

What's New in Stretch Film?

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Introduction

The North American stretch film industry today exceeds 1.3 billion pounds per year. By some analysis it still enjoys double-digit growth although this is beginning to slow, and is more likely predicted to be in the 6 – 7% range. With greater than 65% of all palletized shipments in the U.S. unitized with stretch wrap what can we expect for this industry in the coming years? This paper will provide a little history of the development of stretch wrap. The markets and products historically served and the typical machines that supplied these products will be described. We will then go into a description of some of the new five & seven-layer products, discuss some of the potential opportunities they may open up, and then outline some of the equipment considerations for making these new products. Structures and equipment will not however insure success without an understanding of the process interactions and the effects on finished product properties. Experimental work will provide some of these correlations that will help the processors to get the most out of their stretch film line.

The Beginnings

It is hard to believe that the stretch film market that consumes over 1.3 billion pounds of resin per year in North America did not exist 25 years ago. In 1973 the first commercial LDPE stretch film was introduced. These initial products were primarily manufactured through the blown film process. These early products would hardly be recognized today as stretch film due to the significant improvements in stretch, load retention, and cling that have occurred with the introduction of new materials and processes.

The advent of linear polymers created new film properties never achieved before. Very strong films were created that had excellent extensibility. In the late 1970's Mobil began making LLDPE stretch film by the cast film process. These three layer products had skins that included tackifier and a core of high strength linear low density PE. A more cost effective higher strength product was produced. Production yields for the cast process far exceeded the blown machines in operation while at the same time improving clarity, enhancing load retention, and reducing unwind noise. The three-layer process also provided the opportunity for the value-added feature of differential cling. By using a separate extruder for each layer the tackifier could be added to only one skin providing tack to the wrapped product only and reducing the amount of tackifier required thus reducing product costs. These product offerings and machine configurations dominated the stretch film landscape until the early 1990's.

Throughout this period, in addition to polymer improvements allowing improved product performance with higher stretch values, greater load retention, and more consistent cling, processors were also improving their competitiveness through higher yields. Cast film machinery became wider and faster and more fully automated. By the early 1990's a typical machine speed of 1500 fpm at a finished width of 100" was common. Black Clawson led the automation trend by offering fully automated winders that included roll removal and recoring in under one minute, allowing full speed continuous production of hand wrap rolls.

The next step in the evolution of stretch film is being driven by the new high performance metallocene resins and the slowing growth in North America of pallet wrap. Market growth in North American stretch film has been linked directly to pallet wrap. Today with nearly 70% of palletized shipments unitized with stretch wrap the growth in this segment is beginning to slow. Producers are looking for new markets and applications. The new resins are providing a tool to enhance the value of stretch film for new applications. In addition, new product structures are allowing the producer to improve performance and reduce cost with these new resins.

Five Layers and more

In 1993, Chapparral entered the stretch film market with a novel new five-layer product. Utilizing Cloeren coextrusion technology, Chapparral began introducing metallocenes into a sub-layer to improve film performance with minimum added costs. In addition edge encapsulation was used to provide edge stabilization for high speed processing. This technique, adopted from the extrusion coating industry, provides a separate channel to each end of the die where a high melt strength polymer with superior draw down characteristics can be extruded at a rate of approximately half of the normal edge trim rate. Proper use of a broad molecular weight LDPE should reduce the amount of neck-in and improve the stability of the edges insuring consistent pinning. Depending on the product structure and performance requirements this material can be recycled continuously into the film structure with minimal reduction in overall film performance. In some cases the blending of a small percentage of LDPE in a linear or metallocene rich layer will reduce the extruder torque requirement and the melt temperature, actually improving its processability.

It has been demonstrated that careful product design and incorporation of high performance metallocene resins into the film structure can maintain or enhance the total performance at reduced costs. In a market that is under continual pressure to extend performance while reducing the pounds per pallet, better news could not be heard. This alone could support conversion of the established base of three layer stretch film lines to five layers, however the saturation of the pallet wrap market insures that all new capacity will be five layers or more. The addition of the added structure layers increases geometrically the opportunities

for the product designer to design greater value into the film, opening new market opportunities.

Today, Quintec Films is the first to enter the market with seven-layer Black Clawson stretch film technology. They have several new products that demonstrate some of the versatility of this innovative approach. One of their patent-pending products includes the cling product in a sub-skin layer and a very thin non-cling layer on the skin. The power pre-stretch action breaks down the non-cling skin layer exposing the sub-skin cling layer for an outstanding balance of operational and functional performance. High speed unwinding with less noise and fewer breaks with comparable cling to established products is obtained. Other opportunities come to mind for product enhancement for niche market requirements, the incorporation of a flame-retardant layer for a roll wrap application, a separate fungicide layer for silage wrap, a corrosion inhibitor for automotive wrap. The list of opportunities will only be limited by the new applications that find value in the unitization and protective performance of stretch film.

There are those that will say these opportunities existed with three layer products and there are many producers that have commercial high value three layer products for niche markets. The added value of five or more layers comes in its ability to make high value products while controlling costs by limiting the amounts of high cost materials required to achieve performance.

The Technology

To take maximum advantage of this growing opportunity it is important that the processor consider all aspects of the technology. Exxon and Dow have had available for several years a variety of metallocene resins targeted specifically at cast stretch film. These commercial products are summarized in Tables 1 & 2. In addition, many other suppliers have introduced new enhanced performing resins that may offer special characteristics such as high clarity, enhanced puncture resistance, and inherent cling. In any material selection it is imperative that the processor review the available materials that satisfy the performance and cost requirement for the product. It is equally important that an actual process test evaluation be conducted as well. This evaluation can occur on an existing production line or in a development laboratory such as Black Clawson's coextrusion cast film pilot facility. This allows an initial evaluation of the product performance, in addition a relative comparison of the processing costs can be conducted.

Table 1 Commercial Metallocene Catalyzed Resins For Stretch Film

Manufacturer	Trade Name	Grade No.	Melt Index	Density	Melt Pt.
			ASTM D1238	ASTM D792	
			g/10 min	g/cc	deg. F
Dow	Elite	5210	2.3	0.917	251
Dow	Elite	5220	3.5	0.915	252
Dow	Elite	5230	4.0	0.916	241
Exxon	Exceed	357C32	3.5	0.917	239
Exxon	Exceed	361C33	4.5	0.917	239
Exxon	Exceed	363C32	2.7	0.917	239
Exxon	Exceed	369G09	3.3	0.917	239
Exxon	Exceed	ECD-125	1.5	0.917	244

Table 2 0.8 Mil Film Properties*

	Grade	Haze	Gloss	MD Yield	CD Yield	MD Break	CD Break	MD Elong	CD Elong	MD Tear	CD Tear	Punct.
		%	45	psi	psi	psi	psi	%	%	gm	gm	in-lb
Dow	5210	0.6	96	1300	1250	6500	5500	400	650	400	600	39.5
Dow	5220	0.6	96	1300	1220	5800	5200	450	650	390	600	36
Dow	5230	0.5	95	1385	1240	5900	5200	500	630	360	520	33
Exxon	357C32	1.5	97	1030	1030	9860	6960	420	650	160	450	37
Exxon	361C33	1.3	99	900	1060	6920	5020	420	600	170	500	34
Exxon	363C32	1.3	94	1080	1080	10516	7510	390	650	160	420	36
Exxon	369G09	1.5	97	1030	1030	9860	6960	420	650	160	450	37
Exxon	ECD-125	31.8	21	1200	1210	9770	8490	550	620	240	300	23

* Dow data generated as cast film at 600 fpm, Exxon data except ECD-125 generated as cast film at 750 fpm, Exxon ECD-125 generated as blown film.

Due to the reduced shear thinning characteristics of the narrow distribution, high molecular weight materials existing screw designs may cause overheating during processing. Screws that incorporate high shear mixers or barriers may lead to polymer degradation at high outputs. Alternatively, the increased torque requirements for these materials may limit production capacities. For optimum performance an extruder dedicated to processing these resins may best be fitted with a low shear screw designed specifically for the target materials. Existing extruders may also require regearing to provide adequate torque for proper processing. Each of these factors can be evaluated in a preliminary laboratory evaluation.

Once the material has been selected and matched with the proper screw design for processing the next critical step is the combining of the polymer sandwich. The leader in coextrusion feedblock technology is Cloeren. Together, Cloeren and Black Clawson have pioneered many of the innovations in this field. Black Clawson supplied the first Cloeren seven-layer feed block for stretch film in 1994. Black Clawson has combined with Cloeren to supply cast film edge encapsulation technology as early as 1991. The combining of these techniques in the production of stretch film is only the latest application of proven technology.

The available feedblock technologies include three distinct designs. The Dow style feedblocks are based on the technology originally patented by Dow in the 1960's. In these systems a modular stack of components serve the separate functions of layer arrangement, distribution, and combining. Although superior layer uniformity may be achieved with a correctly designed Dow style block the three separate modules may require a labor-intensive changeover for simple adjustment in layer percentages. As the modules are typically stacked and bolted together this type of change may entail considerable downtime. The second distinct technique is the insert type feedblock. This type block incorporates a layer arrangement module and combines the distribution and combining functions. The layer arrangement module is accomplished with an easily changed selector pin. The combined distribution and combining insert behaves like a mini die within the feedblock. This is incorporated in an insert block that can be changed for each layer if significant output or rheological changes occur. Although a significant change in the product may also require a mechanical change in this design, it is accomplished far easier by replacing an accessible insert. By far the most versatile feedblock is the adjustable vane style feedblock patented by Cloeren. In this block design the arranging function is accomplished as in the insert block. The distribution and combining process however occurs in a "die" that is formed between two moveable vanes. This technology allows for adjustments without disassembly for variations in output or rheology.

The polymer sandwich is then supplied into the slot die. Much advancement has recently occurred in die design for coextrusion. Theoretical work has been conducted by J. Dooley et al at Dow identifying the forces at work in layer rearrangements in flow channelsⁱ. Based on this work, it can be seen that the traditional tear drop manifold designs created high shear corners that due to the elastic characteristics of the polymers caused movement of the layers in coextrusion. The latest die manifolds have used this as well as field experience to reshape the manifold for improved layer uniformity in coextrusion. Typically an elongated rectangular manifold with rounded corners and a tapered entry to the pre-land is used reducing the shear stress on the polymer and the layer rearrangements at the corners and ends of the die. The new dies also enhance the operability through designing for lower pressure drops, reduced clamshelling, and including a parallel manifold backbone, creating a more uniform pressure response.

The next significant advance has occurred in the winding technology. Black Clawson has advanced the capability of winding on 3" shafts with the Black Magic Winder (BMW) II™ and the BMW II CS™. As products are down-gauged the need for faster winding capability is paramount. The advent of high modulus carbon fiber shafts has allowed us to push speeds to 1800 fpm. By added center support capability, the critical frequency of the shafts are pushed beyond 2000 fpm. Proprietary lay-on roll dampening is also incorporated to stabilize the shaft during high-speed transfers. Optimization of the knife geometry and static charging bar ensure that consistent transfers will be achieved. The Tri-Star™ three spindle winder for stretch film offers all the enhancements of the BMW II with continuous lay-on roll contact during indexing for totally scrapless winding. All of the Black Clawson winding systems are designed to be fitted for fully automatic roll removal and recoring.

The Process

Of course all the latest in materials and equipment alone does not guarantee the best stretch film. A key understanding of the process is required to get the most performance out of the equipment and the product. J. A. DeGroot, et al at Dow studied the effects of fabrication variables on film propertiesⁱⁱ. The results of this work are summarized in Table 3. The process interactions can be quite significant on the critical product parameters of stretch, cling, and load retention. From this summary we can see that increasing line speed, winding tensions, and the die lip gap will all have a negative impact on ultimate stretch. Likewise decreasing the air gap or melt temperature will increase the retention force. Attention to these simple correlations will enhance the processors ability to optimize the properties of his film. Equally important is understanding the implications of process changes on film properties. A new screw designed for metallocenes that causes a colder processing temperature for an existing product will change that product. An encapsulation die added to allow higher processing speeds would change the finished product with no other adjustments.

Table 3 Fabrication Variables Impact on Film Performance

	Increasing line speed	Increasing air gap	Increasing melt temp.	Increasing wind tension	Increasing die lip gap	Increasing cooling rate
More ultimate stretch	<	>>	>>	<<	<<	-
More retention force	>	<<	<	-	-	-
More unstretched cling	-	>>	>	<<	-	>

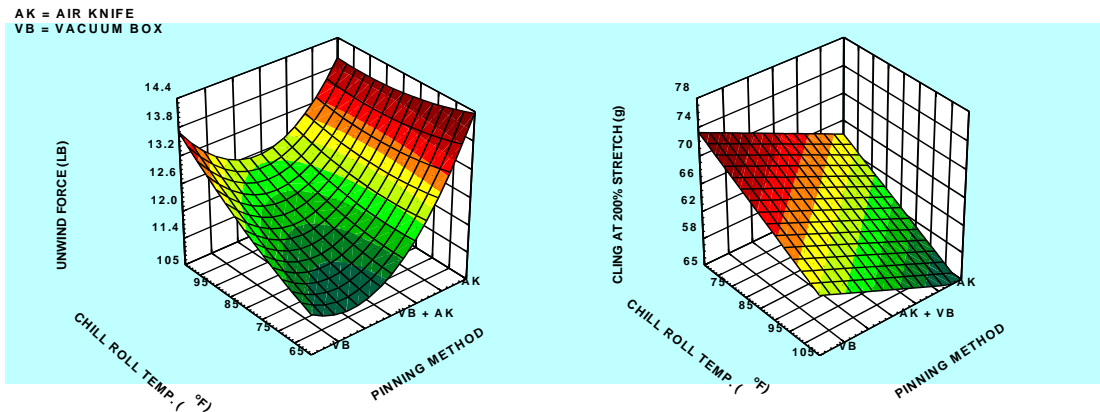
- >> Strong direct correlation
- > Weak direct correlation
- Neutral or untested
- < Weak inverse correlation
- << Strong inverse correlation

Today many processors are changing from the air knife pinning method to the vacuum box method for improved gauge uniformity and easier set up. This change will also have significant impact on the finished film properties. Black Clawson, with support from Exxon Chemical, has recently conducted experiments at our Research and Technical Center in Fulton, New York to evaluate the effects of the pinning method on final film properties. Some of our preliminary findings are presented below.

The experiment was conducted on a five-layer A/B/C/B/A structure using an Exxon LL-3023.32 for the skins and core and an Exxon 357C32 metallocene in the sub-skin layers. The correlations published by DeGroot were confirmed in this study. Specifically, a significant reduction in air gap accompanies the change from air knife to vacuum box with the anticipated increase in retention force and decrease in ultimate stretch and unstretched cling. This reduction in unstretched cling corresponds to a decrease in the required unwinding force. Figures 1 & 2 below summarize the impact of pinning method on unwind force and cling at 200% stretch. From these it can be seen that the use of the vacuum box with a reduced chill roll temperature provides both a reduced unwind force and higher cling values at 200% stretch. At high chill roll temperatures the simultaneous use of the vacuum box and air knife can further reduce the unwind force by speeding the crystallization process with it's cooling effect. At lower chill roll temperatures this effect is dominated by the rapid quenching from the chill roll.

Figure 1

Figure 2



Note: This information is presented in good faith to aid in the understanding of the process effects on film properties. It is the readers responsibility to assure freedom of use and suitability in your business. The author does not accept liability for any loss or damage that may occur from the use of this information nor does he offer any warranty against patent infringement.

Summary

Cast stretch film continues to be an exciting and dynamic market. Although growth in some of the traditional markets may be beginning to slow new materials, new equipment, and new processing techniques will continue to open up new opportunities for value added stretch film products.

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ⁱ J. Dooley et al., An Experimental Study on the Effect of Polymer Viscoelasticity on Layer Rearrangement in Coextruded Structures, Polymer Engineering and Science, Vol.38, No. 7, pp. 1060-1071, July 1998

ⁱⁱ J. A. DeGroot et al., Effects of Cast Film Fabrication Variables on Key Stretch Film Properties, ANTEC, pp. 159 – 164, 1992