Evaluating heat-seal performance with an automatic hot-tack tester

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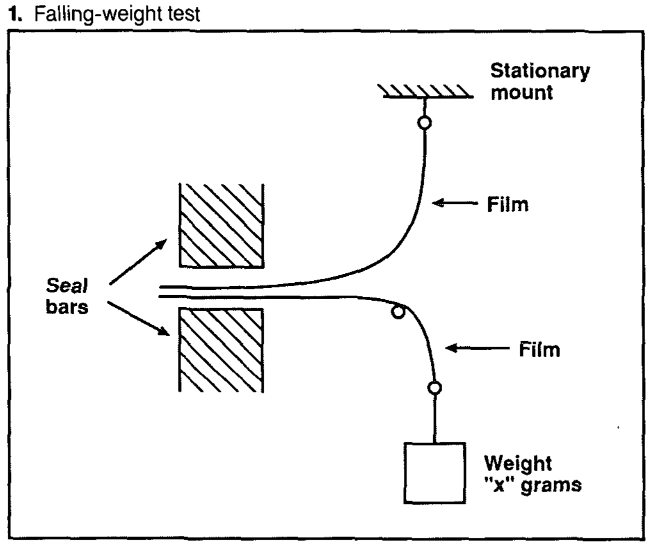
The hot-tack tester can be used to optimize the heat-seal cycle on a packaging line.

Heat-seal applications are constantly evolving. Stronger, tamper-resistant packages are being developed, and shelf-life requirements are continually being extended. Both trends dictate a high degree of seal integrity. Food companies, converters, film producers, and resin manufacturers perpetually strive to shorten the cycle rates on packaging lines. Optimizing the heat-sealing cycle is one way of accomplishing this objective. As new materials emerge in response to environmental demands, their heat-sealing capabilities must be tested.

The list of heat-seal applications is extensive. Films, coextrusions, thermoformed cups and trays, and nonwovens are but a few of the materials that are bonded with heat. As the number of heat-seal applications grows, so does the need for an accurate, reproducible method of measuring heat-seal performance.

Measuring seal strength by cold-peel testing alone does not adequately address the issues concerning heat-seal performance. The seal area is frequently subjected to disruptive forces before it has cooled. In such cases, cold-peel testing cannot be used to establish seal performance. The ability to directly measure a heat seal's hot-tack tensile strength under simulated production conditions would provide a method of predicting film-structure performance during use. This article describes a hot-tack tester that provides this capability.

1. Falling-weight test



Basic requirements

Adequate determination of hot-tack performance requires a test method that provides repeatable results free of operator interference. Many laboratories use the falling-weight test, illustrated in **Fig. 1**, and the spring test, illustrated in **Fig. 2**. Both are difficult to regulate and are best suited for rough pass-fail evaluations. Neither method provides quantitative data, since results are obtained by applying a fixed load on the hot seal. The results are either "peel" or "no peel."

An effective test device would provide meaningful results that could be easily reproduced. A highly sensitive tensile test is required to measure the actual hot-tack peel force. A machine capable of performing such a test would control all pertinent parameters and function over a wide range of operating conditions so that it could simulate actual sealing processes. Finally, it would measure the force required to initiate and completely peel the seal area.

Hot-tack tester

The first automated tensile tester for hot tack was developed in 1982 in cooperation with the Swedish Packaging Research Institute in Packforsk. The first commercial units became available in 1983. Since that time, many developments and improvements of the original tensile testing method have produced an instrument with the sensitivity and flexibility to control all essential parameters.

The instrument consists of a test cabin with built-in laboratory heat sealer, precise controllers for test parameters, a mechanism that automatically folds and inserts the sample, and an accurate tensile tester. The test result can be read as the hot-tack force from the digital display, or a complete graph can be drawn using an optional personal computer.

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For consistent results, operator influence must be prevented. The hot-tack test instrument eliminates this risk by precisely aligning the sample in the seal jaws. This is accomplished by a mechanism that automatically folds and inserts the sample to be tested. The clips that hold the sample in the peel-test fixture are designed to prevent any slipping or unintentional release. Mounting of the substrate in the clips is simple and quick.

The following test parameters are controlled:

Seal pressure: The force per unit area, or

$$P = F/bw$$

where

P = seal pressure

F = seal force

b = seal-bar width

w = sample width

Seal pressure is *not* the air pressure of the connection line to the air cylinder.

Seal time: The time span when the jaws are closed. This does not include the closing or opening of the jaws.

Seal temperature: Each seal jaw is controlled separately.

Peel speed: The peel speed is adjustable up to 600 mm/s.

Delay time: The time delay from end of sealing and loading the seal is adjustable to simulate actual filling speed.

Sample insertion: The sample-inserting mechanism is automatic and easy to operate. Insertion of the sample initiates the test automatically.

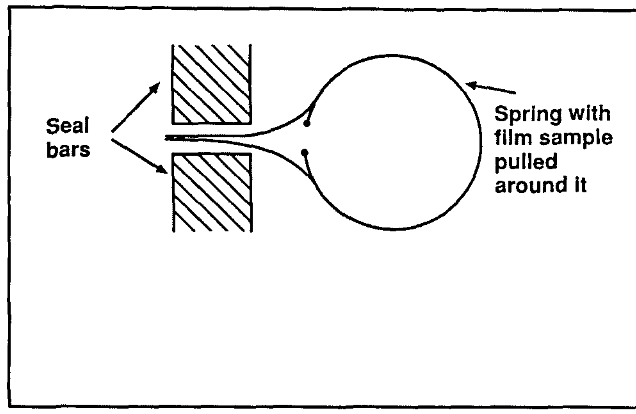
Heat sealing generally is accomplished using seal bars, which conduct heat to the substrate to be sealed. The seal bars are designed to prevent sticking while maintaining heat transfer. Equipment for impulse-heating and forced-convection methods also is available.

Cold-peel testing can be performed on the same instrument. This makes it possible to study both the hot-tack and the cold-peel heat-seal performance, thereby obtaining information about package performance under production conditions as well as in end use.

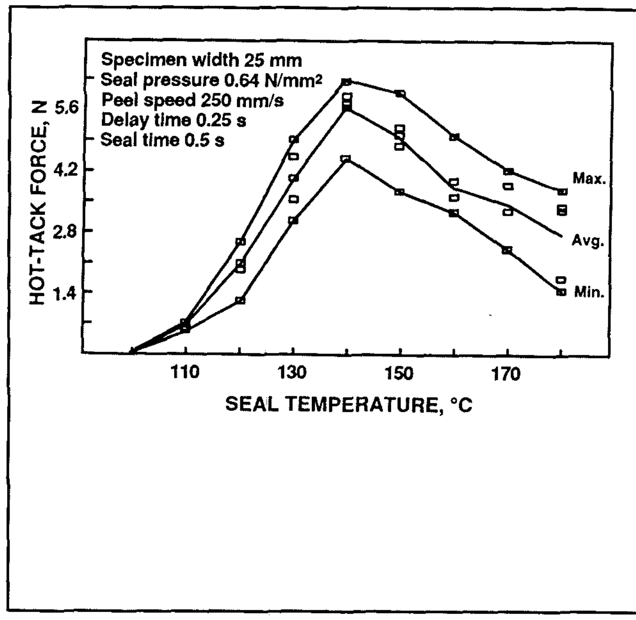
A computer that is interfaced with the test instrument can store data for subsequent manipulation if it is equipped with the appropriate software. Tables and curves can be customized for the specific needs of the user. An automatic data-acquisition system collects test setup data and test results into a personal computer. The system is menu driven, and parameters are easily selected. Setup values and test results are easily displayed. Data can be printed in tabulated form, or they can be plotted. The most commonly used plots are:

- Peak peel force vs. seal temperature

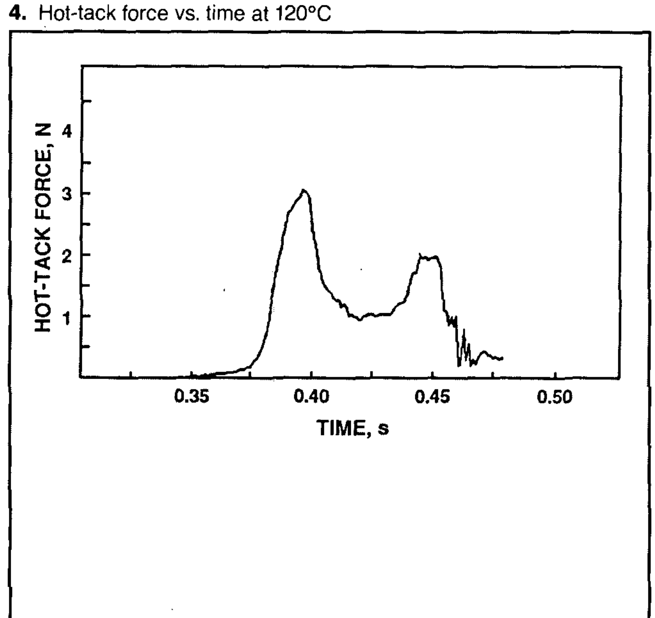
2. Spring test



3. Hot-tack force vs. seal temperature



4. Hot-tack force vs. time at 120°C



- Peak peel force vs. delay time
- Peel force vs. time (lapse of peeling operation).

Peel force vs. time for individual tests can be presented in graphic and/or numeric formats. In the batch mode, the display shows the minimum, mean, and maximum peel forces in relation to seal temperature for an entire group of tests. All data are stored for archive purposes, and the output is compatible with a range of MS-DOS software applications.

Interpretation of hot-tack results

Figure 3 is a plot of peak peel force vs. seal temperature. The three curves represent minimum, maximum, and average peel forces at the various seal temperatures. The measured data points are shown as small squares. Under the conditions tested, the material studied here did not have any hot-tack strength until the seal temperature reached 110°C. The peak hot-tack force in all three curves was obtained at a seal temperature of 140°C. Hot-tack force declined steadily at seal temperatures above 140°C.

Using this curve, it is possible to determine the best seal temperature or range of temperatures for optimum hot-tack performance. For example, if a minimum hot-tack strength of 2.5 N is required, a temperature range of 120°C to 170°C will provide the requisite strength (assuming all other test parameters are held constant). For best performance, 140°C should be specified for this material.

It is useful to know the tensile force at yield point for a given film construction being tested. Some bond strengths exceed the yield force, causing the film to draw before the seal fails. **Figure 4** is a curve of hot-tack force vs. time. This plot, which is representative of many other plots of the same material under the same conditions, shows that the peak peel force was realized on the first edge. A second peak was realized on the opposite edge just before the sample was fully peeled. This type of curve is fairly common and is usually, but not always, caused by edge cooling. This can be confirmed by running more tests at different dwell times.

Another commonly used plot depicts peak peel force vs. dwell time. This type of curve provides insight as to the sensitivity of a material to different cooling periods. Some constructions do not quickly dissipate the heat after sealing.

Applications

The range of heat-seal applications that can benefit from measurement of hot-tack seal strength includes films, sheets, coextrusions, coextrusion-coated film and paperboard, lidded thermoformed cups and trays, and nonwoven fabrics. The following three examples illustrate typical benefits obtained from measurement of heat-seal performance with the automatic hot-tack tester:

- A producer of single-ply polyolefin films changed the resin formulation and reduced the product's thickness by 25% while maintaining hot tack, cold peel, and tensile strength.
- Another resin producer improved hot tack without loss of tensile strength or cold peel by changing the resin formulation.
- A producer of coextruded films and converted products is advising one of its customers on the best heat-seal conditions to maximize production on a vertical form-fill-and-seal machine.

Summary

Measurement of a heat seal's hot-tack tensile strength provides a quantitative measure and prediction of package performance at different temperatures, seal times, and pressures. This information can be used to optimize package cycle rates. The hot-tack tester also can be used to evaluate competitive materials, and standard production material can be quality tested on a routine basis without operator influence.

As competition grows in the packaging industry, the victors will be those who master the technologies that can help them. Automatic testing of hot-tack heat-seal tensile strength is a small but significant performance measurement. Those who understand its application will move forward, while those who overlook this area may fall behind.□

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