FILM PROPERTIES FOR GOOD PERFORMANCE ON VERTICAL FORM/FILL/SEAL PACKAGING MACHINES

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Abstract

Technological improvements of flexible form, fill and seal packaging machines are yielding exceptional line speeds, productivity rates and bag features. This paper discusses the evolution of vertical packaging machine development and how it has impacted plastic film properties (e.g. COF, sealing temperature range, hot tack) required for optimal performance.

Introduction

Technological advancements occur because of the customer's drive for more performance and/or lower cost. In the flexible packaging arena, there have been major developments over the last several decades in film and machine technology. Today we'll review those developments and how they interact with each other. We'll look in detail at how new packaging materials influenced packaging machinery modifications. And we will look at how major machine advances that have brought tremendous productivity improvements and convenient package features, have changed the demands on film properties. Finally we'll take a peek at the future.

This story should provide more than just valuable perspective because older packaging machines and even older film technology are still in use today. This potpourri on plant floors means that a film that runs great on a new high-speed, servo-driven machine may jam and misfeed at another customer running an 30-year old draw-bar machine.

As the flexible packaging arena is so large, this talk will focus on the interchange between vertical form, fill and seal machines (VFFS) and the packaging films, oriented polypropylene (OPP) and oriented polyester (PET). These are typical machines and films used in the snack food, bakery, candy, and cookie/cracker markets.

Discussion

In the 1960's, OPP was a newly invented film that was becoming increasingly appealing to packagers as a replacement for the dominant film: cellophane. Why? It was cheaper and yet was clear, stiff and a good moisture barrier without coating. Unfortunately, the homopolymer film was not heat sealable, generated static, distorted at high temperatures, and had a high COF and low surface energy. But money rules. Films were made usable with additives, coatings, low-tech co-extrusions, or via lamination. Even with these film enhancements, packaging machines had to be modified to accommodate the inherent properties such as static and film distortion at higher temperatures. These modifications are discussed in more detail later.

In 10 – 15 years OPP replaced all but niche cellophane applications. OPP film manufacturers facilitated the revolution by retrofitting packaging machines with the necessary modifications at no cost to the customer.

The packaging machines were the speed-limiting factor at this point. Improvements in film co-extrusion technology, additive technology/formulation, and sealant polymers optimized efficiency, but the machines could only go so fast.

Film manufacturers focused on developing new complex films to forge new markets or replace other materials. Although sometimes, minor machine modifications were required, in general the industry now understood how to address the challenges of polymer films. Most old machines had been "converted" and new machines incorporated the necessary features to run films well. So film developments allowed replacement of higher cost materials or brought advances in product protection. Examples are:

- Cavitated white OPP replaces paper wraps in candy market
- Metallized OPP replaces glassine in potato chip packages
- Metallized OPP and PET replace foil
- Barrier films and hermetic sealants extend shelf life via modified atmospheric packaging (MAP)
- Metallocene-catalyzed PE sparks packaged fresh-cut produce market
- Flexible pouches replace boxes and rigid plastic containers

These film developments and market penetrations are summarized in Table I.

Early vertical form/fill/seal (VFFS) packaging machines were slow, intermittent-running, mechanical devices that applied many stresses to the films running through them. Webs were pulled through the feed and forming sections by a moving forming collar or crimp-sealing unit (while the crimpers are closed and making the end seals). The longitudinal back seal was made by dragging the films between heated flat platens. End seals were made with sharp-angled crimpers, on/off temperature control, and standard-wound cartridge heaters.

OPP will not run under these conditions. Unlike cellophane, OPP is inherently non-conductive (i.e. induces static) and distorts at about 145ºC [~295ºF] (causing unattractive seals at higher temperatures). Although OPP films were modified with heat seal layers and slip additives, packaging machines had to be modified to run them. These modifications also became standard on new machines:

- Static eliminators
- 120^{o} crimp jaw serrations
- PID temperature control
- Preferentially wound heaters
- Coated back sealers

After machine modification, film properties were still important to good machineability:

- Outside COF (for low force over forming collar)
- Seal range
- Hot tack
- Hot slip

In the 1980's, vertical FFS packaging machines experienced revolutionary improvements: film belt drives, film feeding/measuring, and combination net weigh scales. Baggers still operated intermittently (film stopped for stationary crimp sealers to close and make end seals), but productivity increased 50% or more. That is, for a bag cut-off length of 6-8 inches, typical rates rose from 45-50 packages per minute (ppm) with the drawbar and single dump to 70-90 ppm with belt drive and combination scales. Microprocessors controlled temperature, dwells, line speeds, web tension, and operator interface. Many other less dramatic, but highly effective improvements occurred like product catchers (reducing the stress on the hot seal), hot seal cooling, horizontal patterned crimpers (which widened the seal range and improved hermeticity), and reciprocating back sealers (no drag).

In general, the 80's improvements made newer machines more film forgiving. Seal range and strength grew less critical. A low outside COF was no longer as important because film was "fed" to the forming collar rather than being dragged over it. In fact, low outside COF became a problem in some cases. If it were too low the belts would slip and not drive the film properly. Sometime slip additives fouled the belts by leaving a greasy residue. Also, for the first time with VFFS, *inside* COF and hot slip became a critical property – at least with the pressure-style (vs. vacuum-style) belts where the film is sandwiched under pressure between the metal tube and the belt. If the inside sealing surface is tacky it will drag on the tube and misfeed.

In the late 1980's and into the 1990's, OPP films were used more and more in modified atmosphere packaging (MAP) to extend shelf life of products like potato chips, cheese, and nuts. This usually involves gas-flushing on the vertical packaging machine: replacing air headspace in the bag with other gases (typically nitrogen or a mixture of nitrogen and carbon dioxide). Not only were high gas barrier films necessary (PVdC, PVOH, and metallized coatings), but also leak-proof seals. Most sealants don't adequately caulk when heat-sealed at or below the distortion temperature of OPP (145^{o}C/295^{o}F). New metallocene plastomers turned out to be a breakthrough solution. These sealants were not only clear and tough, but created hermetic seals at low temperatures, thereby preventing the exchange of headspace gases with outside air.

Still growing is the stand-up pouch and bag market. Doypacks are a very popular version produced on horizontal machines. Most VFFS machines make pillow packs, but they can be adapted to produce gusseted, box bottom, or four-corner sealed stand-up bags. These features require excellent film stiffness (to stand up as expected) and seal range (to seal adequately through various thicknesses).

Consumers prefer reclosability of food and household product packages. Sargento was the first to respond in a major way in 1986 when they began packaging their shredded cheeses in zippered flexible bags. These zippers were pre-applied to film stock and ran in the machine direction. By 1990, many different systems were being developed that led to a plethora of reclosable packaged products. Many are applied on horizontal equipment, but there have been recent developments focusing on transverse direction closures applied at the VFFS packaging machine without slowing productivity. These include Trans-Zip® and Easy Snap®. The challenge with these systems is that the fastener material must be solidly heat seal-bonded to the top surface of the web before the film reaches the forming collar. If the bond is too weak, the zipper foot may separate from the bag and the reclose feature is ineffective. Heat seal strength and sealing temperature range between the two materials is critical to achieving adequate bonding.

The 1990's saw the introduction of servo-drives into belt-driven machines which increases productivity over 30% to approximately 120 ppm (for 6-8 inch cut-off length). Continuous motion VFFS machines also came out that increased production rates again, to about 150 ppm (same cut-off). The concept of continuous motion is patterned after horizontal form/fill/seal (HFFS) "flowpack" machines where the film does not stop to make reciprocating end seals. Rather, the film moves continuously by employing a crimp sealing head where the closed jaws move with the film - such as with a rotary crimp sealing head or a box motion type. The rotary head method is simpler, but produces a short dwell that requires a high-performance sealant. The box motion-type extends sealing dwell time because the crimpers move with the film for the length of the bag.

These VFFS machine developments and the influence on film properties required are described in Table II.

The sophistication of films and equipment have progressed to the point where in some applications the speed-limiting factor is a physical law of nature: gravity. That is, the product cannot drop as fast as the film and machine are able to package it. Surely, a future development will attempt to overcome gravity with a device to accelerate the natural movement of product into the bag.

Conclusions

Bringing cost and performance benefits, polymer films have replaced cellophane, paper, foil and rigid containers in many applications. Early on, vertical form/fill/seal packaging machines were modified to accommodate static generation and the low distortion temperature of OPP. These machine improvements quickly became standard. Then packaging machines became more complicated as they incorporated sophisticated technology like microprocessors and servo-drives, as well as simple problem-solving modifications like product catchers and new crimper designs. Not only was productivity increased, but also film properties requirements for good machineability and package performance shifted.

There have been many advances in flexible packaging films and machinery. Advances in one area have affected the requirements in the other. Now the state-of-the-art in VFFS systems today has moved the speed-limiting factor from machine to gravity.

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Reference

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Table I: Summary of film developments and when they started to go mainstream

Decade	Film Technology	Market Shifts
60's	Orientation	OPP replaces cellophane
	Limited co-extrusion	
	Surface treatment and coating	
70's	2-3 layer co-extrusion	
	Copolymer improvements	
80's	5-7 layer co-extrusion	PE, PP replace paper Met PP, PET replace foil
	Barrier resin and coating layers	
	Cavitation	
	Terpolymers	
	Improvements in formulations (e.g. slip, adhesion)	
90's	Metallocene-catalyzed polymers	Flexible film replaces rigid
	Improved barrier layers	
	Improved sealants	
00's	Evolutionary improvements	
	Revolutionary introductions?	

Lower Cost and/or Improved Performance

Table II: Summary of VFFS developments and when they started to go mainstream

Decade	VFFS Packaging Machine Developments	*Effect of* or *Influence on* Film
60's	Static and temperature control, jaw design	*Effect of film on machine:* The preferred film, OPP, requires packaging machine modifications to run. Machine manufacturers incorporate these improvements as standard on new equipment.
70's	Static and temperature control, jaw design	
80's	Film belt drives	*Influence of machine on film:* COF now less important for low force over the forming collar and more important for belt drive (outside grab, inside slide). Barrier and seal integrity important for MAP.
	Film feeding/measuring	
	Combination net weight scales	
	Microprocessor-based controls	
	Touch screen control panel	
	Heat seal enhancements (cooling, geartooth pattern, etc.)	
90's	Electronic drives (servo, stepper)	*Influence of machine on film:* Stiffness, sealing range and seal strength are more important on some machines.
	Stand-up bags	
	Reclosure and fitment features	
	PC-based operator interface	
	Continuous motion	
00's	PC-based machine control	
	LAN- and/or Internet connected	
	Overcoming gravity?	

Higher Productivity, New Package Features

Fig I: Pictures of applications where polymer films replaced other materials or created new market

Fig II: VFFS Stand up Bag with 4-corner seals

Fig III: Mira pak Mechanical Draw VFFS

Fig IV: Hayssen Belt Drive VFFS

Fig V: Sasib Continuous Motion VFFS