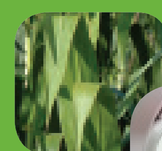
mirel™

Bioplastics by Telles

Injection Molding Guide



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Material Characteristics and Handling

Product Description

Mirel™ Injection Molding Series is a high performance semi-crystalline polyester specifically engineered for high modulus injection molding applications. Made from plant-derived sugar, a renewable resource, Mirel is a blend of polyhydroxybutyric acid (PHB) copolymers, additives and mineral fillers that is biodegradable in home and industrial composting systems, which may not be available in all geographic areas. Your use of this bioplastic demonstrates your company's commitment to meeting real-world needs using renewable materials.

The rate and extent of Mirel's biodegradability will depend on the size and shape of the articles made from it. Mirel is not designed to effectively biodegrade in landfills. For detailed product characteristics, please refer to the Injection Molding Data Sheets. These documents provide general material handling and processing guidelines for the injection molding grades.

Safety Precautions

All Mirel bioplastics are thermally sensitive and must be handled and processed with adequate ventilation and the proper personal protective equipment. Temperatures above 200°C (392°F) or excessive hold times can result in polymer degradation and the evolution of crotonic acid. Therefore, adequate ventilation should be provided where hot polymer may reside for long periods such as in leak areas, above the nozzle, in vent ports, etc. As with most thermoplastics, exposure to harmful vapors and thermal burns from contact with the molten polymer are potential safety hazards. The Mirel Material Safety Data Sheet provides additional handling and processing information and can be downloaded at *www.mirelplastics.com*.

CAUTION: *EXTREME HEATING ABOVE RECOMMENDED PROCESSING TEMPERATURES OR FOR LONG PERIODS WILL RESULT IN EXTENSIVE DEGRADATION AND POLYMER CHANGES THAT CAN AFFECT THE PROPERTIES OF THE MATERIAL.*

Moisture Content

Mirel resins are supplied as dry pellets in lined Gaylord boxes. The liner should be kept sealed before and after use to prevent excessive moisture absorption. The target moisture level for processing Mirel resins is below 0.1%. Certain conditions, including exposure to high humidity, can increase the moisture content. Molded parts that contain air bubbles or stick to the mold may indicate a high moisture level in the pellets. If needed, drying the polymer for approximately 2–4 hours at 80°C (176°F) in a desiccant dryer with a dew point of -40°C (-40°F) will reduce the moisture to an acceptable level.

Use of regrind

Regrind should be stored and handled just like virgin Mirel. Regrind levels up to 30% (on a weight basis) have been successfully processed. The specific regrind level for a particular product will depend on end-user requirements and will need to be qualified.

Additives

Mirel resins are currently supplied in its natural color but pigmentation can easily be achieved with recommended color concentrates. For information on colorants, please contact Telles technical service via e-mail: *techsupport@mirelplastics.com*. The use of conventional petroleum-based color masterbatches or other additives is not advised as the biodegradability, biobased content and properties of the final fabricated part may be compromised.

Injection Molding Equipment

Machine Type

Mirel can be processed on conventional electric and hydraulic reciprocating screw injection molding equipment. For filling complicated geometries, a machine that can provide injection pressure up to 138 MPa (1380 bar, 20,000 psi) is needed. Most parts require a clamp force between 45 and 75 MPa (3–5 tons/in^2) of the part's surface area. The minimum clamp force required can be calculated by multiplying the measured projected area of the part by the estimated cavity pressure. Plunger or ram machines are not recommended for processing Mirel resins as inadequate mixing can lead to material stagnation and subsequent degradation.

Barrel Capacity

To obtain the widest processing window and the most desirable physical properties of Mirel, an appropriate match of barrel capacity to shot size is required. The volumes of cavities, runners and sprue must also be included in the calculation. A barrel volume to shot size ratio between 2 and 3 is recommended to reduce the melt residence time and the presence of localized hot spots in the barrel. This enables injection molding at higher temperatures to optimize melt flow and reduce degradation. If the optimum match is not practical, due to machine availability or some other reason, a barrel volume to shot size ratio as high as 5 to 6 may be used with the understanding that the processing latitude may be significantly compromised. Under these conditions, tighter temperature control in the barrel is also required, and the ideal physical characteristics of the fabricated part may not be achieved.

Screw Design

A low shear general purpose screw having a compression ratio of 2.2:1 to 2.6:1 and a short L/D is recommended for processing Mirel. A standard check ring non-return valve will prevent the molten polymer from flowing back into the screw during the injection cycle.

Nozzle Design

A reverse-taper nozzle, with a length as short as possible, is preferred to minimize shear effects on the material and material drooling. This will prevent a potential source of cold slugs or stagnated, degraded material. An acceptable alternative to this “zero” orifice-land nozzle is a commercially available full-taper nozzle. The nozzle should be completely wrapped with heater bands and fitted with a thermocouple underneath the heater band at the nozzle tip. A separate proportional temperature controller is strongly recommended for successful molding.

Mold Design

Single and multiple cavity, cold runner and hot tip molds can all be used for manufacturing precision parts with tight tolerances. The layout of the mold, however, is a critical design consideration as Mirel is more sensitive to runner and manifold balancing than traditional polymer materials. With a large number of cavities, the runner system must be designed to present a balanced flow to each of the cavities or significant part-to-part variability may occur. Unbalanced flow conditions may result in unfilled parts, overpacked parts, and flashed parts all within a single shot.

If a new mold is being constructed to process a Mirel material, it should be designed to be processed at 55°C (130°F) factoring in the appropriate dimensional tolerances. Metal expansion can result in larger vents and possible binding of ejector pins if thermal expansion is not considered.

Gates

Gates should have a generous cross-sectional area to allow the molten polymer to flow freely with minimal pressure drop. The gates should be polished with no rough edges or sharp corners. The gate land length should be kept to a minimum, preferably 0.8 to 1.0 mm (0.03 to 0.04 in). This will produce the best combination of cycle time and injection speed while reducing shear heating. The gate size should be as large as possible, e.g. up to 80% of the part thickness. Mirel has been successfully molded with gates ranging in size from 0.7 to 1.9 mm (0.029 to 0.075 in). Large gates are preferred for long and extended flow paths to minimize the peak injection pressure and mitigate the potential for vent flashing.

Runners

A runner system should be designed so that the polymer melt reaches all of the gates simultaneously. Full-round, trapezoidal, or modified trapezoidal runners are preferred.

Vents

Sufficient venting is essential to prevent localized burning and short shots. Vents should be as shallow as possible with depths of 0.005 mm to 0.02 mm (0.0002 to 0.0008 in), i.e. similar to those used in nylon molds. Note that larger vents can lead to flash especially when combined with high injection speeds and pressures.

Shrinkage Allowances

Typical mold shrinkage for Mirel is 0.0125 to 0.0155 in/in as measured by ASTM D955.

The equipment guidelines are summarized in Table 1 below:

Table 1. Equipment Recommendations*

Resin Dryer	Desiccant Type
Screw Type	Low Shear General Purpose
Screw Compression Ratio	2.2:1 to 2.6:1
L/D	Short
Nozzle	Reverse-taper
Nozzle Length	Short
Non-return Valve	Standard Check Ring
Gate Land Length	0.8 to 1.0 mm (0.03 to 0.04 in)
Gate Size	Up to 80% of Part Thickness
Runner Shape	Full-round, Trapezoidal or Modified Trapezoidal
Vent Depth	0.005–0.02 mm (0.0002 to 0.0008 in)
Barrel Capacity/Shot Size	2–3

* Recommendations should not be regarded as specifications

Injection Molding Process

Successful injection molding is dependent upon optimizing not only equipment design parameters as described above but also process variables as detailed below. To develop the ultimate physical properties and performance, Mirel should be processed at the maximum allowable melt temperature without causing thermal degradation. It should be injected at a slow speed, packed at the lowest pressure needed to fill out the mold details, and held long enough until the gate seals off. The following sections provide suggested initial processing conditions to achieve the ultimate properties in a molded part.

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Mold Temperature

A mold temperature of 55±5°C (130°F±10°F) should be maintained to obtain optimum part appearance and production rates.

DO NOT USE A COLD MOLD AS PARTS WILL BE VERY DIFFICULT TO EJECT AND CYCLE TIMES WILL BE INCREASED.

For example, running the mold at 33°C (90°F) may triple cycle time. Mold temperatures on the steel cavity and core surfaces should be measured rather than relying on the mold temperature control settings. Water-circulating mold heaters can be used to achieve the desired mold temperature.

Barrel Heating Zones

A reverse temperature profile is suggested for the barrel zone settings as it will minimize thermal degradation of Mirel and produce a more homogeneous melt. Initial barrel settings should include a rear zone temperature of 170°C–175°C (340°F–350°F) and a nozzle temperature of 160°C–165°C (320°F–330°F). Barrel temperatures can then be adjusted to achieve the desired melt temperature.

Melt Temperature

Typical melt temperatures of Mirel resins are in the range of 160°C–175°C (320°F–350°F).

THE AIR SHOT MELT TEMPERATURE SHOULD NEVER EXCEED 190°C (375°F). PROLONGED HEATING ABOVE THE RECOMMENDED MELT TEMPERATURE COULD ADVERSELY AFFECT MATERIAL PROPERTIES. NOTE THAT AS MIREL DEGRADES, ITS VISCOSITY DECREASES BUT ITS COLOR REMAINS UNCHANGED.

When the recommended ratio of barrel capacity to shot size (2–3) is used, Mirel can be melt processed as high as 175°C (350°F). A high melt temperature not only lowers melt viscosity, but also enables a more consistent process and reduces the flash potential. When the ratio of barrel capacity to shot size is very high (>6), lower melt temperatures 160°C–165°C (320°F–330°F) are normally required to prevent extensive degradation due to the longer barrel residence time. The desired melt temperature can be attained by an appropriate combination of barrel temperature settings, screw back pressure and screw speed.

To measure melt temperature, a needle-probe hand pyrometer should be used. Do not use an infrared thermometer which only measures surface temperature. The probe should be accurately calibrated, preheated approximately 15°C (30°F) above the front zone temperature and inserted into the molten plastic for 30 seconds for stabilization. To obtain a representative sample for measurement, the molten polymer should be air shot directly from the nozzle onto a piece of thick cardboard or some other non-conducting material. Multiple measurements in different locations should be taken to establish the actual temperature.

Screw Back Pressure

The screw back pressure will vary from machine to machine but should generally be less than 1.5 MPa (15 bar, 200 psi) to minimize degradation. Back pressure can be adjusted to ensure adequate mixing and melt homogeneity.

Screw Speed

Slow screw speeds, i.e. 50 to 150 rpm, are recommended to preserve Mirel's integrity. Due to their greater circumferential velocity and shear potential, larger screws should generally be operated at a lower rpm than smaller screws to prevent polymer degradation.

Screw back pressure and speed should be adjusted to provide the longest recovery time possible relative to the molding cycle without compromising the homogeneity of the melt for the next shot. Fast recovery cycles typically used for conventional resins generate high localized shears and temperatures in the molten polymer that could potentially degrade Mirel.

Injection Speed

A slow injection speed should be used at the start of the molding run and gradually increased until 95%–99% of the part fills without packing or flashing the mold. A typical injection speed is in the range of 12 to 50 mm (0.5 to 2 inches) per second. Flashing may occur if the injection speed is too fast and the injection pressure exceeds the clamping force.

Injection Pressure

The first stage injection pressure necessary to fill the mold cavity will depend on the mold design and temperature, the injection speed, and the melt temperature. When molding Mirel, the filling or velocity-controlled phase of molding needs to be separated from the packing or pressurization phase. In order to accomplish this, the first stage pressure should be set to the practical maximum.

The stroke transfer setting should be lower than required to fill the mold so that only 95% to 99% of the part is filled when the switch to packing is made. In order that transfer by position always occurs, the time setting for filling should be longer than needed to fill the parts. Packing during the filling stage should be avoided.

A PEAK INJECTION PRESSURE LESS THAN 100 MPa (1000 bar, 15,000 psi) SHOULD BE TARGETED TO MINIMIZE THE RISK OF VENT FLASHING.

Holding Pressure and Time

The second stage holding pressure should be just enough to fill the remaining 1% to 5% of the part, and to maintain a full part while it cools and shrinks in the cavity. The holding pressure should be set low initially, typically in the range of 15% to 30% of the first stage peak injection pressure, and then gradually increased until the part fills but does not flash.

Holding times of 0.5 to 5 seconds are typical to achieve gate freeze, although longer hold times can be used for more complex parts. Part imperfections such as surface waviness, sink marks or voids may indicate an inadequate holding time. A small cushion of material approximately 3 mm (0.125 in) in size should be maintained ahead of the screw after packing.

Cooling Time

The cooling requirements of a part strongly depend on its wall thickness. A long cooling time of around 20 to 30 seconds should be set initially to ensure that the parts can be easily ejected from the mold cavities. The time can gradually be reduced during the run as long as the parts eject freely without sticking and the part ejectors do not penetrate the parts. Mold temperature and cooling time can be balanced to minimize the cycle time.

Typical process conditions for injection molding of Mirel are summarized in Table 2 below. As each process is unique, adjustments will need to be made until acceptable parts are produced.

Table 2. Processing Conditions for Drying and Injection Molding Mirel Resins*

	Typical Conditions
Material Preparation	
Moisture Content of Material	<0.1%
Drying Conditions (if needed)	2 to 4 hours @ 80°C (176°F)
Processing Temperatures	
Melt†	160°C–175°C (320°F–350°F)
Mold‡	50°C–60°C (120°F–140°F)
Barrel Zone Settings	Reverse Temperature Profile
Rear	170°C–175°C (340°F–350°F)
Middle	165°C–170°C (330°F–340°F)
Front	165°C–170°C (330°F–340°F)
Nozzle	160°C–165°C (320°F–330°F)
Processing Conditions	
Screw Speed	50-100 rpm
Screw Back Pressure	1.5 MPa (15 bar, 200 psi)
Injection Speed	Slow, 12-50 mm/sec (0.5-2 in/sec)
1st Stage Injection Pressure	<80 MPa (800 bar, 12,000 psi)
2nd Stage Holding Pressure	15%–30% of 1st Stage Pressure
Holding Time	0.5-5 sec or more
Cooling Time	5-20 sec
Injection Cushion	Approx. 3 mm (0.125 in)

* Typical conditions are not to be regarded as specifications

† Melt temperature should be checked by taking an air shot and measuring the melt with a preheated pyrometer probe

‡ Mold temperature should be measured on the part cavity and core surface

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Start Up Procedure

Mirel is processed at significantly lower melt temperatures than many commodity resins such as polypropylene, polystyrene and nylon. Special startup and shutdown procedures are required for the removal of any higher melt temperature materials.

1. All residual polymers from prior runs should be purged from the equipment with LDPE (preferred) or HDPE at the normal processing temperature of prior run.
2. Set mold temperature, barrel temperatures, screw speed and back pressure to the low end of their operating ranges.
3. Stabilize zone temperatures and introduce Mirel resin. Make air shots of the melt until it is free of purging material and contamination. A minimum of 20 purge shots is suggested prior to sampling.
4. Take air-shot melt temperatures and achieve the desired melt temperature by adjusting temperature settings, screw speed and back pressure. Observe the molten plastic for a smooth, glossy and homogeneous appearance. Swirls and a dull surface indicate non-homogeneity and a low melt temperature. The color of the molten polymer will not change despite changes in its viscosity.
5. If necessary, spray mold release into the cavity and sprue bushing before moving the nozzle into position.
6. Start with a low injection speed and a short shot. Adjust the shot size and stroke transfer position until 95–99% of the part is filled in the first stage. Packing during the filling stage should be avoided.
7. Determine the minimum packing pressure required to fill out the mold and pack until the gate freezes.

Interruptions and Shutdown Procedure

Mirel is susceptible to thermal degradation due to prolonged exposure to high temperatures. If the molding cycle is interrupted then the barrel should be purged. At the end of a molding run, the injection unit and all melt components can be purged with LDPE without changing temperature setpoints.

Questions about Mirel Bioplastics

Further information about Mirel can be found at *www.mirelplastics.com*.

Processors may also call Telles during business hours (U.S. EST) and ask for Technical Support: **1.866.91.MIREL (1.866.916.4735)**.

Mirel PHA Resin Biodegradability Certifications

- BPI-certified to meet U.S. standard for compostable plastics according to ASTM D6400
- Vinçotte-certified as “OK Biodegradable Water” for natural freshwater environments
- Vinçotte-certified as “OK Biodegradable Soil” for natural soil environments
- Vinçotte-certified as “OK Compost” for biodegradability in an industrial composting unit to meet E.U. standard for compostable plastics according to EN 13432 / EN 14995
- Vinçotte-certified as “OK Compost Home” for biodegradability in a home composting system
- Meet the U.S. standard for non-floating biodegradable plastics in a marine environment according to ASTM D7081

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