

AGILITY™ PERFORMANCE LDPE IN BLENDS ELEVATES FILM MECHANICALS AND EXTRUSION OUTPUT TO THE NEXT LEVEL

*Lori Kardos, Teresa Karjala, Yijian Lin
The Dow Chemical Company, Freeport, Texas*

Abstract

Blends of LLDPE (linear low density polyethylene) and LDPE (low density polyethylene) are used in many film applications. This paper shows how several high performance LDPE resins can be used as a blending component to increase output or throughput on blown film lines as well as optimize film mechanical properties. In addition, some of these LDPE resins are utilized in shrink films, providing a good combination of shrink and optics, and are also used in foams and extrusion coating among other applications.

Introduction

Blends of LLDPE and high pressure LDPE are used commonly, particularly for films used in packaging applications such as heavy duty shipping sacks (HDSS), silage and agricultural films, and collation shrink films. There have been studies performed to understand the effect of the addition of small amounts of LDPE, *i.e.* less than 20 wt% to a LLDPE [1-2], specifically in terms of the impact of the LDPE on film physical properties such as Elmendorf tear strength, dart impact strength, etc. However, the effect of the addition of small amounts of LLDPE to LDPE (LDPE-rich blends) has not been studied as much [3], and hence is not as well understood. A previous paper [4] discusses the behavior of LLDPE/LDPE blends over the entire composition range in terms of physical properties such as Elmendorf tear strength, dart impact strength, and puncture strength in order to understand the relationships between these film properties, orientation effects, and intrinsic properties of blends of three different LDPEs with a LLDPE resin.

This paper builds upon previous work [4,5] by showing how several LDPE resins can be used as a blending component, in particular, to increase output or throughput on blown film lines. In addition to being used in blown films to increase output, specific LDPE resins in this product family are also targeted at shrink films, providing a good combination of shrink and optics and are also being used in extrusion coating [6] and foam [7] applications. A short overview of these additional applications is included.

Experimental

Melt index (MI or I_2) was measured by ASTM D 1238, at 190 °C/2.16 kg and is reported in grams per 10 minutes. Density was measured as a quick density according to

ASTM D 1928. Measurements were made within one hour of sample pressing using ASTM D792, Method B.

Melt strength was measured at 190 °C using a Goettfert Rheotens 71.97 melt fed with a Goettfert Rheotester 2000 capillary rheometer equipped with a flat entrance angle (180 degrees) of length of 30 mm and diameter of 2 mm. The pellets were fed into the barrel (length = 300 mm, diameter = 12 mm), compressed and allowed to melt for 10 minutes before being extruded at a constant piston speed of 0.265 mm/s. The extrudate passed through the wheels of the Rheotens located 100 mm below the die exit and was pulled by the wheels downward at an acceleration rate of 2.4 mm/s². Melt strength is reported as the plateau force (cN) before the strand broke.

Dynamic mechanical spectroscopy (DMS) was run on resins which were compression molded into 3 mm thick x 25.4 mm diameter (1 inch) circular plaques at 177°C, for five minutes, under 111 kN (25,000 lb) of force, in air. A constant temperature frequency sweep was performed using a TA Instruments ARES equipped with 25 mm diameter parallel plates, under a nitrogen purge. The experiments were performed at 190°C over a frequency range of 0.1 to 100 radians per second (rad/s) at 5 points per decade.

Monolayer films were produced on a blown film line. The films were 51 micron (2 mil) thick unless otherwise noted and the blow up ratio (BUR) was 2.5. A 20.3 cm (8 inch) diameter die with a 1.78 mm (70 mil) die gap and a polyethylene Davis Standard Barrier II screw was used along with external cooling by an air ring and internal bubble cooling. General blown film parameters are discussed in a previous paper [5]. The films at the standard rates were run at 250 lb/hr. Film samples were made at a controlled rate and a maximum rate (only at 20 wt% LDPE levels).

The maximum output rate for a given sample was determined by increasing the output rate to the point where bubble stability was the limiting factor. The extruder profile was maintained for both samples (standard rate and maximum rate) although the melt temperature was higher for the maximum rate samples, due to the increased shear rate with higher motor speed (rpm, revolutions per minute). The bubble stability at maximum output rate was determined by taking the bubble to the point where it would not stay seated in the air ring. At that point, the rate was reduced to where the

bubble was resealed (maximum output rate) in the air ring. The cooling on the bubble was adjusted by using the air ring and maintaining the bubble. This process determined the maximum output rate while maintaining bubble stability.

Elmendorf tear testing in both the machine direction (MD) and cross direction (CD) was measured by ASTM D1922, type B. Dart A testing was performed via ASTM D1709. The puncture test was performed using a modified ASTM D 5748 with a 0.5" diameter stainless steel probe. Total haze was measured according to ASTM D 1003-07. The 2% Secant Modulus in the MD and CD was measured by ASTM D882-10. The MD and CD tensile strength was measured by ASTM D882-10. Shrink tension was measured according to the method described in [8].

Materials

The AGILITY™ Performance LDPE resins discussed in this paper are listed in Table 1 along with their film applications, melt index, density, product additives, and extrusion technology used to convert the resin into a film. Those used for high throughput or high bubble stability are listed first in the table and range in melt index from 0.18 MI to 1.85 MI with a relatively constant density of 0.920 – 0.921 g/cc. One of these grades, AGILITY™ 1200, is a newly introduced grade that will be highlighted. AGILITY™ 1200 is an alternative grade to AGILITY™ 1000, offering a higher melt index and ease of processing for a wider range of converters and improvements over standard 0.25 MI LDPE resins. As can be seen from Table 1, these resins are used as blend components in application areas of agricultural, lamination, shrink, and stretch films. Other resins are used in the areas of high performance collation shrink (AGILITY™ 2001), extrusion coating and foams (AGILITY™ EC 7000, AGILITY™ EC 7200), and high speed extrusion coating (AGILITY™ EC 7080). AGILITY™ 1021 is also used in foam applications.

Results and Discussion

Resin Characterization

The melt strength of AGILITY™ 1200 and a standard fractional melt index LDPE (0.25MI) is shown in Figure 1. As can be seen, the melt index alone is not the sole correlating factor for the melt strength since two samples of the same melt index of 0.25 MI have over 6 cN or a 33% difference in melt strength.

Figure 2 shows the melt viscosity behavior at 190 °C of the same resins shown in Figure 1. Although the AGILITY™ 1200 had the highest melt strength, due to its higher melt index it has a lower viscosity throughout the frequency or shear rate range. It is expected that this lower viscosity will result in improved processability.

Figure 3 shows the melt strength of these same resins when blended at different levels with a standard LLDPE, DOWLEX™ 2045G. All melt strength results were measured on the films. This plot shows the advantage of the LDPE's, in that they dramatically improve the melt strength of the LLDPE, which is measured at approximately 3.5 cN. At 10% LDPE, the melt strength of the blend increases to approximately 7-9 cN, at 20% LDPE to 12 – 13 cN, and at 50% LDPE to 23 – 27 cN, which is synergistically even greater than that seen for the 100% LDPE in the range of 19 – 23 cN [4,5,11]. From the melt strength results, the AGILITY™ 1200 shows distinct advantages at 50% LDPE and higher, and also shows good performance in the LLDPE-rich regime. This improved melt strength is one property that is known to correlate with improved bubble stability [9-10].

Blown Film Results:

DOWLEX™ 2045G / AGILITY™ 1200

Figure 4 shows the blown film output of DOWLEX™ 2045G, and this LLDPE with 20% of a standard 0.25 MI LDPE and 20% of AGILITY™ 1200. For the standard 0.25 MI LDPE at 20% LDPE, the output increases by 18% over the LLDPE. For the AGILITY™ 1200 at 20% LDPE, the blown film output increases dramatically to 57%. These results generally correlate with the differences seen in melt strength of these resins shown in Figure 1.

Figure 5 shows the screen pressure of these two blends with LDPE at 20% LDPE when processed into blown film, and the measured screen pressure during extrusion. The AGILITY™ 1200 is shown to process easier, with reduced pressures. There is a 13% reduction in screen pressure at 20% LDPE and an 8% reduction in screen pressure at 50% LDPE.

Figure 6 shows the dart of results of these two LDPE in LLDPE at 20% LDPE and 50% LDPE. These results are essentially the same for both LDPEs. Figure 7 shows the MD tear results. Again, similar to Figure 6, the MD tear results are essentially similar whether a standard 0.25 MI LDPE or AGILITY™ 1200 is used.

Figure 8 shows the haze as a function of LDPE for AGILITY™ 1200 and a standard 0.25 MI LDPE. Optics are very similar up to 20% LDPE. At a much higher % of LDPE at 50%, the higher melt strength AGILITY™ 1200 does have reduced optics.

Figure 9 shows the MD shrink tension as a function of % LDPE for these two resins. Both resins have similar shrink tension and both can be used in shrink films. They are especially recommended for the core of shrink structures, where optics are not critical.

INNATE™ LLDPE / AGILITY™ LDPE

Another set of examples illustrating the use of AGILITY™ LDPE resins paired with INNATE™ LLDPE resins are discussed in this section. These high performance blend partners give a superior balance of processability and abuse performance.

Figure 10 shows spider plots at 10% LDPE and 20% LDPE utilizing three of the AGILITY™ LDPE resins shown in Table 1 at 10% LDPE and 20% LDPE in INNATE ST50. At 10% loading, the AGILITY™ 1200 shows the best balance of properties. At 20% loading, the AGILITY™ 1200 shows the best abuse-output balance, and at 20% loading, the AGILITY™ 2001 shows the best abuse-optics balance.

Figure 11 shows the dart vs. LDPE type and percentage in INNATE™ ST50. These results show the ability to use less AGILITY™ LDPE (10%) to maintain output and provide higher abuse performance. Specifically over 60% improved dart is shown as LDPE content is reduced from 20% to 10%.

Figure 12 shows the MD tear vs. LDPE type and percentage in INNATE™ ST50. Over 20% improved abuse performance in MD tear is shown when LDPE content is reduced from 20% to 10% while maintaining high output with AGILITY™ LDPE.

Foam and Extrusion Coating

As mentioned, aside from films, two other applications in which these high performance LDPE resins are used are foams and extrusion coating. In particular, as seen from Table 1, both AGILITY™ 1021 and AGILITY™ EC 7000 are used in foams as discussed further in [7], while AGILITY™ EC 7000 (along with AGILITY™ EC 7200 and AGILITY™ EC 7080) are also used in extrusion coating as discussed further in [6].

Conclusions

Blends of LLDPE (linear low density polyethylene) and LDPE (low density polyethylene) are used in many film applications. This paper shows how several high performance LDPE resins can be used as a blending component in particular to increase output or throughput on blown film lines. These resins have melt indexes in the range of 0.18 – 1.85 MI resulting in a range of melt strengths from 8 – 22 cN. These high melt strengths for a given melt index as well as synergies or further improvements in melt strength upon blending with LLDPE result in high output and high shrink resins. In addition, these high performance LDPEs are advantageous for applications such as silage/agricultural films, heavy duty shipping sacks, frozen foods, lamination films, and shrink films. Aside from being used in blown films to increase output, some of these LDPE resins are also

targeted at shrink films, providing a good combination of shrink and optics, as well as foams, and extrusion coating among other applications.

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Table 1: LDPE resins discussed.

Commercial Product	Film Applications	Melt Index (g/10 min, 190 °C)	Density (g/cm ³)	Product Additives	Extrusion Technology
AGILITY™1000 Performance LDPE	Agricultural, lamination, shrink	0.18	0.920	None	Blown Films
AGILITY™ 1200 Performance LDPE	Agricultural lamination, shrink	0.25	0.919	None	Blown Films
AGILITY™1001 Performance LDPE	Stretch films for logistics packaging	0.65	0.920	None	Blown Films
AGILITY™1002 Performance LDPE	Food packaging and lamination films	0.65	0.921	AB	Blown Films
AGILITY™ 1021 Performance LDPE	Protective foams, food packaging and lamination films	1.85	0.920	None	Blown and Cast Films
AGILITY™1022 Performance LDPE	Food storage bags	1.85	0.921	S/AB	Blown and Cast Films
AGILITY™ 2001 Performance LDPE	High clarity retail collation shrink film	0.4	0.924	None	Blown Films
AGILITY™ EC7000 Performance LDPE	Board laminates, food sachets, pouches, release liners for labels, imaging paper, medium to high density foams for protective packaging	3.9	0.919	None	Extrusion Coating, Lamination Polyolefin Foams
AGILITY™ EC 7200 Performance LDPE	Paper & board coating & lamination for liquid board laminates and pouches, very low density foams for protective packaging	1.5	0.918	None	Extrusion Coating, Lamination Polyolefin Foams
AGILITY™ EC 7080 Performance LDPE	Very high speed / lights weights for extrusion coating & lamination	8.0	0.918	None	Extrusion Coating, Lamination

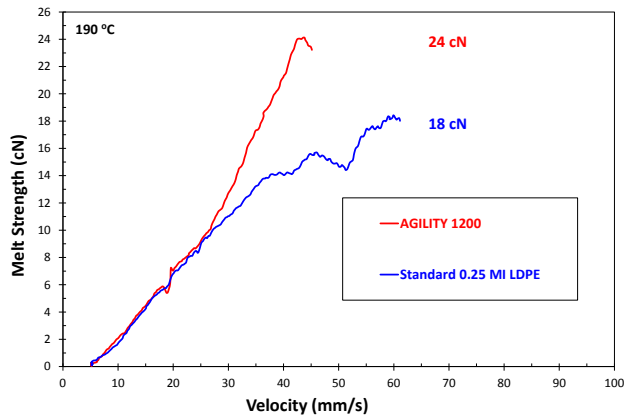


Figure 1. Melt strength of AGILITY™ 1200 and a standard 0.25 MI LDPE.

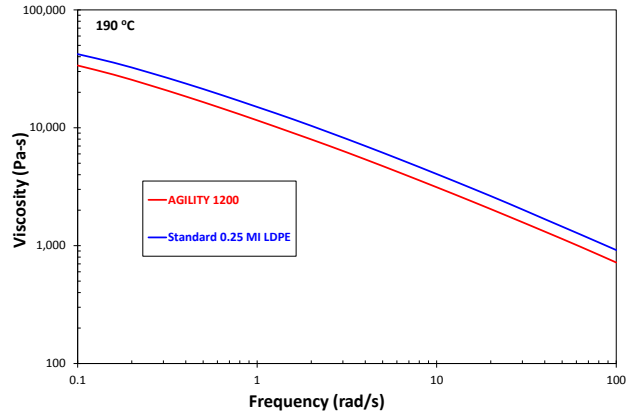


Figure 2: Melt viscosity of AGILITY™ 1200 and a standard 0.25 MI LDPE.

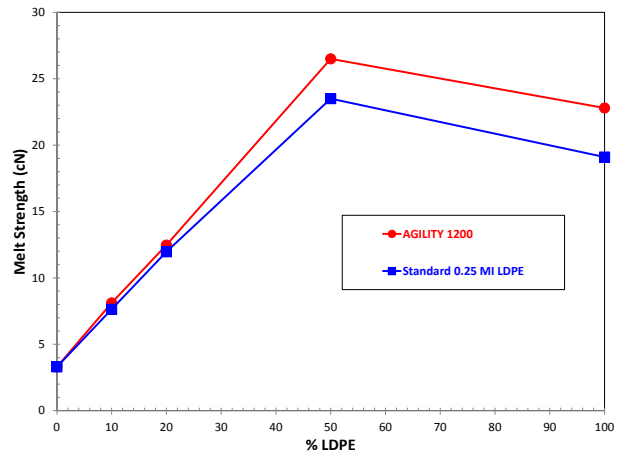


Figure 3: Melt strength of LLDPE/LDPE blends.

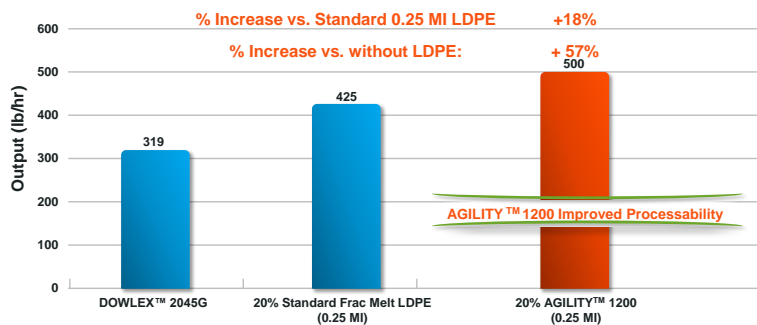


Figure 4. Blown film output of DOWLEX™ 2045G, and with 20% of a standard fractional MI LDPE (0.25 MI), and with 20% of AGILITY™ 1200 (0.25 MI). 2 mil films.

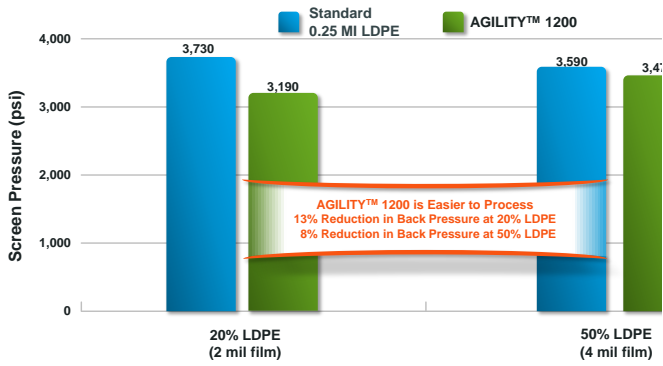


Figure 5. Screen pressure reduction during blown film extrusion at 2 mil (20% LDPE) and 4 mil (50% LDPE) of a standard 0.25 MI LDPE and AGILITY™ 1200 LDPE.

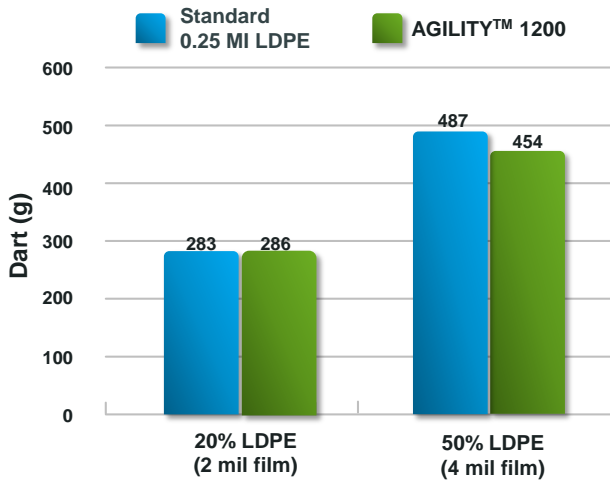


Figure 6. Dart at 2 mil (20% LDPE) and 4 mil (50% LDPE) of a standard 0.25 MI LDPE and AGILITY™ 1200.

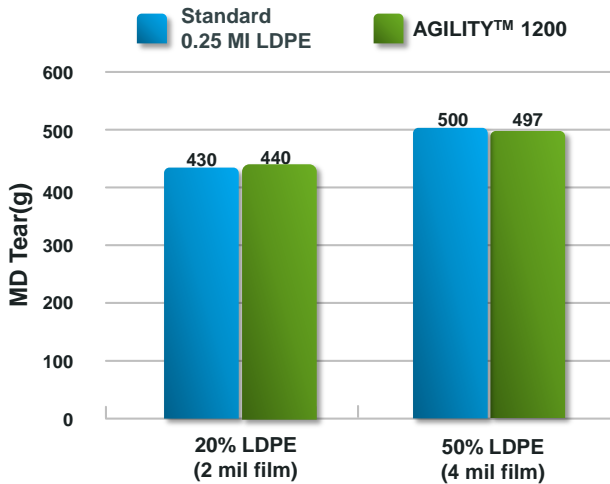


Figure 7. MD tear at 2 mil (20% LDPE) and 4 mil (50% LDPE) of a standard 0.25 MI LDPE and AGILITY™ 1200.

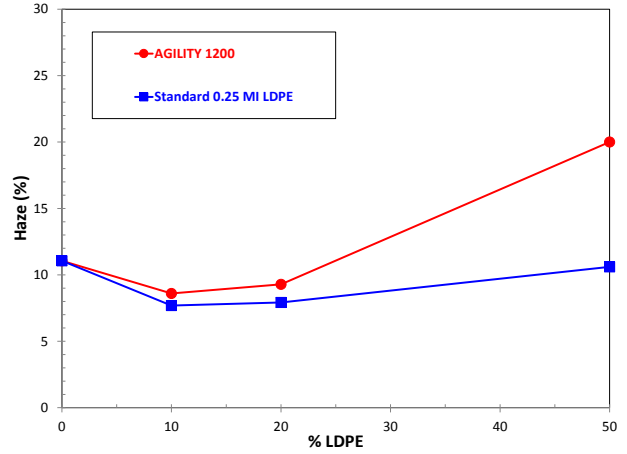


Figure 8: Haze vs. LDPE. 2 mil films.

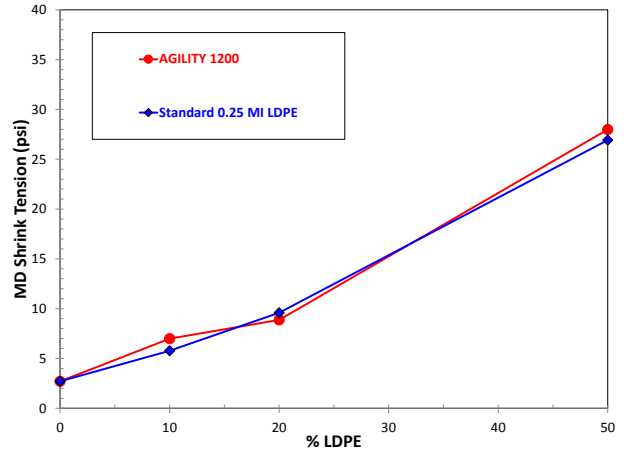


Figure 9: MD shrink tension vs. LDPE. 2 mil films.

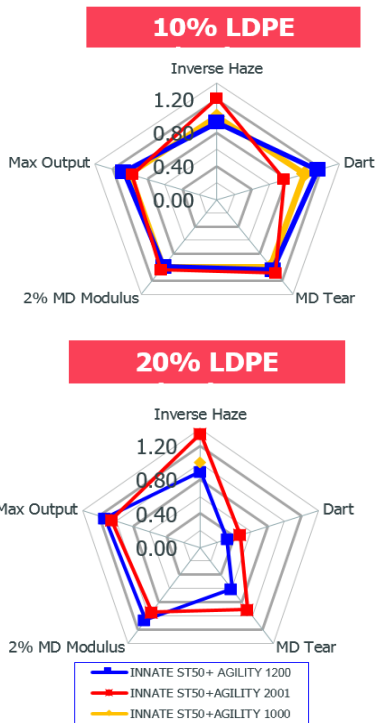


Figure 10: Film and processing properties of INNATE™/AGILITY™ blends at 10% and 20% LDPE. 1 mil films.

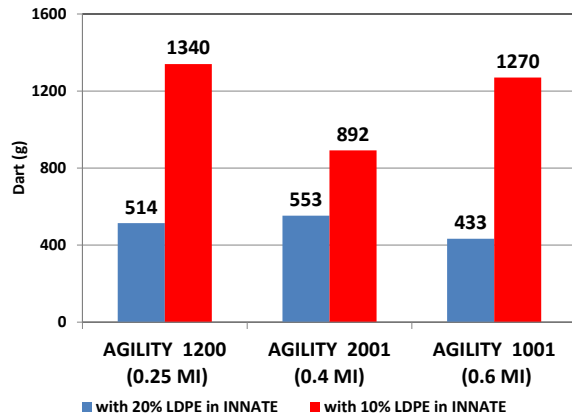


Figure 11: Dart vs. LDPE type and % (1 mil films).

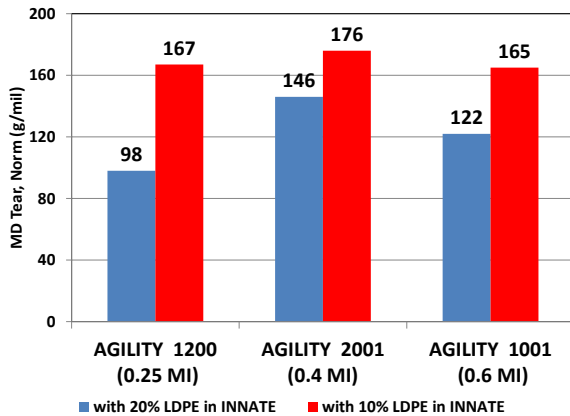


Figure 12: MD tear vs. LDPE type and % (1 mil films).