Preface

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Polyethylene

End-Use Properties and their Physical Meaning

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Introduction

Every commercial information sheet describing a polyethylene resin, every professional discussion of the application range for a resin, every issue of the resin pricing—they all involve the same short list of resins' end-use properties. Although the items in the list may vary depending on application, they are universally understood throughout the "insider's" word without any need for an explanation. For commercial film-grade LLDPE resins these parameters usually include the melt index, the melt flow ratio, the melting point, the dart impact strength, and the tear strength in two directions of the film. For blow-molding HDPE resins the usual parameters are the high-load melt index, environmental stress cracking resistance, the top-load strength, and so on. Tables I.1 and I.2 show two representative examples of these parameters taken from commercial product data-sheets.

Table I.1 ExxonMobil LLDPE resin, LL 1001 Series

	SI units	English units
Density	0.918 g/cm^3	0.0332 lb./in^3
Melt index (190 °C, 2.16 kg)	1.0 g/10 min	1.0 g/10 min
Peak melting temperature	121°C	250 °F
Tensile strength at yield, MD	9.4 MPa	1,400 psi
Tensile strength at yield, TD	9.5 MPa	1,400 psi
Tensile strength at break, MD	50 MPa	7,700 psi
Tensile strength at break, TD	35 MPa	5,100 psi
Elongation at break, MD	580%	580%
Elongation at break, TD	850%	850%
Secant modulus, MD, at 1%	190 MPa	28,000 psi
Secant modulus, TD, at 1%	220 MPa	32,000 psi
Dart drop impact strength	100 g	100 g
Elmendorf tear strength, MD	80 g	80 g
Elmendorf tear strength, TD	400 g	400 g

Table I.2 Braskem GM7746C Blow Molding HDPE Resin

	SI units	English units
Density	0.944 g/cm^3	0.0341 $lb./in^3$
Melt index (190 °C, 21.6 kg)	4.5 g/10 min	4.5 g/10 min
Vicat softening point	126°C	259°F
Tensile strength at yield	23 MPa	3,340 psi
Tensile strength at break	42 MPa	6,090 psi
Elongation at yield	13%	13%
Elongation at break	880%	880%
Flexural (secant) modulus at 1%	890 MPa	129,000 psi
Secant modulus, TD, at 1%	220 MPa	32,000 psi
Environmental stress-cracking resistance (100% Igepal)	≥ 1,000 h	≥ 1,000 h

These terms and these values have become "the lingua franca" of all product engineers, plant operators, and catalyst chemists throughout the world involved in the production and testing of polyethylene resins. However, the exact physical meaning of the end-use properties and the correlations between their values and the basic "scientific" properties of polymers, such as the average molecular weight, the molecular weight distribution, the content of α-olefin in an LLDPE resin or a VLDPE plastomer, are not clearly defined.

This book provides a necessary bridge between the values of engineering end-use parameters of polyethylene resins and their scientific molecular and structural characteristics. The main goal is to translate such common parameters as the melt index of a resin or the dart impact strength of a film sample into the universal language of the polymer science. After this translation is completed, many facets of the resin properties became transparent and easily explainable. For example:

- What happens with the melt flow ratio of a resin after the catalyst used to produce it is modified to increase its sensitivity to an α-olefin?
- What happens with the dart impact strength or the tear strength of LLDPE film when butene is replaced with hexene or octene in an ethylene/α-olefin copolymerization reaction employing the same catalyst and why does it happen?
- Why are the melting points of metallocene LLDPE resins so much lower compared to the melting points of LLDPE resins of the same density and molecular weight prepared with supported Ziegler-Natta catalysts?

These are the types of questions this book provides answers to. Detailed analysis of many such links between the end-use engineering properties of a resin and molecular characteristics of the polymer turn out to be quite complex. For this reason, a description of each such linkage is accompanied by numerous examples of practical significance and by explicit data for common commodity polyethylene resins.

This book is written with three audiences in mind. The first, the most populous, includes product engineers, the specialists who evaluate properties of resins and judge their usefulness (as well as pricing) for a particular application. These specialists are very adept at measuring and evaluation of end-use engineering properties of the resins they are working with. However, they are usually less surefooted when asked which of the molecular characteristics of the polymers they think should be changed, and in what direction, to improve a particular end-use property.

The members of the second audience are plant and pilot plant operators in the polyethylene industry. These individuals deal with large-scale, steady production processes and need to know which of the process variables they control are crucial for maintaining or achieving the desired end-use parameters of the resins.

The members of the third audience are catalyst chemists, specialists in designing new polymerization catalysts and modifying the existing ones. These professionals often judge success or a failure of the catalyst they develop based on properties of a small amount of polymer prepared in the laboratory, from ~ 10 to ~ 200 g. Their principal interest is to know which of the small-volume, bench-type tests of the polymers has the highest predictive power and how to translate the changes they make in the catalyst recipe into the changes in the end-use properties of the resins manufactured on the commercial scale. One has to take into account that the measurement of some end-use properties requires large quantities of resins far exceeding what can be prepared in the laboratory.

This book is intended to improve communication bridges between these three groups of specialists and to aid them in understanding each other better and faster.

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