Modified polyester resins for improved processing in extrusion operations

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New polyester resins specifically designed for improved processing in extrusion operations provide a range of melt points and tailored crystallization behavior to meet specific packaging needs.

Advantages of polyester

Polyester offers many advantages as a packaging material: It provides an excellent barrier to flavors, odors, and solvents, is a moderate oxygen and water barrier, and does not impart flavor or odor to food.

The melt temperature of homopolymer polyester makes it suitable for use in microwave or conventional ovens. Polyester also has good grease resistance, strength, and toughness.

Polyester has a long history of use in food packaging and meets U.S. Food and Drug Administration (FDA) regulations for direct food contact. Its optical properties—good clarity, gloss, and sparkle—give articles packaged in polyester high shelf appeal. Typical packaging uses for polyester are oriented film, blow molded bottles, and crystallized trays.

Disadvantages of polyester

Polyester is often difficult to process on conventional extrusion equipment because it does not have much melt strength. This has limited the widespread use of polyester in many extrusion operations. Polyester often requires more power to process than polyolefins, limiting the production rates on equipment that is also used to process polyolefins.

Although the melt temperature of polyester is often an advantage for the end user, it limits the converter's ability to use polyester in coextrusions with heat-sensitive materials. Because polyester is often easily crystallized, it is not usually considered as a heat-seal material unless there is a secondary coating on the heat-seal surface. If a secondary heat-seal coating is used, the nonflavor-scalping properties of the polyester are often sacrificed.

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Uses for polyester

Polyester is a versatile material and is found in many applications. Polyester filament is known for resiliency and resistance to chemicals and abrasion, making polyester fiber useful in apparel, furnishings, industrial hoses, and belts. Polyester engineering resins, usually glass filled, are used extensively in hardware, electrical components, furniture, and automotive applications. These engineering resins are extremely stiff and have high temperature resistance.

Polyester is also a versatile packaging material. One of the most familiar uses for polyester in packaging is oriented polyester film. First introduced by Du Pont under the Mylar® tradename in 1952, oriented polyester film is a popular packaging material because of its high strength, dimensional stability, outstanding barrier properties, and printing characteristics. Oriented polyester film is found in applications such as lids for frozen food trays, microwave items, meat and cheese wrap, and bags for snack foods.

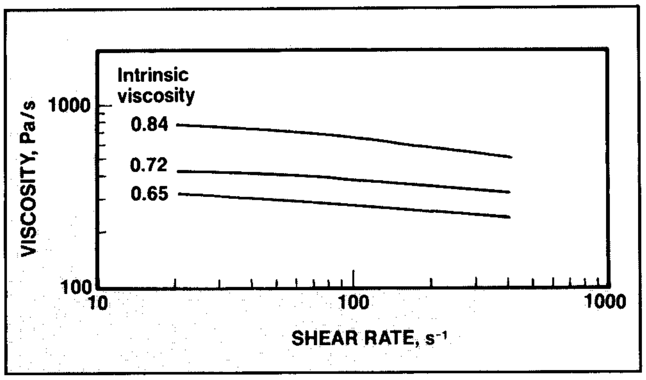
Another familiar use for polyester in packaging is the crystallized polyester (PET) soft drink bottle. Patented in 1973 and introduced in 1978, this injection stretch blow molding process developed by Du Pont makes clear, tough bottles with good CO_2 barrier, perfect for carbonated soft drink beverages.

Polyester copolymers are used to make clear trays and other thermoformed parts with good optical properties and toughness. In extrusion coating applications, polyester is found as a coating on paperboard for dual ovenable applications. Copolymers can be used to provide a nonflavor-scalping layer in liquid packaging applications. In these extrusion processes, the difficulty of processing polyester is apparent.

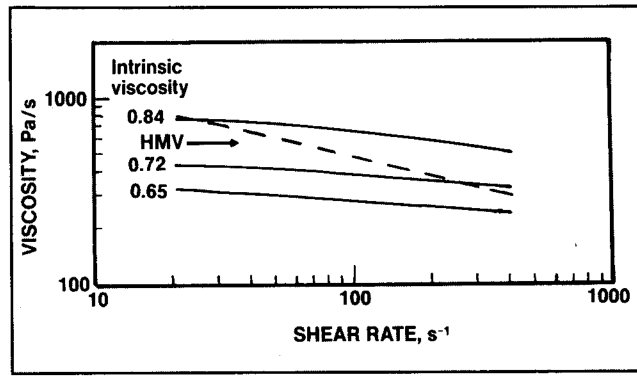
HMV polyester resins

A new family of polyester resins is now available. The HMV (high melt viscosity at low shear rates) polyester

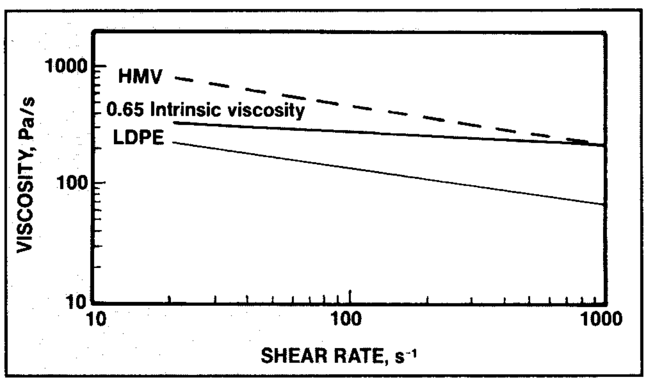
1. Rheology of standard polyesters at 280°C



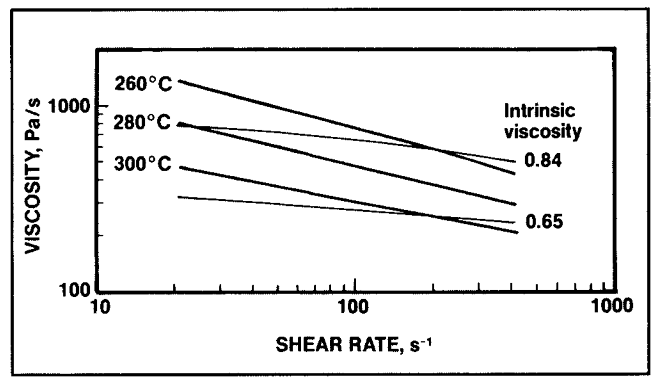
2. Rheology of HMV polyesters at 280°C



3. Rheology at 280°C



4. Rheology of HMV polyesters vs. temperature



resins are designed specifically for extrusion processes such as extrusion coating and cast sheet. The rheology of these resins has been modified to provide a polyester with "polyolefin-like" processing. There are currently three resins in the family of HMV polyesters: one homopolymer and two copolymers. The melt points are 255°C for the homopolymer and 230°C and 220°C for the copolymers. These different grades provide a range of melt points and crystallization behavior that can be tailored to meet specific packaging needs. All of the HMV polyester resins comply with FDA regulations for food contact (21CFR 177.1630).

Rheology characteristics

The majority of polyester resins currently used in extrusion processes are often difficult to process. The viscosity versus shear rate curve for these resins is relatively flat (**Fig. 1**). In many extrusion processes, such as blow molding, cast sheet, and extrusion coating, it is desirable to have high viscosity at the exit of the die. This has made it necessary to use a resin that also has a relatively high viscosity in the processing equipment, limiting production to the pumping ability of the extruder.

Alternatively, if a resin was chosen because it has lower viscosity in the high-shear zones of the extruder to obtain adequate output, it will also have lower viscosity at the exit of the die. Because of this low viscosity and lack of melt strength, special procedures or equipment were often required to pin, or freeze, the edges of the web in place.

The HMV polyester resins have a steeper viscosity versus shear rate curve (**Fig. 2**). With these resins it is possible to maintain good melt strength as the polymer exits the die, yet achieve good throughput rates. The HMV polyester resins exhibit viscosity behavior that is similar to polyolefin resins typically used in extrusion (**Fig. 3**).

In addition to the modified rheology of the HMV polyester resins, grades with different melt points are available. The processor can obtain even better melt strength by choosing a resin that can be processed at a lower temperature (**Fig. 4**). The range of resins at different melt points also provides a range of crystalline behavior.

Extrusion coating

The unique features of the HMV polyester resins are exhibited clearly in the extrusion coating process. The melt strength of the resin being processed will influence such parameters as neck-in, edge weave, and draw rate. The improved melt strength of the HMV polyester resins enables the processor to improve productivity by minimizing neck-in and edge weave when compared to the polyester resins currently used for extrusion coating. With the HMV resins, no special procedure or equipment is required for edge pinning. **Table I** shows a comparison of the HMV homopolymer polyester with a 0.72 intrinsic viscosity homopolymer polyester often used for extrusion coating. Both resins were run on a 4.5-in. extruder, with a melt temperature setting of 330°C. Measurements of

I. Comparison of the HMV homopolymer polyester with a 0.72 intrinsic viscosity homopolymer polyester

Resin	*Total neck-in, cm*	*Edge weave,* cm*
HMV	18	0
0.72 instrinsic viscosity	25	10

*Sum of both sides

II. Comparison of HMV homopolymer melt swell to standard polyesters

Resin	*Swell, %*
HMV polyester	42
0.65 intrinsic viscosity polyester	6
0.85 intrinsic viscosity polyester	15
6.5 melt index LDPE	35

III. Power requirements at 160 kg/h

Resin	*Amps*
HMV	188
0.72 intrinsic viscosity	265
LDPE	190

IV. Coextrusion can be used to minimize cracking.

Structure	*Cycles to failure*
Monolayer	11,300
Coextrusion	48,800

neck-in and edge weave were taken while running a 25-μm coating at 105 m/min.

The high melt strength of the HMV resin also makes it possible to draw the polymer thinner and to run at higher line speeds. Again, the HMV homopolymer was compared to a standard 0.72 intrinsic viscosity polyester homopolymer. The coating thickness limit is the minimum thickness that can be coated with stable edges. With the HMV resin, a stable coating was made at 18 μm. At a 25-μm coating thickness, the 0.72 intrinsic viscosity polyester was not stable. The maximum line speed at which a stable coating of 25 μm could be extruded was also compared. At 105 m/min, the 0.72 intrinsic viscosity polyester could be coated, but it was not stable. A stable 25-μm coating at a line speed of 275 m/min was achieved with the HMV resin. This limit was due to extruder output limitations, not web instability.

The improved processing of the HMV polyester resins is also seen in the melt swell of the resin (**Table II**). Melt swell corresponds to the elasticity of the resin. This property contributes to the reduced neck-in and improved edge stability of resins that process well in extrusion coating. The melt swell of the HMV polyester homopolymer was compared to that of standard polyesters and to a low-density polyethylene (LDPE). A strand was extruded from a Kayeness rheometer into a solution that provided buoyancy. The diameter of the strand was compared to the diameter of the capillary. The results given were measured at a shear rate of 117 s^{-1}.

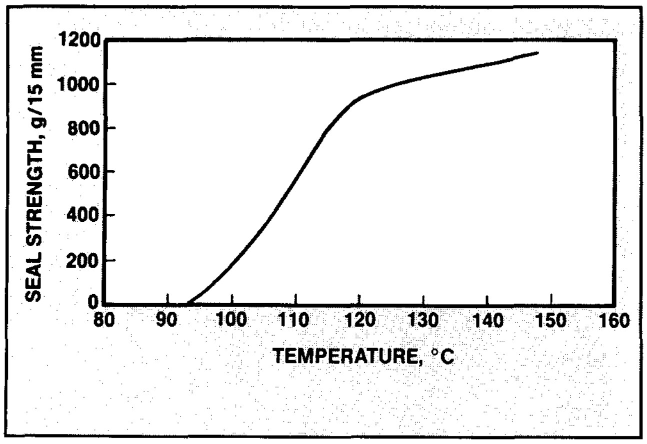
It is often necessary to choose a polyester resin with high viscosity to obtain the required melt strength for processing. This limits output due to lack of extruder power. Because of the more steeply sloped viscosity versus shear rate curve of the HMV polyesters, it is often possible to run higher rates using the same power. **Table III** shows the power requirements for standard 0.72 intrinsic viscosity polyester, HMV homopolymer polyester, and 6.5 melt index LDPE at an output rate of 160 kg/h. The power required to pump the HMV polyester is similar to that required for LDPE.

Coextrusion

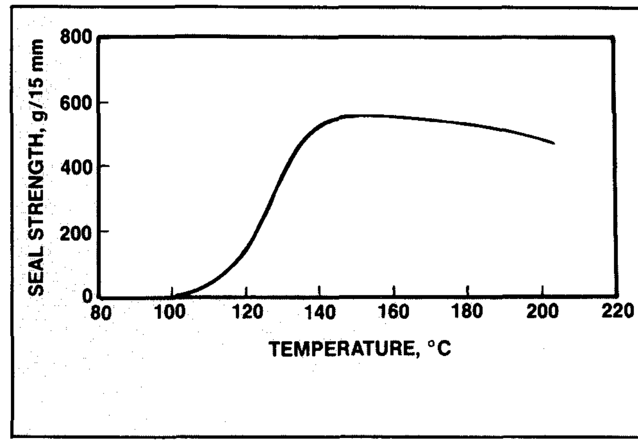
Coextrusion is often used to combine the favorable properties of different polymers. It could be desirable to minimize the cost of a structure containing a more expensive barrier layer, such as polyester, by using a lower priced bulk layer, such as LDPE. Coextrusion can also be used to overcome the deficiency of a particular resin. For example, a relatively thick layer of polyester can be brittle and could score crack if folded. By using coextrusion, the polyester can be combined with a flexible polyethylene layer to minimize cracking (**Table IV**).

The monolayer structure is kraft paper coated with 25-μm HMV copolymer polyester. The coextrusion is the same paper coated with 7.5-μm LDPE/7.5-μm coextrudable adhesive/17-μm HMV copolyester. The structures were formed into small tubes and flexed until air pressure could no longer be maintained in the tubes. The results are in

5. Heat-seal strength (18-μm seal layer, 1-ft bar, 0.5-s dwell time)



6. Heat-seal strength of polyethylene to HMV copolymer (1-ft bar, 40 psi, 0.5-s dwell time)



cycles (flexes) to failure. Although the coextruded structure is slightly thicker, which is often a disadvantage for flex cracking, it was able to withstand four times the flexing of the single-layer coating.

Because the HMV polyester resins are available in a range of melt points, it is possible to choose the optimum resin for a specific application. The lower-melt-point resins can be used in coextrusions with temperature sensitive materials such as ethylene vinyl alcohol (EVOH). The lower-melt-point resins can be processed at a lower temperature to take even more advantage of the increased melt strength.

Matching the viscosity of the various layers in a coextrusion can be more easily accomplished with the processing temperature range available with the HMV polyesters. Because the slope of the viscosity versus shear rate curve for the HMV polyesters is similar to that of polyolefins, it is also easier to match the viscosity in the different shear rate regions in the process. Coextrudable adhesive resins are available to adhere the polyester resins to a range of substrates, including foil, oriented polypropylene, and other polyolefin films. Adhesion to other molten polymer layers such as polyolefins, nylon, and EVOH is also easily achieved. This allows the converter to make a wide variety of structures that can be tailored for specific needs.

Crystallization

Polyester can be used in packaging applications either in the amorphous or crystalline phase. It is often important that the crystallization be controlled for a specific end use. Polyester that will be subjected to high temperatures, such as in an oven, must be crystallized. If polyester is to be used for a heat-seal layer, it is important that it remain amorphous to maintain maximum ability to heat seal. When used in thermoforming applications, it is important that crystallinity is achieved at the proper time in the forming process, or not at all if clear parts are desired.

The HMV polyester resins are tailored to provide the crystallization behavior needed in a variety of applications. The homopolymer crystallizes the most rapidly, while the copolymers crystallize slower and are more easily kept amorphous.

Processing

The HMV polyester resins can be easily processed on extrusion coating equipment currently used for polyester or polyolefins. A general purpose screw or a screw designed for polyester can be used. The optimum temperature profile should be developed for each individual extrusion system. To maintain the maximum melt strength, the temperature should be kept to the minimum at which adequate adhesion to the substrate still can be achieved.

No special equipment or procedure is needed to maintain stable edges, and the HMV resins can be run with an edge bead.

As with any polyester, adequate drying of the resin before processing is critical. The HMV polyester resins are available as crystallized pellets, which minimizes possible drying problems such as bridging in the hopper. An in-line dehumidified hopper dryer is recommended.

Applications

The HMV homopolymer polyester has the high temperature resistance of any homopolymer polyester, which makes it suitable for dual-ovenable applications in structures such as coated paperboard. Ease of processing makes the HMV polyester an attractive alternative to the polyester resins currently available for extrusion coating.

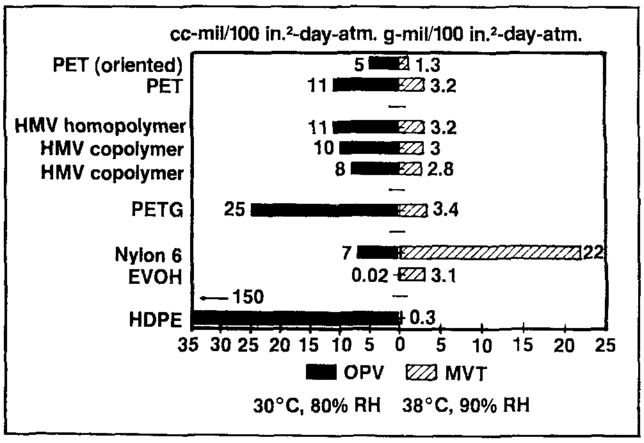
The copolymer polyesters available in the HMV series are ideal candidates for use as a nonflavor-scalping heat-seal layer in applications such as liquid packaging or bags for highly flavored snacks. **Figure 5** shows a heat-seal curve for an HMV copolyester heat-seal-layer extrusion coated onto oriented polypropylene (OPP) using a coextrudable adhesive. The values shown are for a copolyester-copolyester seal.

The HMV copolyester can also be flame sealed to polyethylene for applications such as a gable-top juice carton. **Figure 6** represents this by showing the heat-seal strength of the copolyester sealed to an LDPE. Because it is easy to keep the copolyester resins in the amorphous state, the ability to achieve uniform heat sealing is assured.

Polyester properties retained

Although the processing characteristics of the HMV

7. Barrier comparisons



polyesters have been greatly improved over currently available polyester resins, the properties that make polyester attractive to the food packager are retained.

Figure 7 compares the barrier properties of the HMV polyester resins to other materials used in packaging. The barrier of the HMV homopolymer is the same as that of a standard, unoriented polyester homopolymer. The barrier of the HMV copolymers is better than that of the homopolymer, and two to three times better than other polyester copolymers such as PETG, a copolymer of cyclohexane dimethanol and ethylene terephthalate.

The HMV polyesters have flavor barrier properties similar to other polyester resins. This makes them suitable for packaging highly flavored liquids, snacks, or powders. The grease and moisture barrier of the HMV polyester resins makes them attractive for packaging frozen, microwavable foods. The optical properties of the HMV polyesters provide an attractive package when coated on a clear substrate such as OPP, which provides excellent product display.

Conclusion

The properties of polyester make it an attractive material for use in the packaging industry. As the need for high-quality plastic packaging to provide barrier, flavor retention, and convenience in today's demanding marketplace grows, polyester will be chosen for an increasing number of applications.

There are many different converting and package assembly processes. Each of these processes requires polymers with different characteristics. The polyester resins designed for oriented bottles or film are not the ideal resins for use in extrusion processes such as cast sheet and extrusion coating. To maximize productivity and package integrity, converters need a polyester resin that is tailored to meet the requirements of the specific converting process. The new series of HMV polyester resins are designed for improved processing. These new resins are available with a range of melt points and crystallinity to give the processor the ability to choose the resin that is best suited to meet his or her unique needs.□

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