: Max Line Speed vs. Line Width**
Figure #3: 3.2 M (128”) Pivoting Shaft with Center Support

Figure #4: Side by Side Dual Winders
Figure #5: New “Bleedless” S4 Winder