

Achieving LDPE Coating Adhesion to Clay-Coated Board Using Calcium Carbonate Addition

F. A. Ruiz
Heritage Plastics, Inc.
1002 Hunt Street
Picayune, MS 39466 USA

Abstract

LDPE-based pelleted calcium carbonate (CaCO_3) concentrates were used to add 0, 15, & 30wt.% fine-ground, surface-treated mineral to a 5.0 MI, 0.923 ρ autoclave-process LDPE homopolymer. These dry blends were extrusion coated onto flame-treated clay-coated board. Polymer melt temperature and coating air gap were varied to determine how the addition of CaCO_3 affected adhesion response to variation in these process conditions.

The combined flame pretreating of the board plus the addition of 30wt.% CaCO_3 to the LDPE coating resin yielded adhesion level which prevented coating removal without fiber tear. This adhesion was achieved without major changes in extrusion conditions or web neck in. Reductions of 33% in coating WVTR and 30% poly-to-metal COF were observed at 30wt.% calcium carbonate addition. The economics of utilizing calcium carbonate concentrates make this technology attractive as a commercial method of promoting LDPE coating adhesion to clay-coated board, reducing coating C.O.F., and WVTR.

Discussion

A previous paper detailed the potential for increased coating-to-substrate adhesion with calcium carbonate addition to LDPE¹. Other papers^{2,3,4,5} have discussed the mineral factors (particle morphology, particle size distribution, particle surface chemistry, and chemical purity) and polymer factors (molecular weight, molecular weight distribution, branching type and distribution, density/crystallinity, and polymer chemistry, e.g. polar/non-polar) which affect the processing and product properties with mineral addition. Proper mixing and dispersion of the mineral into the polymer matrix is a critical processing factor in the complete realization of the benefits of this technology. Most commercial extrusion equipment in good condition with modern screw designs have proven more than adequate to achieve the necessary level of homogenization.

Several polymer and process variables are known to affect the adhesion of LDPE to the coated substrate. One important extrusion coating process variable is melt temperature. A melt temperature of $>316^\circ\text{C}$ (600°F) is generally necessary to promote adequate oxidation of the molten web for proper adhesion to the substrate. The air gap, or distance from the die lips to the point at where the molten polymer contacts the substrate, also must be adequate to allow enough time for this oxidation to occur.

There are drawbacks to both of these methods of increasing coating adhesion. High melt temperatures may cause a burnt odor to the coating. Increasing the air gap may cause added web neck-in, reducing the width of the coating being applied.

Mineral and Polymer Selection

A 5.0 MI, 0.923 ρ autoclave-process polyethylene homopolymer was selected as the base resin. Materials of this MI & density are commonly used for coating cup stock and coated board.

A wet-ground calcium carbonate with a 1.0 μ mean particle size (MPS) and 8 μ top-cut (maximum particle size) was selected for both evaluations. This material was surface-treated to form a hydrophobic coating on the mineral. This allows the polyethylene to "wet" the mineral surface, greatly improving the dispersion of the mineral into the polymer matrix and processability of the mineral/LDPE composite.

Polymer Processing and Substrate Coating

A commercially-supplied concentrate, comprising 75wt.% surface-treated calcium carbonate in an autoclave-process LDPE homopolymer, was used to prepare pellet/pellet dry blends. This allowed processing of CaCO_3 -containing coatings on a standard extrusion coating line. The concentrate utilized was H-TEC™, a standard product of Heritage Plastics of Picayune, MS, and is specially designed for use in high temperature extrusion coating applications.

A 114mm (4.5") 30/1 L/D extruder fitted with a flat die deckled to 710mm (28") exit width was run at a constant screw speed of 34 RPM.

Dry blends of concentrate and LDPE base resin were prepared to yield 0% (control), 15, and 30wt.% calcium carbonate loadings (20 & 40wt.% concentrate addition). Samples of clay-coated board were coated at each mineral loading and the proper line speed to achieve a 25μ (1.0 mil) coating thickness. Each compound was run at melt temperatures of 316° and 327° C (600° and 620° F). At both melt temperatures, die to nip-point draw distances of 178mm and 229mm (7" and 9") were employed.

The clay-coated board surface was flame-treated at a level of 14,000 BTU/in. to simulate typical commercial processing conditions. Neither corona treating nor primer coating were employed to improve adhesion.

Slight changes in motor current and extruder head pressure with calcium carbonate addition were observed, as shown in Figures 1 and 2, respectively. These results are consistent with what has been observed in previous tests.

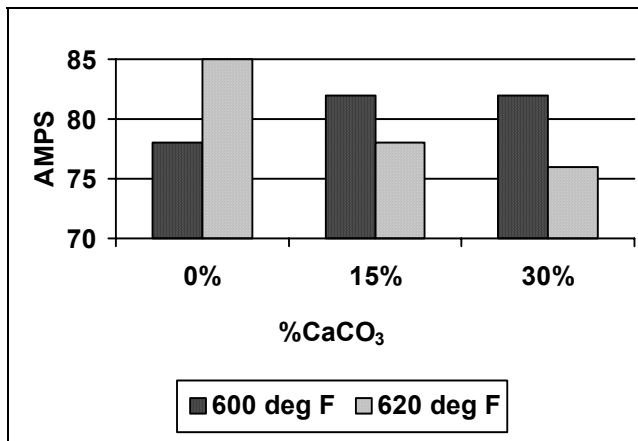


Fig. 1. Extruder Motor Current Response to CaCO_3 Addition to 5.0 MI/0.923p LDPE

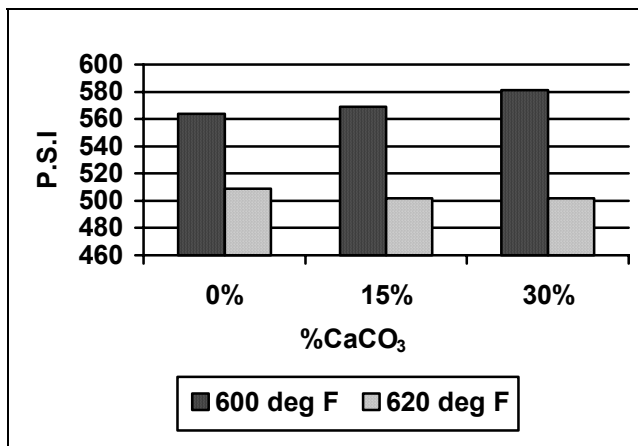


Fig. 2. Extruder Head Pressure Response to CaCO_3 Addition to 5.0 MI/ 0.923p LDPE

Coating-to-Substrate adhesion response with addition of up to 30wt.% Calcium carbonate to 5.0 MI/0.923p LDPE

Coating-to-substrate adhesion was measured qualitatively by judging the difficulty in peeling the LDPE coating from the clay-coated surface of the board. The results obtained are summarized in Figure 3.

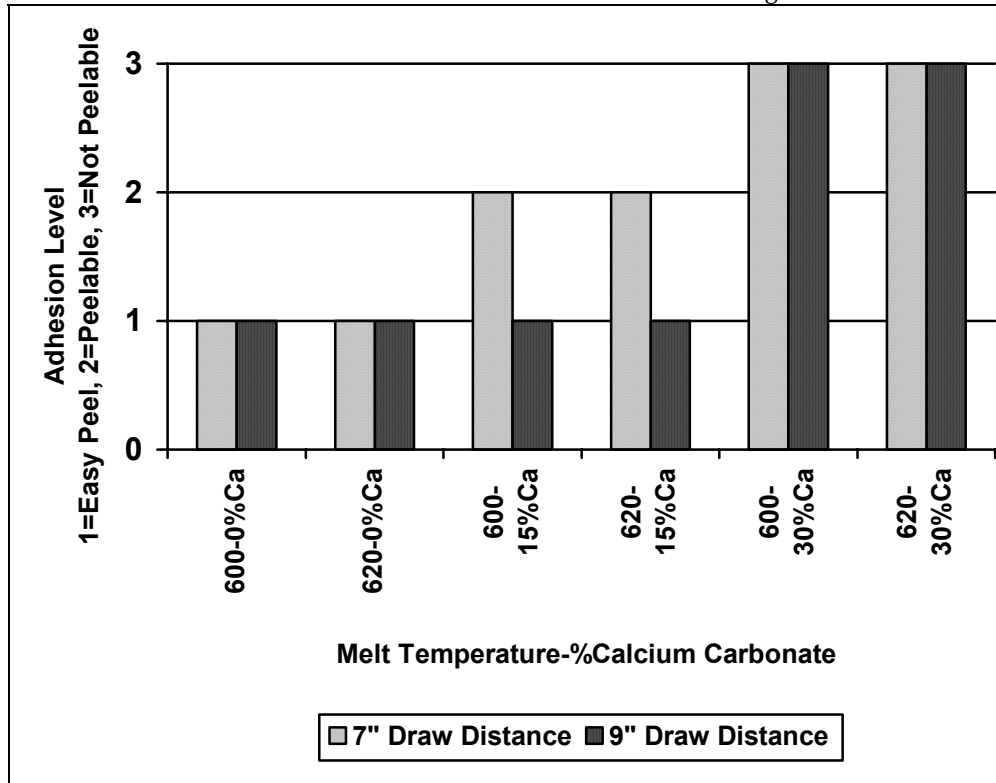


Figure 3. Coating-to-Substrate Adhesion Response to Calcium Carbonate Addition and Coating Process Conditions.

Unmodified LDPE could be peeled easily from the clay-coated surface of the board at all four coating conditions.

At 15wt.% CaCO₃ addition and 178mm (7") draw distance, the coating adhesion was improved over the control, but could still be peeled with difficulty.

At 30wt.% CaCO₃ addition and all four coating conditions, the coating could not be peeled from the surface of the board without causing fiber tear.

A possible explanation for the observed increases in coating adhesion is that increased thermal conductivity of the polymer with mineral addition (see Fig. 4) allows faster heat transfer from the bulk of the web to the polymer/substrate interface. This allows the polymer to stay molten and improves the wetting of the polymer onto the substrate surface.

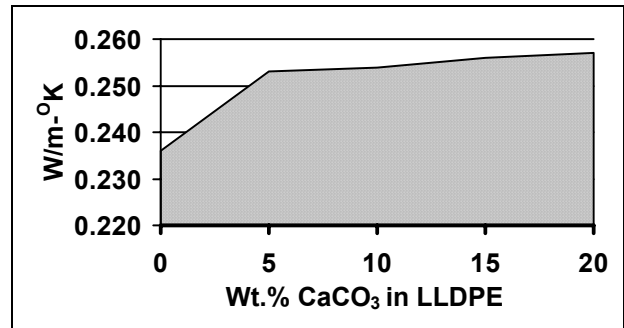


Fig. 4. Increase in LLDPE Thermal Conductivity with CaCO₃ Addition.

Modifications to LDPE Coating Properties with CaCO₃ Addition

The addition of calcium carbonate to the LDPE coating reduced the MVTR, as shown in Figure 5.

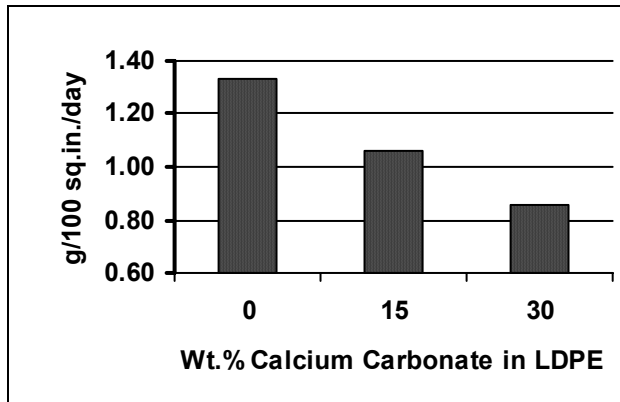


Fig. 5. Decrease in coating MVTR with CaCO₃ Addition.

This is due to the formation of a "tortuous path" for the passage of water vapor, as it must diffuse around the calcium carbonate particles in the coating.

Calcium carbonate addition also reduces the coefficient of friction between the coating surface and metal surfaces over which the polymer must slide, as shown in Figure 6. This should prove advantageous in forming operations where this is required, as in forming the lip of a paper cup.

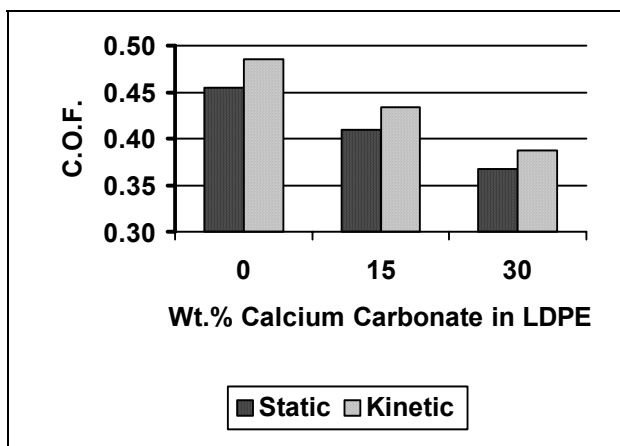


Fig. 6. Average Poly-to-Metal C.O.F. of LDPE coating with CaCO₃ Addition

Summary

Calcium carbonate mineral enhancement of extrusion coated LDPE has developed into a commercially applied method of modifying polymer processing and product properties. Mineral addition increases polymer coating adhesion to the surface of clay-coated board to the point of fiber tear, when combined with substrate flame treatment, but without the need to use primer coating or

corona/ozone treatment. The reductions in coating MVTR and C.O.F. observed should be of interest to flexible package converters and end-users.

References

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