Basic Sealing Theory for OPP Films

This technical paper covers the basic theory behind making properly sealed packages with oriented polypropylene (OPP) based films on horizontal flow wrappers and vertical baggers. The relationships between the three factors of the sealing equation (heat, time and pressure) are analyzed and explained in order to provide a basis for real-world application and problem solving.

Introduction

This article covers the basic theory behind obtaining good seals with oriented polypropylene (OPP) based films on both horizontal form/fill/seal wrappers and vertical baggers.

There are three critical factors which we'll discuss in detail, and these are shown in the basic sealing equation: **heat** + **time** + **pressure** = **seal**. The factors are closely related in that an increase or a decrease in any one will have an impact, positive or negative, on the others. For example, if line speed is increased (and dwell time reduced), then often an increase in heat or pressure is required in order to maintain seal integrity.

Before we get into the details we should first consider what is meant by the term "good seal". The answer can vary greatly, from lab to real world, from line to line and from product to product. In a daily production situation, with product moving down the line, you might test seal integrity by squeezing a package in your fist to see if it pops. Maybe you hold it to your face as you squeeze, trying to feel the small jet of air that would be forced out through a leak in the endseal. Or, if you want to get more sophisticated, maybe you squeeze the package while it's submerged in a bucket of water, looking for the telltale bubbles from a leak. The obvious disadvantage of this "squeeze" method is that the force exerted is variable and immeasurable, but, as unscientific as this testing method may be, it is also perfectly adequate in many situations. More sophisticated techniques such as gas detectors, vacuum burst or creep tests and seal strength measurements are, of course, used when applicable. Anyway you measure it though, a good seal is one that is strong enough to hold the product in the package and hermetic enough to keep it fresh for the term of its intended shelf life. For the purpose of our discussion it doesn't need to be any more complicated than that. The basic principles of *obtaining* a good seal are the same no matter what type of test you use, no matter how hard you normally squeeze the package, and no matter what shelf life you require.

Heat + Time + Pressure = Seal

Heat

Let's first take a look at heat. OPP alone is not heat sealable, and it will distort at approximately 295° F (145° C). In order to be used for flexible packaging, OPP requires either a heat activated sealant layer such as LLDPE or Surlyn, or a cold seal adhesive layer which seals at room temperature. Often other coatings, laminations or co-extrusions are also used to improve functional properties such as coefficient of friction (COF) or gas permeability. Our discussion of heat is applicable to heat seal film only. Cold seal adhesives will be discussed further in the section on pressure.

Improper temperature can impact both seal strength and integrity. Excessive heat may cause poor hot tack and distortion, fracturing or melting of the film. Inadequate heat can result in open packages, channel leaks or seals that are not strong enough to hold the product.

A heat seal film will have a seal initiation temperature (SIT) and an operating window. The SIT is the temperature at which the sealant layer is activated enough to obtain the minimally acceptable seal strength. The operating window is the temperature range between the SIT at the low end and the point at the high end where the film becomes noticeably distorted. Keep in mind that we talk about the SIT and operating window we are measuring the temperature reached by the film, which is not the same as the temperature setting on the heat control.

Regulating heat is, unfortunately, not as straightforward as simply adjusting the temperature on the controller to the recommended setting for the film you are running. Temperature controls and heaters can vary in their accuracy, recovery time and ability to maintain a constant temperature. In addition, the thermocouple reads the temperature at some point inside the crimper body, so the reading on the control does not tell us the true temperature of the sealing face, nor does it tell us anything about the temperature profile over the width of the seal.

The heat generated must be effectively transferred to the sealant layer of the film. Crimper or sealing jaw materials and designs may promote or inhibit thermal conductivity, and the composition of the film itself as well as the style of the package can make it more difficult to drive heat through to the sealant. A higher heat setting may be required for thick or metalized films, for instance, or for packages with gussets.

As we'll see in the following sections, the factors of pressure and line speed will also impact heat transfer and, in turn, temperature settings.

Time

The more time the crimpers or sealing jaws spend in contact with the film, the greater the penetration of heat to the sealant layer and the better the chance for a good seal. If line speed is significantly increased (and dwell time reduced) then frequently the temperature setting must also be raised in order to reach the required seal initiation temperature. For this reason lower SITs make it easier to run the film at higher line speeds.

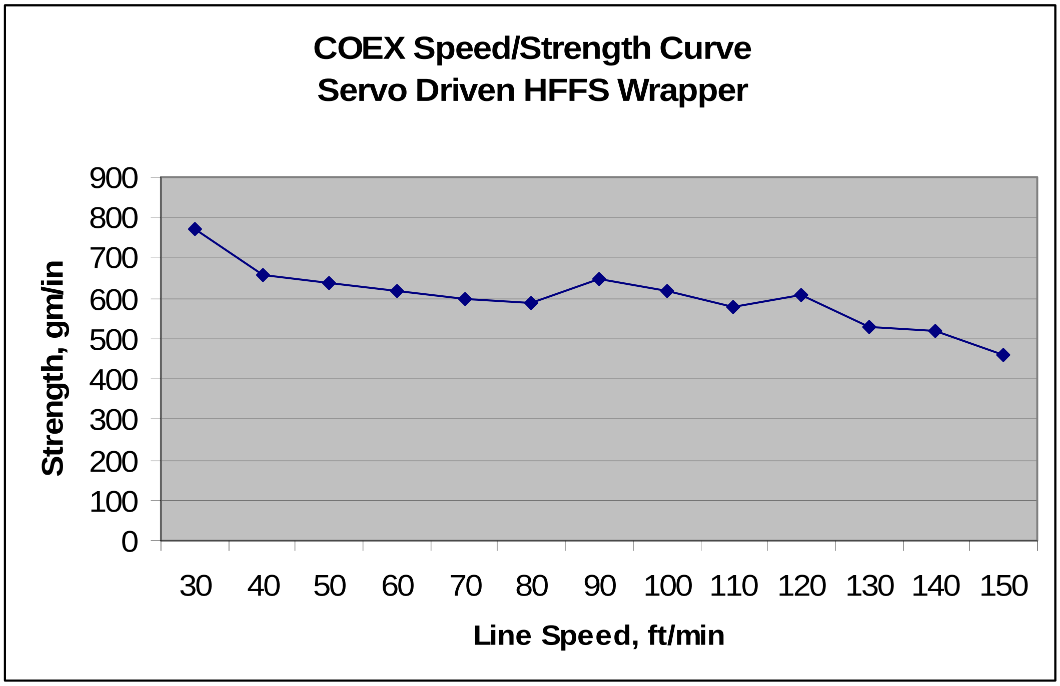
Conversely, a significant reduction in line speed may create problems if temperature settings are not reduced and the crimpers get too hot. In fact, this is one of the most overlooked causes of bad seals.

For our purposes, when we use the term "line speed" we are referring to the measurement (inches, feet, meters, etc) of film per minute rather than packages per minute, because this is a more functionally and comparatively accurate reflection of dwell time. The line or film speed figure eliminates the variance of package length.

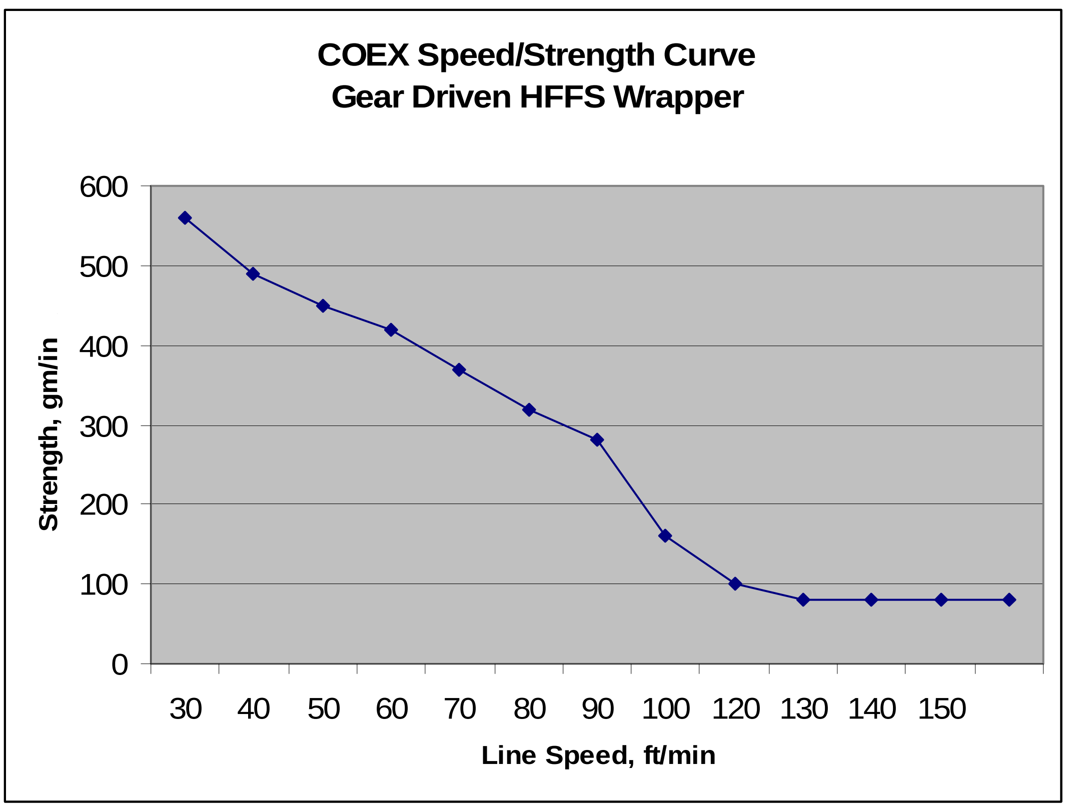
On vertical baggers the combination of what is commonly a reciprocating jaw action and relatively slow speeds means that dwell time is not often a problem. On most machines the full faces of the sealing jaws are in contact while the upper and lower seals are made.

Horizontal flow wrappers are a different story. Speeds are generally higher, and with the rotary sealing action found on most machines, the dwell time can be considerably shorter. In effect, only a portion of the sealing faces are in full contact or mesh at any given instant as the crimpers rotate through to make the trailing and leading end seals. (Many packaging machine manufacturers also now offer "long dwell" machines for situations where very high seal integrity is a necessity. These wrappers, frequently used in the medical and pharmaceutical industries, are often designed so that the sealing jaw faces fully contact the seal area and briefly travel along with the package, so that reasonable line speeds can still be achieved without sacrificing dwell time.)

Tests done on flow wrappers have shown that seal strength and integrity will decrease as line speed increases. The effects of this are especially evident with older, mechanical wrappers. More recent servo driven wrappers are better able to optimize dwell time at higher line speeds. The difference in results is evident in the charts shown below.



Data provided by AET Films.



Data provided by AET Films.

Beyond its impact on temperature settings, perhaps the most important thing that can be said about speed is that adjustments become more critical and problems become more apparent as the rate is increased. For example, a slight crimper misalignment which was previously unnoticed may cause fracturing at higher line speeds. Or weak spring pressure which had been compensated for by a relatively long dwell time could cause channel leaks when dwell is reduced. Ultimately, when you're running fast, imperfections are magnified and the margin for error shrinks.

Pressure

The relationship between heat and time is fairly straightforward. It's the pressure factor that causes the most confusion, and in turn it is often the most overlooked. There is usually no pressure reading on wrapping or bagging machinery. Proper pressure adjustment is dictated by experience and results. If there is a poor impression on the set-up paper or the package itself, then there may be too little pressure. A heavier impression on one side could mean that there is uneven pressure. If the film is being fractured then the pressure might be too high.

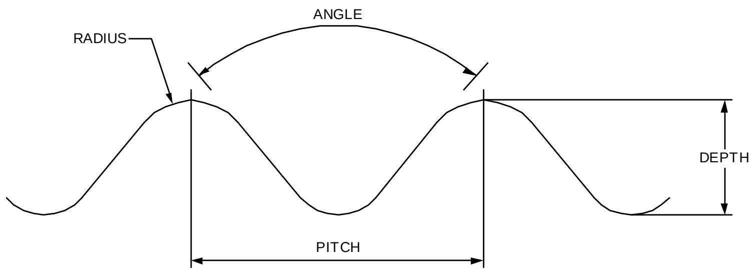
However, a misdiagnosis often occurs because these problems can also be caused by other factors such as improper heat, crimper misalignment or incorrect clearance, which makes it difficult to determine for sure whether pressure is set properly or not.

Pressure is applied to the seal in two ways. The face of one sealing jaw or crimper is forced into the face of another, with the film between the two (upper/lower crimpers on horizontal flow wrappers and front/rear sealing jaws on most vertical baggers). In addition, pressure is applied by utilizing serrated sealing faces on the jaws or crimpers. The action caused by the serrations, also referred to as shear or flow, plays a key role in the seal making process. With heat seal films the objective is to increase the effective area of the sealing surface in order to "stretch" the film, enhance pressure and heat transfer and force the sealant layer to flow into the gaps that would otherwise cause leaks. Functionally, springs control the quantity of pressure, and the serrations serve to determine the location and quality.

For cold seal films, pressure is the key factor in the sealing equation, and serrations create the shear action that helps to join the cohesive sealant layers together to form a strong bond. Heat and time play either minor or non-existent roles, as concerns about dwell time and heat penetration are eliminated. Speed constraints with cold seal usually have more to do with machine set-up or design than film issues.

Subsequent technical papers will deal with the concept of serration design in more detail. For the purpose of understanding basic theory it's simply important to know that results can vary greatly with different serrations. Serration geometry (angle, pitch, depth and radii) and direction (horizontal, vertical or diagonal) can be altered to suit specific films, machinery and objectives. The goal is to impart as much shear as possible without fracturing the film and to direct the pressure to those specific areas of the seal where it is required most.

Serration Design



Package design will also have an impact on the application of pressure, as the extra layers of film created by fin seals, lap seals, gussets and folds may produce an uneven pressure distribution across the width of the end seal. Serration design is the primary tool used to overcome difficulties in these situations, with designs specifically engineered to compensate for the varying film thickness.

As we've mentioned, problems with pressure can be difficult to diagnose and solve. Future technical papers will also deal with this issue in more depth, from set-up through troubleshooting. For now we will just mention that, on horizontal flow wrappers in particular, *jaw clearance* and *jaw pressure* are often confused. These are usually two separate adjustments, and, even thought the clearance adjustment is often easier to access on a wrapper, it usually does not require modification unless something significant occurs, such as a crimper or film change. Use of the pressure adjustment can be much more effective in the effort to fine tune set-up and obtain a good seal.

Generally speaking, if the quantity and the quality of pressure can be increased without fracturing the film, then hermetic seal quality will improve, as will the chances for running successfully at higher speeds.

Ultimately, in order to produce good seals with OPP films, all factors in the sealing equation must function in concurrence. A good understanding of the basic sealing theory will hopefully aid in finding the proper balance between them.

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