PP-I-7

Analysis of Low-Cost, BMWD, HMW HDPE Blown Film Resin Polymerized In A Single-Stage Reactor

M. Smith [(1)], **E. Benham** [(1)], **B. del Amo** [(2)], **A. Sukhadiah** [(3)], **R. Krishnaswamy** [(3)]

(1) **Chevron Phillips Chemical Company, Kingwood, TX 77339 (USA) (smithmi@cpchem.com)**
(2) **Repsol-YPF, Technology Division (bdelamo@repsolypf.com)**
(3) **Chevron Phillips Chemical Company, Bartlesville, OK 74004 (USA)**

1. INTRODUCTION

It has been a goal of polyethylene producers to develop an inexpensive Broad Molecular Weight Distribution (BMWD), High Molecular Weight (HMW) High Density Polyethylene (HDPE) blown film resin. This inexpensive HMW resin would be used in typical applications such as merchant bags, grocery sacks, institutional can liners and consumer trash bags. In order to obtain the BMWD, this type of film resin has traditionally been made with multiple-stage reactors that can be significantly more expensive to construct and operate than single-stage reactors[1]. By using a single-stage slurry loop reactor and special catalyst, such a resin has been produced, D574, and is evaluated in this report. **Typical performance requirements for this HMW film resin would include:**

- **Density >0.950 g/cm^3 (for tensile strength)**
- **Dart impact strength >300 g (for toughness)**
- **Machine direction (MD) tear resistance >22 g**
- **Stable blown film bubble**
- **Smooth film surface**
- **Comparable output to expensive, multiple-stage reactor HMW resins**

2. DISCUSSION OF RESULTS

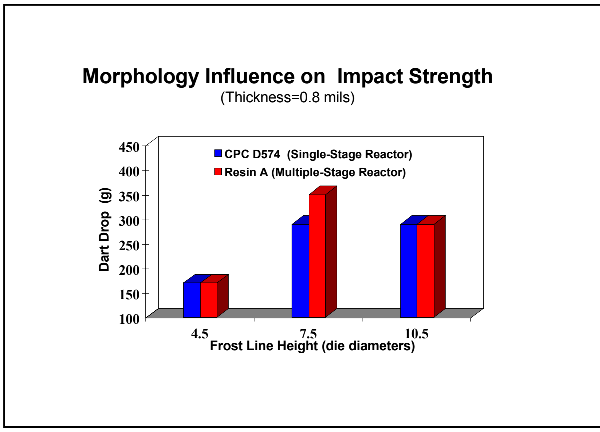
As can be seen from the table below, Chevron Phillips D574 met and surpassed all of these requirements. The single-stage gas phase reactor product, Resin C, listed below had unacceptable dart drop and MD tear, so it was dropped from further study. The multiple-stage loop/gas phase reactor product, Resin B, could barely be made into 25-micron film, much less thinner film, because of severe bubble instability. Consequently, Resin B was dropped from further study. Thus, Resin A became the de facto commercial control for this study.

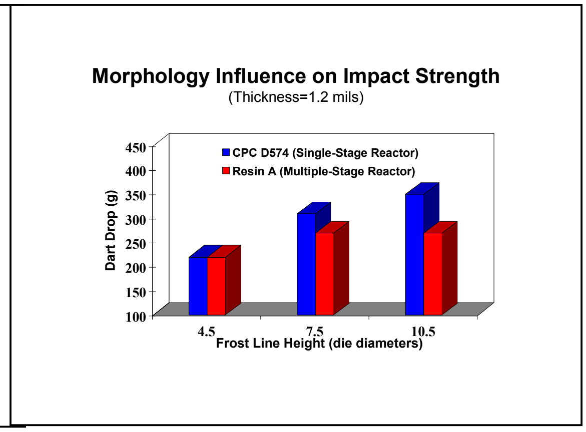
ANALYSIS OF HMW HDPE BLOWN FILM RESINS

Polymerization Process	**Multiple-Stage Reactor System**		**Single-Stage Reactor System**	
Process Details	Continuous, Stirred-Tanks in Series	Super-Critical Loop / Gas Phase in Series	Gas Phase	Slurry Loop
	Resin A	**Resin B**	**Resin C**	**Chevron Phillips D574**
Density, g/cm3	0.952	0.951	0.948	0.951
HLMI (21.6), g/10 min.	7	7	9	6
HLMI / MI	200	90	130	170
Blown Film Properties*				
Dart Drop, g	360	340	220	330
Elmendorf Tear, g MD	35	25	17	30
Elmendorf Tear, g TD	185	150	160	180
Min. Gage Obtained, micror	15	25	15	15

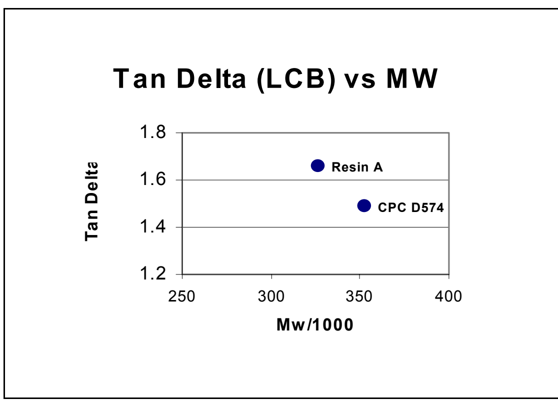
* Film properites based on 25-micron film

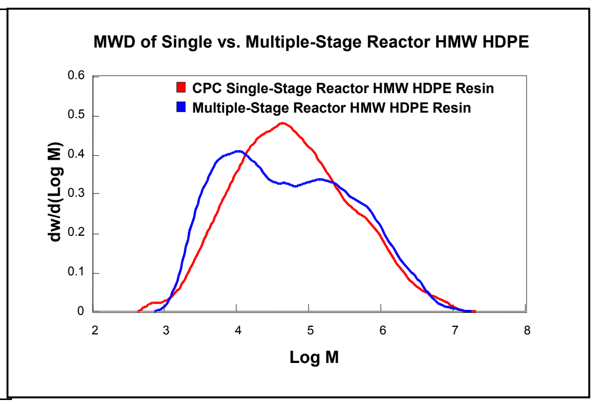
It is also obvious from the previous table that density, HLMI, MI and GPC curves (below) are inadequate tests for predicting final film performance.[2] These four resin tests were also ineffective at predicting how HMW HDPE resins would perform under different blown film processing conditions as illustrated in the two figures below. In this study the effects of frost line height and draw down ratio (thickness) were determined on both the single and multiple-phase reactor resins.





What is not apparent from the GPC curves below is that the single-stage reactor product, D574, has more very high molecular weight species (more of the longest polyethylene molecules) with an $\mathbf{M_z}$ of 4,800, kg/mol vs an $\mathbf{M_z}$ of 2,200 for the multiple-stage reactor product. These longer molecules aid in penetrating the surrounding lamellae to hold them together during lower draw down rates (thicker film), but tend to be less effective at higher draw down rates (thinner film).[3]





In addition to having a higher $\mathbf{M_z}$, D574 also has a slightly higher amount of Long Chain Branching (LCB) than the other resin (i.e. lower Tan Delta) as seen in the figure above.

3. Conclusions

Both higher $\mathbf{M_z}$ and higher LCB, as seen in single-stage reactor HMW HDPE film resin D574, contribute to a higher degree of molecular orientation and lameller stacking during film blowing which can produce film with better impact strength at lower draw down rates (thicker film) compared to higher rates (thinner film).

---

[1] K.B. Sinclair, "The New Generation Polyethylene Technologies: A Comparison", POLYOLEFINS XI International Conference (February 21-24, 1999), 1-20

[2] R. Krishnaswamy, "Structure-Property Relationships in HMW-HDPE Films", 2001 ANTEC p 111-

[3] J.Lu, H-J. Sue and T.P.Rieker, *Polymer,* **42**, 4635 (2001)