PACKAGING ADHESIVES

High-value adhesives for a low-cost process

BRADLEY R. ZECHMAN

ABSTRACT

High-value hot-melt adhesives use unique polymers in original formulations to achieve high-temperature performance, improved sub-ambient adhesion, excellent thermal stability, and low density. These adhesives cost more than average hot-melt formulations, but they achieve a lower cost process for the packager. The adhesives not only outperform standard hot-melt formulations but also discount taping as an alternative for packaging operations. While tape sealing may be best for low-speed production environments and packages with some head space, the high-value adhesive approach reduces replacement parts, decreases production downtime, and improves workplace safety while meeting typical packaging requirements.

Application:

Low-application temperature hot-melt adhesives with improved thermal stability offer advantages in case and carton sealing over tape sealing.

STANDARD HOT-MELT ADHESIVE formulations use an organic polymer, a tackifying resin, and a diluent for the system. The packaging industry has used such hot melts for nearly 40 years for sealing corrugated cases and for forming of modified paper cartons. Although hot-melt adhesives revolutionized the packaging process by improving process versatility and production speed, the hydrocarbon-based systems were always susceptible to degradation on prolonged heat exposure. The organic polymers decomposed and charred in idle application stations at 177°C. Degradation products and char interrupted production by clogging pumps, hoses, filters, or nozzles.

In 1993, a reformulated hot-melt system not only changed the way packagers sealed their products but also addressed the need for improved thermal stability. The system used a unique polymer instead of the standard ethylene vinyl acetate (EVA) polymer. The formulated system—177°C high-value adhesive—exceeded the required thermal stability performance for case and carton sealing hot melts while increasing end-use temperature performance. **Figure 1** compares the range of temperature performance for the 177°C high-value adhesive to conventional EVA and polyethylene hot-melt products.

In 1994, extrapolation of the same principle yielded an improved system—111°C high-value adhesive—with a lower application temperature of 111°C. Although the 177°C and 111°C application temperature adhesives had prices 50–100% higher than standard packaging grade adhesives, packagers welcomed the value of superior thermal stability.

This paper will address the costs associated with the use of high-value hot-melt adhesives in the market today. It will also address four common issues of tape use vs. an adhesive sealing process. These are reduced spare parts, lower total cost, safety, and recyclability.

TAPE VS. HIGH-VALUE ADHESIVES

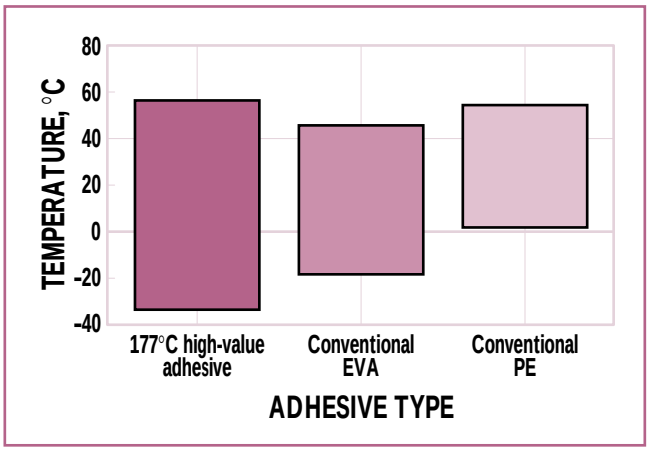
Tape is more cost effective than adhesives for low-speed, low-volume packaging operations. Tape is also the choice for sealing packages with some head space because of limited compression for adhesive applications. Hot-melt adhesives are the choice for high-speed lines in both case sealing and carton forming. This paper will compare the costs and benefits in the large void between these two categories.

REDUCED SPARE PARTS

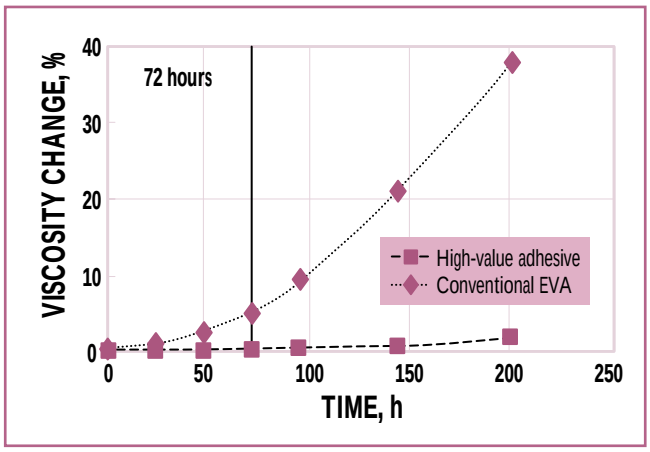
Many problems that packagers associate with hot-melt adhesives stem from using low-grade, low-priced products. All organic systems—especially these low-grade hot-melt adhesives—increase in viscosity, degrade, and eventually char upon exposure to heat. This char formation fuels the need for replacement parts in an applicator station. Current packaging data shows that use of a low-quality adhesive can add replacement part costs of US$ 0.25–0.50 for each pound of adhesive used. This equates to US$ 25,000–50,000 in replacement pumps, hoses, and nozzles for 100,000 lb of hot-melt adhesive.

The high-value adhesives are advantageous because they minimize the degradation process. They require fewer spare part replacements and less downtime for part changes. Packaging operations therefore can maintain constant production. The Packaging Machinery Manufacturers Institute (PMMI) estimates the cost of downtime at US$ 150 per minute. This is critical, since each nozzle change can take 10 min.

The 177°C high-value adhesive exhibits superior thermal stability compared with other adhesives applied at the same temperature.



1. 177°C high-value adhesive end-use performance



2. 177°C high-value adhesive thermal stability

	Average-quality tape	High-quality tape	High-value hot melt
Cost per case, US$	0.01524	0.06267	0.01035
Cost per month, US$	3,072	12,634	2,087
Cost per year, US$	36,869	151,572	25,039

I. Cost comparison of high-value adhesive to average- and high-quality tapes

Figure 2 plots the percentage of viscosity change vs. time for the 177°C high-value adhesive and for a conventional EVA system after thermal aging at 177°C. The 177°C high-value adhesive develops no char through 100 h. This obviously translates to less downtime from clogged adhesive delivery systems and results in extended equipment life.

The use of the 111°C high-value adhesive exaggerates this principle. A visual comparison of thermal stabilities of the 111°C high-value adhesive with a standard 177°C EVA adhesive at corresponding application temperatures clearly shows advantages of the new product. The 111°C high-value adhesive did not char through 1000 h of exposure at its application temperature as **Figs. 3 and 4** show.

Maintenance costs for taping operations have many causes. The largest is for replacement rolls of tape and the downtime for such replacement. For a low production rate operation, the tape roll change may be possible without a line stoppage. In more popular high-speed lines, production ceases during the changeover. The time to change the tape is 1–3 min and increases by approximately 3–5 min per incident, if additional time is necessary to clear any line jams.

This changeover can grow rapidly. A plant running a 51-cm case at 10 cases/min while sealing both top and bottom will encounter 8 min of downtime per two shifts of production each day. At the PMMI calculated cost of US$ 150 per minute of downtime, the changeovers add US$ 1200 per day. With any associated line jams because of no pressure monitors, the plant could add 24 min to the roll change for an accumulated cost of US$ 4800 per day.

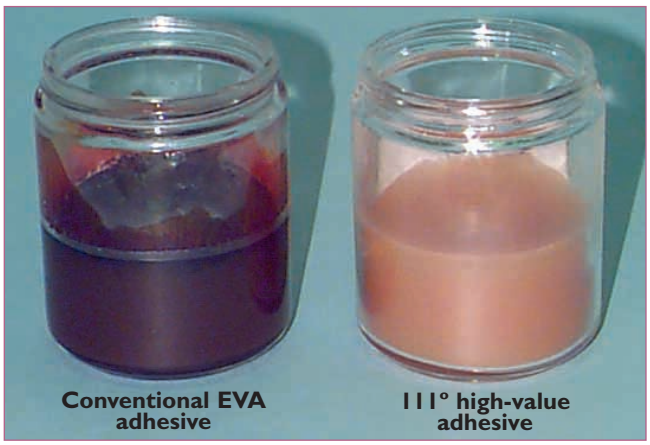
KEYWORDS
Adhesives, economic analysis, hot melts, low temperature, packaging sealants, value added.

LOWER OVERALL COSTS

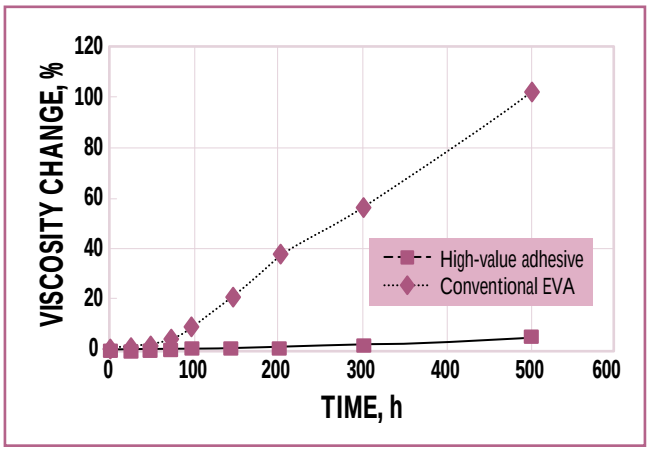
Using a high-value adhesive will also save the packager in volume of adhesive vs. that of the tape used. Consider again the previous example of a 51-cm-long case with 13-cm flaps sealed at a rate of 10 cases/min and assume the following:

- An average-quality tape costs US$ 18.50/roll, and a high-quality tape costs US$ 47/roll
- The average-quality roll is 5 cm wide and 1500 m long, and the high-quality roll is 5 cm wide and 914 m long
- 1.22 m of tape are necessary to seal the case.
- The high-value adhesive costs US$ 3.30/kg
- Average bead length is 7.6 cm with two beads per flap for a total of 1.22 m
- The bead width is 0.23 cm
- Two 8-h shifts run 5 days/ week for 21 days in a month.

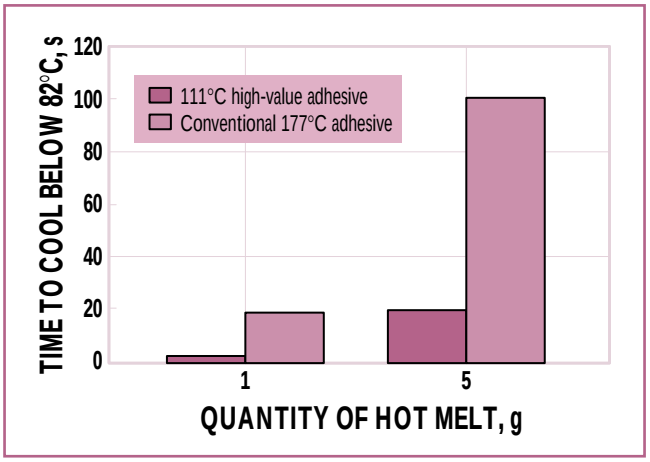
Table I provides a comparison of the costs of the high-value adhesive to an average-quality tape and to a high-quality tape. For the average- quality tape, the high-value adhesive provides a savings of US$ 11,830 annu-



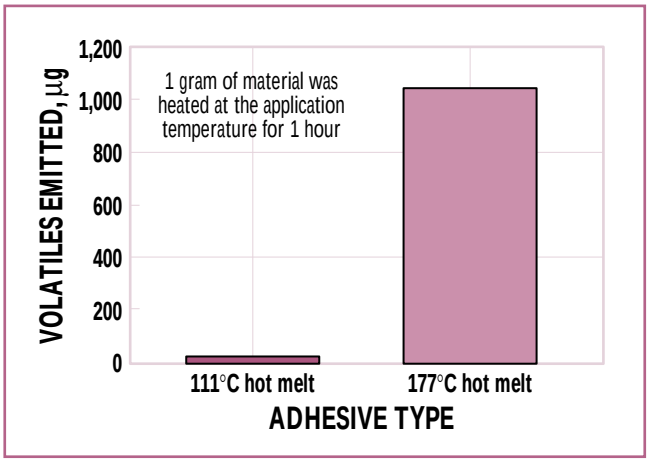
3. Visual comparison of 300-h thermal stability



4. 111°C high-value adhesive thermal stability



5. Time for hot melt product to cool below 82°C



6. Gas chromatographic head space analysis for 1 g of material heated at the application temperature for 1 h

ally. For the high-quality tape, the savings increase to US$ 126,572 /year.

Safety

The idea that hot-melt adhesives constitute an unsafe sealing operation stems from the traditional application temperature of 177°C. Similar to the problem of spare part costs, the high-value adhesives treat the source of the problem and affiliated safety risk—charring that mandates part changes—with improved thermal stability. The elimination of char in these high-value adhesives over the first 100 h of exposure at application temperature means operators only need to change clogged parts infrequently.

The 111°C high-value adhesive has the added advantage of a lower application temperature besides its thermal stability. Studies have shown that one gram of this adhesive at 111°C cooled below the burn threshold of 82°C in only two seconds. The same amount of 177°C fluid adhesive needed 18 s to cool below 82°C as **Fig. 5** shows. For reference, a typical 51-cm case has 2.77 g of hot melt where each bead is only 0.173 g.

The 111°C high-value adhesive also reduces smoke and odor associated with a hot-melt applicator station. **Figure 6** is a comparison of this low-temperature adhesive and a conventional 177°C adhesive. A tape sealer does not use heated equipment, but each tape roll change during production creates an exposure to the sharp knife used for cutting purposes. Care and caution are necessary for threading the tape through the machine. A worker must also bend over the case sealer with the spool of tape to make this change. This operation exposes the worker's back to possible injury. Repeating this exercise can cause back pain and a lost time accident. Obviously safe manufacturing practices are always necessary for both tape and hot-melt sealing systems.

RECYCLABILITY

Since tape removes easily from a case, a case can cleanly enter the paper recycling process. That tape still requires disposal in some way. The high-value adhesives are unique. Their low density means easy separation from paper in the recycling process. For both high-value adhesives, the density is less than the threshold of 0.98 g/cm^3 for separation.

CONCLUSION

While tape sealing systems may work well for packages with head space and for low-speed production rates, one must examine the total process cost to determine the best sealing alternative. Package operations must explore the total raw material cost, the downtime potential, the process speed versatility, and the substrate variation. With completion of a process cost analysis, high-value adhesives show lower operating costs combined with superior thermal stability. **TJ**

Zechman is technical market development supervisor at National Starch and Chemical Co., 10 Finderne Ave., Bridgewater, NJ 08807.

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