Modifying Film Conversion and End-Use Characteristics with Mineral Reinforcement

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Abstract

Mineral reinforcement of polyethylene films has been shown to increase extrusion efficiency and process output, and to improve the ductile performance of LLDPE films without a loss of stiffness. Mineral reinforcement may also be used to modify the surface characteristics of blown and cast polyethylene films. Film blocking of linear-low density (LLDPE), very-low/ultra-low density (VL/ULDPE), and metallocene-catalyzed PE (mPE) can be eliminated with mineral addition. Film surface energy is increased, improving ink adhesion and ease of treating without increasing the film's tendency to block. Film coefficient of friction (COF) can be modified without the use of migratory additives. Depending on polymer type and additive package, the COF of "barefoot" LLDPE, VL/ULDPE, and mPE films is generally reduced with mineral addition, while that of HMW-HDPE films is increased.

Discussion

The addition of minerals to polyethylene film introduces a new set of variables which affect polymer processing and product properties. These include particle morphology, particle size distribution, particle surface chemistry, and chemical purity. Polymer and equipment factors still affect the processing conditions observed and product properties obtained with mineral enhancement technology, as discussed in previous papers.[1,2,3,4]. Polymer factors include molecular weight and molecular weight distribution, branching type and distribution, density/crystallinity, and polymer chemistry (polar/non-polar). Since mineral reinforcement is a heterogenous effect, proper mixing and dispersion of the mineral into the polymer matrix is a critical factor in the optimization of product properties and performance.

This previous work has shown that proper application of polyethylene film mineral reinforcement can yield increases in processing efficiency and product performance. Extrusion output rate can be increased 2% for every 1% of calcium carbonate addition. Increases of up to 250% in dart impact strength without a loss of tensile yield strength or stiffness have been observed with mineral addition to higher alpha olefin LLDPE.

Polymers and Minerals Evaluated

A number of different film grade resins have been evaluated with mineral reinforcement, including narrow MWD Ziegler-Natta catalyzed linear PE's of approximately 1.0 MI and 0.920 g/cm^3 density, and a 0.05MI, 0.948ρ ethylene/1-butene HMW-HDPE.
A metallocene-catalyzed polyethylene (mPE) of 0.8MI/0.904ρ also was tested.

The following minerals were evaluated as to their effectiveness at modifying film surface and conversion characteristics:

- a 1.0μ average particle size (A.P.S.) calcium carbonate with an 8μ top-cut, or maximum particle size,
- a 3.0μ A.P.S. calcium carbonate with a 15μ top cut.
- A 2.5μ A.P.S. platy talc with a 25μ top-cut.

Both calcium carbonate mineral were surface treated with 1.2% stearic acid to allow the polyethylene to wet the mineral surface, and to improve the dispersion into the PE matrix. The talc mineral was not coated, as this is not necessary to achieve dispersion and wetting in polyolefins. Mineral loadings up to 20 wt. % were processed.

Polymer Processing and Film Conversion

All LLDPE and mPE films were extruded and converted on a 70mm (2.75") 24/1 L/D smooth bore extruder fitted with a 225mm (9") spiral mandrel die having a 1.4mm (0.055") die gap.

This extruder is part of a commercial in-line industrial can liner production line located at the Heritage Bag Company facility in Atlanta, GA.

HMW-HDPE bags were extruded and converted on an 80mm grooved-feed extruder fitted with twin 175mm (7") dies having 1.0mm (0.040") die gaps.

Both of these lines are fitted with shuttle-type, bottom-seal bag machines which simultaneously seal and perforate bags in-line.

Minerals were incorporated into the film resins via dry blends of pellet concentrates compounded at the Heritage Plastics facility in Picayune, Mississippi.

Coefficient of Friction Response to Mineral Addition

Proper film coefficient of friction (COF) is critical to proper conversion and end-use characteristics in various packaging applications.

COF is typically controlled by the use of slip agents, additives which operate by migrating to the film surface. Difficulties with this method include the tendency of these additives to interfere with adhesion of inks and laminations to the film surface, the change in COF depression with gauge at constant additive level, and low levels of slip agent required to affect minor reductions in COF (i.e. to go from high to medium COF, reproducibly).

and the steep response of COF in the medium to high COF range with low levels of slip agent addition.

The following figures display the effect of calcium carbonate addition to several different resins on film COF.

The COF of LLDPE films can be reduced moderately with the addition of calcium carbonate, as shown in Figure 1.

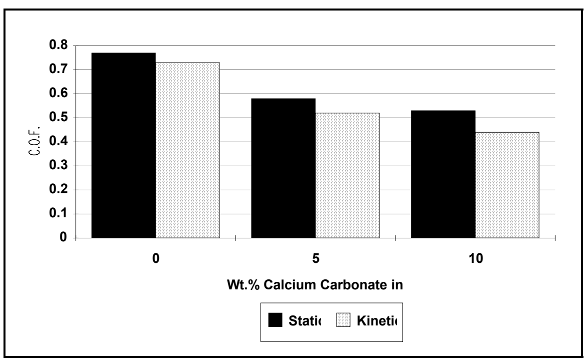

Figure 1. COF Response of 1.0 MI, 0.918ρ LLDPE Hexene Copolymer to 1μ $CaCO_3$ Addition

Metallocene-catalyzed polyethylenes are gaining in use due to their excellent sealing characteristics and lack of low-molecular weight oligomers at very low densities. Unmodified, these materials may have very high COF's. Figure 2 shows how the COF of a 0.8 MI, 0.904ρ metallocene PE may be reduced with calcium carbonate addition.

High molecular weight, high density polyethylene films inherently have a very low COF. This may be a liability if the bags must be stacked, as is required in the manufacture of industrial can liners or grocery carryout sacks. The maintenance of stack

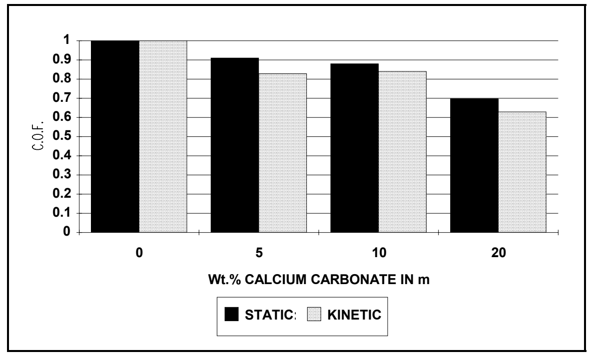

Figure 2. COF of 30μ Film Extruded from 0.8MI, 0.904ρ Metallocene-Catalyzed PE: Decrease with $CaCO_3$ Addition

registration may be difficult due to the tendency for the bags to slide over each other.

Figure 3 shows how calcium carbonate addition actually increases the COF of HMW-HDPE films. This improves stack registration and the handling and packaging of converted bags.

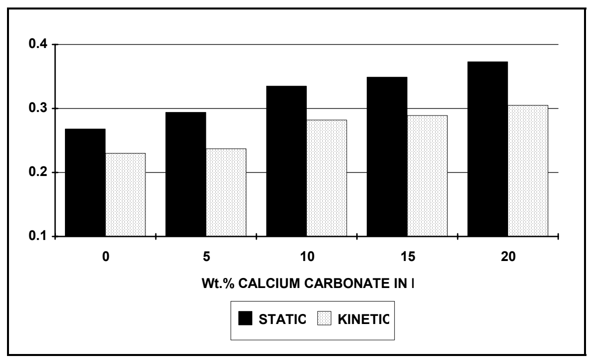

Figure 3. COF Response of 18μ HMW-HDPE Film to 1μ $CaCO_3$ Addition

Film Blocking Response to Mineral Addition

Minerals, primarily diatomaceous earth and talc, are widely used as antiblocking agents to allow the separation of film layers, as in the opening of a bag or package, or the unwinding of film off a roll.

Calcium carbonate may also be used as an antiblock, although somewhat higher levels of addition are required to achieve the same openability, as shown in Figure 4. In this example, diatomaceous earth, talc, and both 3μ A.P.S. and 1μ A.P.S. calcium carbonates were added to a 1.0 MI, 0.915ρ Ziegler-Natta catalyzed LLDPE.

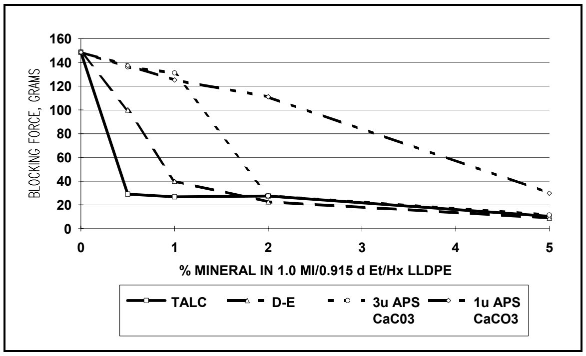

Figure 4. The Effectiveness of Different Mineral Types and Particle Sizes As Antiblocking Agents.

Metallocene-catalyzed polyethylenes of very low density have become available commercially for use as sealing layers in flexible packaging. Due to their low density, these materials also have a tendency to block. Figure 5 shows how calcium carbonate addition to a 0.8MI, 0.904ρ metallocene catalyzed PE can eliminate blocking with films made from this polymer.

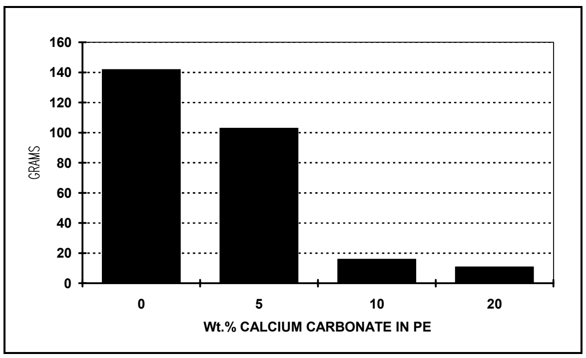

Figure 5. Blocking Force Response to Calcium Carbonate Addition: 30μ Film, 0.8 MI, 0.904ρ Metallocene-Catalyzed PE

Effect of Mineral Addition to Polyethylene on Film Surface Energy.

Polyethylene films are commonly corona-treated to oxidize the surface and allow inks and lamination substrates to adhere. In general, the surface energy of the film must be raised from the 32 dynes/cm^2 of unmodified PE to 38 dynes/cm^2 for solvent inks, or as high as 42 dynes/cm^2 for adhesion of water based inks.

Addition of 1μ A.P.S. calcium carbonate has been observed to raise the surface energy of LLDPE films, as shown in Figure 6.

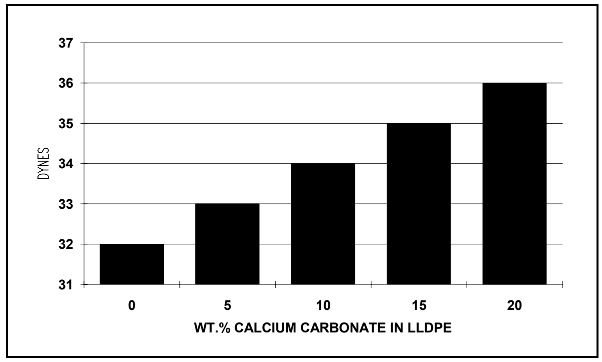

Figure 6. Surface Energy of Film Produced from 1.0MI, 0.918ρ LLDPE Hexene Copolymer with 1μ A.P.S. Calcium Carbonate Addition

Barrier Properties of Mineral Reinforced Films

The addition of mineral to polyethylene films has been observed to reduce the rate of water vapor transmission.[5,6,7] Platy minerals, such as talc, are the most effective at improving the barrier properties. Figure 7 shows how the addition of talc to a LLDPE reduces the rate of moisture vapor transmission through the film.

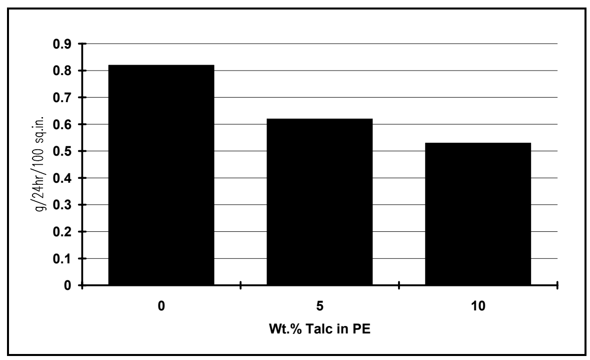

Figure 7. MVTR Response of 1.0 MI, 0.920ρ LLDPE to talc addition

Conclusions

In addition to providing a method of improving the process efficiency and mechanical properties of polyethylene films, mineral reinforcement offers the extruder and converter the means to effect changes to the surface characteristics and end-use performance films. Film COF can be modified without the use of migratory additives. Mineral addition at reinforcing levels can totally eliminate film blocking. Film surface energy is increased, improving ink and laminating adhesion characteristics. The addition of platy minerals, such as talc, can improve the barrier properties of extruded films.

References

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