TECHNICAL BULLETIN:
FLEXIBLE-PACKAGING HEAT SEALING

POLINTER

1. Introduction

The Packaging used for massive consumer products are mostly of flexible type because they allow maximizing the quantity of product to pack as a function of the package weight.

Flexible packaging production begins with film extrusion, then printing (if applies), and finally packaging forming and its closure. Usually, the latter one is done by heat sealing.

Heat sealing occurs when two sides of plastic films are heated until their contacted faces melt in such a way that an intimate union of both sides takes place. When this melted interface cools down and solidifies, a package is formed. This sealed package has to guarantee protection and integrity for the product that it contains, unless an easy open seal (peelable seal) is required.

Most of modern industrial heat-sealing machines are capable to seal from 60 to 300 packages per minute. Consequently, it is important to understand all variables that affect this process, so it can be optimized. In this sense, a small reduction of sealing time might lead to an important increase in package production.

2. Heat sealing of flexible packaging

Heat sealing consists in heating up (mainly through conductive heat transfer) a section of two plastic films that are in contact, then thermal effect propagation occurs through their thickness, until the contact interface shows melting signs and an intimate union of films faces happens (Figure 1). The heat is supplied to films using heating bars (Figure 2).

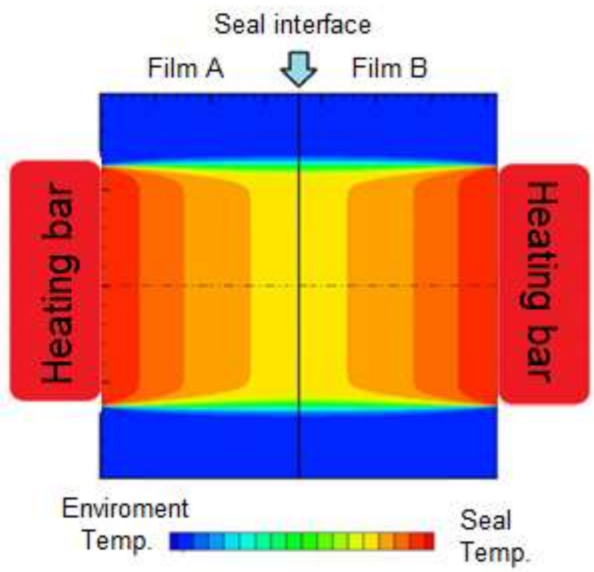

Figure 1. Sealing Heat Transference

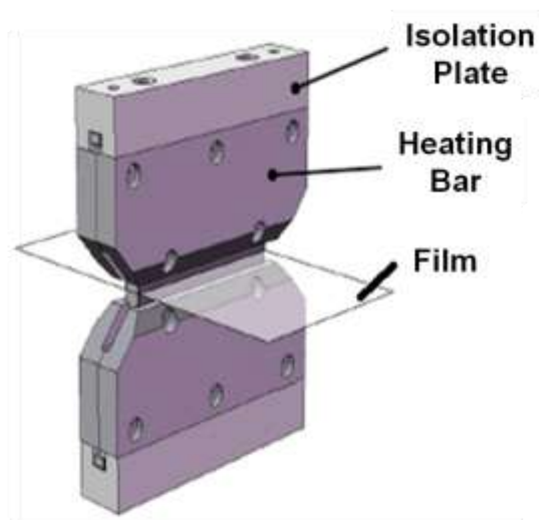

Figure 2. Heat Sealing Sketch.

Once the films are joined together, the seal cools down through a natural convective heat transference process and, eventually, it solidifies. The cooling process is produced by surrounding air (usually, at room temperature). A diagram of the interface temperature behavior during sealing process is shown in Figure 3, and the time when the interface is melted is highlighted.

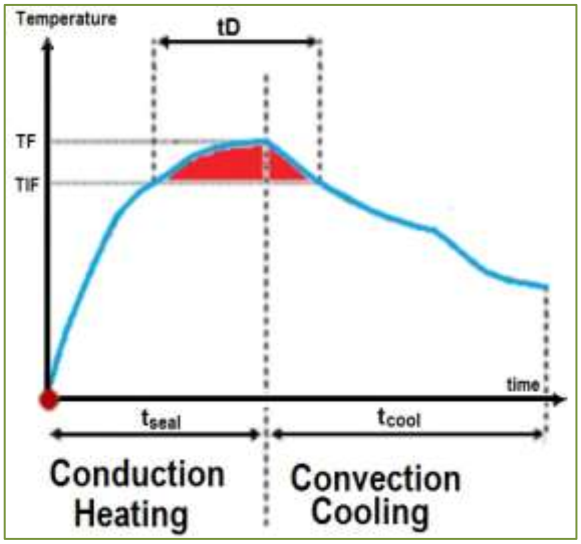

Figure 3. Variables of heat sealing process.

Heat sealing process is widely used in packaging industry for its versatility, process speed and simplicity. Depending on final application, films are made of polyethylene (PE) and/or its blends, in monolayer or multilayer structures. These multilayer films can also be made of PE coextruded with other materials, such as EVA, EVOH and polyamides, which promote certain specific properties to final product.

In form-fill-sealing (or FFS) packages, filling is done simultaneously with package formation, including sealing (Figure 4), Therefore, the product to be packaged strikes the seal (still weak and hot) when it is falling into it. This is why the appropriate selection of sealing conditions is very important, in order to achieve high production speed (in some cases, 300 packages per minute). The seal process under these conditions is known as "hot tack process" or "hot seal process".

On the other hand, when cooling time is long enough, the process to join films is known as "sealability". A common application is the supermarket bag, where several weeks may pass from bag-formation and sealing to product packing.

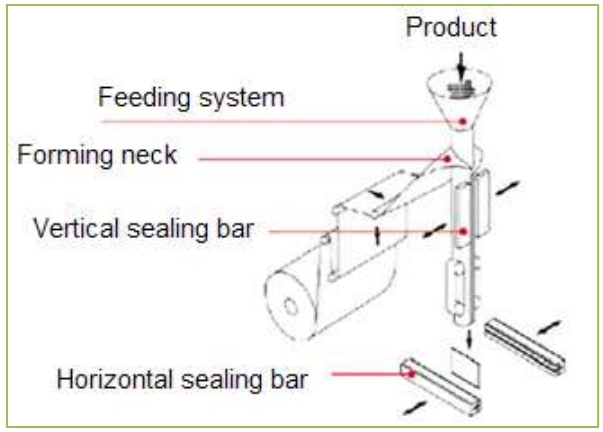

Figure 4. Industrial Heat Sealing Process (FFS).

2.1 Finding optimal conditions for package sealing: Hot-tack lab test

Optimal heat sealing conditions for a given film are usually determined by hot-tack test (1). In this test, the industrial heat sealing is simulated by heating two or more film surfaces (usually stripes of 15 or 25 mm width), making the seal, and then performing a tensile test after cooling the seal in an elapsed time. The result gives the peeling force that the seal resists at given conditions of time (heating and cooling) and seal temperature.

The aim of this test is finding an adequate combination of operational conditions which achieves the highest seal force response in the minimum seal time. Operational variables are:

- Material: thermal properties of polyethylene types (LLDPE and LDPE) for flexible packaging applications vary depending on the PE grade. Besides, seal properties could be affected by additives, pigments, and surface treatment. As a general rule, the lesser the density is, the lower the seal temperature will be. The higher the molecular weight (i.e. the lower melt flow index) is, the stronger the seal will be.
- Film thickness: because of heat has to flow from jaws to interface through all film thickness, the thicker the film is, the lower the seal force and the higher the total seal time (heating + cooling) will be. If total seal time increases, productivity will be affected.

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- Sealing time: it refers to total time when heat is applied to the film. In order to maximize production, this should be kept minimum, just enough to guarantee complete diffusion at the interface.
- Cooling time: it refers to the time where the seal is cooled before discharging a load of product into the package. As before, this variable should be kept as lowest as possible.

Hot tack response variables (Figure 5) are:

- Seal initiation temperature (SIT): it is the temperature at which seal force is registered (usually between 0.5 and 1 N/25mm).
- Sealing zone: it is the temperature range where suitable forces are obtained. The wider this zone, the better. There are two areas in this zone: peeling seal (useful when the seal can be opened without destroying the package) and cohesive seal. The latter is the one with major uses. Here the force is generally over 2 N/25 mm. The objective is finding the required seal force using the minimum sealing time possible.
- Maximum seal force: is usually associated with cohesive seal. It is the plateau zone on the response graph (Figure 5). At this zone, seal force is obtained regardless the temperature applied.

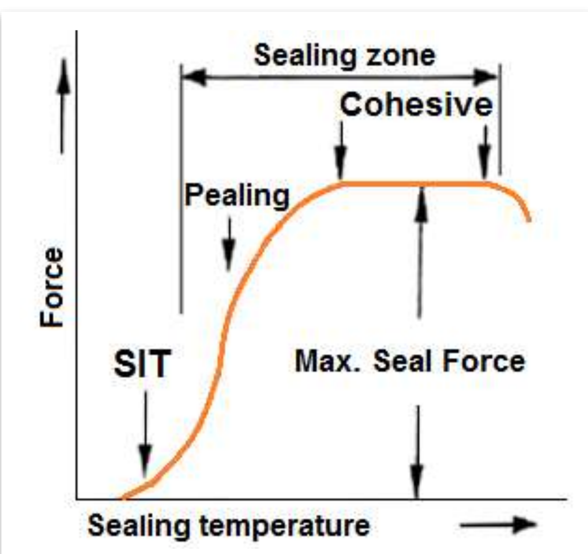

Figure 5. Hot Tack Test Response graph.

All these variables are interrelated, if one variable is changed, the others will be affected. This is why isolated effects are difficult to obtain.

Properties predictors (3, **¡Error! No se encuentra el origen de la referencia.**) have been developed to make it easier finding appropriate seal conditions (processing time, pressure, thickness and material).

3. Applications

The main application of heat sealing of flexible packaging is to guarantee integrity and protection of the contained product. Heat sealing is used for packaging many kinds of products and presentations that have different heights and shapes: low-weight package such as rice, tea or coffee, and heavy-duty packs like industrial bags; for solid or liquid products.

For this reason, flexible packaging design should be done according to final application to ensure that the package (and its seal) protects its content and avoid any leakages.

4. Processing conditions optimization

Based on hot-tack tests and some research works (2, **¡Error! No se encuentra el origen de la referencia.**, **¡Error! No se encuentra el origen de la referencia.**), a typical industrial processing condition can be optimized. For example, consider a low-density-polyethylene film (90µ thick), using $t_{seal} = 0.8$ s and t_{cool} =0.6 s, give around 1310 million packages per year. This amount can be raised if cooling time is reduced, because seal force is barely affected as shown in Table 1.

Changes in heat-seal conditions allows raising production up to 1500 million packs per year (30% increment) with a small change in sealing force.

Table 1. Sealing Time Optimization.

5. Total time reduction (%)	6. Seal force reduction (%)	7. Pack (Millon/year)
8. 10	9. 2,9	10. 1370
11. 20	12. 5,8	13. 1434
14. 30	15. 8,6	16. 1505

If more information is required, Polinter offers technical assistance to its customers to develop and optimize polyethylene flexible packaging that will perform in an optimal manner, not only in sealing, but also in all other required properties.

17. References

1. ASTM Standard F1921, 2004, "Standard Test Methods for Hot Seal Strength (Hot Tack) of Thermoplastic Polymers and Blends Comprising the Sealing Surfaces of Flexible Webs," ASTM International, West Conshohocken, PA, 2004, DOI: 10.1520/F1921-04, http://www.astm.org/Msgs/www.astm.org
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