Machine Direction Orientation **for Print Webs**

Answering the performance and sustainability challenges using MDO-PE films

Design for Recyclability is a core pillar of Dow's sustainability strategy. We are consistently seeking new ways to achieve a circular economy for plastics – through products, technologies, and initiatives. Machine Direction Orientation (MDO) technology is an important component in our toolbox.

The Challenge

Packaging structures that utilize traditional biaxially oriented PET (BOPET) or biaxially oriented polypropylene (BOPP) reverse print webs (RPWs) are not compatible with existing recycling streams. Multi-material films cannot be recycled because they are made of dissimilar materials with varying melting temperatures or are otherwise incompatible. However, all-PE or PE-rich flexible packaging (if clean and dry) is recyclable via store drop off. But, polyethylene poses performance challenges with optics, stiffness, machinability, and printability (for example, typical HDPE films are not optimized for print web applications).

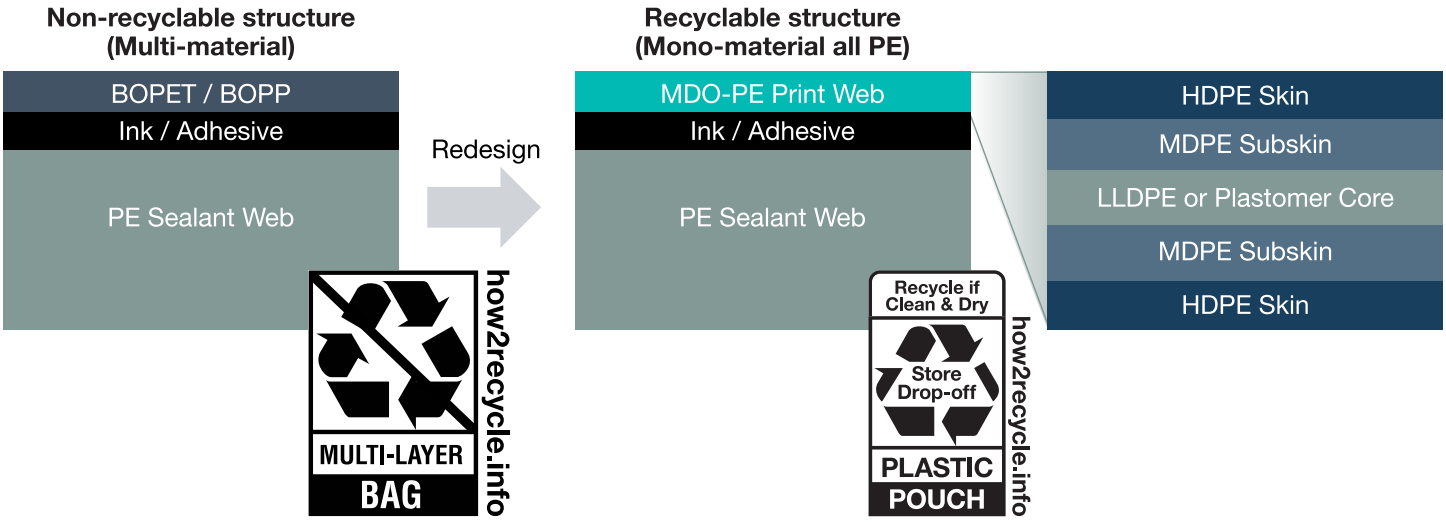
These performance challenges can be addressed by orienting polyethylene RPWs in the machine direction. When it comes to creating film structures for MDO, however, there is a science in choosing the right resins and designing the right structure. When designed properly, the properties of all-polyethylene films can be optimized via the MDO process, improving the properties like toughness and clarity at an optimized gauge.

Our Solution

Through value chain collaboration, Dow has developed a portfolio of resins and experience that enables all-PE, recyclable films without sacrificing aesthetic and physical performance. Imagine mono-material, all-PE structures with enhanced stiffness and excellent dimensional stability, improved printability and machinability, and optical properties that invite shelf appeal. Recyclability and performance! Here's how:

We have developed a number of blocked and non-blocked MDO-PE print web solutions – all made possible through Dow's PE resins portfolio. As shown in Figure 1, by utilizing these options, converters are offered the valuable opportunity for material substitution – using MDO-PE structures instead of BOPP or BOPET.

Figure 1: MDO-PE redesign to enable recyclability and improved performance



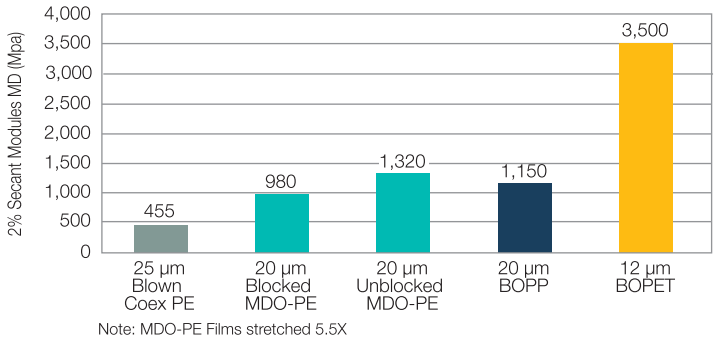
The **proof**

The following figures compare two MDO films – one blocked and one non-blocked – versus conventional blown polyethylene, a BOPP print web, and a BOPET print web against a series of important packaging criteria. Both MDO structures were created as a BOPP substitute.

Stiffness

Stiffness is critical to many packaging applications, for production, transport, shelf appeal, and product use. MDO technology can greatly enhance stiffness over conventional PE films, boosting it toward the range of BOPP films, which was the goal of this particular design. Figure 2 illustrates a nearly 3x increase in machine-direction stiffness over the conventional PE option.

Figure 2: Print web performance comparison, stiffness

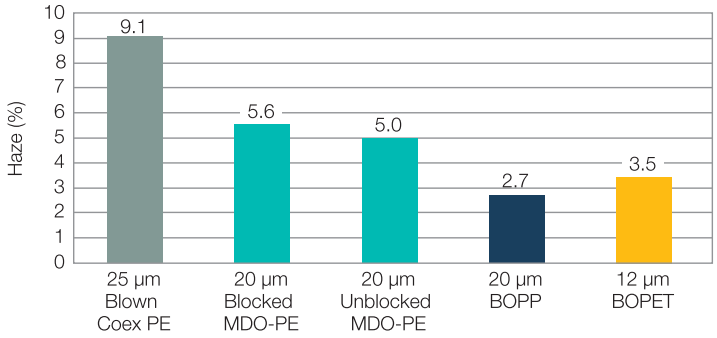


Note: MDO-PE Films stretched 5.5X

Optics

A significant step-change can be realized in optics, too. With the right design, haze, gloss, and clarity can all be improved simultaneously in the same film structure. As shown in Figure 3, the haze levels of MDO-PE are closer to those of BOPP and BOPET than that of conventional PE. Enhanced optics are critical to reverse print visibility and shelf appeal.

Figure 3: Print web performance comparison, optics

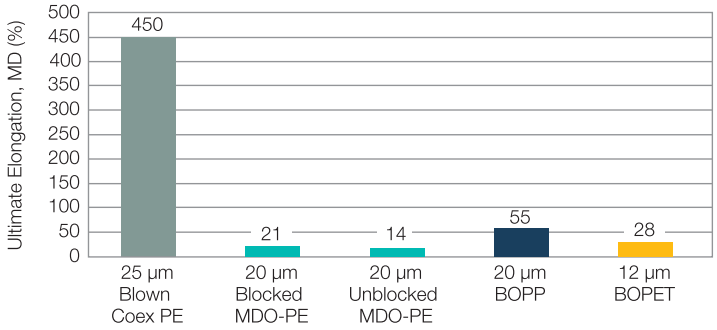


Note: MDO-PE Films stretched 5.5X

Extensibility

The extensibility of conventional polyethylene can present a challenge for efficient machining and maintaining print registration throughout print production. By orienting PE print webs, extensibility is significantly reduced to the same range as traditional print webs (Figure 4). This reduces the amount of adjustments necessary to run PE-rich film structures through packaging lines.

Figure 4: Print web performance comparison, extensibility

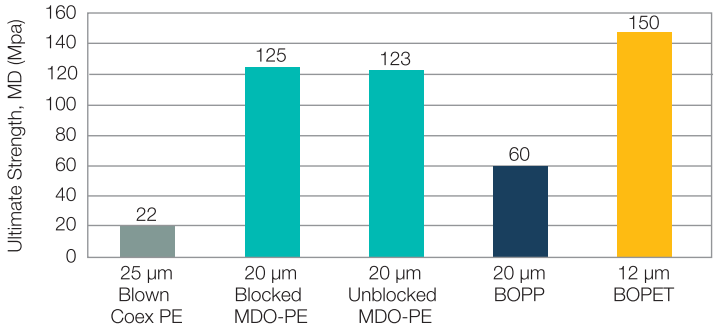


Note: MDO-PE Films stretched 5.5X

Tensile strength

Figure 5 shows that MDO-PE provides a significant boost in tensile strength over conventional PE. Machine direction tensile performance of MDO-PE film print webs can exceed conventional polyethylene and BOPP and near the range of BOPET.

Figure 5: Print web performance comparison, tensile strength



Note: MDO-PE Films stretched 5.5X

Blocked and non-blocked film options

Blocked films provide a symmetrical final film structure with slightly higher toughness, though a slight compromise in stiffness is found.

Non-blocked films provide the opportunity to produce a non-symmetrical structure with a little higher stiffness. They also can enable a higher output rate of the extrusion line, but thickness distribution control is more challenging.

Figure 6 illustrates options for all-PE blocked and non-blocked film structures.

The performance of these structures is dependent on a combination of resin selection, structure design, and MDO conditions. Table 1 provides popular resin options with physical and functional properties.

There are also many resin options for use with MDO-PE print web, but most ideal structures use a thin density gradient approach, which provides an I-beam-like affect which provides stiffness.

Table 1: Suggested film layers, blocked & non-blocked

	Density	MI	Benefit
HDPE skin			
ELITE™ AT6900 Enhanced Polyethylene Resin	0.969	1.2	Outstanding stiffness and thermal resistance
ELITE™ 5960G1 Enhanced Polyethylene Resin	0.962	0.85	Excellent stiffness, thermal resistance, and broad stretching window
MDPE sub-skin			
ELITE™ 5940G Enhanced Polyethylene Resin	0.940	0.8	Excellent stiffness, toughness, optics balance and broad stretching window
INNATE™ ST70 Precision Packaging Resin	0.926	0.85	Balanced toughness and stiffness improvements and overall enhanced dimensional performance
LLDPE core – non-blocked			
ELITE™ 5400G Enhanced Polyethylene Resin	0.916	1.0	Unique balance of high impact resistance, good tear, performance, and excellent processability.
Plastomer core – blocked			
AFFINITY™ EG8100G Polyolefin Plastomer	0.870	1.0	Effective bubble blocking; Low melting temperature and good operating window

Figure 6: MDO-PE print web structures

Typical property ranges	MD	CD
2% Sec. Modulus, (MPa)	950-1150	850-1100
Ultimate Elongation, (%)	20-35	600-700
Ultimate Strength, (MPa)	120-190	30-35
Tear Resistance (cN)	25-55	200-300
Haze/Gloss 20°, (%)	5-9/70-95	

Typical property ranges	MD	CD
2% Sec. Modulus, (MPa)	1000-1350	900-1200
Ultimate Elongation, (%)	15-35	600-700
Ultimate Strength, (MPa)	120-180	30-35
Tear Resistance (cN)	20-45	200-300
Haze/Gloss 20°, (%)	5-9/70-95	

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