White Paper

AFFINITY™ GA Polyolefin Elastomer-based Hot Melt Adhesives for Case and Carton Sealing Applications

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AFFINITY™ GA Polyolefin
Elastomer-based Hot Melt
Adhesives for Case and
Carton Sealing Applications

In 2007, the packaging industry will use in excess of 400 MM pounds of ethylene vinyl acetate (EVA), which roughly corresponds to more than one billion pounds of hot melt adhesive (HMA). EVA-based HMAs have been the workhorse of packaging adhesives for the past 40 years. Despite their shortcomings, they served the market well during these years. However, the introduction of AFFINITY™ GA Polyolefin Elastomers (POEs) in the late 1990s led to the launch of a new family of HMAs, which quickly proved to be superior to EVA-based HMAs. Those who believed that the issues associated with the use of EVA-based HMAs were just the nature of the business quickly came to the realization that this was not the case.

Table 1: Performance Attributes of High Flow AFFINITY™ GA POEs Compared to Traditional Product

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<th>Performance Attribute</th>
<th>Observations</th>
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<tr>
<td>Increased mileage</td>
<td>Reduced adhesive usage, lowered cost as much as 15-30%, depending on application.</td>
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<td>Reduced gel and char formation</td>
<td>No plugged filters and nozzles, reduced downtime and lost production.</td>
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<td>No stringing and spider webbing</td>
<td>Enhanced package appearance, reduced labor cost, reduced downtime.</td>
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<td>Improved thermal stability</td>
<td>Excellent control of viscosity resulting in precise control of bead size and bead placement.</td>
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<td>Wide service temperature range</td>
<td>Final bonds resist extreme heat and cold, reducing waste, product returns, and replacement costs.</td>
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<td>Color/clarity</td>
<td>Enhances package appearance.</td>
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<td>Clean machining</td>
<td>Reduced wear and tear on the equipment, reduced downtime.</td>
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<tr>
<td>Virtually odor free</td>
<td>Enhanced workplace conditions.</td>
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Figure 1: HMA Pillows Based Upon AFFINITY™ GA POEs versus HMA Pillows Based Upon EVA

High flow HMAs based on AFFINITY™ GA POEs combine performance with customer-demonstrated cost savings. These products offer processability, performance, cosmetic appearance, and, most importantly, they help save money for end users. These HMAs offer high mileage due to aggressive bonding, as well as lower density. They run clean and char-free, resulting in savings in maintenance expenses such as filters and nozzles. As a result, end users experience lower rates of line shut down and thus increased production utilization. Additionally, the ease of cleaning spilled or misfired beads from the machinery and the lack of angel hair or spider webs result in more savings in terms of reduced labor costs. Reduced wear and tear on the equipment, primarily due to the low acid content of the base polymer, has been documented. HMAs made from these polymers offer a wider service temperature range than those of traditional EVA-based hot melt adhesives. The clarity of the product in molten form and the much improved heat stability of the product as compared to competitive polymers results in better color and increased intervals between product changes in the melt tank. Finally, the lack of odor and smoke from the product helps improve workplace conditions. These attributes are summarized in Table 1. Use of these polymers in a wide variety of applications has been discussed and documented. Figure 1 shows the HMA pillows based on AFFINITY™ GA POEs versus the HMA pillows based on EVA. AFFINITY™ GA POEs are novel polyolefins manufactured using INSITE™ Technology. These polymers have distinct low density and low molecular weight combinations for a polyolefin. They are designed to be used in hot melt and hot melt pressure sensitive adhesive formulations in a variety of applications. These include:

1.) Case and Carton Sealing
   a. Folding Carton Sealing
   b. Corrugated Container Closure
   c. Tray Forming
   d. Pallet Stabilization
2.) General Packaging
3.) Bottle Labeling
   a. Roll Feed
   b. Magazine Feed
4.) Graphic Arts
   a. Lay-flat
   b. Hard Cover
   c. Soft Cover
5.) Multi-wall and Specialty Bag
   a. Film Laminating
   b. Pinch Bottom
   c. Spot Paste
   d. Valve Assembly
   e. Longitudinal Seam and Bottom Paste
   f. Plastic Bags
   g. Vacuum Bags
   h. Security Bags
   i. Wax Bags
6.) Nonwoven Hygienics
   a. Diaper Construction
   b. Core Stabilization

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Polymer Test Methods

The differential scanning calorimetry (DSC) data were gathered on a TA Q1000 using 5-8 mg of sample pressed into a thin film. The sample was heated to 180°C and kept isothermal for three minutes to ensure complete melting (first heat). The sample was then cooled at 10°C/min to -90°C and kept isothermal for three minutes. The sample was then heated to 150°C (second heat) at 10°C/min. The second heat curve and data are reported in this work. Additionally, from the cooling curve the crystallization temperature (T_c) and the glass transition temperature (T_g) are reported.

The viscosity data were measured both by dynamic mechanical spectroscopy (DMS) and by capillary rheometry. The DMS data were gathered on a Rheometrics ARES with 50 mm parallel plates in a nitrogen purge at 150 percent strain. A separate sample was used at each temperature of 110°C, 150°C, and 190°C, with each frequency sweep being conducted from 0.1-100 rad/s. The capillary data were gathered on a Goettfert Rheograph 2003 with a 0.5 mm diameter die and 30 length-to-diameter die ratio from 100-10,000 s⁻¹. An overlay of the DMS and capillary data is presented in this work.

Density was measured according to ASTM D 792. Brookfield viscosity was measured according to ASTM D 3236 on a Brookfield LVDVII+ with Thermosel. Data are reported at either 175°C, the conventional HMA testing temperature or 120°C, the temperature commonly used for low application temperature hot melt adhesives. The melt index at 190°C with a 2.16 kg weight was estimated based upon the Brookfield viscosity.

Polymers

AFFINITY™ GA 1950 POE and AFFINITY™ GA 1900 POE are high flow polymers intended for use in hot melt adhesives for case and carton sealing. The physical characteristics of these polymers are shown in Table 2.

DSC heating curves of AFFINITY™ GA 1950 and AFFINITY™ GA 1900 are shown in Figure 2. It should be noted that the low crystallinity of these polymers, coupled with low molecular weight (low viscosity) are primarily responsible for their excellent performance in HMA. Figure 3 shows the viscosity of these two polymers as a function of shear rate and temperature. It should be noted that these polymers have a Newtonian behavior up to about 1,000 sec⁻¹. Much more detailed structure/property relationships of this general class of polymers are discussed elsewhere.

Table 2: Physical Properties of Adhesive Grade AFFINITY™ GA POEs

<table>
<thead>
<tr>
<th>Product</th>
<th>Density (g/cm³)</th>
<th>Melt Index, g/10 min 190°C, 2.16 kg weight</th>
<th>Viscosity, cP @ 175°C</th>
<th>T_m (°C)</th>
<th>T_c (°C)</th>
<th>% Crystallinity</th>
<th>T_g (°C)</th>
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<tbody>
<tr>
<td>AFFINITY™ GA 1900 POE</td>
<td>0.870</td>
<td>1,000(F)</td>
<td>8,200</td>
<td>68</td>
<td>54</td>
<td>16</td>
<td>-58</td>
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<tr>
<td>AFFINITY™ GA 1950 POE</td>
<td>0.874</td>
<td>500(F)</td>
<td>17,000</td>
<td>70</td>
<td>53</td>
<td>18</td>
<td>-57</td>
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*Data per tests conducted by Dow. Test protocols and additional information available upon request. Properties shown are typical, not to be construed as specifications.

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HMA Performance

Cost Savings
High flow HMAs based upon AFFINITY™ GA POEs help lower overall cost as compared with EVA- or ethylene n-butyl acrylate (EnBA)-based HMAs. In one case study, a pound of HMA based upon AFFINITY™ GA POEs sealed significantly more cases than a pound of incumbent HMA. The mileage advantage in this case study resulted in savings of 15 to 30 percent. These savings resulted from aggressive bonding, improved thermal stability, and lower density. Additional savings were achieved due to the ability to bond to a wide range of substrates, reduction in waste, reduction in maintenance, and lower inventory due to a wide service temperature range. Figure 4 shows the mileage advantage achieved with HMAs based upon AFFINITY™ GA polymers, such as Advantra® Packaging Adhesive.

In another case study, a Dow plant, which used to change filters and nozzles on a monthly basis and therefore experienced a lot of downtime, switched from an HMA based upon EVA to an HMA based upon AFFINITY™ GA 1950 POE and operated with no downtime and no need to change nozzles and filters for a period of 18 straight months. Figure 5 shows cross sections of delivery hoses used for EVA and Advantra® Packaging Adhesive after two and four years of service. Please note that the EVA delivery hose is black, filled with charred adhesive. However, the hose used for Advantra® Packaging Adhesive based upon the AFFINITY™ GA POEs is clean with no visible chars.

Gardner Color and Color Change
High flow HMAs based upon AFFINITY™ GA POE formulations produce exceptionally clear and virtually odor-free hot melt adhesives. This is attributed partly to the polymer component and partly to the hydrocarbon tackifiers used in the formulations. Figure 6 shows color change for high flow HMAs based on AFFINITY™ GA POEs and EVA at 175°C for up to four days. As can be seen, both the initial and aged color is substantially improved for the HMAs based upon AFFINITY™ GA POEs. These properties make high flow HMAs based upon AFFINITY™ GA POEs a preferred product when improvement in cosmetic aspects of the packaged goods and work environment conditions are needed. Figure 6 also shows the clarity of HMAs based upon AFFINITY™ GA POEs versus EVA-based HMAs.

Figure 4: Mileage Advantage of HMAs Based Upon AFFINITY™ GA POEs versus EVA

Precise bead size and placement, clean cut-off, and less adhesive used with HMA based on AFFINITY™ GA POE

Figure 5: Comparison of Dispensing Hoses Used for an EVA Packaging Line versus an HMA Based on AFFINITY™ GA POE Line

Figure 6: Color Change at 175°C Over 96 Hours (4 Days) for HMAs Based on AFFINITY™ GA 1950 POE versus EVA

Photos courtesy of Nordson Corporation
Percent Fiber Tear
Hot melt adhesives formulated with high flow AFFINITY™ GA POEs provide excellent adhesion to a wide variety of substrates due to the low crystallinity and the very low molecular weight of these polymers. These include the many difficult-to-bond coatings used in the production of folding cartons. This aggressive bonding is maintained over a wide temperature range. HMAs based on EVA polymers and other competitive HMAs are not comparable to the performance of high flow HMAs based upon AFFINITY™ GA POEs. Typical percent fiber tear results for HMAs based upon AFFINITY™ GA POEs and EVA are shown in Figure 7.

Service Temperature Range
Hot melt adhesives formulated with high flow AFFINITY™ GA POEs exhibit exceptional performance at both ends of the temperature scale, due to the very low glass transition temperatures of the polymers and the heat resistance offered by the optimum tackifier. These polymers are an excellent choice when the packaging needs call for freezer-to-microwave exposure. Formulations prepared with high flow AFFINITY™ GA POEs have the potential to save money for both the formulator and the end-user, as the number of HMAs kept in inventory and on the plant floor can be reduced. One HMA may solve both the low temperature and high temperature needs of the line operator. Frequent changes from one HMA grade to another will no longer be necessary. The service temperature range for HMAs based upon AFFINITY™ GA POEs and EVA is shown in Figure 8.

PAFT, SAFT, and Heat Stress
High upper service temperature, as measured by peel adhesion fail temperature (PAFT), is very important for warehouse storage purposes, especially in warm climates. HMAs based upon AFFINITY™ GA POE, such as Advantra®, Packaging Adhesive, offer exceptional PAFT performance when compared with competitive samples. Formulations that offer PAFT values in excess of 70°C have been prepared. Use of high performance HMAs based on AFFINITY™ GA POEs could reduce the failure rate in cases sealed with these HMAs, thus reducing returned boxes and associated expenses.
Viscosity and Thermal Stability

The thermal stability of HMAs based upon AFFINITY™ GA 1950 Polyolefin Elastomer and AFFINITY™ GA 1900 Polyolefin Elastomer, such as Advantra® Packaging Adhesive, is clearly exceptional. These formulations owe their stability to both the pure hydrocarbon nature of the backbone (no double bonds or oxygen atoms as in the case of styrenic block copolymers or EVA) and the type of tackifying resins used in the preparation.

In another study, the viscosity change as a function of time was measured at the 175°C application temperature for both an EVA and an HMA based on AFFINITY™ GA 1950 POE. These results are shown in Figure 9. The excellent performance of the HMA based upon AFFINITY™ GA POEs, over that of the EVA, is clearly evident at this conventional application temperature. The HMA based upon the AFFINITY™ GA POEs showed essentially no change in viscosity over seven days, while the EVA-based system showed substantial changes after one day and a change of 65 percent over seven days.

Tackifier Selection

The performance of a hot melt adhesive is highly related to the compatibility of its components. As the tackifier is one of these critical components, studies were undertaken to assess the compatibility of AFFINITY™ GA POEs with several types of tackifiers. The compatibility of a resin with a given polymer depends mainly on its polarity and to a lesser extent on its molecular weight. The high molecular weight fraction of the resin, measured by its Mz value, may lead to symptoms of incompatibility such as turbid melts or migration upon aging. Therefore, it is customary to measure the compatibility of a hot melt adhesive by determining its cloudpoint. There are, however, several problems with this method, among these being that it is time consuming and that the wax component can often obscure the cloudpoint.

To avoid these issues, the dual polymer/resin (1:1) cloudpoint measurements or the Hercules modified diacetone alcohol (MDA) method was used.[8,9] An isothermal compatibility contour for the AFFINITY™ GA POEs is shown in Figure 10. In this plot, the Mz value is plotted as a function of the diacetone alcohol cloud point (DACP) value for several types of tackifiers. Fully or partially hydrogenated C5 and C9 tackifiers are shown to be compatible with AFFINITY™ GA POEs. In particular, EASTOTAC® tackifier resins show excellent compatibility.
Summary

Novel high flow AFFINITY™ GA Polyolefin Elastomers offer distinctive properties which deliver exceptional performance in hot melt adhesives (HMAs). Designed to be used in both conventional and low application temperature HMAs, these polymers offer the potential to save money for both the HMA manufacturer and the end user.

References


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