DOWLEX™ GM LLDPE AND AGILITY™ PERFORMANCE LDPE FOR GREATER MEANS IN INDUSTRIAL AND CONSUMER PACKAGING APPLICATIONS

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Abstract
Powered by a new leading-edge catalyst technology, DOWLEX™ GM Linear Low Density Polyethylene Resins (LLDPE) offer Greater Means for customers to achieve differentiated performance and new growth opportunities for a range of demanding film applications. Applications discussed are those primarily in the industrial and consumer packaging applications of consumer liners, collation shrink film, heavy duty shipping sacks, and cast and blown stretch film.

Introduction
LLDPE resins are produced by the copolymerization of ethylene and longer α-olefins or comonomers such as butene, hexene, and octene [1]. Several different processes are used to produce LLDPE resins including the solution and gas phase processes. Additionally, depending on the catalyst and process conditions, a wide range of products can be produced with a diverse set of properties for a host of applications. This paper will focus on a new family of LLDPE resins designed with new leading-edge catalyst technology. DOWLEX™ GM LLDPE offers Greater Means for customers to achieve differentiated performance and new growth opportunities for a range of demanding film applications. Applications discussed are those primarily in the industrial and consumer packaging application space of consumer liners, collation shrink film, heavy duty shipping sacks, and cast and blown stretch film.

Experimental
Resin Testing
Melt index (MI or I₂) 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.

Blown Film Testing
Elmendorf tear 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 and gloss by ASTM D2457. The shrink force was measured according to the method described in [2].

Stretch Film Testing
Two types of stretch tests were performed. One involves the use of a Highlight Industries tester, which consists of a test stand which simulates the stretching of the film in the stretch wrapper. The most important measurement obtained is the value of ultimate stretch, which indicates the maximum level of stretch that could be applied during pallet wrapping. The Highlight tester was also used to measure Highlight Retention force, which is obtained by stretching the film a specific percentage pre-stretch (250%) one time around the tester’s metal drum. The drum has an opening through which a force probe is extended to measure the retention force the film applies on the tip of the probe.

A second set of tests utilizes a Lantech stretch wrapper which has been outfitted in-house with a 44-inch by 35-inch by 60-inch tall metal frame to simulate pallet wrapping. Two tests were performed with this set-up to capture the toughness or abuse properties of the film. First, on-pallet puncture was measured by wrapping the film at a specific pre-stretch (250%) around the frame with a protruding metal probe (4-inch by 4-inch square base) placed at a specified distance (12 inch). The only variable parameter is the force-to-load or F2 force, which is the force applied to the film after pre-stretching in order to avoid relaxation on the pallet. The film was first wrapped three times with a low force of 7 lbs. If the film was not punctured by the probe, the test was repeated at an increased F2 force at increments of 0.5 lbs until failure. To decisively determine the failure force, the test was performed 6 times at the F2 force which caused puncture and the test was considered completed if the film broke more than 3 out of 6 times. If not, the force was increased 0.5 lbs and the test was repeated. The failing F2 force represents the film’s on-pallet puncture (average from three replicates).

The second toughness test is on-pallet tear, which measures the resistance for a tear to initiate and propagate through the entire film web in the cross or transverse direction after the film is punctured. The method involves the wrapping of the film onto the Lantech frame with a protruding metal probe fixed at 5 inches with a sharp razor blade with its blunt side facing the film. This set-up guarantees the film is always punctured. Similarly as with on-pallet puncture,
the pre-stretch levels used were 250%. The F2 force was increased from an initial low value of 7 lbs in increments of 0.5 lbs. An on-pallet tear value was recorded as the F2 force that results in the initial puncture propagating through the entire width of the film causing its failure. A similar pass/fail approach was taken as for on-pallet puncture.

**Consumer Liner Fabrication**

Monolayer blown films were produced at 25.4 micron (1 mil) thick, with a blow up ratio (BUR) of 2.5, and an output rate of 250 lb/hr. 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. All films contained 100% LLDPE.

**Collation Shrink Film Fabrication**

Multilayer blown films were produced at 51 micron (2.0 mil) total thickness, with a blow up ratio (BUR) of 2.5 and an output rate of 310 lb/hr on an Alpine 7-Layer Blown Film line. A 25.0 cm (9.84 inch) diameter die with a 2.0 mm (78.7 mil) die gap was used along with external cooling by an air ring and internal bubble cooling. All films contained LLDPE, LDPE (Low Density Polyethylene), and MDPE (Medium Density Polyethylene).

**Heavy Duty Shipping Sack Fabrication**

Monolayer blown films were produced at 114 micron (4.5 mil) thick, with a blow up ratio (BUR) of 2.0, and an output rate of 250 lb/hr. 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. All films contained 10% LDPE.

The maximum output rate for a given sample was determined by increasing the output rate (in this case at a BUR of 2.5) to the point where bubble stability was the limiting factor. The same extruder profile was maintained at 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 reseated (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.

**Cast Stretch Film Fabrication**

Cast films were made on a 5-layer Egan-Davis Standard cast line. Cast stretch films are typically 3-5 layer structures containing cling and release outer layers around 1-3 core layers. However, in this case the core resin was used in all 5 layers at 100% to effectively create monolayer films of each core resin of interest. This was done so as to directly compare the core resin performance as the cling and release materials may affect the overall stretch behavior. Films were cast at gauge of 0.8 mil, which represents the typical upper limit of commodity film. Fabrication conditions were melt temperatures between 525–560 °F (274–293 °C), extruder speeds between 20–60 rpm, output rates of 370–440 lbs/hr, and extruder pressures of 1,720–2,440 psi. All films contained 100% LLDPE.

**Materials**

The primary resins discussed in this paper are shown in Table 1. The first resin, DOWLEX™ GM 8070G, 0.9 MI and 0.917 g/cm³ density, is designed for collation shrink and heavy duty shipping sack applications. Film property advantages are improved optics, package integrity, abuse resistance, and sealing performance in blends with AGILITY™ Performance LDPE. DOWLEX™ GM 8071G, 0.9 MI and 0.920 g/cm³ density, is formulated with slip and antiblock for liners applications. Film property advantages are improved dart and puncture, and consistent processing at high extrusion and converting rates. DOWLEX™ GM 8480F, 3.0 MI and 0.917 g/cm³ density, is designed for cast stretch and artificial turf applications with improved load containment and on-pallet puncture.

The utilization of these resins in applications of liners, collation shrink, heavy duty shipping sacks, and cast and blown stretch film will be discussed in the following sections.

**Results and Discussion**

Powered by a new leading-edge catalyst technology, DOWLEX™ GM LLDPE Resins offer Greater Means for customers to achieve differentiated performance and new growth opportunities for a range of demanding film applications. From processing consistencies and efficiencies to abuse resistance, DOWLEX™ GM resins offer strong performance advantages for consumer liners, collation shrink films, heavy duty shipping sacks, and cast and blown stretch film. Examples of these four types of films are shown in Figure 1.

**Consumer Liners**

DOWLEX™ GM LLDPE Resins are designed to address specific requirements for consumer liners, including ease and consistency of processing as well as a unique combination of dart impact and puncture resistance properties. As shown in Figures 2-3, DOWLEX™ GM 8071G demonstrates comparable or better performance in dart, puncture, and tear comparisons. For film producers serving the consumer liners market, DOWLEX™ GM LLDPE Resins enable the production of films with an improved balance of mechanical properties, while maintaining the recognized consistency and ease of processing for which
DOWLEX™ Polyethylene has long been known. Figure 4 shows the ease of processing of DOWLEX™ GM resins in comparison to DOWLEX™ Polyethylene in terms of back pressure and melt temperature measured while producing blown films. Both the back pressure and temperature are essentially the same between both resins.

Collation Shrink Film
For film producers serving the retail collation shrink market with multilayer blown film, DOWLEX™ GM LLDPE enables the production of coextruded films with metalloocene (m) LLDPE-like mechanical and optical properties plus the recognized ease of processing and consistency of DOWLEX™ Polyethylene Resins. DOWLEX™ GM resins offer customers Greater Means to optimize their structures for excellent optics, mechanical properties, and shrink tunnel and package performance.

When paired with AGILITY™ 2001 [3,4] in the skin layers (Figure 5) of a multilayer coextruded retail collation shrink structure, DOWLEX™ GM 8070G delivers very low haze levels and high gloss (Table 2). Furthermore, DOWLEX™ GM 8070G also offers robust performance with the flexibility to be used with a wide range of LDPE resins, while still producing excellent optics.

DOWLEX™ GM resins are designed to address specific requirements for coextruded films in collation shrink applications. DOWLEX™ GM LLDPE Resins deliver:

- Consistent film optimized for shrink tunnel performance,
- High optical properties (clarity, low haze, high gloss),
- Exceptional shrink tunnel performance and packaging integrity.

The introduction of DOWLEX™ GM 8070G together with the proven performance of DOW™ LDPE and AGILITY™ Performance LDPE resins, as well as DOW™ MDPE resins, creates a comprehensive resin portfolio to suit all collation shrink needs – crystal clear optics, excellent shrink, and tight holding force. Furthermore, not only do these products offer answers for retail collation shrink films where sparkling optics are a critical requirement, but they can also be used in logistical monolayer shrink and provide excellent shrink tunnel and package performance.

Heavy Duty Shipping Sack (HDSS) Film
For film producers serving the HDSS market using monolayer blown film lines, DOWLEX™ GM LLDPE Resins enable the production of films with unprecedented balanced toughness (Figure 6) and the recognized ease of processing and consistency of DOWLEX™ Polyethylene Resins (Figure 7). With mLLDPE-like mechanical properties, DOWLEX™ GM blown films are designed to address specific requirements in monolayer blown film for HDSS. DOWLEX™ GM LLDPE Resins offer:

- Exceptional puncture and tear resistance performance,
- Lower melt temperature and back pressure than mLLDPE,
- Broad heat sealing window for faster packaging speeds.

For applications such as HDSS, DOWLEX™ GM resins’ unprecedented property balance translates into benefits such as puncture resistance for packaging aggressive contents like wood chips, landscape rocks, mulch, and more, as well as downgauging potential for films used in numerous end-use applications. With lower seal initiation temperatures (Figure 8), DOWLEX™ GM resins benefit brand owners and co-packers with a broader seal window on their form fill seal (FFS) lines and increased FFS line speeds for greater productivity.

Cast and Blown Stretch Film
For stretch film producers seeking strong holding force and greater elongation and mechanical properties, DOWLEX™ GM LLDPE Resins offer numerous advantages for stretch film applications. DOWLEX™ GM resins can help optimize structures for improved mechanical properties and high load containment. They deliver high ultimate stretch with improved on-pallet tear, on-pallet puncture, and load retention resulting in good unit load stability during transport (Figure 9). Whether used in cast or blown film stretch film applications, DOWLEX™ GM resins are designed to address specific requirements, including:

- Low gel product for consistent film performance and integrity,
- Greater stretchability for improved ultimate performance and less film per unit load,
- Strong holding force for improved load stability,
- Puncture and tear resistance to maintain load integrity,
- Potential for downgauging without sacrificing performance,
- Low haze and high gloss when optical properties are desired.

In summary, DOWLEX™ GM LLDPE Resins enable the production of coextruded stretch films with robust mechanical properties – all with the recognized ease of processing and consistency expected of DOWLEX™.

Conclusions
Powered by a new leading-edge catalyst technology, DOWLEX™ GM LLDPE Resins offer Greater Means for customers to achieve differentiated performance and new growth opportunities for a range of demanding film applications. Applications discussed are those primarily in the industrial and consumer packaging application space of consumer liners, collation shrink film, heavy duty shipping sack film, and cast and blown stretch film.

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References

Tables and Figures

Table 1: Resins discussed.

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<tr>
<th>Name</th>
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<th>Film Advantages</th>
<th>Applications</th>
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<td>DOWLEX™</td>
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<td>0.917</td>
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<td>Low haze and high gloss, improved dart, tear, and puncture, improved package integrity, improved sealing performance</td>
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<td>GM 8070G</td>
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<td>DOWLEX™</td>
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<td>0.920</td>
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<td>Improved dart and puncture, Consistent processing at high extrusion and converting rates</td>
<td>Liners</td>
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<td>DOWLEX™</td>
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<td>0.917</td>
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<td>Improved load containment and on pallet puncture</td>
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Table 2: High optics retail collation shrink film results.

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<th>Three-layer film, 2.0 mil</th>
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<th>Competitive mLLDPE + AGILITY™ 2001 in skins</th>
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<td>Tear CD (g)</td>
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Figure 1: Examples applications areas.

Figure 2: Dart impact and puncture of liner resins.

Figure 3: MD and CD tear of liner resins.

Figure 4: Ease of processing comparison of liner resins.

Figure 5: Collation shrink structure.
Figure 6: Toughness properties in monolayer films.

Figure 7: Processing behavior of film resins.

Figure 8: Broad seal window for FFS lines.

Figure 9: Cast stretch film properties.