

Blown Films Using RAPREX[®] R-300

RAPREX[®] R-300 is a linear low density polyethylene (LLDPE) based resin that exhibits an excellent balance of melt processability and physical properties because of its unique branched structure. It is a thermoplastic material and is fully recyclable. Because of its fractional melt index, high melt strength and improved film properties, RAPREX[®] R-300 is used in film applications where enhanced processability is required. It contains a robust stabilization package providing good melt stability as well as long-term thermal stability.

Film Properties

As part of a proprietary process, Sterigenics uses its highly controlled, in-house radiation processing technology on a selected conventional LLDPE to create a branched material without sacrificing its crystallinity, which in part gives RAPREX[®] R-300 its desirable properties. No additional co-monomer is required to achieve this.

Table 1 illustrates the blown film properties in comparison with the un-irradiated conventional LLDPE used to produce RAPREX[®] R-300 for 1 mil and 3 mil films.

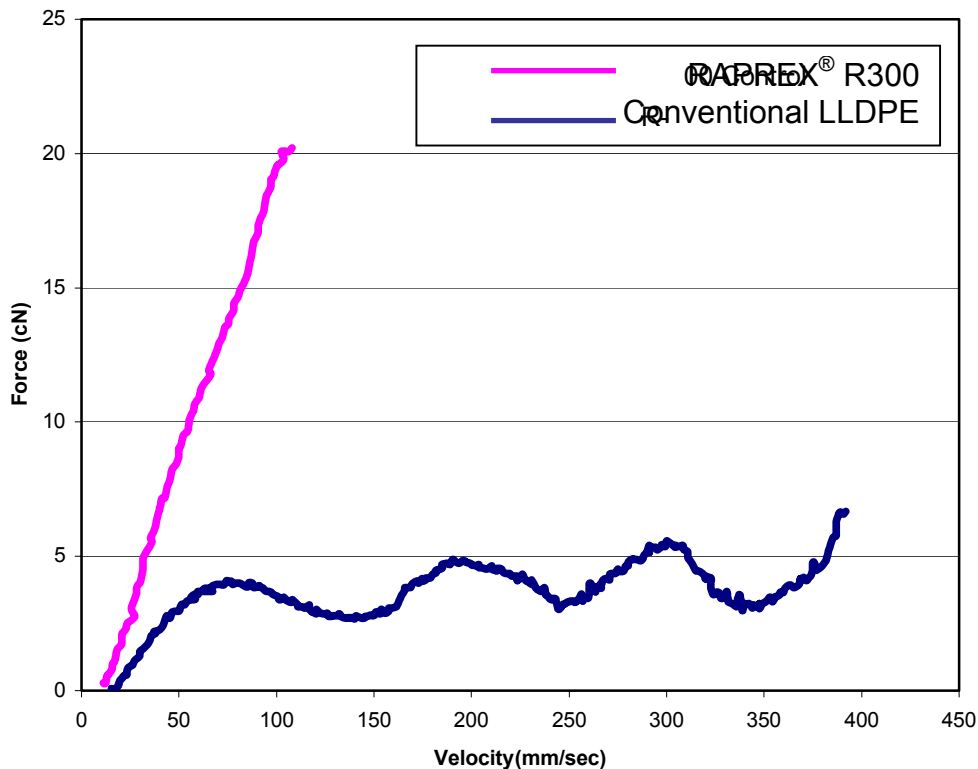
Table 1

Property	Units	1 mil Film		3 mil Film	
		Conventional LLDPE	RAPREX R-300	Conventional LLDPE	RAPREX R-300
Melt Flow Index, 190° C, 2.16 kg	g/10 min	1.0	0.25	1.0	0.25
Melt Flow Index, 190° C, 10 kg	g/10 min	7.7	3.5	7.7	3.5
Film Thickness	µm	25	25	76	76
Tensile Strength at Yield					
MD	MPa	9.8	17.7	11.1	14.3
TD	MPa	8.2	14.1	11.9	12.9
Tensile Strength a Break					
MD	MPa	35.4	50.8	28.7	30.8
TD	MPa	27.9	46.0	27.6	32.4
Elongation at Break					
MD	%	600	750	780	720
TD	%	710	790	770	810
Tear Strength					
MD	g/micron	7.0	12.2	11.1	10.8
TD	g/micron	7.7	13.4	10.1	11.6
Puncture Resistance	g	481	921	2,134	2,588

Blown Film Processability

Conventional LLDPE, while having more desirable physical properties compared to low density polyethylene (LDPE), exhibits poor melt processability because of its linear structure and lack of melt strength. When stress is applied to the polymer melt during blown film production, conventional LLDPE exhibits shear thinning causing poor gauge uniformity and bubble instability. Because of its branched structure, RAPREX[®] R-300 exhibits strain hardening, or an increase in extensional viscosity with the increase in drawing velocity. Figure 1 shows these differences with data taken using a Goettfort Rheotens extensional rheometer. The polymer melt is captured from the capillary die and pulled at an increasing rate. Tension on the extrudate is measured and reported in centi-newtons. Since melt tension and extensibility are measured simultaneously, a comprehensive view of the polymer's melt behavior is developed. The comparison in Figure 1 shows that RAPREX[®] R-300's superior melt strength which should give much better gauge uniformity and bubble stability.

Figure 1



As stress is applied to the conventional LLDPE, the polymer chains begin to slip over one another at about 70mm/second, resulting in a thick-thinning or resonating behavior while the RAPREX[®] R-300 extensional viscosity continues to increase dramatically. The relatively straight line represents the material's ability to *deform uniformly*.

Balancing Film Properties and Processability

In packaging applications where the film is heat sealed to form a bag or a pouch, blown film converters strive to achieve a **balance** between heat seal strength and the film strength by combining the desirable characteristics of different resins through blending. The blend must also exhibit suitable processability on their blown film equipment (ease of start-up, bubble stability, gauge uniformity). Assuming a minimum seal strength for the application, the Seal Strength Factor is expressed as a ratio between Seal Strength and the Tensile Strength of the film.

Figure 2

$$\frac{\text{Seal Strength (MPa)}}{\text{Tensile Strength of Film (MPa)}} = \text{Seal Strength Factor}$$

Expressed as a Ratio:
1 is ideal, 0.8 is typical

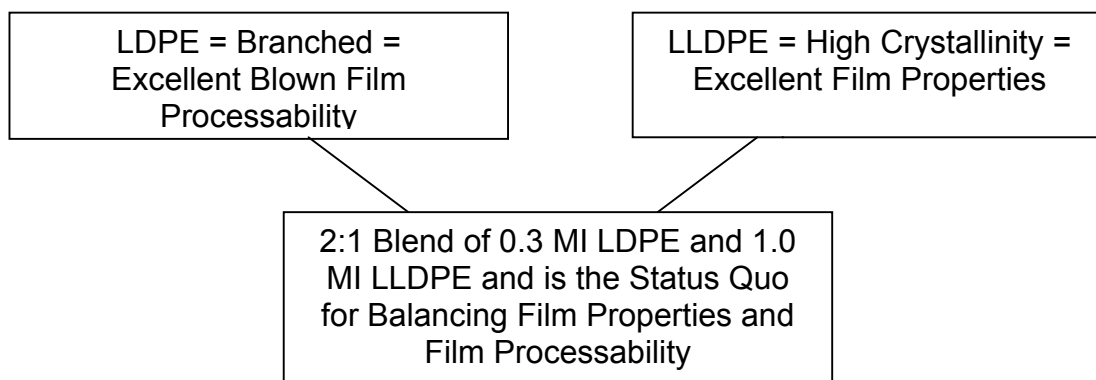
When the Seal Strength Factor has a value greater than one (where the seal strength is higher than the tensile strength of the film), the film thickness is commonly increased to achieve the balance. However, this is not an economically desirable solution. Ideally, having a resin that produces a film with a higher tensile strength is a better solution.

From a processability point of view, LDPE offers excellent bubble stability because of its high melt strength which is attributed to its branched structure. There are a number of LDPE “film” grades (low gels & low contamination) available in the market place. The most desirable ones, from a property and processability point of view, have fractional Melt Indices. LDPE, however, inherently has low film tensile strength making the film weaker than the seal (high seal strength factor).

On the other hand, LLDPE grades have excellent film properties with typical film tensile strength of around 28MPa. But as mentioned earlier, they have poor blown film processability because of their low melt strength.

Processors commonly use blends of LDPE and LLDPE at a 2:1 ratio to obtain the balance of properties and processability, but with tradeoffs. RAPREX[®] R-300 reduces the tradeoffs by offering properties superior to LLDPE while providing the good processability of LDPE.

Figure 3



In the 2:1 LDPE to LLDPE blend shown above, a lower LLDPE melt index (MI) is desired as it would be more rheologically compatible with the LDPE. To make very low MI LLDPE in the polymerization process, both catalyst yield and productivity decrease, negatively affecting economics. Further, it is difficult to achieve lower MI without reducing crystallinity because lower MI usually comes with a higher concentration of comonomer, so film properties would be sacrificed.

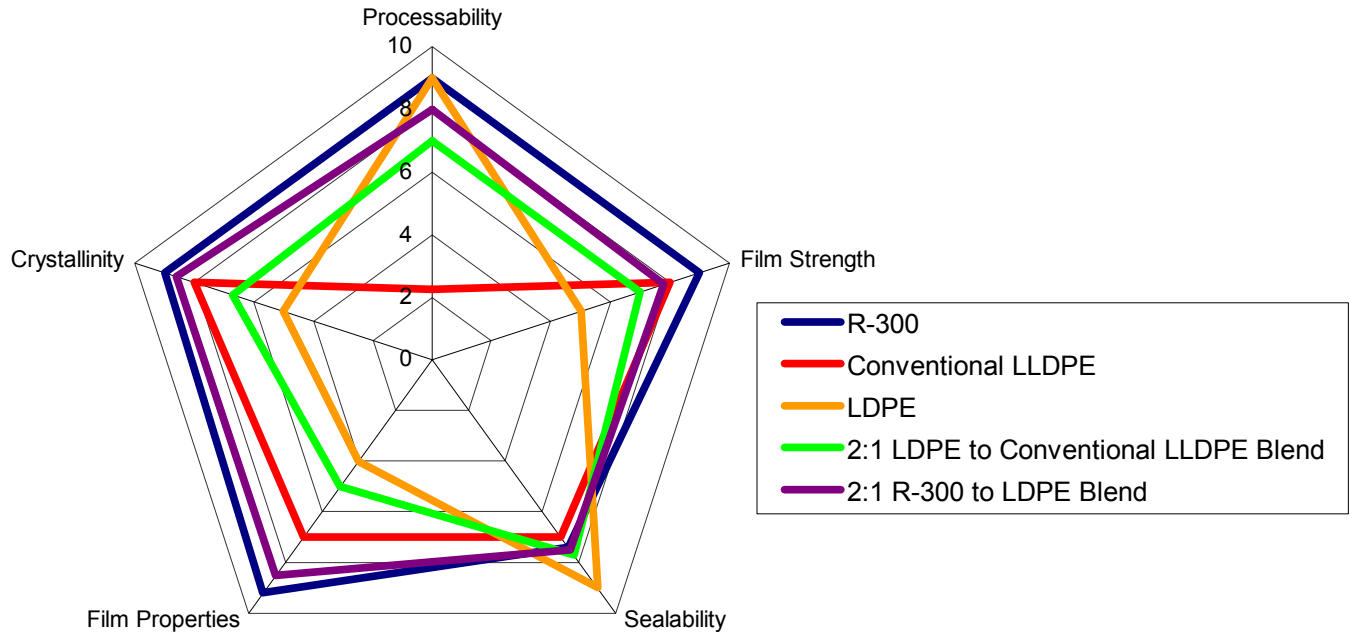
In the RAPREX[®] process, Sterigenics' Advanced Applications produces a highly branched LLDPE based polymer with a MI of 0.25 without changing crystallinity. This makes RAPREX[®] R-300 an ideal blend component for greatly expanding the film property envelope while maintaining excellent blown film processability. Table 2 suggests that RAPREX[®] R-300 can be used in a 1:2 LDPE / R-300 blend with a 0.35 MI to achieve improved processability, while having an immediate improvement in film properties which can give the converter the option to downgauge.

Table 2

Blended Amount	LDPE	100%	0	0	67%	33%
	LLDPE	0	100%	0	33%	0
	RAPREX[®] R-300	0	0	100%	0	67%
Film Strength (MPa)		13	28	>28	20	26
MI, 190° C, 2.16 kg		0.3	1	0.24	0.6	0.35
Seal Strength		Excellent	Good	Good	Excellent	Excellent
Processability		Excellent	Poor	Excellent	Good	Excellent
Film Properties (puncture resistance and tear strength)		Fair	Excellent	Excellent	Good	Excellent

Figure 4 graphically illustrates a qualitative comparison of the strengths and weaknesses of blends and individual components looking at the five main characteristics of blown films.

Figure 4



In addition to thin gauge films for sealed bags and pouches, blown film converters producing heavy duty and agricultural films, roofing and geomembranes and other challenging markets will benefit from the unique physical and melt properties of RAPREX® R-300.

To learn more about how the improved processability and properties of RAPREX[®] R-300 will help you achieve improved bubble stability, improved gauge uniformity, improved film properties and downgaugability, contact:

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