Improved Strength and Adhesion: New EVA Material Developments for Thermal Lamination and Flexible Packaging Applications

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We have developed a class of new ethylene vinyl acetate (EVA) copolymers with high adhesion to substrates in the extrusion coating process. Using a laboratory set up designed to model the extrusion coating of EVA onto polymer films, we coated both conventional and high-adhesion EVA copolymers onto corona-treated polyester films, and measured the force required to separate EVA from the substrate. The force required to separate the improved EVA from the polyester substrate was approximately six times greater than the peel force measured with conventional EVA. Additional experiments were conducted on a commercial-scale extrusion coating line, where conditions were systematically varied. For corona-treated polyester films run during the commercial-scale trial, the force required to separate improved EVA from the substrate ranged from 2.5 to 3.5 times greater than comparable control films. Large increases in adhesion were also encountered when corona-treated films were chemically primed, and the EVA extrudate curtain was ozone treated.

INTRODUCTION

Ethylene vinyl acetate (EVA) copolymers are used in a variety of thermal laminations and flexible packaging applications, including cheese packaging, document protection films, and loyalty cards.[1] In many of these applications, extrusion coating and extrusion lamination processes are used to put together multi-layer film structures.

In an extrusion coating process, a molten polymer is extruded onto a solid web (or substrate) – such as paper or polymer film – leaving a thin coating of the now solid polymer on the substrate. EVA polymers are commonly extrusion coated onto polyester and polypropylene films, although other substrate materials are also used.

The central requirement of the extrusion coating process is that the polymer and the substrate must stick together. The strength of the bond between coating and substrate is of critical importance, and producing a strong bond between these two layers can be difficult. For this reason, extrusion coating practitioners have developed a variety of strategies to improve the bond strength between a coated polymer and a substrate. These strategies include corona treatment of the substrate,[2] coating the substrate with chemical primers,[3] treating the extruded polymer curtain with ozone,[4] and manipulating the time it takes molten polymer to traverse the air gap.[5] All of these approaches can be used individually or in combination with each other.

However, there are practical limits to the application of each of these techniques. There remains a need to further improve the adhesion between the extruded EVA and the substrate. This paper describes a new developmental EVA designed to bond strongly with various substrates during extrusion coating, comparing it with a conventional EVA that is commonly used in extrusion coating applications.

EXPERIMENTAL DETAILS

Materials

A series of materials were made to evaluate a new class of EVA copolymers with improved substrate adhesion during coating processes. Two conventional EVA copolymers with a 16% by weight vinyl acetate content were used as control samples. These materials have melt indices of 8.4 dg/min (Ateva 1609, Celanese EVA Polymers) and 15 dg/min (Ateva 1615, Celanese EVA Polymers).

Additionally, two EVA materials that have been specifically tailored to have improved adhesion with film substrates in extrusion coating were evaluated. These copolymers also are 16% by weight vinyl acetate, and have flow and melting characteristics that are essentially identical to the 8.4 dg/min and 15 dg/min melt index control materials.

Small-Scale Fabrication Method

EVA films of both the standard and improved versions of the 8.4 dg/min melt index material were cast using a monolayer cast film extruder. Molten EVA was cast between two rolls forming a "nip;" one roll was a chilled metal roll with a glossy finish and the second roll was a rubber roll.

The extruder output was adjusted to produce a 38 micron thick EVA film with a film take-up speed of 6 m/min. Under these conditions, the extruder output was approximately 4.5 kg/hr. The EVA melt temperature was maintained at a nominal value of 240°C for the duration of the study.

40 cm x 30 cm sheets of corona-treated 92 gauge polyester (PET) film were fed into the nip in order to simulate the extrusion coating of EVA onto polyester. The PET film was hand-fed onto the rubber roll as shown in Figure 1.

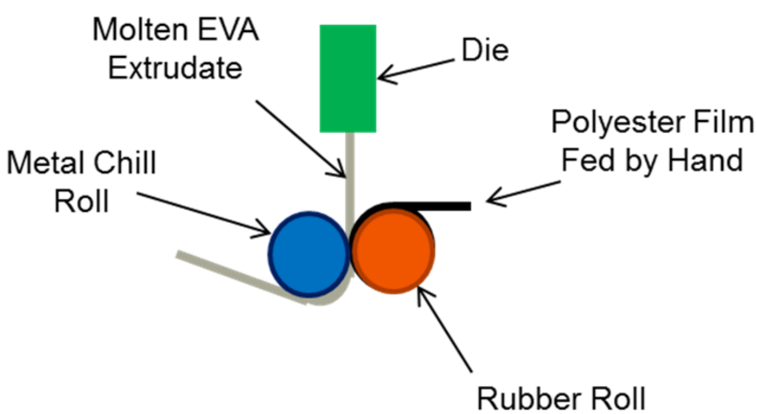

Figure 1. Diagram of small-scale extrusion coating experiment.

Large-Scale Processing Trial

Standard and improved versions of the 16% VA, 15 dg/min melt index EVA copolymer were evaluated on a commercial-scale extrusion coating line. Both samples were extruded at a nominal melt temperature of 227°C. The air gap was maintained at nominal length of 178 mm throughout the trial. EVA was coated at a thickness of 25 microns onto 48 gauge PET film. Samples were run at line speeds of 107 m/min and 214 m/min.

During this trial, three different treatment configurations were evaluated. In the first configuration, untreated PET film was directly coated with EVA. In the second configuration, EVA was coated onto corona-treated PET film. In the third configuration, corona-treated PET film was chemically primed with a water-based primer, and the EVA curtain was ozone treated during the extrusion coating step.

Test Method

The strength of the bond between EVA and polyester for each sample was measured by cutting one inch wide strips from each sample and measuring the force required to separate EVA and polyester during a T-peel test.[6] Five samples from each film were tested in order to assess the variability of the method.

During the T-peel measurements, the force initially increased before reaching a stable level after a peel displacement of two inches. The full test was completed after six inches of displacement. The stable force data recorded between three and six inches of displacement was used for subsequent analysis.

During T-peel tests made on small-scale samples, there was a large degree of scatter in the experimental force measurement. To appropriately characterize the full breadth of experimental uncertainty, each sampled force data point collected between displacements of three and six inches on five different test specimens was used for the analysis. These data were used to produce the box and whisker plot shown in the results section.

RESULTS

Small-Scale Laboratory Experiments

Figure 2 compares the peel force required to separate EVA from polyester for both the standard and improved EVA materials (16% VA, MI=8.4 dg/min) using a box and whisker plot. The upper and lower bounds of each box indicate the third and first quartiles of the sampled force data, respectively. The numerically labeled middle line in each box indicates the median peel force. The upper and lower "whiskers" indicate the highest and lowest measured peel force for each sample.

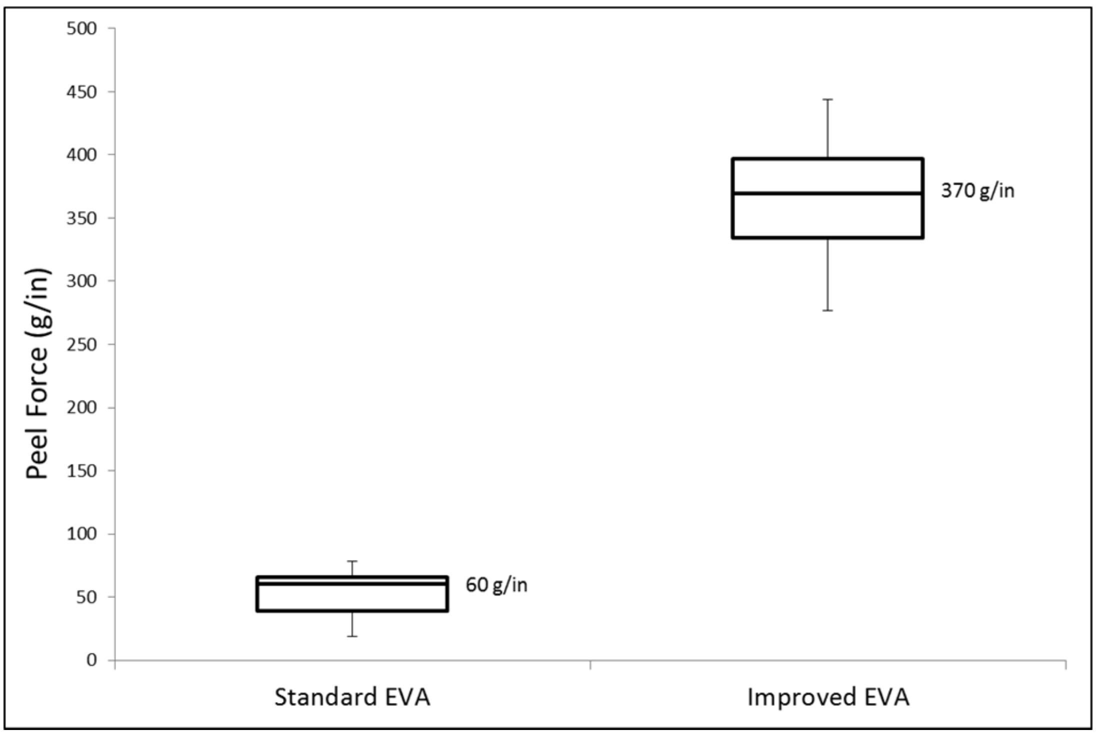

Figure 2. Box and whisker plot comparing the measured peel force from samples produced using standard EVA and high-adhesion EVA.

There is considerable spread in the individual measurements made on the two materials, as reflected in the box and whisker plots. We attribute this to the variety of practical issues encountered during sample preparation, where films are hand-fed into the apparatus.

Despite this experimental variance, there are significant differences between the standard EVA and improved EVA in terms of the force required to separate the EVA coating from the PET substrate. In this configuration, the improved EVA shows a roughly six-fold increase in the force required to separate the EVA coating from the polyester film when compared with a standard material. The standard EVA exhibited a median peel force of 60 g/in, compared with the 370 g/in median peel force for the new material. There is no overlap between the two populations of force measurements. The lowest individual measurement for the improved EVA (275 g/in) was substantially greater than the highest individual measurement of the standard EVA (80 g/in).

Large-Scale Processing Trial

Encouraged by the success of our small-scale lab study, we ran a second study to validate our new materials on commercial-scale processing equipment. A standard 16% VA, 15 dg/min melt index EVA copolymer was selected as an experimental control, as this material is widely used in extrusion coating applications. This control was compared with an equivalent high-adhesion EVA.

The coating trial focused on three different treatment configurations, running at two different line speeds. In all cases, a constant coating thickness of 25 microns was maintained, meaning the extruder output was increased when running the faster line speed cases. The adhesion force testing results are summarized in Table I.

Table I. Adhesion peel force for 16% VA, MI=15 dg/min conventional and high-adhesion copolymers.

	Peel Force (g/in)	
	16% VA Control	High-Adhesion 16% VA
Untreated Film		
107 m/min	20	30
214 m/min	20	40
Corona-Treated Film		
107 m/min	40	140
214 m/min	60	160
Corona/Primer/Ozone		
107 m/min	280	440
214 m/min	270	440

In general, the results of this study appear to be independent of line speed. There are only small differences seen in the measured peel forces for otherwise equivalent samples produced at 107 m/min and 214 m/min; these small differences likely fall within the realm of standard experimental variation.

The adhesion of EVA to untreated and unprimed PET films was weak. This result was expected; PET films are typically treated in some way prior to extrusion coating with EVA for this very reason. The high-adhesion EVA exhibited a modestly greater peel force under the no treatment condition, although this improvement is perhaps not large enough to be of practical use.

The corona treatment of PET is a common strategy that is used to improve adhesion during extrusion coating. Extrusion coating of the standard EVA control material onto corona-treated PET resulted in a somewhat higher peel force when compared with untreated PET, increasing from 20 g/in to 40 to 60 g/in in our tests.

When the high-adhesion EVA was extrusion coated onto corona-treated PET film, the adhesion improvement was dramatic. Peel forces for this material under this treatment condition ranged from 140 g/in to 160 g/in, which was approximately a 2.5 to 3.5-fold improvement when compared with the control EVA under the same processing conditions. This large improvement when coated onto corona-treated PET is at least qualitatively consistent with our small-scale laboratory work, where a similarly large difference was observed between the control and high-adhesion EVAs when coated onto corona-treated films.

Beyond corona treatment, there are a variety of tools available to improve adhesion during extrusion coating. Chemical primers are commonly applied to substrates and additional adhesion benefits are generally observed when the extruded EVA curtain is treated with ozone. Our third treatment configuration combined all of these treatments – corona treatment, chemical primer application, and ozone – to enable an evaluation of our improved-adhesion EVA relative to a control material in this situation.

The combination of these three treatments substantially increased the measured peel force of both the control EVA and the improved-adhesion EVA. The peel forces measured for the control EVA ranged from 270 to 280 g/in, which is roughly a five to seven fold increase in peel force when compared with control EVA coated onto a corona-treated PET film with no additional treatment.

The measured peel force of the improved-adhesion EVA was even greater, reaching a peel force of 440 g/in, which is approximately 1.5 times the peel force measured on the control EVA under identical conditions.

Over all three sets of treatment conditions, the improved-adhesion EVA exhibited a larger peel force than the control material. While this improvement is perhaps too small to matter on untreated PET film, the improvement is large in the cases where typical treatment methods are used to promote adhesion to PET.

SUMMARY

This paper reports results obtained on a new group of EVA copolymers designed to have substantially improved adhesion with substrates when applied by extrusion coating. In small-scale lab evaluations, the measured peel force between the improved EVA and a corona-treated PET substrate was approximately six times greater than that measured between a comparable control EVA and PET. Commercial-scale trials revealed that while only small improvements were realized when this improved EVA was coated onto untreated PET, 1.5 to 3.5-fold improvements in peel force were encountered when some sort of adhesion promoting treatment was used.

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