THE USE OF ENCAPSULATION DIES FOR PROCESSING LINEAR POLYOLEFIN RESINS IN EXTRUSION COATING

Kelly R. Frey, Chevron Phillips Chemical Company
Gary D. Jerdee, Chevron Phillips Chemical Company
Clint D. Cleaver, Chevron Phillips Chemical Company

As presented at SPE's ANTEC 2001 Conference

Abstract

Traditionally highly branched autoclave low-density polyethylene resins have been ideal for extrusion coating due to their inherent melt strength characteristics. Encapsulation coating dies have been used with other polymers to overcome melt strength deficiencies and improve processing. This study evaluates the effectiveness of encapsulation with linear materials such as high-density polyethylene and linear low-density polyethylene.

Introduction

Extrusion coating is performed using flat dies of varying widths and designs. Due to the inherent nature of flat dies having two unsupported edges, melt strength is a critical attribute for extrusion coating resins. The predominate resins employed are high-pressure autoclave low-density polyethylene resins and copolymers. These materials exhibit minimal neck-in while offering excellent draw properties and web stability for uniform coatings. Today it is common to see coextrusion employed where dissimilar resins are coextruded adjacent to each other in the die. In coextrusion, the high melt strength resin will often "carry" low melt strength resins. Historically, in a flat die, resins with low melt strength such as LLDPE and HDPE have been difficult to extrude. Extruded as a monolayer, these resins exhibit severe instability due to the lack of long chain branching. The instability manifests itself with severe edge instability and draw resonance. Draw resonance is the oscillation of the extrudate in the air gap. Blending high-pressure resins with the linear materials helps stabilize the extrudate and allows for a commercially viable process using a flat die. A method gaining acceptance is the use of encapsulation to stabilize melt curtains of heretofore difficult or impossible to run materials in flat dies. This paper will discuss the use of the encapsulation coating method to process HDPE and LLDPE polymers in extrusion coating.

Encapsulation Coating

Encapsulation coating is the use of a second extrudate positioned along the outer edge of a core material in a flat die (figure #1). The resin is extruded by a satellite extruder and is fed into the die via the feedblock or feedpipes. The encapsulating material travels to the end of the die and then flows laterally along an internal flowpassage or internal deckle toward the die center until it reaches the main manifold. At this point the encapsulating material meets the resin to be encapsulated which is die center fed. Both materials then flow down to the die lip.

A highly branched polymer such as high pressure LDPE has proven to be highly effective in stabilizing low melt strength resins. Traditional use of the encapsulation method is to reduce neck-in and stabilize polyester resins.

Encapsulation Experiment with Linear Materials

In order to evaluate the effectiveness of encapsulation on linear resins an experiment was designed, which evaluated the response of LLDPE and HDPE with and without encapsulation. Blends of these linear resins with high-pressure LDPE resins were also examined. It is well known that blending high-pressure LDPE resins with linear resins increases their stability and processability in flat dies. The purpose of evaluating the blends was to determine the effectiveness of the encapsulation to reduce neck-in and determine the minimum level of high-pressure material needed to stabilize the linear resins.

Four resins were used in this study. Two high pressure LDPE resins, one HDPE homopolymer and one LLDPE butene copolymer. A summary of these resins are shown in table 1. Further references to these materials will be labeled as LDPE A, LDPE B, HDPE C & LLDPE D. The purpose of this study was to measure the process parameters of these linear materials when using the encapsulation die design. Blends used in this study are shown in table #2.

The encapsulation materials used were high-pressure low-density polyethylene (LDPE A) & blue dye. Autoclave high-pressure low-density resins have long chain branching, providing excellent melt strength as illustrated by the edge stability and drawdown.

These highly branched LDPE materials are also noted for their broad molecular weight distributions, which provides characteristics such as low neck-in. The broad molecular weights distributions of LDPE A&B are illustrated in figure #2 and are compared to the molecular weight distribution of the linear materials. Trisec Light Scattering Overlays (figure #3) shows that the long chain branching contributes to the broad molecular weight of LDPE. Polymers that have broad molecular weight distributions combined with a high degree of long chain branching provide excellent processing characteristics. Good processabiliy is generally noted by low extruder motor loads and back pressures due to the lubrication and shear thinning that the low molecular weight materials and long chain branching provide (figure #4).

Both the HDPE homopolymer and the LLDPE butene copolymer reveal a narrower molecular weight distribution and less long chain branching than the LDPE's. As mentioned the broad molecular weight distribution and long chain branching characteristics provide specific properties that are needed to optimize processing using a flat die extrusion coater.

<u>Equipment</u>

This evaluation was conducted on a 4 ½ inch 24:1 Egan extrusion coating line with a 40-inch Cloeren encapsulation featured flat die and a 2 ½ inch Egan extruder ran at drool speeds to perform the encapsulation feature. Constant trial study parameters were temperatures (barrel zones & die), matte chill roll, and corona treatment for adhesion to the Kraft substrate. Details of these parameters are listed in tables #3&4.

<u>Measurable Variables</u>

The function of the extruder is to melt and deliver a homogeneous polymer with a uniform pressure drop and constant output to the die by the application of heat and shear energy. The die function is to form the polymer into a final shape before cooling. However these functions do not solely effect processability, other entities such as line speed and air gap effects processing as well. For example, line speed is inversely proportional to neck-in and time in the air gap is proportional to neck-in. A basic understanding of extrusion coating is required to ensure optimum processing conditions are utilized.

These linear materials were evaluated for their processing effectiveness using several measurable variables, which are listed in table #5. Line speeds were varied to measure processing characteristics such as neck-in and edge weave. Neck-in and edge weave were quantified using mechanical and visual observations. These observations were then related to the concentration of high-pressure LDPE resins used to blend with the HDPE homopolymer and the LLDPE butene copolymer. Processing and performance of these blend materials were also characterized by evaluating extruder motor amps and barrel pressures.

Results & Discussion

<u>Processability of Linear Materials</u>

As mentioned, low-density polyethylene resins are typically characterized as easy to process, usually yielding relatively low extruder back pressures, low extruder motor loads, and providing good pumping and energy efficiencies. This good processability is due to the fact that high-pressure autoclave LDPE resins generally have broad molecular weight distribution combined with high amounts of long chain branching

As expected, both extruder drive currents and back pressures increased proportionally with the concentration of linear materials in each blend (figures #5&6). Increases in back pressures and extruder drive current were greater for the LLDPE blends than the HDPE blends. LLDPE back pressure increases were as much as 200% over straight LDPE. Extruder drive currents increased by as much as 300% over straight LDPE. LDPE A / LLDPE blends processed slightly harder than LDPE B / LLDPE blends due to the fact that LDPE A has a higher overall molecular weight and lower melt index than LDPE B (5.1MI vs. 16.0MI).

<u>Neck-in & Edge Weave Performance with Encapsulation</u>

All three blends showed decreases in the amount of neck-in with an increase in line speed, even with encapsulation (figures #7-9). This relationship between line speed and neck-in is normal for extrusion coating. An increase in line speed will reduce the amount of time in the air gap, therefore reduces the amount of the time the material has to relax and neck-in. Neck-in also increased proportionally with the concentration of linear materials. Again this is a typical response as the addition of linear materials dilutes the amount of highly branched LDPE, reducing the overall melt strength of the blend. Neck-in values increases as much as 200% with the addition of LLDPE even with encapsulation. Increases in neck-in appear to be more predominant with the addition of LLDPE vs. HDPE. However neck-in readings could not be measured at 100% LLDPE due to excessive edge weave or edge instability.

Edge weave observations of all blends were made at a fixed line speed of 900fpm (figure #10). All blends demonstrated an increase in edge weave with an increase in linear materials, even with encapsulation. All blends were very stable with concentrations of linear material up to 40% and were relatively stable even at concentrations of 70% linear. The web became very unstable for the LDPE A blends at 90% linear and all blends were very unstable at 100% linear. 100% linear materials demonstrated very high degrees of edge weave and draw resonance.

Comparison – With & Without Encapsulation

To evaluate the effectiveness of encapsulation, processing comparisons were made with and without encapsulation. For this experiment, and to easily compare processing performance, acceptable product was defined as a web with neck-in less than 3.0" per side and edge weave less than +/-0.5" per side. However, acceptable can only be truly defined by the processor/converter and is application and process specific. The LLDPE A / HDPE blend produced product with acceptable neck-in and edge weave at concentrations of HDPE up to 55%, with and without encapsulation. Edge weave for this HDPE blend remained acceptable at concentrations up to 70% both with and without encapsulation (table #6). Encapsulation did showed a benefit, such as reductions in neck-in and edge weave, with the LDPE A / HDPE blend. However reductions in neck-in and edge weave due to encapsulation only prevailed at higher concentrations of linear materials, that is concentrations greater than 70% linear. Although improvements due to encapsulation were noted at these higher concentrations the product was defined as being unacceptable at these concentrations. Both of the LLDPE blends produced acceptable product at concentrations of linear materials up to 40% (tables #7&8). LLDPE blends showed only very minor improvements in neck-in and edge weave reduction due, to encapsulation, and again this only occurred at higher linear blend ratios where the product was defined as unacceptable.

Conclusions

The addition of linear materials to high-pressure autoclave LDPE produced a blend that is more difficult to process, particularly when blending LLDPE with LDPE. Extruder back pressures and motor loads increased proportionally with the addition of linear materials. Even with encapsulation, characteristics such as neck-in, edge weave, and draw resonance increased with the addition of linear materials to LDPE. Encapsulation significantly reduced neck-in and edge weave at higher concentrated HDPE blends, however at these higher concentrations edge weave and neck-in were defined as unacceptable. Encapsulation coating appeared to be ineffective in controlling neck-in and edge weave with LDPE/LLDPE blends.

Future Considerations

Although only limited success was demonstrated in this study, using encapsulation coating with blends of linear polyethylenes, further studies might show additional benefits of encapsulation coating. Further considerations may be to study the following items:

1. Effects of other high melt strength materials as an encapsulation material.
2. Effects of varying amounts (thickness and widths) of encapsulation materials.
3. Effects of different linear materials.
4. Effects of die gap on encapsulation coating.
5. Effects of air gap on encapsulation coating.

Acknowledgments

Chevron Orange Tech Lab – Randy Sonnier, Gary Locke, & Terry Mullen
Chevron Analytical Support – Becky Green & David Gillispie
The Cloeren Company - Todd Stansbury

Table #1 - Resin Properties

	HIGHLY BRANCHED LDPE		LINEAR MATERIALS	
	Chevron LDPE 4517 (A)	Chevron LDPE 1019 (B)	Chevron HiD 9608 (C)	Chevron LLDPE 6335 (D)
	LDPE A	LDPE B	HDPE	LLDPE
Melt Index (g/10min)	5.1	16.0	8.0	3.5
Density (g/cc)	0.923	0.917	0.962	0.925
Mw - Ave. Mol. Wt.	119,387	133,853	82,323	91,070
Mz – Z Ave. Mol. Wt.	428,749	473,166	329,026	246,085
MWD – Mw/Mn	5.01	6.38	4.79	3.8
Melt Strength (Tension)@160C (g)	5.25	1.95	0.4	0.75

Table #2 - Blends Used for Experiment

LDPE "A" + 0%, 10%, 30%, 45%, 55% HDPE "C"

LDPE "A" + 0%, 10%, 30%, 45%, 55% LLDPE "D"

LDPE "B" + 0%, 10%, 30%, 45%, 55% LLDPE "D"

Table #3 - Process Conditions

Barrel Temperature	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Extruder 4 1/2	350	500	600	600	600
Extruder 2 1/2	350	500	550	550	550
Adapter thru Die	600	600	600	600	600
Draw Distance	8 1/2		Die Width	34 inch.	
Chill Roll Type	Matte				
Substrate	Kraft 32 Width				

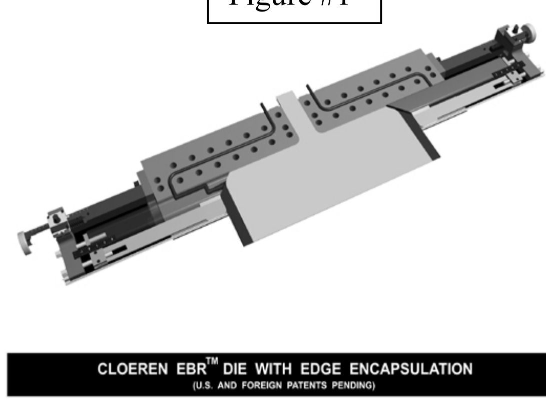
Table #4 - Equipment & Constant Parameters

- Extruder Equiment
  - 4 1/2 & 2 1/2 Egan
  - 40 in. Cloeren Die
  - Matte Chill Roll
  - Corona Treatment
- Constant Parameters
  - Substrate Kraft Paper
  - Die Opening 34-inch
  - Chill Temp. 70 F.
  - 4 1/2 -31Rpms 200 lbs./Hr
  - 2 1/2 -15Rpms - Drool
  - Temperature Profiles

Table #5 - Fabrication - Measurable Variables

- Neck-in vs. Line Speed - 300, 500, 700 & 900 fpm
- Motor Amps & Barrel Pressure
  -compared to linear blends using LDPE
- Edge Weave - calculated with digital Camera
- Laminated Substrate at 1 & .5 Mils.
  - coating thickness and surging (defects & voids)
- Visual Process Observations
  - acceptable or unacceptable

Figure #1



CLOEREN EBR™ DIE WITH EDGE ENCAPSULATION
(U.S. AND FOREIGN PATENTS PENDING)

Figure #2 - Molecular Weight Distribution by Conventional GPC

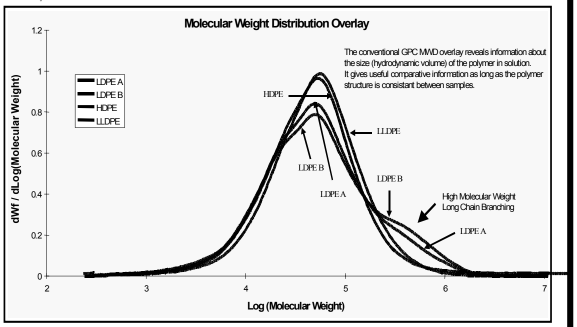


Figure #5 - Effect of Extruder Drive Current on Linear Materials

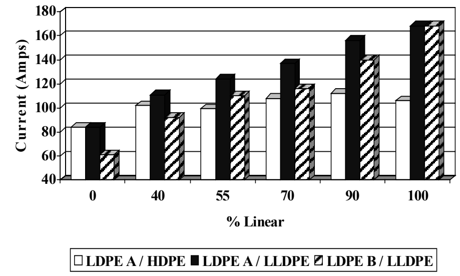


Figure #3 - Trisec Light Scattering Overlay

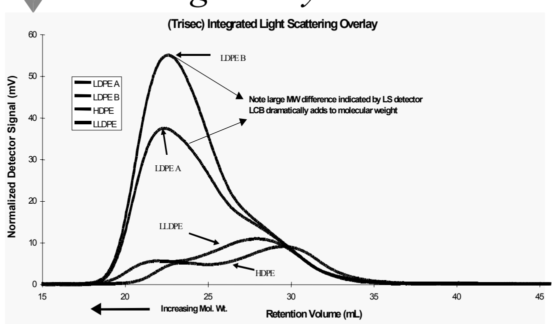


Figure #6 - Effect of Extruder Back Pressure on Linear Materials

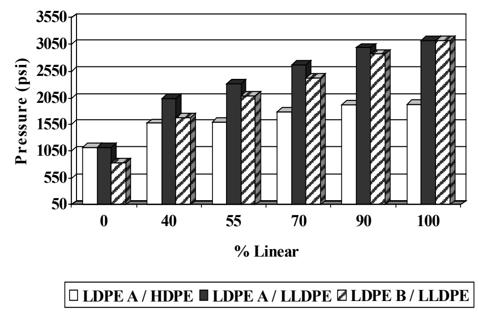


Figure #4 - Capillary Rheology - Shear Thinning Due to LCB

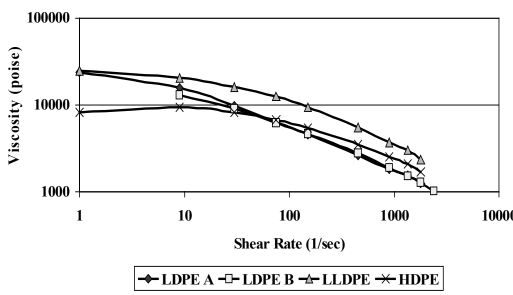


Figure #7 - LDPE A / HDPE Blends Neck-In with Encapsulation

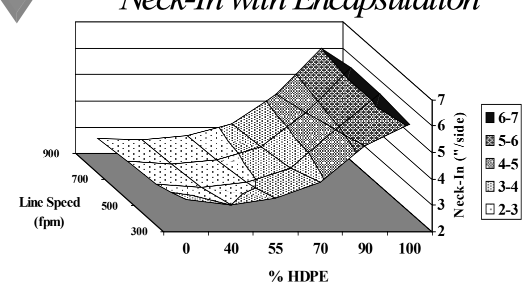
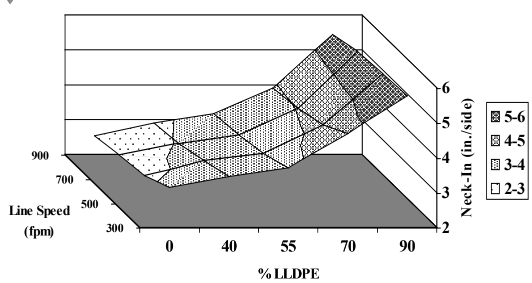
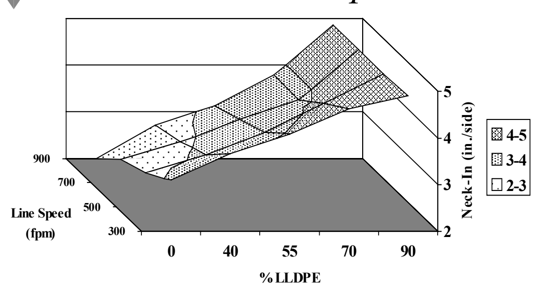


Figure #8 - LDPE A / LLDPE Blends Neck-In with Encapsulation



Note: Edge weave too great to obtain neck-in measurements at 100% LLDPE.

Figure #9 - LDPE B / LLDPE Blends Neck-In with Encapsulation



Note: Edge weave too great to obtain neck-in measurements at 100% LLDPE.

Figure #10 - Edge Weave @ 900 fpm with Encapsulation