Effect of Calcium Carbonate Properties on the Reinforcement of HMW-HDPE Film

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Abstract

LLDPE-based pelleted concentrates were used to add 0, 7.5%, & 15wt.% of different fine-ground, surface-treated calcium carbonate ($CaCO_3$) minerals to a high-molecular weight HDPE film resin. These dry blends were extruded into film on a 50mm, 18/1 L/D grooved-feed extruder fitted with a 100mm (4") die and 0.9mm (0.036") die gap. Neck height and blow-up ratios (BUR) also were varied to determine how the addition of $CaCO_3$ affected film property response to variation in these process conditions.

Mineral addition yielded output rate increases of 5% at 7.5% $CaCO_3$ and 10% at 15% $CaCO_3$ while simultaneously decreasing melt pressure and motor load (current). Depending upon calcium carbonate grade, mineral loading, and processing conditions, increases in dart impact strength and/or tensile yield stiffness were achieved. Calcium carbonate mineral grades also exhibited differences in the level of extrusion and bubble stability. Mineral reinforcement of HMW-HDPE films increases film coefficient of friction, which improves stacking of liners or merchandise bags.

Introduction

The blown film processing and product property enhancements possible with the use of calcium carbonate ($CaCO_3$) in particular and minerals in general as a reinforcing additives have been described in a number of papers and patents [1-8]. Mineral addition reduces the heat necessary to melt a given weight of material, and increases the thermal conductivity of the molten polymer. These papers also 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 has proven more than adequate to achieve the necessary level of homogenization.

Experimental

Polymers and Minerals Evaluated

A commercial HMW-HDPE resin was dry blended with three different concentrates containing 75wt.% of wet-ground ultrafine calcium carbonates. The minerals were treated with stearic acid by the suppliers to form a hydrophobic coating on the surface. This allows the polyethylene to "wet" the mineral surface, allowing the dispersion of the calcium carbonate into the polymer matrix and the processing of the mineral/HDPE composites. Addition rates of 10% and 20% concentrate yielded 7.5wt.% and 15wt.% $CaCO_3$ in the films. Films without mineral but containing 5wt% LLDPE were run as controls.

Polymer Processing and Film Extrusion

HDPE/LLDPE and HDPE/concentrate dry blends were extruded into film on a 50mm 18/1 L/D grooved-feed extruder fitted with a 100mm die and 0.9mm die gap. Processing conditions were varied to determine how the addition of $CaCO_3$ affected film property response to variation in operating parameters. Stalk heights of 6X and 9X the die diameter and blow-up ratios of 3:1 and 4:1 were employed with the three calcium carbonate concentrates during the experiment.

Results and Discussions

Changes in Polymer Processing Conditions with Calcium Carbonate Addition

On average, mineral addition yielded output rate increases of 5% at 7.5% $CaCO_3$ and 10% at 15% $CaCO_3$. With one of the calcium carbonate grades, film could not be produced under all conditions due to the presence of holes in the film. These holes were caused by large particles of calcium carbonate in the melt which prevented drawing the film down without difficulty.

Effects of Mineral Reinforcement on Film Properties

Dart Impact strength, as measured by ASTM D 1709, is commonly used as a measure of the ability of film to resist local failure in a loaded bag or package. Figure 1 shows the effect of mineral addition on the dart impact of extruded films at low and high stalk height, and 3:1 and 4:1 BUR.

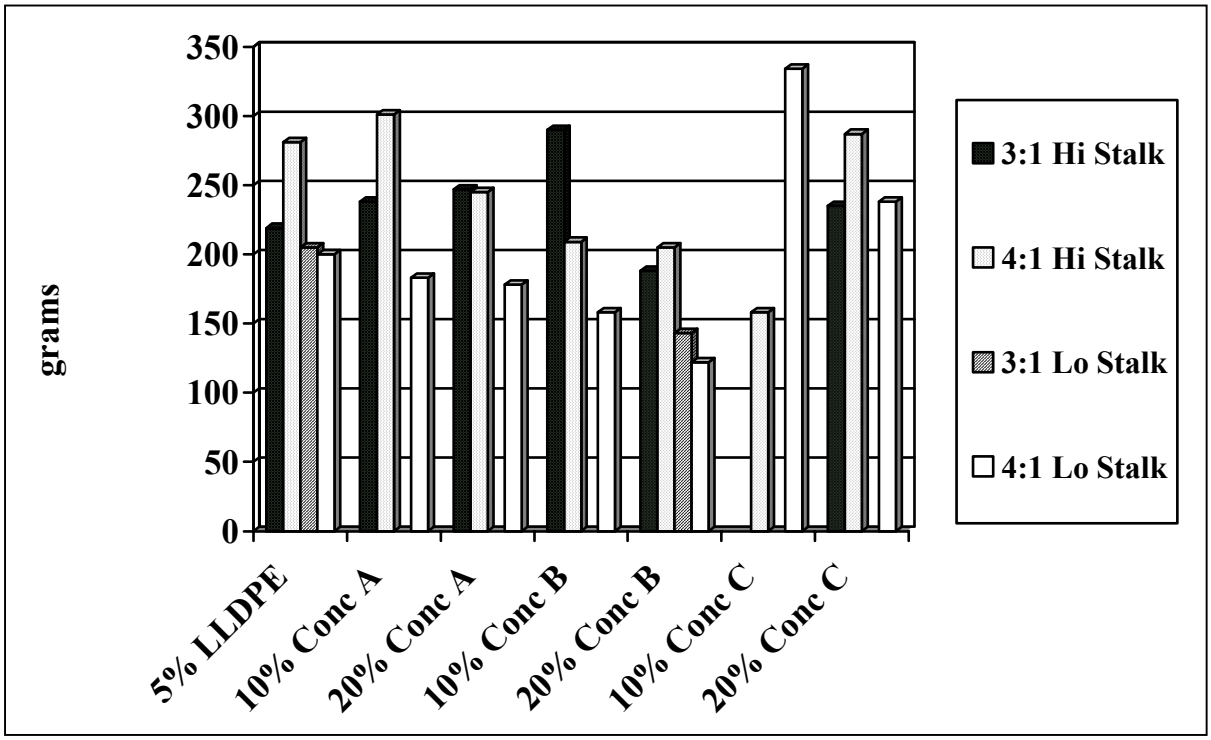

Figure 1. Effect of Mineral Addition, Stalk Height, and Blow-up Ratio on Dart Impact Strength

Dart impact strength varies depending on film processing conditions. With 5% LLDPE, 10% concentrate A, or 20% concentrate C, the best dart impact was under 4:1 BUR/high stalk conditions. Using Concentrate B the best dart impact was at 3:1/hi stalk conditions. With the use of Conc. C the best dart impact was observed at 10% loading and 4:1 BUR/lo stalk height. These differences are most likely due to the differences in mineral particle size and distribution.

Tensile yield strength is a critical property of HMW-HDPE films, as it directly relates to the load-bearing capacity of a converted can liner or retail carry out sack. In general, very little, if any loss in this property can be tolerated, as it would require an increase in film thickness to maintain load capacity.

Figure 8 shows the effect of mineral reinforcement on the effect of tensile yield strength under the same process variations as detailed for dart impact strength above. With the exception of Concentrate C, mineral addition under several conditions actually increased MD tensile yield strength.

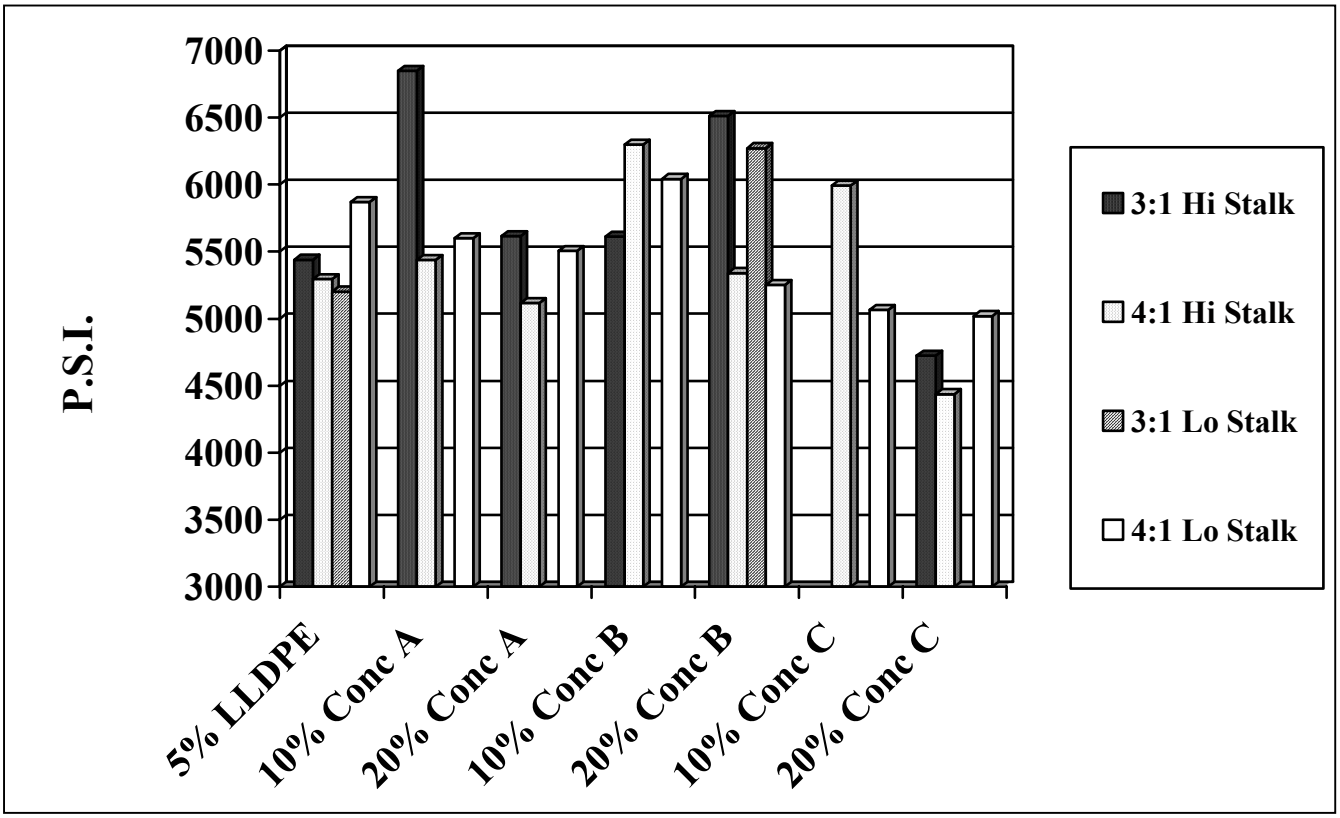

Figure 2. Effect of Mineral Addition, Stalk Height, and Blow-up Ratio on MD Tensile Yield Strength

Summary

Mineral reinforcement of HMW-HDPE films using fine-ground, surface treated calcium carbonate is shown to be a commercially viable method of increasing extrusion output rate without penalty in terms of processing difficulty. Depending on resin type and specific processing conditions, motor load and melt pressure may actually decrease while output rate is increased.

Differences in molecular weight, molecular weight distribution, and density between commercially-available HMW-HDPE film resins result in differing responses of film dart impact with calcium carbonate addition and changes in films extrusion conditions. These differences suggest that those interested in exploring the application of mineral reinforcement technology to their processes and products explore a wide range of base resins and processing conditions to determine the optimum combination for their given equipment and desired film properties.

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