DuPont™ Crastin® PBT

thermoplastic polyester resins

Molding Guide

The miracles of science™

Molding manual for CRASTIN® PBT

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We recommend that you refer to the injection molding recommendations for CRASTIN® PBT on pages 31-32.

1 General information

1 Foreword

CRASTIN® PBT glass reinforced thermoplastic polyester resins are unique among polyester systems. These products contain uniformly dispersed glass fibers and/or other fillers, specially formulated for rapid crystallization during the injection molding process. This offers the possibility of producing high performance parts by conventional injection molding techniques.

This brochure contains general handling and processing techniques.

1.2 Description

CRASTIN® thermoplastic resins are based on polybutylene terephthalate (PBT) resin, which have been specially formulated for rapid crystallization during molding process and may contain uniformly dispersed glass fibers or glass beads.

CRASTIN® thermoplastic polyester resins have an outstanding combination of properties so that they can fulfil the demands of various applications. The CRASTIN® thermoplastic resin family is known for properties like high strength, stiffness, excellent dimensional stability, outstanding chemical and heat resistance and good electrical properties.

CRASTIN® resins are noted for their excellent melt flow characteristics, close molding tolerances and high productivity from multicavity molding. The combination of good physical properties, processing characteristics and competitive price of CRASTIN® resins lead to high value-in-use and lower part costs.

Please refer to the CRASTIN® PBT product and properties guide for more detailed product descriptions and their properties.

1.3 Safety precautions

While processing CRASTIN® resins is ordinarily a safe operation when DuPont's processing recommendations are followed, consideration should be given to the following:

A. CRASTIN® resins are molded at high temperatures and molten resin can inflict severe burns. At temperatures above the melting point, moisture and other gases may generate pressure in the cylinder which, if suddenly released, can cause the molten polymer to be violently ejected through the nozzle.

   To minimize the chance of an accident, the instructions given in this manual should be followed carefully. Potential hazards must be anticipated and either eliminated or guarded against by following established procedures including the use of proper protective equipment and clothing.

   Be particularly alert during purging and whenever the resin is held in the machine at higher than usual temperatures or for longer than usual periods of time – as in a cycle interruption. Please read the section on molding conditions thoroughly.

   In purging, be sure that the high volume (booster) pump is off and that a purge shield is in place. Reduce the injection pressure and "jog" the injection forward button a few times to minimize the possibility that trapped gas in the cylinder will cause "splattering" of the resin.

   Put the purged resin immediately into a metal container with cold water to limit the evolution of smell and gasing.

   If there is any suspicion that gases are being formed in the cylinder, move the purge shield in place, back the nozzle away from the mold, turn off all heat except to nozzle and the nozzle adapter, and leave the machine until it cools below the melting point of the resin (225°C for CRASTIN®). With purge shield still in place reheat the cylinder to the minimum or screw temperature. If jogging the injection or screw rotation buttons do not produce melt flow, a plug exists. In that case, shut off cylinder heat as before and follow your established safety practices for removing the nozzle. A face shield and protective long sleeve gloves should be used.

   In the event that molten polymer does contact the skin, cool the affected area immediately with cold water or an ice pack and get medical attention for thermal burn. **Do not attempt to peel the polymer from the skin.**

B. Since CRASTIN® resins are dried at high temperature, contact with hot hoppers, ovens or air hose lines could result in severe burns. Insulation of these components will reduce this possibility.

C. Small amounts of gases and particulate matter (i.e. low molecular weight modifiers) may be released during the molding, purging or drying of CRASTIN®. We recommend that adequate local exhaust ventilation be provided during the processing of CRASTIN®. We have calculated that a ventilation rate of 5 m^3 of air per minute per kg of resin processed per hour will keep the concentration of dust particles below 10 mg/m^3 while being processed at the maximum recommended times and temperatures (molding, purging and drying).

D. CRASTIN® like all thermoplastic polymers, can form gaseous decomposition products during long hold-up times at the maximum recommended melt temperatures.

E. Adequate local exhaust ventilation should also be provided during the regrind operation.

F. Prior to cleaning of any barrel that contains CRASTIN® resins, the machine should be thoroughly purged with polyethylene or polystyrene.

G. If CRASTIN® resin is accidentally purged over the heater bands, it should be removed and not allow to degrade.

H. Adequate local exhaust ventilation must be provided during the burnout of any equipment that contains CRASTIN® resin, e.g. nozzles, etc.

I. Granules of CRASTIN® present a slipping hazard if spilled on the floor because of their size and shape. They should be swept up immediately.

J. Avoid molding/purging with polycarbonate (PC) before or after CRASTIN®. Please use some intermediate purging steps as described in chapter 3.1.2.

K. For any further information please refer to the Safety Data Sheets.

1.4 Handling and preparation of materials

1.4.1 Packaging

The precautions for handling CRASTIN® resins are generally the same as those for similar glass-reinforced hygroscopic materials, e.g. polyesters, polycarbonates. CRASTIN® resins are packaged in moisture-proofed bags, but the moisture content of the resins in this special moisture-proof bag can be higher than the maximum allowed moisture level for molding.

Broken bags should be well closed or sealed in order to prevent excessive moisture pick-up over time.

1.4.2 Storage

All CRASTIN® resins should be stored dry and storage should allow a “first in/first out” inventory policy. Even though the bags are protected against moisture by a special lamination, some pickup could occur over time.

1.5 Environment and disposal of waste

The good melt stability of CRASTIN® allows in general the recycling of properly handled production waste. If recycling is not possible, DuPont recommends, as the preferred option, incineration with energy recovery. The incinerator has to be equipped with a state of the art scrubber in order to clean the flue gases before release.

CRASTIN® is not soluble in water and has practically no additives which can be extracted by water. Therefore CRASTIN® represents no known risk to human health or the environment when land filled.

For any disposal, local regulations have to be observed which can vary significantly from locality to locality.

Polybutylene terephthalate is mentioned on the “green list” of the European Regulation EEC 259/93, Annex II. CRASTIN® is not restricted for inter European transport of waste destined for recovery.

2 Drying principles

2.1 Effects of moisture

Crastin® is affected by moisture and must always be dried to ensure that optimum mechanical properties are obtained.

The affects of molding resin with excessive moisture are shown in Table 2.1 and Figure 2.1.

Table 2.1 How to recognize excess moisture content

Polymer	Influence on mechanical properties	Visible symptoms on molded parts	Symptoms when molding
Crastin®	Reduction in impact and tensile strength	No surface streaks (splaying) are visible	• No significant symptoms • More flash formation

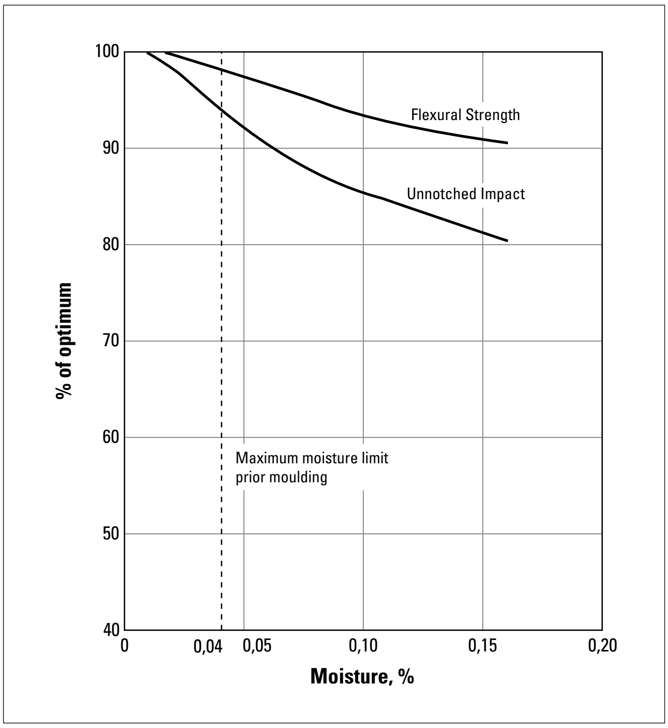


Fig. 2.1 **Effect of resin moisture level on properties of Crastin® SK605**

2.2 Moisture absorption

Crastin® pbt will reach the maximum recommended moisture level for processing within approximately 2 hours at ambient conditions of 23°C and 50% RH (See Figure 2.1).

2.3 Drying conditions

Moisture in the granules causes a hydrolytic reaction that results in a reduction of the molecular weight during processing which causes a reduction in strength and toughness of molded parts.

Crastin® always needs pre-drying to obtain the best properties for molded parts.

Table 2.2 summarizes the drying recommendations. Further details are in the processing recommendations table at the end of this molding guide.

Table 2.2 Recommended drying conditions

	Maximum allowed moisture for processing (%)	Drying temper. (°C)	Drying time (h)
Crastin®	0,04	120	3-4

Too low drying temperatures, i.e. 80°C as used for polyamides, result in insufficient drying, and the required moisture limit cannot be reached. This fact is important when using central drying systems, that do not allow individual temperature setting of the drying containers.

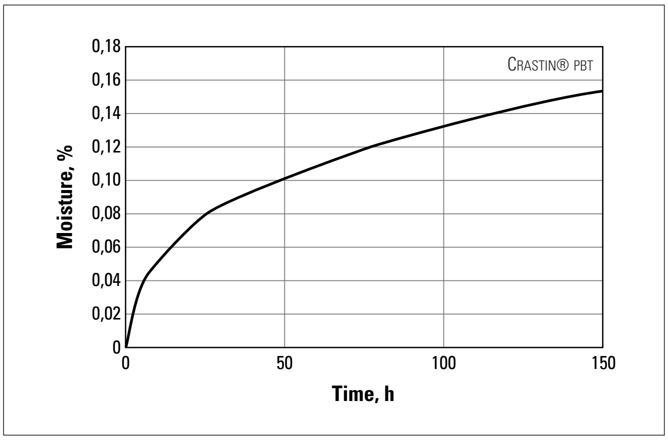


Fig. 2.2 **Moisture pick up of Crastin® S600F10**

2.4 Drying equipment

a. Desiccant driers

Pre-drying with desiccant driers is the most reliable and economical drying method. Monitoring and controlling of desiccant driers takes place by determination of the dew point. The dew point indicates directly the proportion of water in the air. Values of –20°C and below for the dew point make for efficient drying. Drying with desiccant driers is independent of atmospheric influences.

b. Circulating air oven

The quality of the drying depends on the atmospheric conditions. High humidity of the air reduces the acceptable level of drying and therefore we can not recommend the use of circulating air dryers.

c. Vacuum driers

Vacuum driers are for economical reasons normally used only in laboratories. In vacuum, heat energy is transferred almost exclusively by radiation. This results in a long heating time. The recommended drying time is therefore 50% longer than the recommended drying time in Table 2.2.

d. Degassing

The use of degassing units on injection molding machines is, with the current state of the art, not a fully equivalent alternative to pre-drying. The main reason for this is the CRASTIN® hydrolitic degradation of the polymer melt before it reaches the vent port.

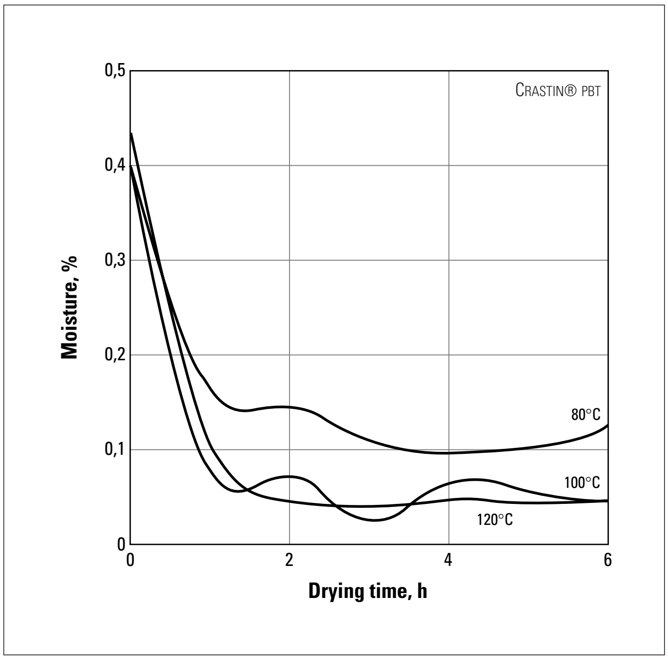


Fig. 2.3 **CRASTIN® PBT never reaches 0,04% moisture when dried at 80°C**

e. Conveying systems

Taking into account the relative short moisture absorption time of polyester, it is recommended to use dryed air in the conveying system. The dryed resin should not stay longer than 10 minutes in the hopper under normal atmospheric conditions.

3 Molding

3.1 Process

3.1.1 Injection unit

3.1.1.1 Screw

CRASTIN® can be processed on all commercially available screw injection molding machines. In order to obtain good homogenization and to ensure careful processing, the L/D ratio of the screws used should not be too small (min. 20D). Standard three-zone screws with shut-off rings, such as those commonly used for polyamides, can be used for CRASTIN® resins.

3.1.1.2 Back flow valve

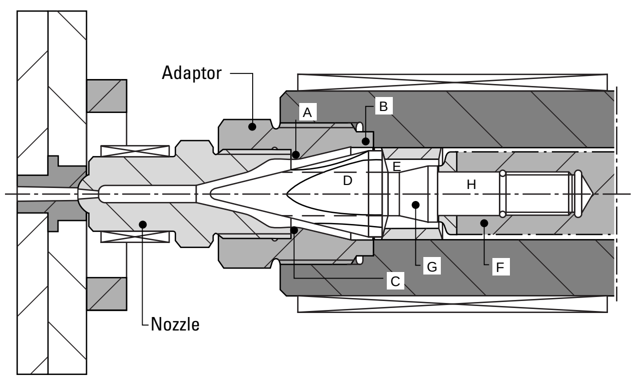


Fig. 3.1 **Design of adaptor and back flow valve**

The back flow valve or check ring shown in Fig. 3.1 prevents melt from flowing backward during injection. Sometimes this unit is not properly designed to eliminate holdup of resin and flow restrictions. Malfunctioning that allows resin backflow is also a common experience and is caused by poor design or maintenance. A leaking non-return valve will add to screw retraction time, which can increase cycle, and it will also cause poor control of packing and dimensional tolerances.

The non-return valve must meet the following requirements:

- No holdup spots.
- No flow restrictions.
- Good seal.
- Control of wear.

These requirements are provided for in the back flow valve shown in Fig. 3.1.

The slots or flutes (D) in the screw tip are generously proportioned, and the space (E) between the check ring and tip is sufficient for resin flow.

The seating of the fixed ring is cylindrical where it joins both the end of the screw (F) and the screw tip (G) to permit accurate matching of these diameters and avoid holdup.

The screw tip thread has a cylindrical section (H) ahead of the threads that fits closely in a matching counterbore for support and alignment of the screw tip and seat ring.

The screw tip and check ring seat should be harder (about Rc 52) than the floating ring (Rc 44), because it is less expensive to replace the floating ring when wear occurs.

Wear resistant steel is suggested for the tip. Good matching of cylindrical diameters is essential to avoid holdup spots.

3.1.1.3 Corrosion/abrasion

CRASTIN® resins, like other glass-reinforced resins, can cause wear in certain areas of the barrel, screw and mold. When molding large quantities of these resins, certain precautions should be taken to minimize wear effects in the equipment and molds. To improve the injection unit when processing glass-reinforced resins such as CRASTIN®, hard surfacing alloys and/or high loaded steels should be used for barrels, screws and back flow valves. Tests on bi-metallic specially treated injection units (barrel, screw and back flow valve) show a lifetime improvement of 5 to 10 times compared to standard equipment. In order to minimize screw wear, special abrasion and corrosion resistant steels and treatments are available.

Please contact your machine and screw manufacturer for further details and recommendations. Specific corrosion resistance treatments of the injection unit is normally not required for molding.

3.1.1.4 Nozzles

CRASTIN® can be processed with open nozzles. However, decompression of the melt must be carried out after the end of plasticizing (see Fig. 3.2).

Long, unheated nozzles are unsuitable, as the melt can freeze very rapidly if the tip of the nozzle touches the cold tool. If extended machine nozzles are used, good temperature control must be maintained over the whole nozzle length in order to prevent overheating.

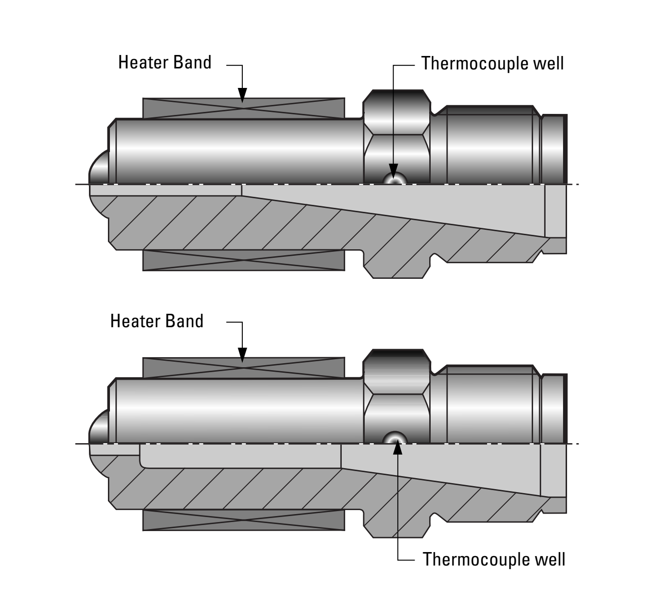


Fig. 3.2 **Recommended open nozzles**

Self-closing nozzles, particularly those with complicated flow channels, should not be used. With certain needle-type self-closing nozzles, problems due to wear and blocking of the needle can occur when glass fiber reinforced materials are processed.

If self-closing nozzles are used for processing CRASTIN® containing glass fibers, the cylinder and nozzle should be purged with an unreinforced material (e.g. PE) before shutting down the machine. This prevents glass fibers from being deposited when the machine is reheated.

Except in the case of hot runner tools, the nozzle should be withdrawn from the tool after completion of the metering operation. If the nozzle remains in contact with the tool it cools rapidly and consequently the temperature of the nozzle must be increased to prevent freezing. That leads to thermal degradation of the melt. Nozzle diameters should not be too small, to prevent premature freezing.

The nozzle should always be equipped with an independent temperature controller because a simple power control is often too inaccurate to guarantee precise temperature regulation.

3.1.1.5 Accumulator for thin wall applications

CRASTIN® glass-reinforced grades generally require fast injection speed. Machines equipped with an accumulator may help to increase flow length especially in applications with thin walls.

3.1.2 Start-up and shutdown procedures

3.1.2.1 Purging

Purging is essential before and after molding CRASTIN® resins because many other plastics degrade at CRASTIN® melt processing temperature. Contamination of CRASTIN® with other resins such as nylon, polycarbonate, acetal, polyethylene terephthalate (PET), or polyarylate may cause molding difficulty and/or resin decomposition.

The best purging materials are polystyrene, cast acrylic (the nozzle must be removed during purging) and high density polyethylene (or glass-reinforced polyethylene, followed by high density polyethylene). The following purge procedure is recommended for standard injection molding equipment:

A. Retract screw injection unit from sprue bushing and keep the screw in the forward position.
B. Run the screw at high RPM and pump out as much of the material as possible. Add and extrude purge compound until it comes out clean. Cylinder temperatures may have to be adjusted, depending on purge material used.
C. It is good practice to “shoot” several air shots at a fast injection rate to scrub walls of cylinder before switching to another resin. Care should be employed to avoid possible splatter of molten resin when this is done.

The following purge procedure is recommended for hot runner systems:

A. Shield personnel from mold.
B. Raise manifold temperatures 30°C above first resin’s melt temperature or 10°C above desired CRASTIN® melt temperature (but less than 280°C actual), whichever is lower.
C. Extrude dried CRASTIN® through open mold using machine back pressure, until purge is “clear”.
D. Drop manifold temperature to operating conditions. Purge out “hot” CRASTIN® (1 to 2 minutes maximum).
E. Drop pressures to usual lower CRASTIN® levels.

3.1.2.2 Start-up

A. Start with a clean machine and a closed feed hopper slot.
B. Set the cylinder temperature to 30°C below the minimum molding temperature and the nozzle at the operating temperature. Allow heat to “soak in” for at least 20 minutes. Raise cylinder temperature to the operating levels.

C. Check to see if the nozzle is at the right temperature.
D. Jog screw. If the screw will not rotate, allow a longer soak time for cylinder temperature.
E. When the screw begins to rotate, open feed slot briefly and then close it. Check the torque on the screw drive. If it is excessive, increase rear zone temperature. The nozzle must be open at this time.
F. Open the feed slide and keep the screw in forward position. Start screw rotation and increase the front zone temperature if unmelted particles are seen.
G. Adjust the stroke to the approximate shot weight and run a few minutes at the approximate overall cycle. The melt temperature should now be checked with a needle probe pyrometer. Make any adjustments in the cylinder temperatures necessary to obtain the recommended melt temperature. (This procedure should be repeated when a significant cycle change occurs.)
H. Bring injection cylinder forward. Start at a low injection pressure (except where short shots will interfere with part ejection) and adjust the molding variables for the best part appearance and maximum part weight.

3.1.2.3 Shutdown

The machine should be purged thoroughly (see 3.1.2.1 "Purging") which cuts the time required for subsequent start-up and reduces problems of contamination. The following shutdown procedure is suggested:

A. Shut hopper feed slide, while continuing to mold on cycle.
B. Empty hopper, add a quantity of polystyrene or polyethylene, extrude until the screw pumps itself dry.
C. Leave screw in forward position.
D. Shut down power supply.

3.1.2.4 Interruptions

If short molding interruptions occur which exceed 2 minutes, it is essential that the cylinder is purged with fresh granulate. Failure to purge after interruptions to the molding cycle will lead to defective parts being produced due to thermal degradation of the material. The actual number of unacceptable parts will depend upon the shot weight.

These measures are also necessary when processing CRASTIN® on hot runner molds. Particularly with small shot weights, the hot runner must also be purged with fresh granulate after a cycle interruption. If the molding interruption duration exceeds 15 minutes, it is recommended to empty the cylinder and to lower the cylinder temperature to 215°C for CRASTIN® in order to avoid excessive thermal degredation.

3.2 Parameters

3.2.1 Melt and cylinder temperature

The melt temperature is taken directly from the molten polymer (using a needle pyrometer) and should be checked periodically during a molding run to ensure that it does not exceed the recommended limits.

Figure 3.3 shows the relationship between shot weight, cycle time and melt temperatures for CRASTIN®. In order to take into account the sensitivity of the melt to overheating, processing temperatures must be matched to hold up times. The longer the residence time of the melt in the cylinder, because of low shot weight or long cycle times (e.g. due to insert placing), the lower should be the cylinder temperatures. When selecting the machine or the screw diameter, care should be taken that the resulting shot weight is not too low.

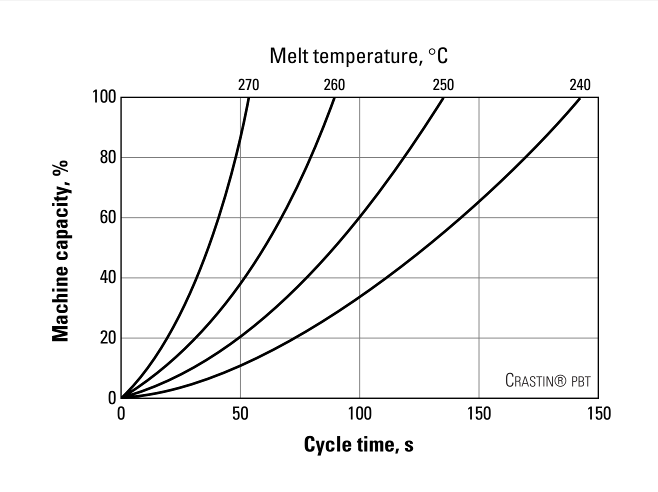


Fig. 3.3 **Permissible cycle times for CRASTIN® as a function of shot weights at various melt temperatures**

Generally for molding semi-crystalline polymers like CRASTIN® PBT, the cylinder temperature profile should be relatively flat. Figure 3.4 proposes temperature profiles as function of residence time and per cent of stroke. It should be avoided to set any cylinder temperature zone below the melting point of polymer.

For more detailed information please refer to processing recommendation table.

3.2.2 Cavity temperature

In order to produce molded CRASTIN® parts with optimum characteristics and low post-shrinkage, a sufficient degree of crystallization of the polymer must be achieved. Crystallization is influenced by the mold temperature.

For CRASTIN® processing can be carried out with mold temperatures in the range of 30-130°C. Mold temperature should be increased as the wall thickness of molded parts is reduced.

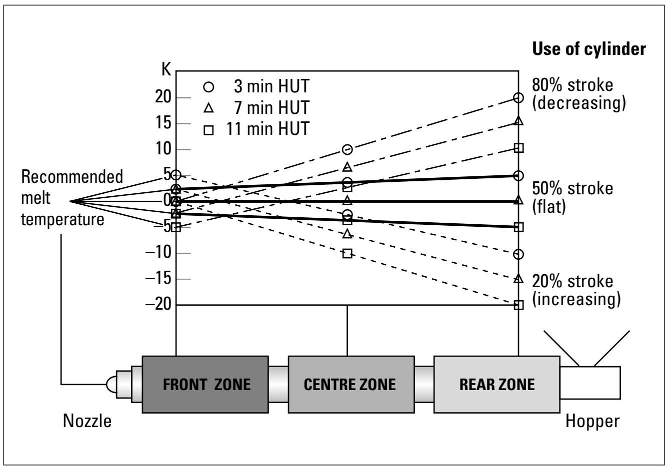


Fig. 3.4 **Cylinder temperature profile for a constant melt temperature**

Generally, a mold temperature of approximately 80°C is sufficient to obtain parts with low post-shrinkage. For precision parts which will be subject to high temperature in service a mold temperature of over 100°C may be necessary, particularly with unreinforced CRASTIN®. High mold temperatures reduce the risk of dimensional changes caused by post-crystallization (post-shrinkage).

For some CRASTIN® types, a minimum mold temperature of 80°C must be observed.

3.2.3 Injection phase

Glass-reinforced CRASTIN® grades generally require medium to fast injection speeds.

The optimum filling time is dependant on part design, wall thickness, flow length, shot volume, gate and runner design. It is important to provide adequate venting to avoid burn marks.

The injection pressure during the dynamic mold filling phase is a function of:
- the programmed injection speed;
- material viscosity at its melt temperature;
- material crystallization speed;
- cavity flow resistance (geometry, wall thickness, flow length).

The resulting injection pressure may be much lower than hold pressure, i.e. for thick parts and short flow length, or even much higher than hold pressure, i.e. for thin parts and long flow length.

3.2.4 Hold pressure phase

The recommended specific hold pressure level is 60 MPa for CRASTIN®.

As for any other semi-crystaline polymer the hold pressure level should be constant over the hold pressure time.

The correct hold pressure time is easy to determine on the injection molding machine. Several different hold times are set 0 to 1,0 seconds a part, depending on the required resolution, and the resultant moldings weighed on a laboratory balance after removing the runner and sprue. The optimum hold pressure time will be in the region where there is no longer any change in the weight of molded parts. This presupposes that the gate has been correctly positioned and designed.

Table 3.1 helps to roughly estimate the required hold pressure time for a given wall thickness.

Table 3.1 Crystallisation rate for a wall thickness of 3 mm

Material	Crystallisation time per mm wall thickness
PBT	3,5–4,5 seconds/mm
PBT GF30	2,5–3,5 seconds/mm

In order to optimize the cycle time, the cooling time is usually set just above the plasticising time.

3.2.5 Screw retraction phase

Even though CRASTIN® grades are not specifically sensitive to high shear, it is recommended to respect the maximum rotational speed as in Figure 3.5.

This will limit screw abrasion for glass reinforced grades and will avoid excessive heat through shear.

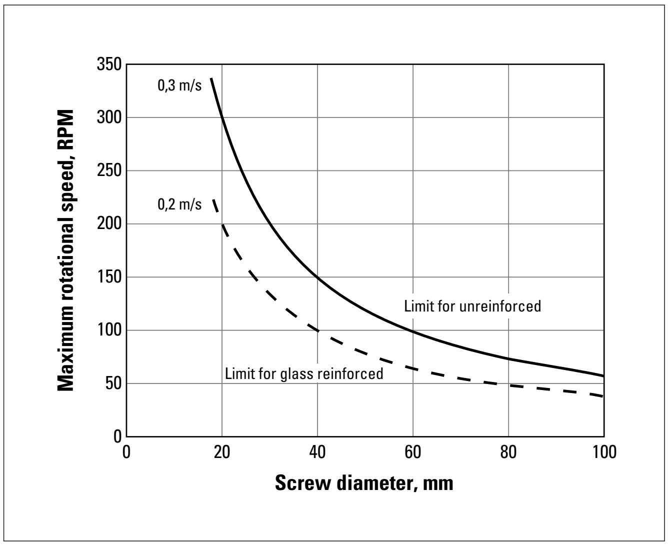


Fig. 3.5 **Screw speed vs. screw diameter**

No or low back pressure should be used. The effect of back pressure is to produce additional screw working which can cause fiber breakage that causes reduction in the physical properties of the molded part. Increasing back pressure increases the work done by the screw on the molten polymer. This could incrementally increase melt temperature and uniformity. Where melt quality is marginal, higher back pressure may reduce unmelted particles, but it will not substantially increase melt quality.

Increasing back pressure also increases recovery time. The lowest possible back pressure consistent with good melt quality is recommended during the molding of DuPont polyester resins.

Normally only melt decompression, is required in order to avoid leakage of material from the nozzle. The use of decompression helps to prevent nozzle drool from hot-runner tools and to stop vent discharge in vented cylinders.

Use of excessive decompression can cause air to be sucked in through the nozzle. This can result in oxidation of material which will be seen as areas of discoloration in the molding. Another consequence could also be the injection of a cold slug in the next shot leading to surface defect and to part weakness.

3.2.6 Processing recommendation table

The injection molding recommendations at the end of the molding guide contain specific information about drying conditions, melt temperature, mold temperature and ISO shrinkage.

4 Mold

4.1 Mold temperature control

Mold temperature control must be a part of the overall design concept for the mold. As already mentioned mechanical properties, cycle time, dimensional accuracy and distorsion of the part are influenced by mold temperature.

In order to achieve a consistent cavity surface temperature, it is essential to have a well designed regulation circuit in the mold beside the temperature controller with suitable pressure, heating and cooling capacity.

Basic recommendations:

- When molding CRASTIN®, the mold surface temperature is much higher than room temperature. In order to shorten the time needed to heat the mold and to maintain constant temperature, insulating plates should be provided between mold and machine.
- For large molds and temperatures above 100°C, it is recommended to thermally insulate the mold on its outside walls.
- Flat mold areas should be adapted with spiral- or drilled cooling channels. Recommended diameters and their approximate distance from the surface of the mold are shown in the table of Fig. 4.1. Depending on the size of the part it may be necessary to provide several separate cooling circuits. The temperature difference between entering and exiting fluid should be as small as possible (<5°C).

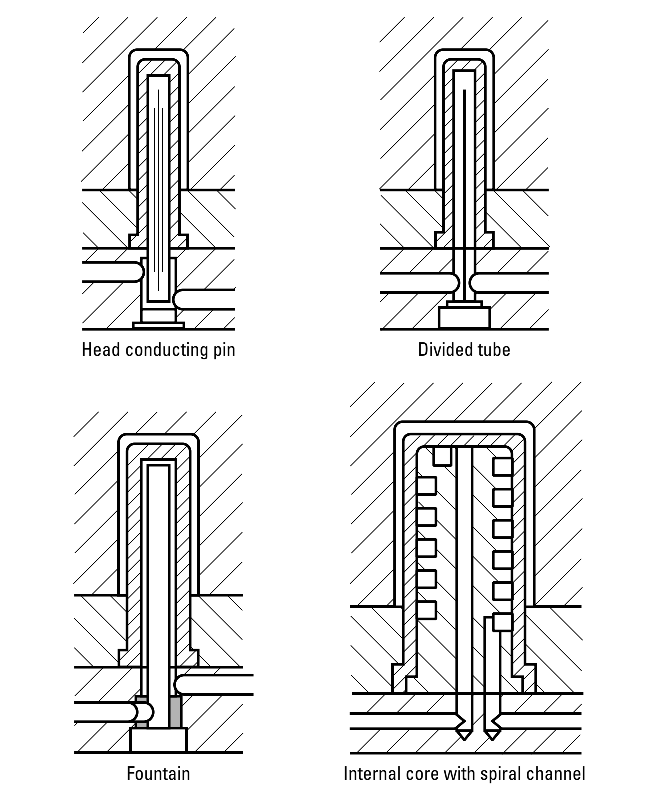
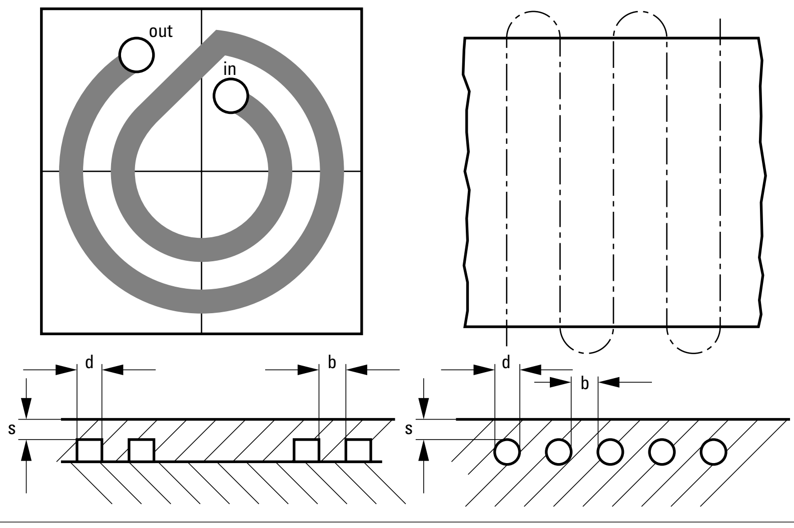


Fig. 4.2 **Possible methods of cooling cores**

- A separate or serial cooling circuit is recommended for multi-cavity tools, because the flow rate can easily be controlled. A parallel configuration may lead to different surface temperature as chocking over time causes different flow rates in the parallel channels.



Wall thickness of the molding	Channel diameter or width (d)	Distance (s)	Channel spacing (b)
up to 2 mm	8 mm	4 mm	~ 1 d
up to 4 mm	10 mm	7 mm	~ 1 d
up to 6 mm	12 mm	9 mm	~ 1 d

Fig. 4.1 **Mold temperature control for flat parts**

- It is important to have an efficient core cooling in order to obtain possible shortest cycle time. Figure 4.2 shows some constructions of cooling cores.
- Temperature control should also be provided in slides and pulling cores.

4.2 Mechanical structure

CRASTIN® requires medium to fast injection speeds. Especially in thin wall applications the specific injection pressure may exceed 100 MPa. Therefore, a stiff mold construction (see Fig. 4.3) will have an important contribution to:

- flash free molding;
- longer mold lifetime;
- larger processing window (i.e. faster injection speed).

Recommendations for increasing mold stiffness:

- use thick platens;
- use large spacer blocks;
- use very stable frame when using many inserts or large hot runner systems;
- use support pillars between rear clamping plate and support plate.

4.3 Runner system and gate layout

In designing the feed system, the first point to be considered is the wall thickness (t) of the molded part (see diagram). The diameter of the runner should not be less than the wall thickness of the injection molded part. Starting out from the gate, the runner diameter at each branch point can be widened so that an almost constant shear rate is maintained.

To prevent the inevitable cold slug reaching the molding from the injection nozzle, the gate should always be extended so that the cold slug can be intercepted. This extension should have roughly the same diameter as the gate to ensure that the cold slug really is retained.

When molding semi crystalline, unreinforced polymers, the minimum gate thickness should be 50 per cent of the wall thickness of the molded part. This would also be adequate for reinforced resins. To minimize the risk of damage to the fibers and also bearing in mind the higher viscosity of these compounds, the gate thickness should be up to 75 per cent of the wall thickness of the molded part.

Gate length is especially crucial. This should be <1 mm to prevent premature solidification of the gate. The mold will heat up near the gate, so that the holding pressure is at its most effective.

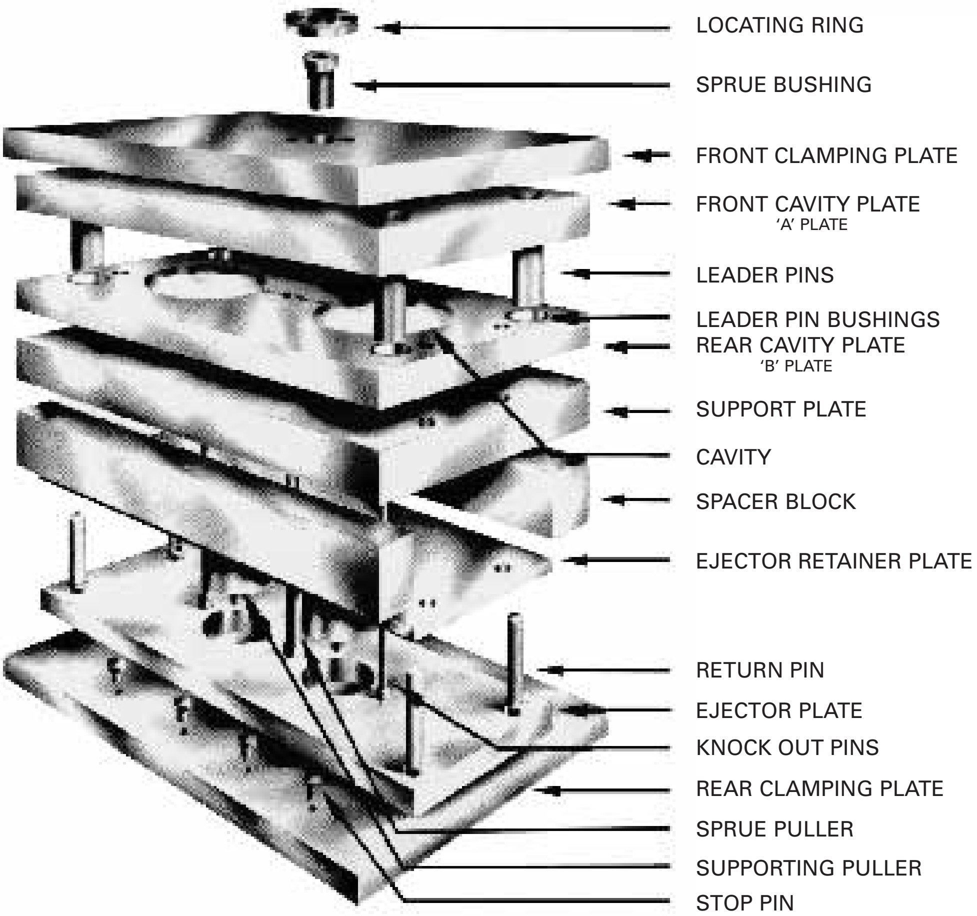


Fig. 4.3 **Exploded view of mold**

All types of gates have been successfully used with DuPont™ CRASTIN® resins. The location, size and number of gates are important considerations.

Round gates are preferred for automatic three-plate (pin gates) and tunnel-gated (submarine gates) molds because of ease of gate separation and part ejection.

In addition to round and rectangular gates, there are many other types of gates such as film gate, fan gate, rectangular gate illustrated on Figure 4.4. However, "Banana" gates are not recommended.

Generally, gate thickness should be 50% to 75% of the part thickness. Figures 4.5, 4.6, 4.7 and 4.8 show design recommendations for the most commonly used gate designs.

To summarize the basic rules:

- always provide a means of intercepting the cold slug;
- make the runner diameter bigger than the molded part wall thickness;
- gate thickness should be at least 50% of the molded part wall thickness.

4.4 Hot runner

When injection molding partially crystalline engineering thermoplastics like CRASTIN® PBT, the choice of the correct hot runner system and its installation determines the function of mold and molded part quality. Hot runner tools are thermally very complex systems. Therefore it is important to consult the hot runner manufacturer in order to get advice on the manifold and nozzle type selection, dependant on the choosen polymer.

Some basic rules can be applied when planning a hot-runner mold with semi-crystalline PBT: The manifold must be naturally balanced. Rheological balancing (i.e. adapting nozzle or subrunner gate size) can only optimize for either equal Filling Time (dynamic balancing) or Hold Pressure Level (static balancing). Both together are often contradictory.

Direct gating on the part should be avoided:

- for small shot weights or long cycle times (total hold up time above 10 minutes);
- for aesthetic parts, as surface defects may occur in gate area;
- for safety relevant parts, as there is always a cold or inhomogeneous slug coming from the nozzle tip, which might move to a mechanically critical area;
- when no hanging over residue or filaments from gate breakage can be accepted.

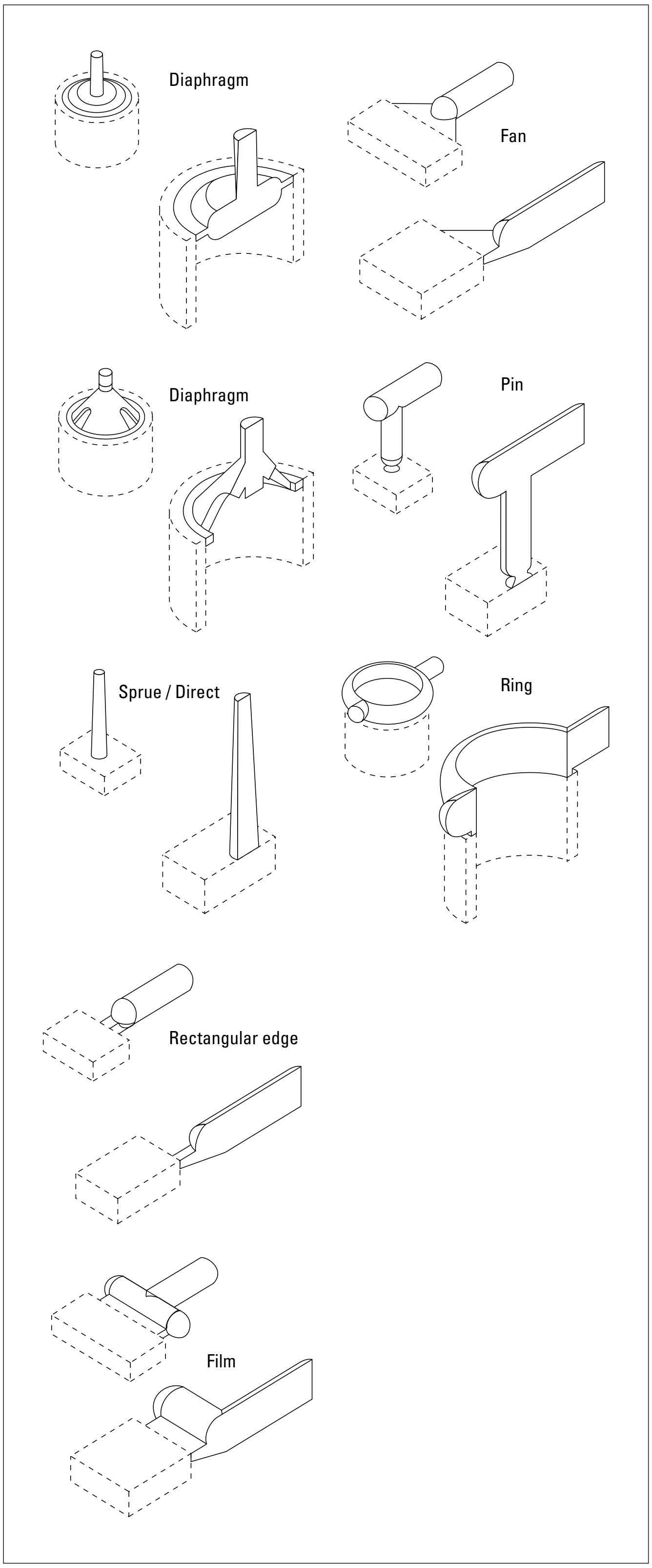


Fig. 4.4 **Different types of gate**

Manifold and nozzles must be perfectly streamlined, in order to avoid any hold-up spot.

Externally heated manifolds are preferred versus internally heated ones, as they allow better streamlining at intersections and generate less shear for the polymer.

The thermal balance must be optimal. Temperature differentials of more than 20°C can not be tolerated in a hot runner system. Therefore it is essential to have the right combination of hardware (manifold, nozzles, heaters), software (heating control) and set-up (optimum thermal insulation between hotrunner and mold).

"Self-insulating" nozzles should be avoided. This kind of nozzle requires the polymer to flow into a calotte shaped gap between nozzle tip and mold surface, in order to optimize the thermal insulation of the nozzle tip. However, with semi-crystalline polymers, like PBT, the resin in this gap stays in most systems at a temperature above the freezing point and will therefore thermally degrade. This can create surface defects in irregular intervals.

"Free Flow" nozzle types are preferred to those with torpedos at the tip, unless there are specific requirements for the breaking at the gate area.

Specific abrasion resistant metals or treatments are preferred for reinforced grades, specifically at the nozzle tip, where shear is highest. Hard metal tips have led to much longer life-times of the tip.

Nozzle tips should be exchangeable. This allows an easier control of abrasion, and reduces the cost in case of necessary modifications.

When heating up a hot runner which contains CRASTIN®, it is important first to heat up to approximatively 20°C below the melting point, thus 210°C for CRASTIN® and to wait at least 30 minutes at this temperature before heating up to operation temperature. This allows heat to soak in and to get a convenient heat balance. Modern controllers allow such an automated stepwise start-up procedure.

When there is a doubt about hold-up spots in the hot-runner, it is adviseable to make a color change on the cylinder and then to mold for 10 minutes continously. Then the system can be shut down and the hot runner/nozzle should be disassembled to identify the spots, which still contain the first color. With the help of the hot runner manufacturer it should be possible to improve the streamlining of the hot runner and nozzle.

4.5 Venting

Inadequate mold venting can cause the following problems:

- Poor weld line strength.
- Discoloration (burning).
- Erosion or corrosion of the mold.
- Dimensional variation on the molded part.
- Short shots.

Both cavities and runners should be vented at the parting line or at the ejector as recommended on Fig. 4.10, 4.11 and 4.12.

The area of the vent must be large enough ($W \times d$) to prevent a rise of gas pressure in the mold cavity. The vent length should not exceed 1 mm. The area of the escape passage leading from the vent should increase in proportion to its distance from the cavity edge. In the case of low viscosity grades and where there must be a minimum of flash, vent slits should be shallower to start with.

4.6 Draft angles

Mold surfaces that are perpendicular to the parting line should be tapered to allow easy part ejection. These include ribs, bosses and sides. A taper (draft angle) of 0,5 to 1° is usually satisfactory with CRASTIN® resins.

4.7 Sharp corners

Part design and mold finish should consider the basic rule to round sharp corners. As shown in Fig. 4.9, unreinforced resins are by far more sensitive to the notch effect of sharp corners.

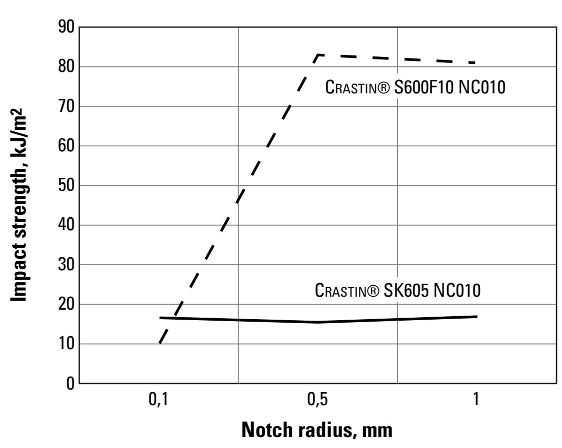


Fig. 4.9 **Effect of notch radius on impact performance**

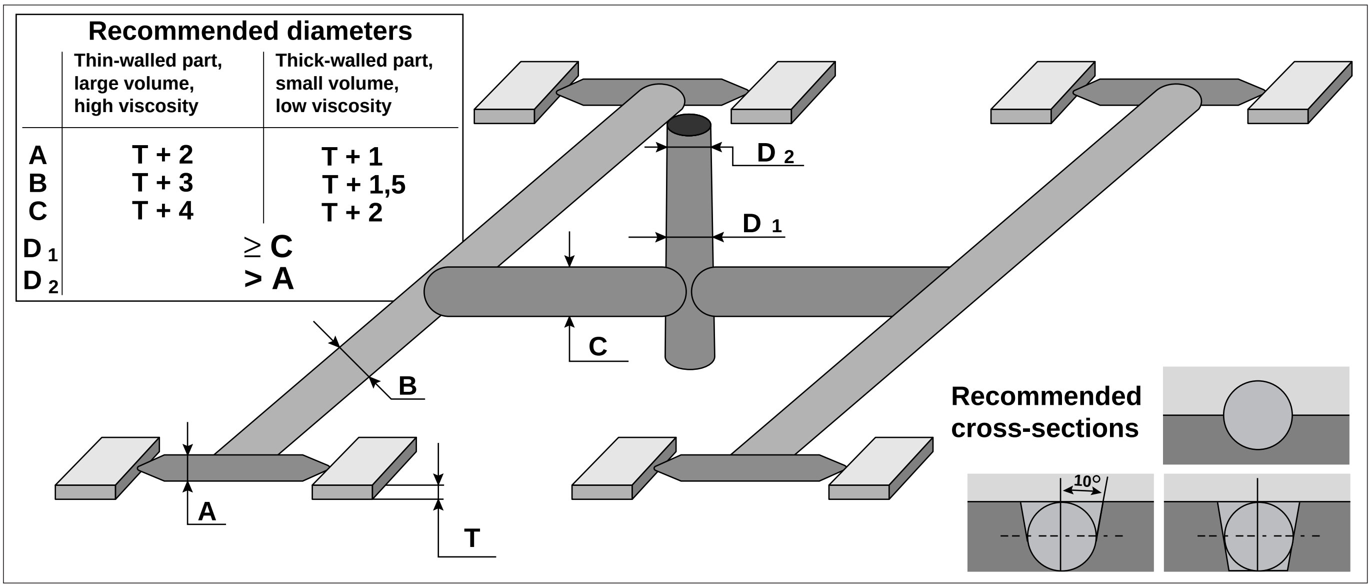


Fig. 4.5 **Design of a multiple runner**

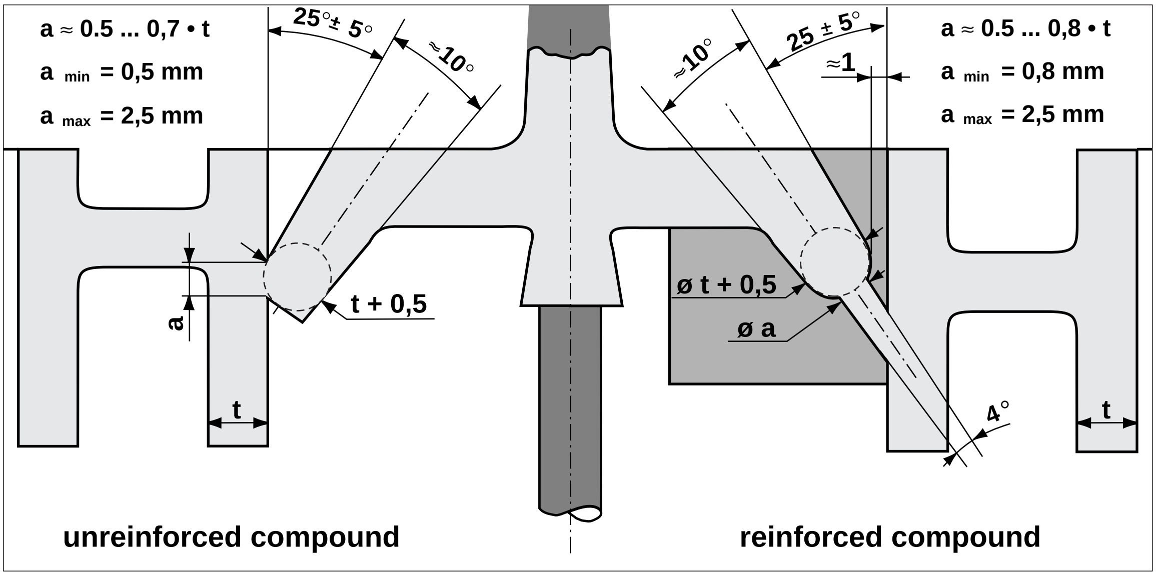


Fig. 4.6 **Tunnel gates**

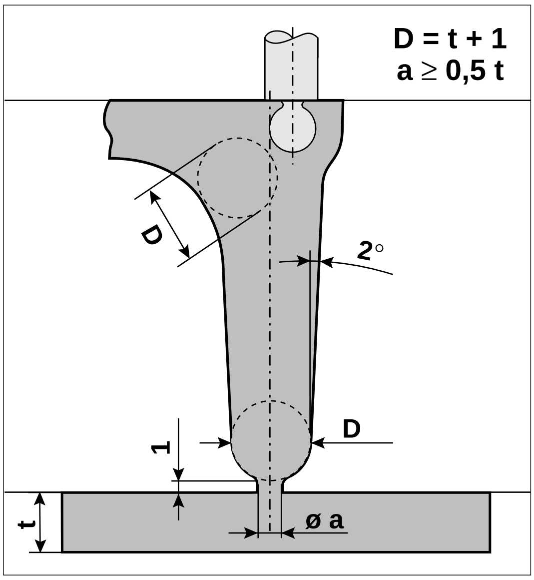


Fig. 4.7 **3-Plate gate**

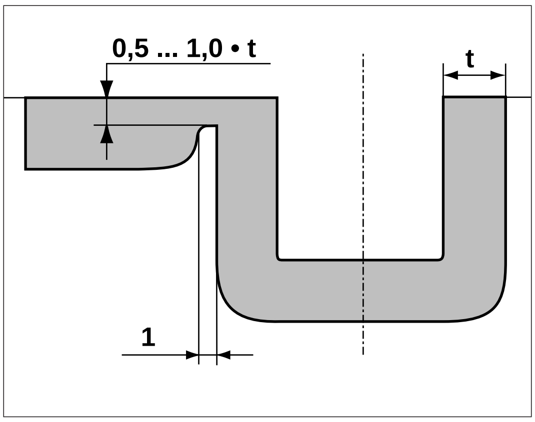


Fig. 4.8 **Direct gate**

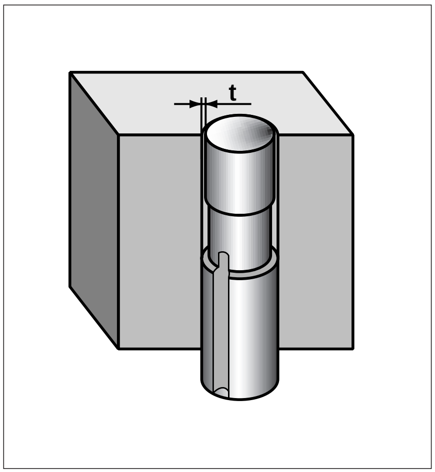


Fig. 4.10 **Ejector Venting**

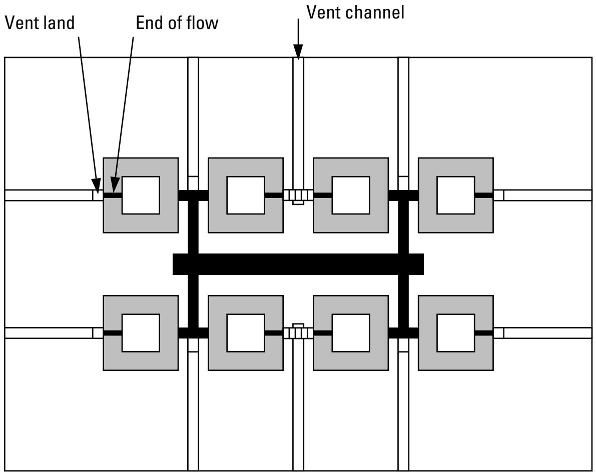


Fig. 4.11 **Vent geometries ejector**

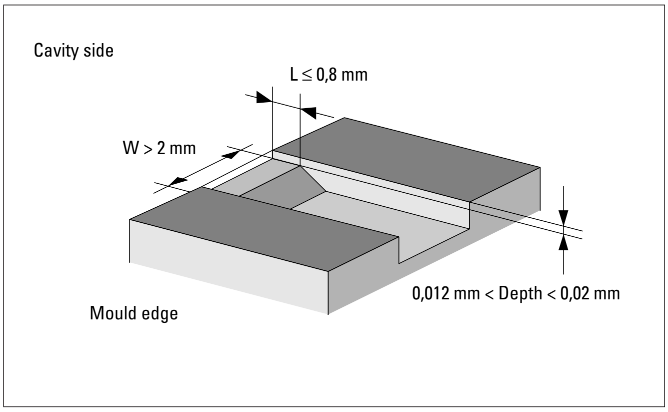
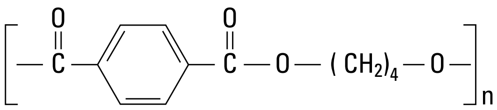


Fig. 4.12 **Parting Line Venting**

5 Material behavior

5.1 Chemical structure

The chemical structure of CRASTIN® PBT is:



CRASTIN® PBT exhibits high modulus, strength, melting point, glass transition temperature and fast crystallization, due to the large monomer structure.

5.2 Flow length

CRASTIN® polyester resin has very good flow properties. Parts with long flow paths and narrow wall thickness are easily molded. The good flow properties also contribute to achieving high surface finish quality, even with glass fiber reinforced products. Mold details are precisely reproduced.

Flow length data are generated on molds with a “spiral” or “snake” flow pattern. Data from one study can vary a lot compared to some from other studies, as flow length is highly dependent on:

- molding parameters (melt temperature, moisture, hold up time);
- mold layout (channel width, gate design);
- type of molding machine (valve response time, ability to avoid hydraulic pressure peaks at v/p switch point).

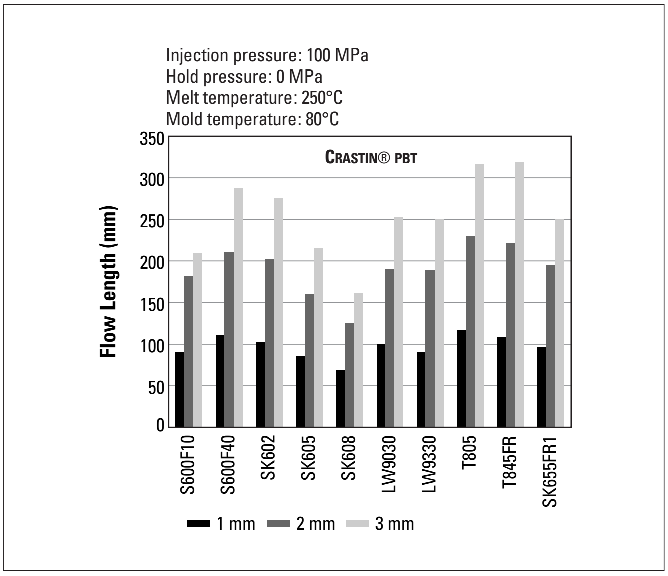


Fig. 5.1 **Flow length with wall thickness of 1, 2 and 3 mm for several grades of CRASTIN®**

Figure 5.1 shows the flow properties of standard CRASTIN® types. The indicated flow lengths, at wall thickness of 1, 2 and 3 mm, were determined with the aid of a test spiral.

Figures from a.1 to a.41 show flow length in the sections up to 1 mm. The table 5.1 indicates the page where the flow length diagram of each polyester grade may be found.

CRASTIN® global product offering

Extrusion grades

CRASTIN® 6129/C	PBT unreinforced high viscosity
CRASTIN® 6130/C	PBT unreinforced high viscosity
CRASTIN® CE1085	PBT unreinforced high viscosity hydrolytically stabilized

Unreinforced injection molding grades

CRASTIN® S600F10	PBT unreinforced high viscosity
CRASTIN® S600F20	PBT unreinforced medium/high viscosity
CRASTIN® S600F30	PBT unreinforced medium/low viscosity
CRASTIN® S600F40	PBT unreinforced low viscosity
CRASTIN® S620F20	PBT unreinforced fast cycling medium viscosity

Unreinforced toughened grade

CRASTIN® ST820	PBT unreinforced, super tough

Other unreinforced grades

CRASTIN® BM6450XD	PBT unreinforced, blow molding grade
CRASTIN® S600LF	PBT unreinforced, TEFLON® powder lubricated

Glass reinforced grades

CRASTIN® SK601	PBT reinforced with 10% glass
CRASTIN® SK602	PBT reinforced with 15% glass
CRASTIN® SK603	PBT reinforced with 20% glass
CRASTIN® SK605	PBT reinforced with 30% glass
CRASTIN® SK608	PBT reinforced with 45% glass
CRASTIN® SK609	PBT reinforced with 50% glass
CRASTIN® HR5315HF	PBT reinforced with 15% glass hydrolytically stablized, high flow
CRASTIN® HR5330HF	PBT reinforced with 30% glass hydrolytically stablized, high flow

Toughened glass reinforced grades

CRASTIN® T801	PBT reinforced with 10% glass toughened
CRASTIN® T803	PBT reinforced with 20% glass toughened
CRASTIN® T805	PBT reinforced with 30% glass toughened

Low warp grades

CRASTIN® LW9020	PBT alloy reinforced with 20% glass low warp
CRASTIN® LW9030	PBT alloy reinforced with 30% glass low warp
CRASTIN® LW9130	PBT reinforced with 30% glass ultra low warp
CRASTIN® LW9320	PBT alloy reinforced with 20% glass low warp
CRASTIN® LW9330	PBT alloy reinforced with 30% glass low warp
CRASTIN® SO653	PBT reinforced with 20% glass bead

Unreinforced flame retardant grades

CRASTIN® S660FR	PBT flame retardant
CRASTIN® ST830FR	PBT flame retardant, supertough

Glass reinforced flame retardant grades

CRASTIN® SK652FR1	PBT reinforced with 15% glass flame retardant
CRASTIN® SK655FR1	PBT reinforced with 30% glass flame retardant
CRASTIN® SK662FR	PBT reinforced with 15% glass flame retardant ultra high flow
CRASTIN® SK665FR	PBT reinforced with 30% glass flame retardant ultra high flow

Toughened glass reinforced flame retardant grades

CRASTIN® T841FR	PBT reinforced with 10 % glass toughened with high flow
CRASTIN® T843FR	PBT reinforced with 20% toughened with high flow
CRASTIN® T845FR	PBT reinforced with 30% toughened with high flow

Low warp flame retardant grades

CRASTIN® LW9320FR	PBT alloy reinforced with 20% glass flame retardant
CRASTIN® LW9330FR	PBT alloy reinforced with 30% glass flame retardant
CRASTIN® LW685FR	PBT reinforced with 30% glass and mineral flame retardant

High CTI FR

CRASTIN® HTI668FR	PBT reinforced with 45% glass and mineral, high CTI

5.3 Shrinkage

For amorphous thermoplastics, shrinkage is caused primarily by contraction of the molded part as it cools to room temperature.

In semi-crystalline thermoplastics, which include CRASTIN® grades, shrinkage is also influenced considerably by the crystallization of the polymer. The degree of crystallization depends largely on the transient and local temperature changes in the molding. High mold temperatures and heavy wall thickness (high heat content of the melt) promote crystallization and therefore increase shrinkage.

Optimum runner and gate design, as well as adequate hold pressure time are necessary in order to achieve minimum shrinkage with those semi-crystalline polymers.

Shrinkage of CRASTIN®

The influence of wall thickness on shrinkage of unreinforced CRASTIN® is shown in Figure 5.1 This shows the shrinkage of plates 100 × 100 mm, with a wall thickness of 1-4 mm, using standard processing conditions.

The shrinkage behavior of filled CRASTIN® types or of unreinforced, flame-retardant CRASTIN® types is similar to that of CRASTIN® S600F10.

For glass-fiber reinforced CRASTIN®, shrinkage is considerably influenced by the direction in which the glass-fibers are oriented. As a result, there is a difference in shrinkage parallel and normal to the direction of flow and this makes accurate prediction of the shrinkage difficult. Depending on the fiber orientation, which is determined by the way in which the mold fills, shrinkage can also occur between the longitudinal and transverse shrinkage shown in Figure 5.2. In extreme cases, the difference in shrinkage may be greater than shown.

This depends on the degree to which the glass-fibers orient themselves as determined by the design of the part and the position of the gate.

The amount of glass-fibers also have an effect on the shrinkage behavior of the CRASTIN® resin. As shown in Fig. 5.3 the shrinkage in flow will be higher for a smaller percentage of glass-fiber reinforcement.

Please refer to the end of this molding manual to find the exact data on shrinkage for CRASTIN® PBT resins.

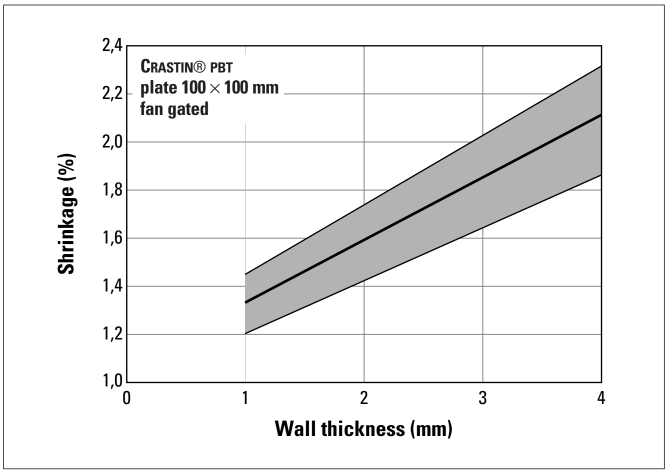


Fig 5.2 **Shrinkage of unreinforced (e.g. S600F10) and filled (e.g. SO655) CRASTIN® types as a function of wall thickness. Not valid for toughened grades**

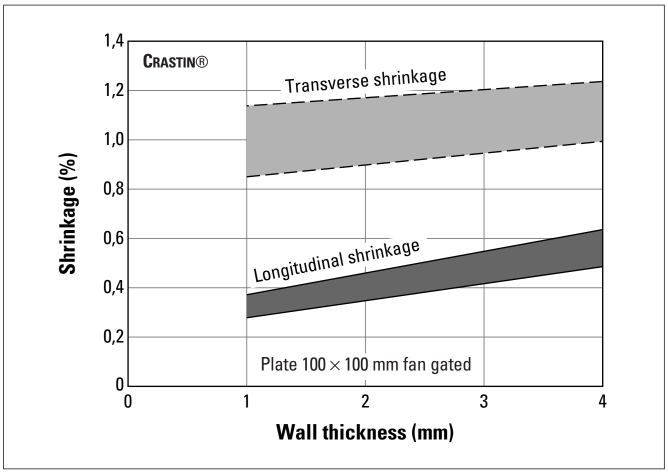


Fig 5.3 **Shrinkage of 30% glass-fibre reinforced CRASTIN® types (e.g. SK605, SK655FR1) as a function of wall thickness**

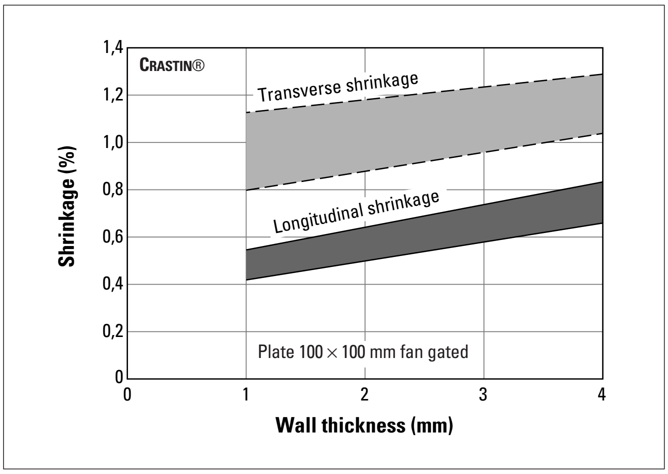


Fig 5.4 **Shrinkage of 30% glass-fibre reinforced CRASTIN® types (e.g. SK602, SK652FR1) as a function of wall thickness**

5.4 Post-shrinkage

Post-shrinkage can be defined as the dimensional change (in %) of a molded part measured at 23 ± 2°C after annealing for a specific period at a specific temperature.

The table on pages 32-33 contains shrinkage values after annealing (= molding shrinkage + post-shrinkage). The annealing conditions of those plates were 3 h/160°C for CRASTIN® PBT.

Complex parts may require lower annealing temperatures and time, in order to minimize deformation at annealing temperatures. We recommend some trials in order to find optimum annealing conditions when annealing is necessary.

Within the group of semi-crystalline thermoplastics, CRASTIN® types exhibit low post-shrinkage values. As can be seen in Figures 5.4 and 5.5, post-shrinkage is an inverse function of processing or mold shrinkage. Increasing the mold temperature reduces post-shrinkage for a given, constant conditioning temperature. However, it increases as the wall thickness increases. In the case of glass-fiber reinforced types, these effects are minimal.

This means that precision parts with very narrow tolerances should be produced using higher mold temperatures, particularly if the parts have thin walls. The degree of crystallinity will then be sufficiently high so that little or no post-shrinkage occurs if the parts are used at continuous high temperatures.

As well as processing shrinkage, glass-fiber reinforced products also exhibit different degrees of post-shrinkage in parallel and normal orientations (Figure 5.6).

Comparison of Figures 5.5 and 5.6 shows that glass-fiber reinforced CRASTIN® types exhibit even lower post-shrinkage than the unreinforced or filled types.

At a given conditioning temperature, post-shrinkage is virtually complete after 24 hours.

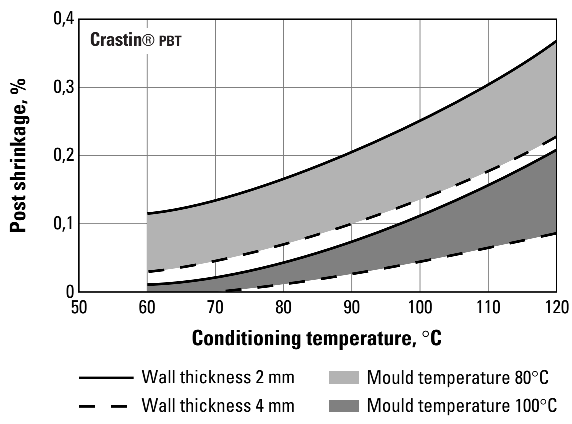


Fig 5.5 **Post-shrinkage of unreinforced (e.g. S600F10) and filled (e.g. SO655) CRASTIN® types, as a function of conditioning temperature, mold temperature and wall thickness**

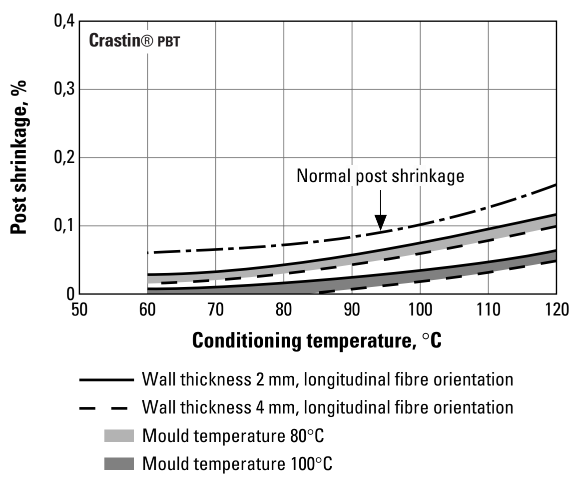


Fig 5.6 **Post-shrinkage of 30% glass-fibre reinforced CRASTIN® types (e.g. SK605, SK645FR) as a function of conditioning temperature, wall thickness and mold temperature**

6 Auxiliary operations

6.1 Regrind

Only regrind from optimally processed original material should be used.

The actual amount of regrind which can be added must be determined for each part by testing. Only the operational and performance requirements of a molded part can determine the amount of regrind that can be acceptable.

Because of the irreversible chemistry of polyester resins, material that has been previously degraded because of its high moisture content and/or too long Hold-Up Time (HUT) in the barrel **cannot** be re-used. Molded parts that become brittle as a result of poor material handling (too high moisture content in the granules) or material left in the barrel (too long HUT) must be discarded and **not** re-used, thus avoiding any dramatic deterioration in properties when mixed with good regrind and/or virgin resin.

In order to keep the loss of strength and toughness at a low level, not more than 30% by weight of regrind should be added to unreinforced products. In the case of glass-fiber reinforced types, increased loss of strength must be expected due to the reduction of fiber length which occurs during regrinding. For this reason, not more than 25% by weight of regrind should be added to reinforced materials. The reduction in the flexural and impact strength of CRASTIN® SK605 with various regrind percentages and repeated use is shown in Figure 6.1.

In the case of parts subjected to mechanical loads, regrind should be used only rarely. A higher amount of regrind is feasible, for example, when in addition to electrical insulating properties, the part needs only a high heat deflection temperature. Recycled material should have approximately the same granule size as fresh granulate. Grinder screens with a mesh size of about 5 mm yield a grain size of approximately 3 mm in diameter.

A screen with a mesh of approximately 2,5 mm can be used for removing dust particles in the regrind. Before processing, the regrind should be dried to avoid the possibility of degradation due to the presence of moisture in the granulate.

6.2 Coloring

A range of cube-blended standard colors is available for certain polyesters. The freedom of design is even greater in that almost any coloring system can be used: dry pigment, paste, liquid color or dyes. But such systems can also lead to variations in properties and/or performance.

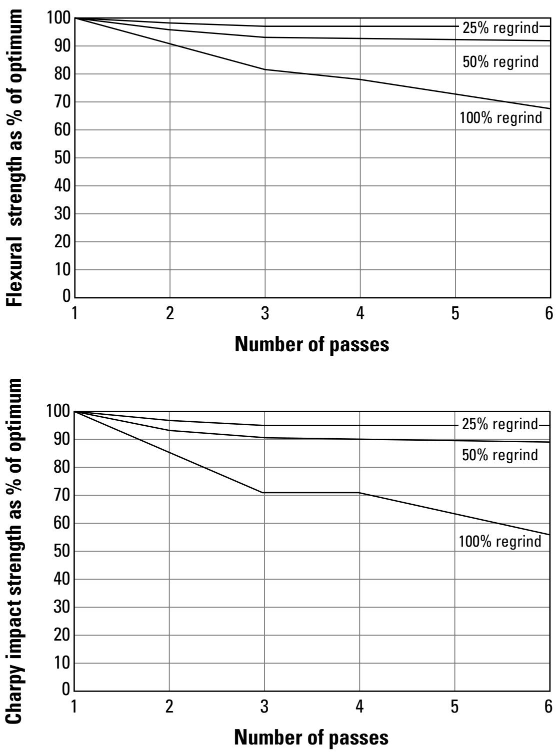


Fig 6.1 **Reduction of the flexural and impact strength of CRASTIN® SK605 for various regrind percentages and repeated use**

When using masterbatch or dry pigments, special attention should be given to these aspects:

- The dry pigments or masterbatch used have to be chemically compatible with polyester resins and must have good thermal stability above the processing temperature of the resin.
- Pigments usually affect the crystallization rate and consequently the shrinkage. Additionally the carrier of liquid colors has an effect on molding.
- The carrier can be considered as a surface lubricant, which may, theoretically, cause screw slippage leading to filling problems.
- The key issue when molding with coloring techniques is to ensure a homogeneous dispersion and mixing of the pigment in the polymer matrix.

When using a coloring technique, the following points should be carefully observed:

- Use of reasonable ratio between polymer and masterbatch.
- Use of high-compression screws.
- Use of screw retraction stroke less than 30% of the maximum screw retraction of the machine.

Important note
DuPont cannot give any guarantee for the performance and properties of molded parts when DuPont manufactured polyester resins are mixed with other products like masterbatches, liquid pigments or colorants.

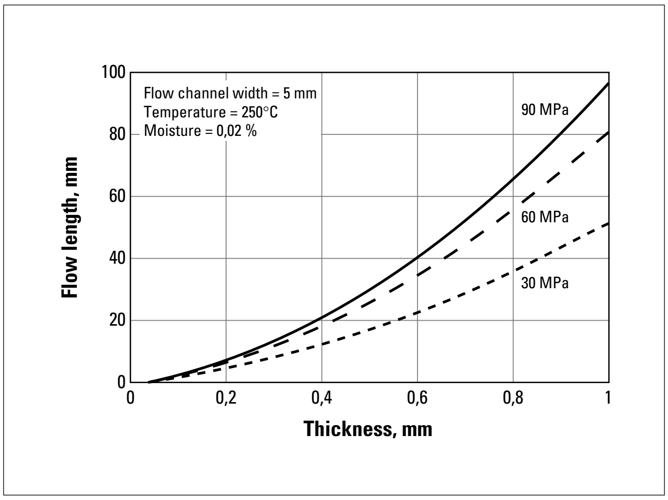


Fig. a.1 **Crastin® 6129 NC010**

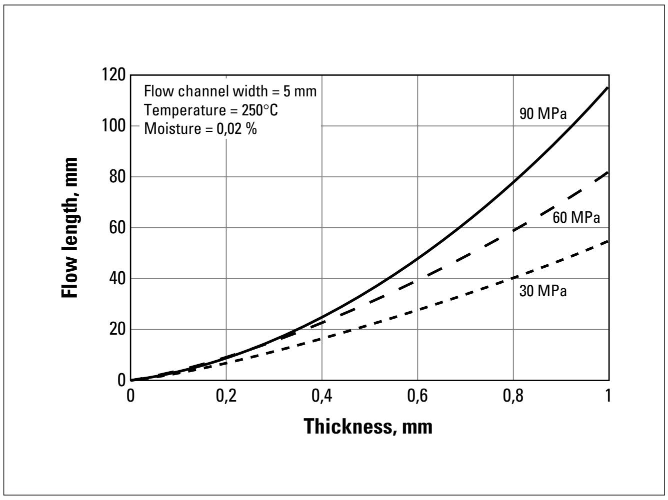


Fig. a.2 **Crastin® 6130 NC010**

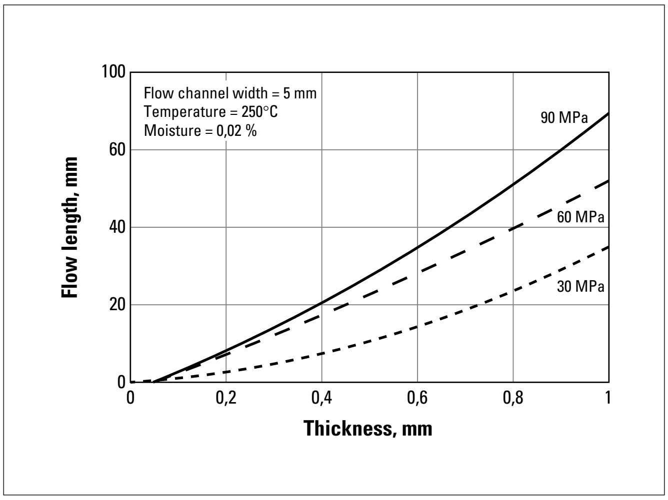


Fig. a.3 **Crastin® CE1085 NC010**

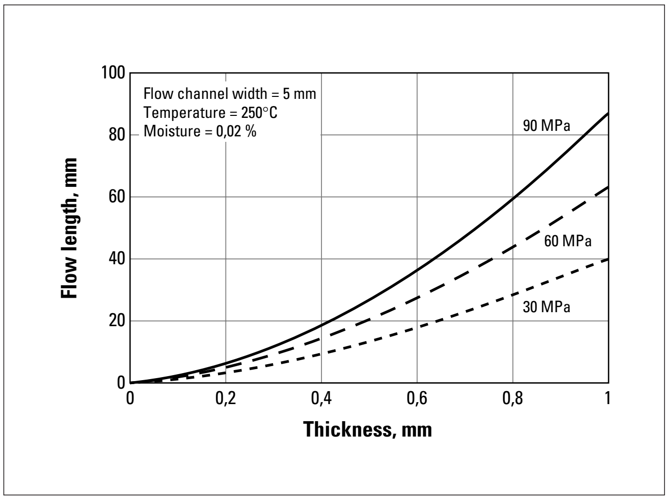


Fig. a.4 **Crastin® S600F10 NC010**

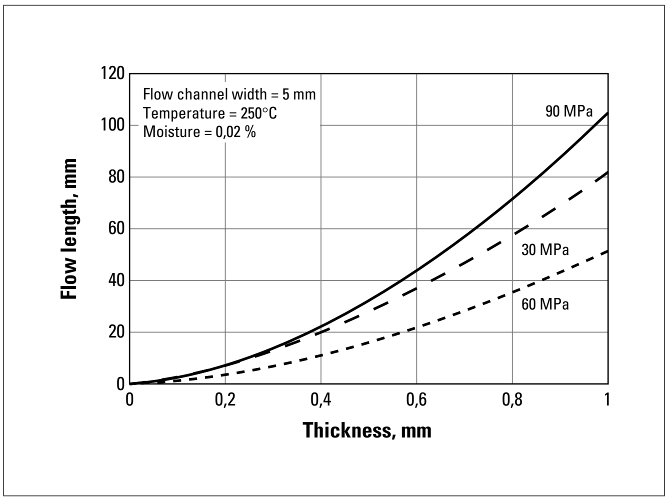


Fig. a.5 **Crastin® S600F20 NC010**

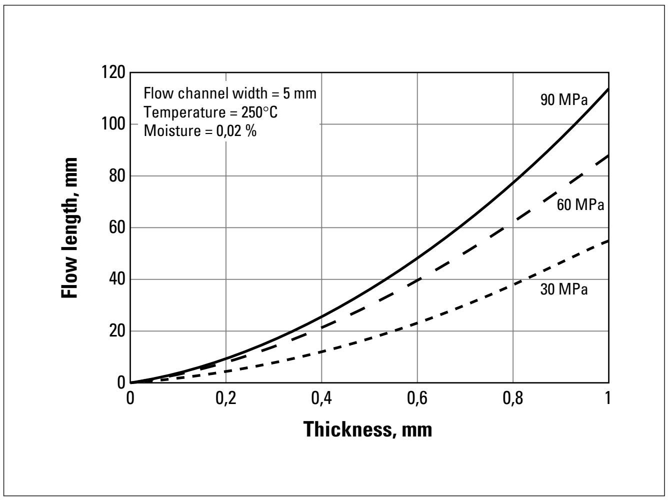


Fig. a.6 **Crastin® S600F30 NC010**

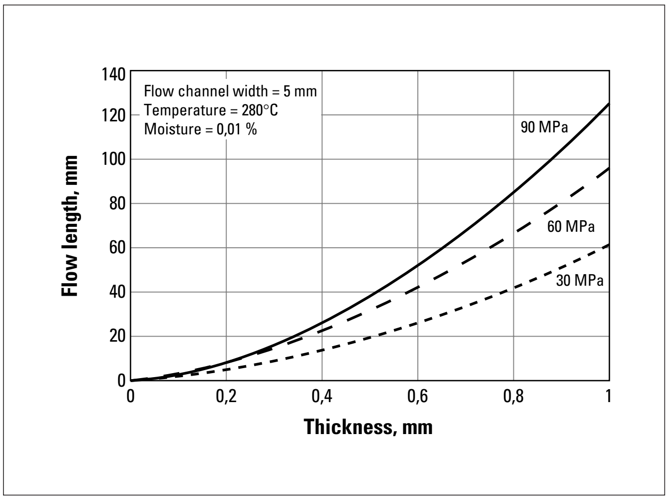


Fig. a.7 **Crastin® S600F40 NC010**

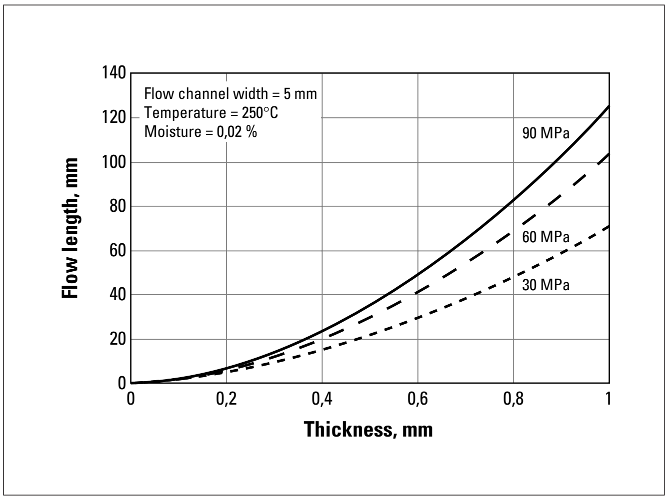


Fig. a.8 **Crastin® S620F20 NC010**

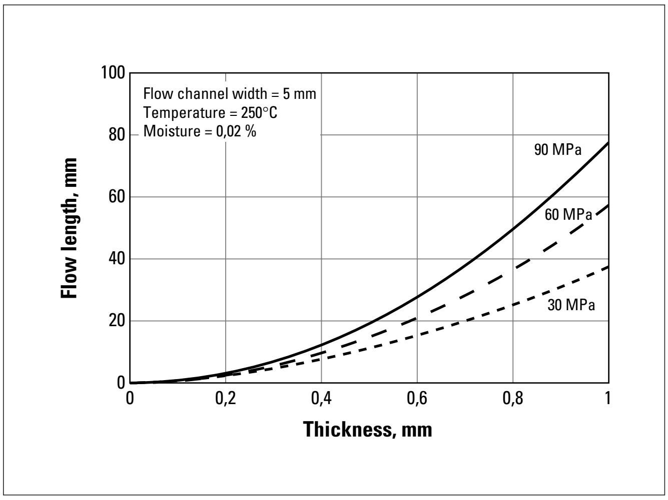


Fig. a.9 **Crastin® ST820 BK503**

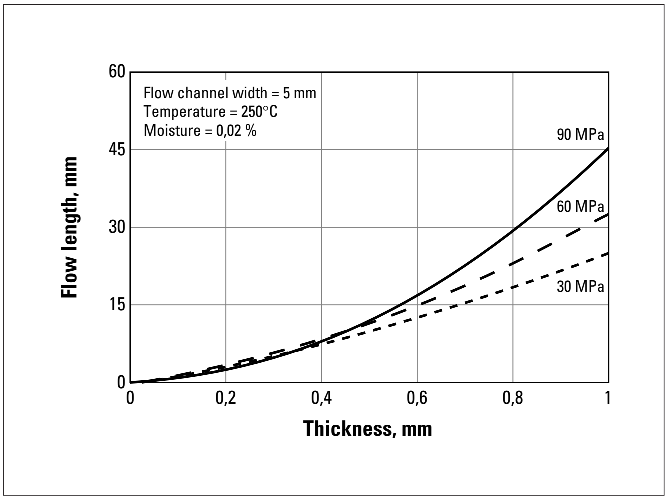


Fig. a.10 **Crastin® BM6450XD BK560**

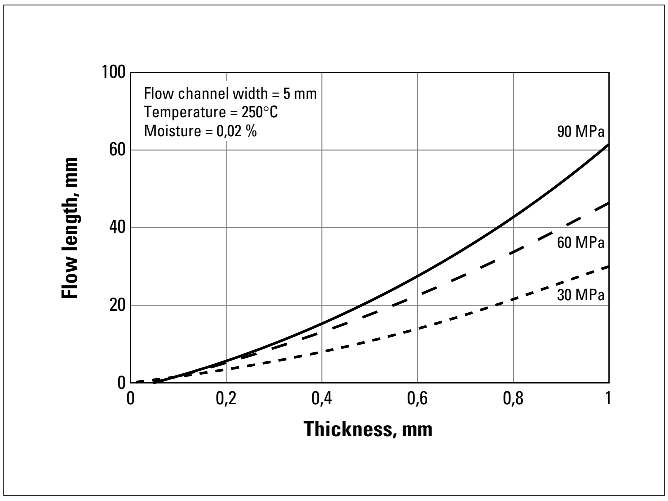


Fig. a.11 **Crastin® S600LF NC010**

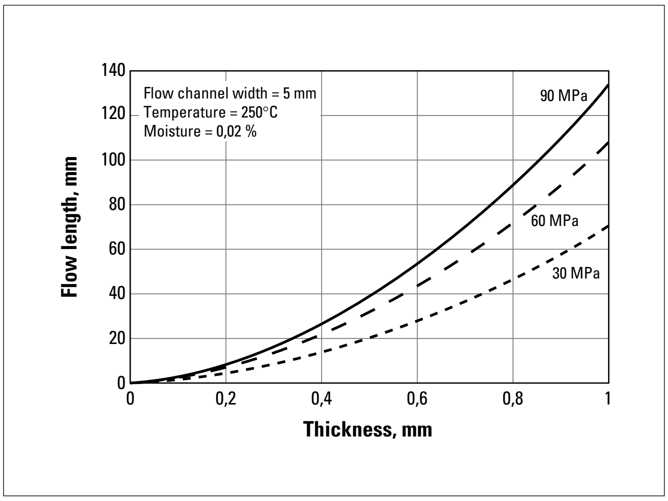


Fig. a.12 **Crastin® SK601 NC010**

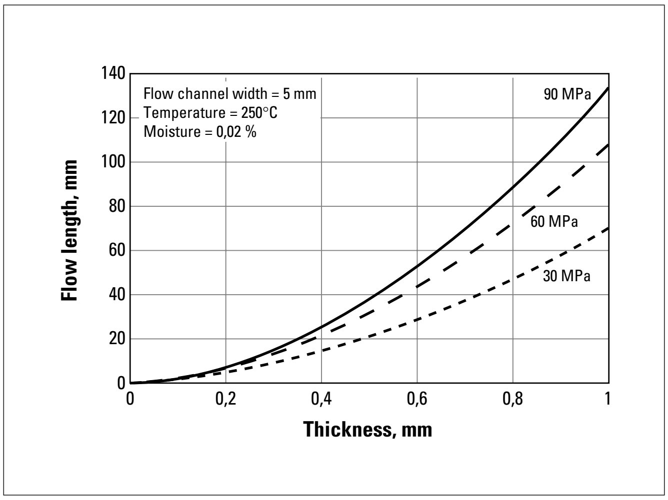


Fig. a.13 **CRASTIN® SK602 NC010**

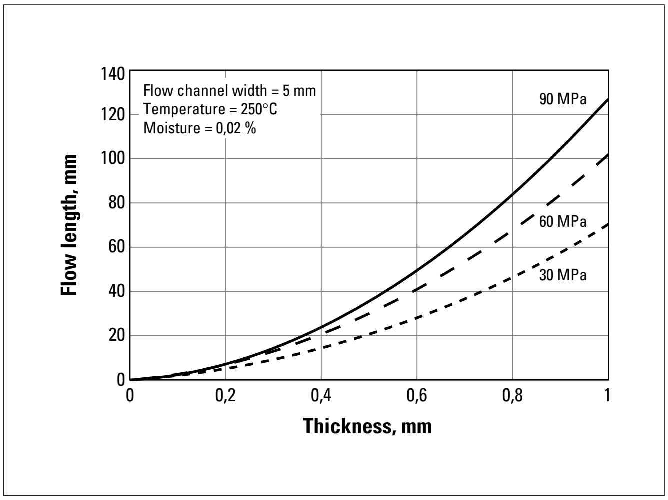


Fig. a.14 **CRASTIN® SK603 NC010**

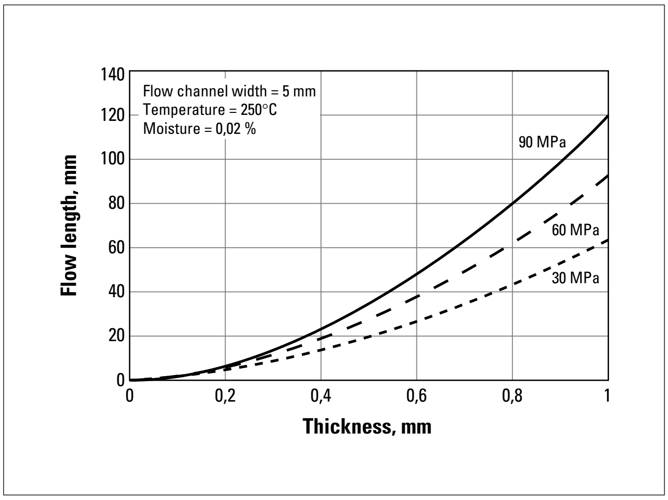


Fig. a.15 **CRASTIN® SK605 NC010**

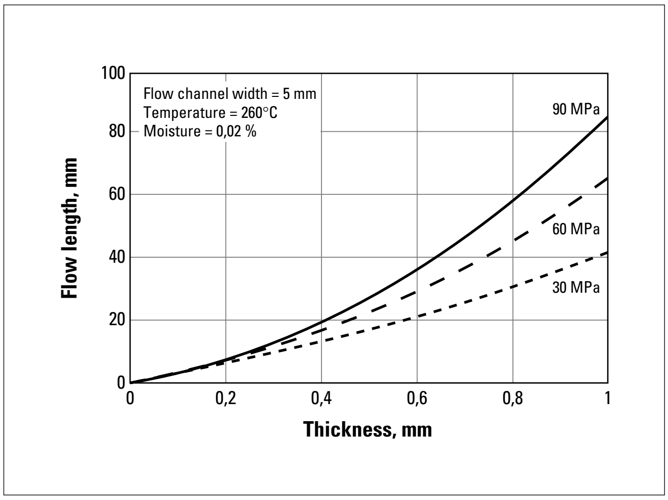


Fig. a.16 **CRASTIN® SK608 BK**

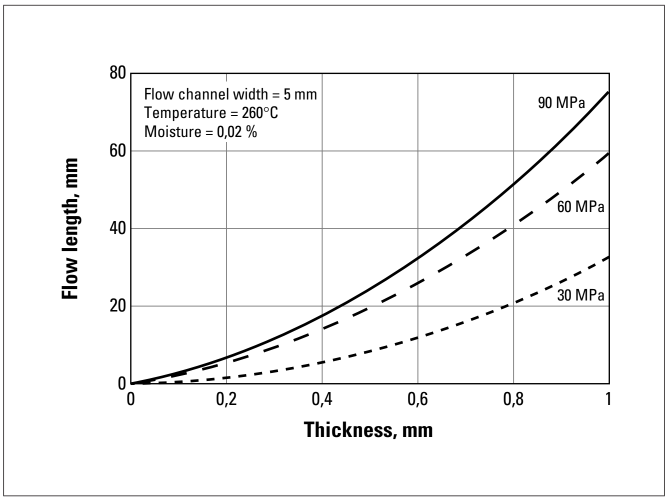


Fig. a.17 **CRASTIN® SK609 NC010**

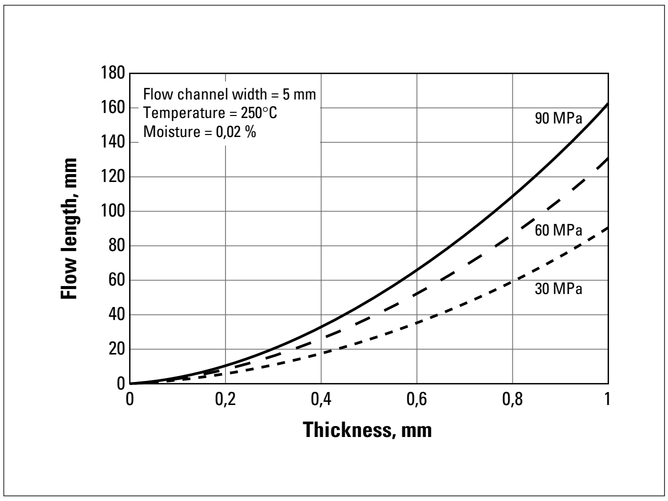


Fig. a.18 **CRASTIN® T801 NC010**

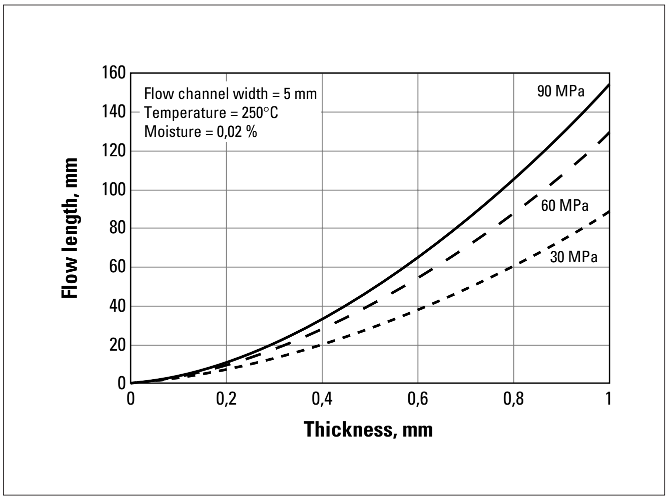


Fig. a.19 **Crastin® T803 NC010**

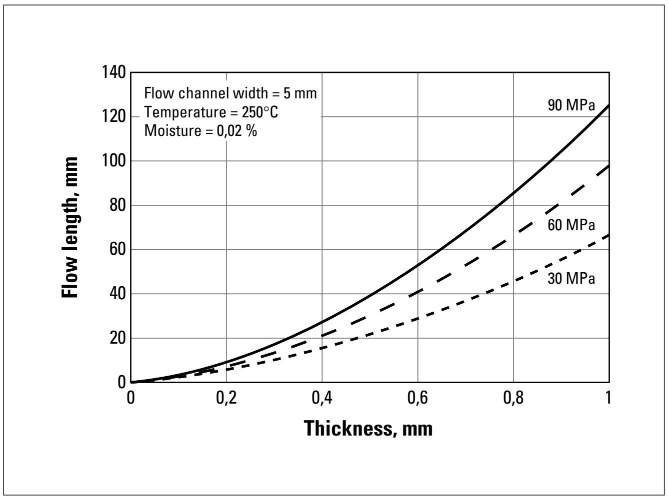


Fig. a.20 **Crastin® T805 NC010**

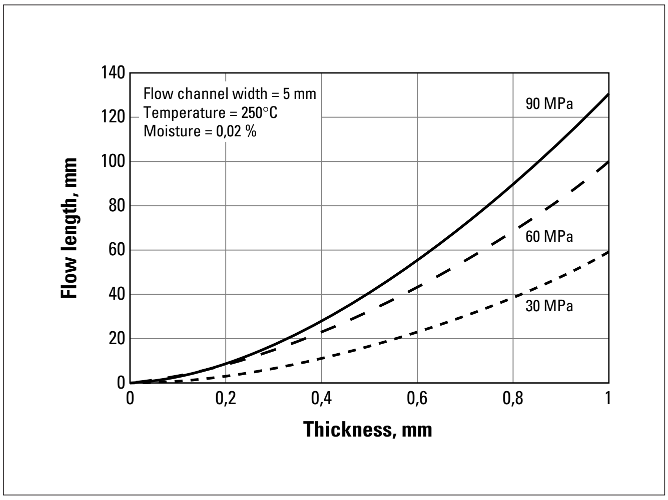


Fig. a.21 **Crastin® LW9020 NC010**

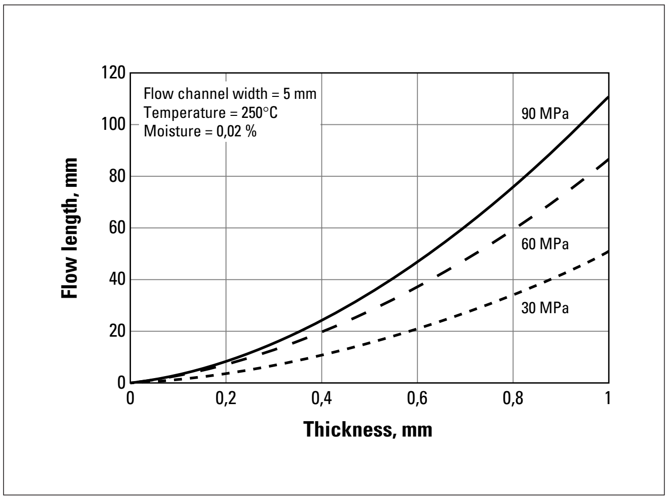


Fig. a.22 **Crastin® LW9030 NC010**

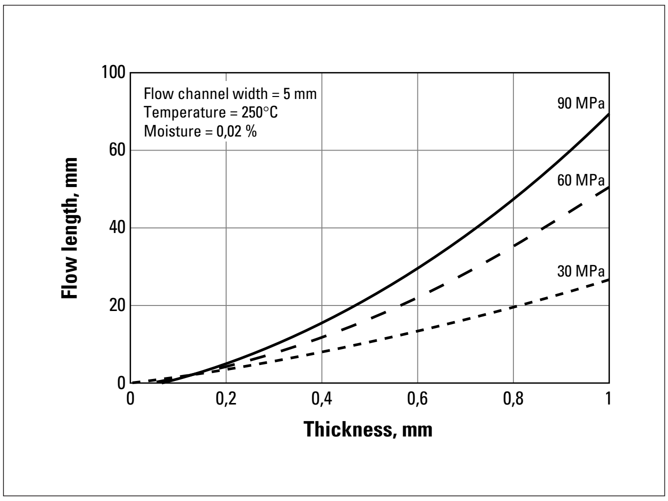


Fig. a.23 **Crastin® LW9130 NC010**

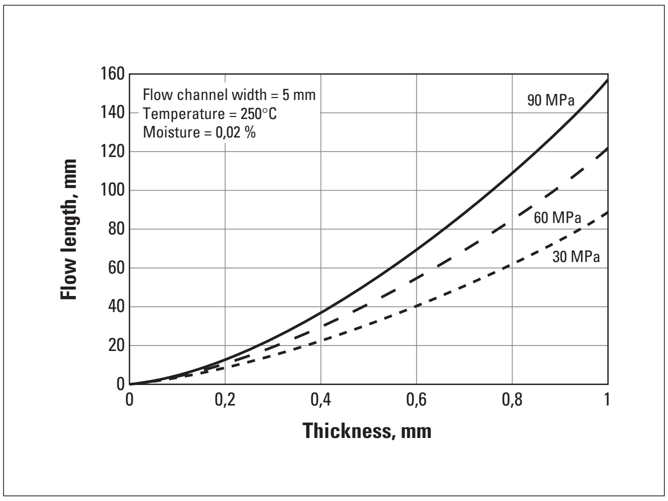


Fig. a.24 **Crastin® LW9320 NC010**

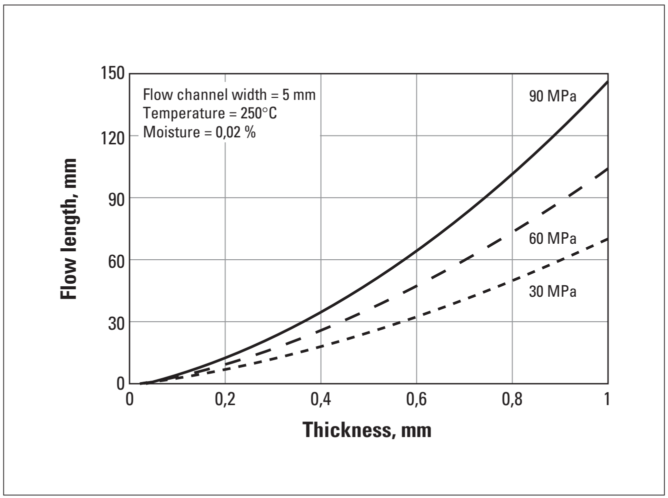


Fig. a.25 **Crastin® LW9330 NC010**

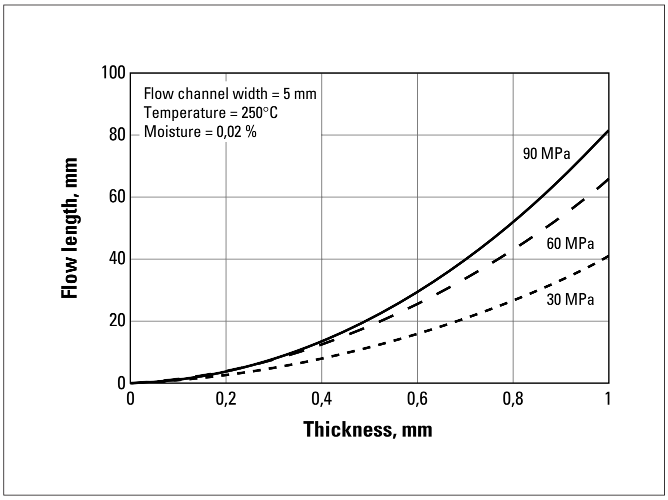


Fig. a.26 **Crastin® SO653 NC010**

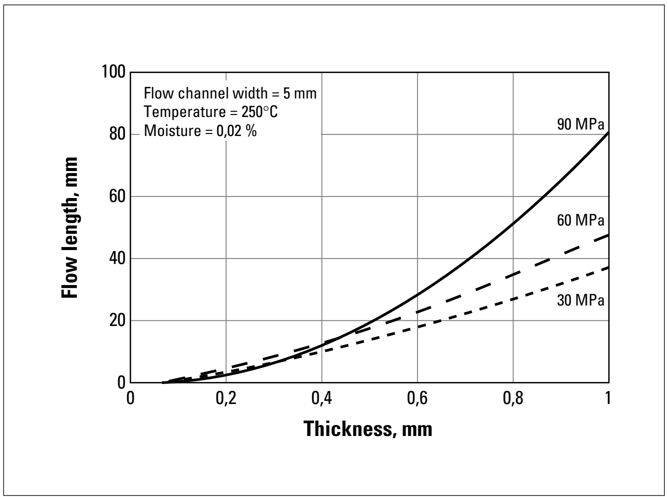


Fig. a.27 **Crastin® S660FR NC010**

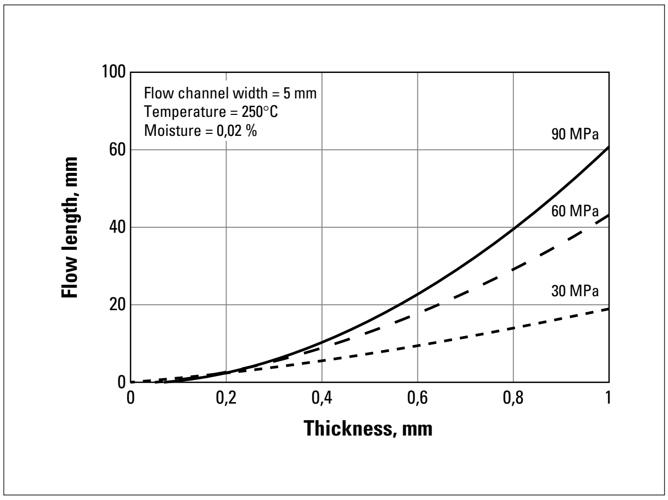


Fig. a.28 **Crastin® ST830FR NC010**

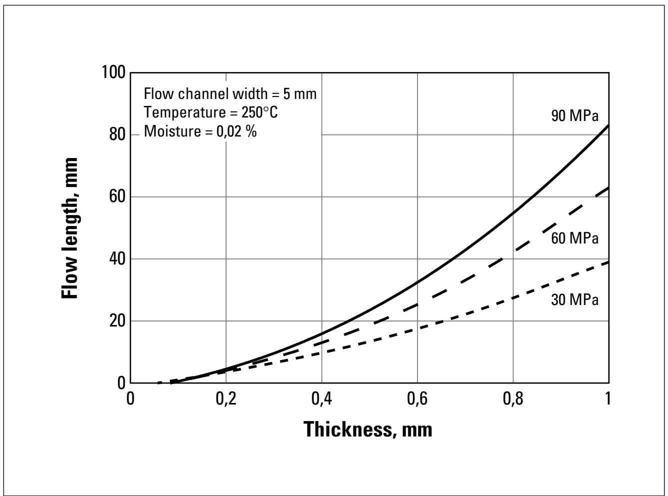


Fig. a.29 **Crastin® SK652FR1 NC010**

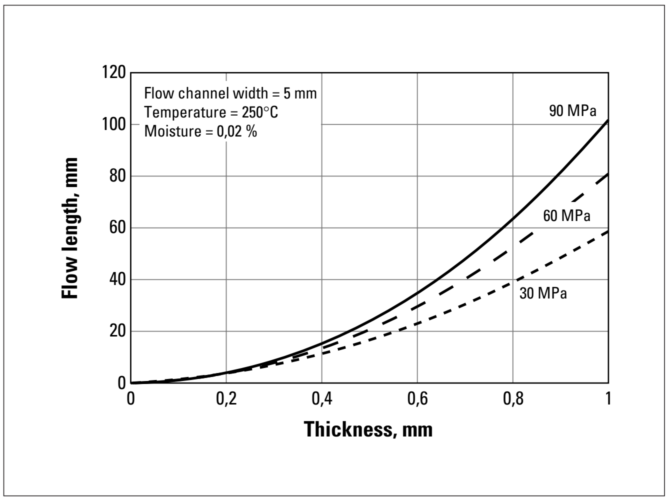


Fig. a.30 **Crastin® SK655FR1 NC010**

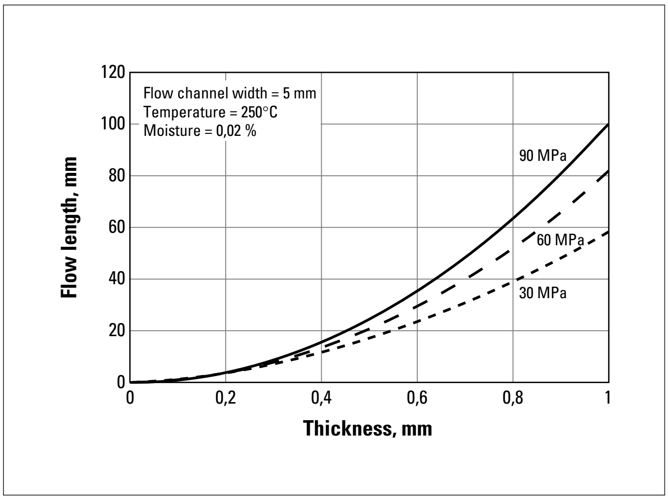


Fig. a.31 **Crastin® SK662FR NC010**

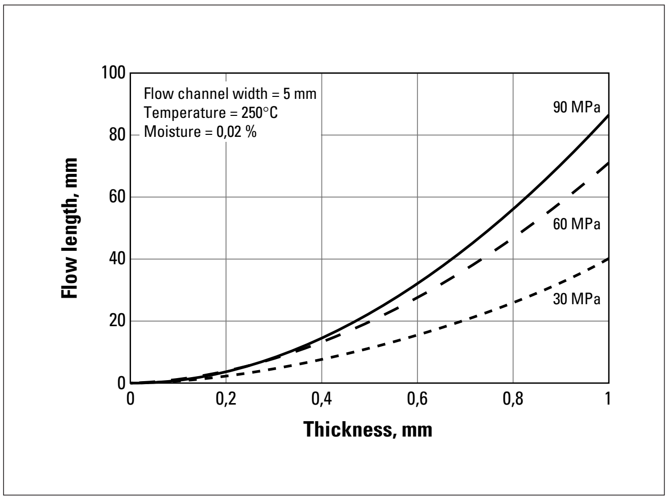


Fig. a.32 **Crastin® SK665FR NC010**

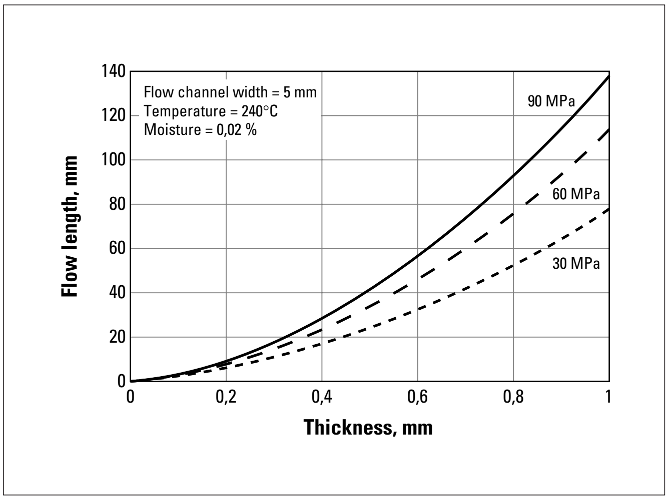


Fig. a.33 **Crastin® T841FR NC010**

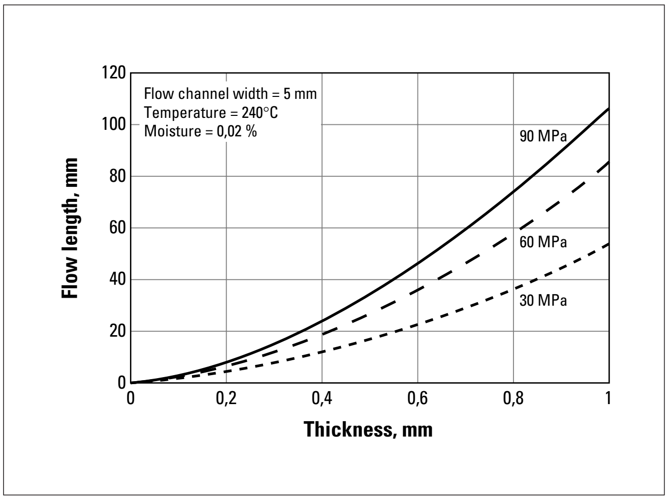


Fig. a.34 **Crastin® T843FR NC010**

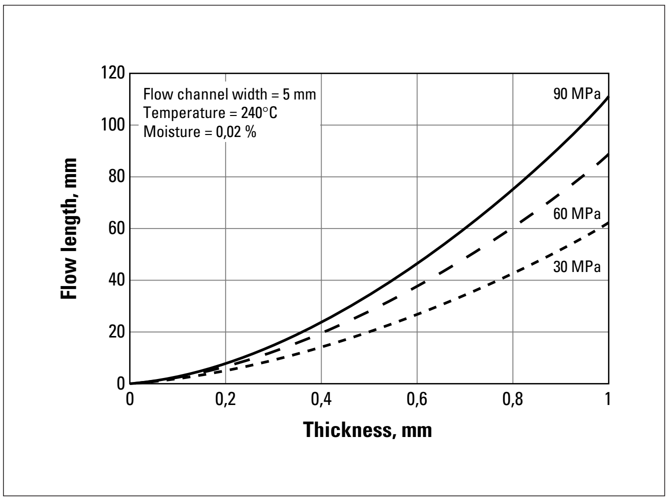


Fig. a.35 **Crastin® T845FR NC010**

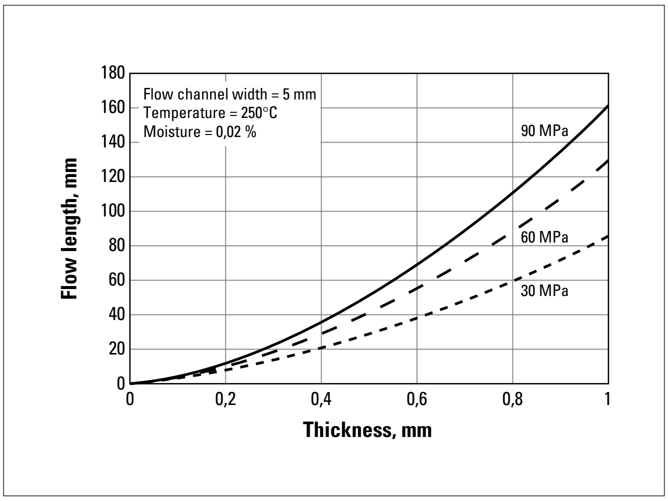


Fig. a.36 **Crastin® LW9320FR NC010**

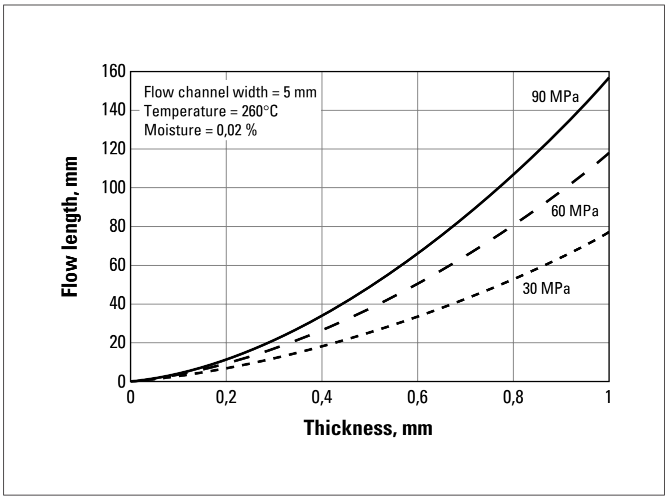


Fig. a.37 **Crastin® LW9330FR NC010**

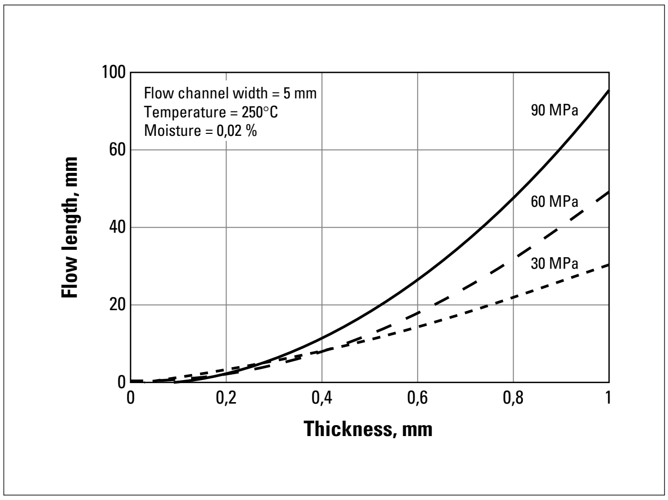


Fig. a.38 **Crastin® LW685FR NC010**

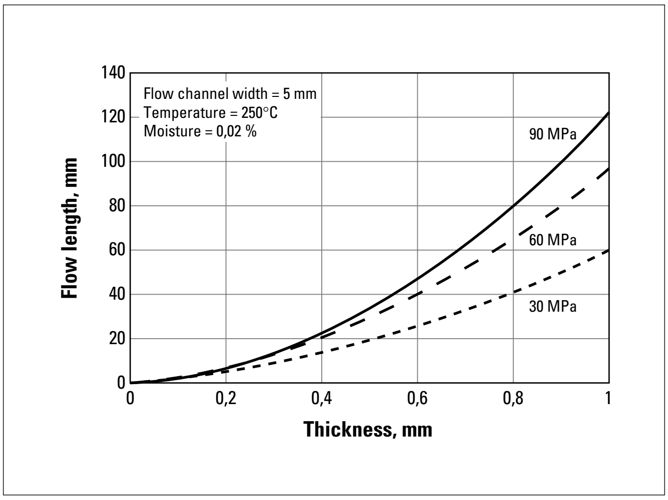


Fig. a.39 **Crastin® HTI668FR NC010**

Injection molding recommendations for CRASTIN® PBT

	Description	Denomination	Drying temperature	Drying time	Melt temperature optimum	Melt temperature range	Mold temperature optimum	Mold temperature range	Molding shrinkage ISO 294-4 (2 × 60 × 60 mm)		Annealed	
									⊥	‖	⊥	‖
			°C	h	°C	°C	°C	°C	%	%	%	%
Extrusion grade												
CRASTIN® 6129	extrusion grade	PBT	110-130	2-4	250	240-260	80	30-130	1,5	1,7	2,1	2
CRASTIN® 6130	extrusion grade	PBT	110-130	2-4	250	240-260	80	30-130	1,45	1,6	2,05	1,95
Crastin® CE1085	extrusion grade	PBT	110-130	2-4	250	240-260	80	30-130	1,7	1,75	2,3	2,1
Unreinforced injection molding grades												
Crastin® S600F10	high viscous	PBT	110-130	2-4	250	240-260	80	30-130	1,6	1,7	2,1	2
Crastin® S600F20	easy flow	PBT	110-130	2-4	250	240-260	80	30-130	1,55	1,7	2,1	2
Crastin® S600F30	medium/low viscosity	PBT	110-130	2-4	250	240-260	80	30-130	1,7	1,8	2,0	2,05
Crastin® S600F40	very high flow	PBT	110-130	2-4	250	240-260	80	30-130	1,8	2,0	2,0	2,05
Crastin® S620F20	fast cycling	PBT	110-130	2-4	250	240-260	80	30-130	1,8	1,9	2,3	2,4
Unreinforced toughened grade												
CRASTIN® ST820	impact modified	PBT	110-130	2-4	250	240-260	80	30-130	1,55	1,7	2,25	2,5
Other unreinforced grades												
Crastin® BM6450XD	blow molding grade	PBT	110-130	2-4	250	240-260	80	30-130	1,8	1,65	2,3	2,6
Crastin® S600LF	low friction and wear	PBT	110-130	2-4	250	240-260	80	30-130	2,0	2,1	2,5	2,7
Glass reinforced grades												
Crastin® SK601	PBT reinforced with 10% glass	PBT GF10	110-130	2-4	250	240-260	80	30-130	1,15	0,65	1,45	0,8
Crastin® SK602	PBT reinforced with 15% glass	PBT GF15	110-130	2-4	250	240-260	80	30-130	1,1	0,4	1,4	0,55
Crastin® SK603	PBT reinforced with 20% glass	PBT GF20	110-130	2-4	250	240-260	80	30-130	1,05	0,35	1,35	0,5
Crastin® SK605	PBT reinforced with 30% glass	PBT GF30	110-130	2-4	250	240-260	80	30-130	1,1	0,3	1,35	0,4
Crastin® SK608	PBT reinforced with 45% glass	PBT GF45	110-130	2-4	260	250-270	80	30-130	1,25	0,3	1,45	0,4
Crastin® SK609	PBT reinforced with 50% glass	PBT GF50	110-130	2-4	260	250-270	80	30-130	1,1	0,25	1,25	0,35
Crastin® HR5315HF	hydrolysis resistant and high flow with 15% glass	PBT GF15	110-130	2-4	250	240-260	80	30-130	1,15	0,5	1,4	0,7
Crastin® HR5330HF	hydrolysis resistant and high flow with 30% glass	PBT GF30	110-130	2-4	250	240-260	80	30-130	1,2	0,3	1,45	0,4
Toughened glass reinforced grades												
Crastin® T801	toughened	PBT GF10	110-130	2-4	250	240-260	80	30-130	0,9	0,55	1,3	0,8
Crastin® T803	toughened	PBT GF20	110-130	2-4	250	240-260	80	30-130	0,85	0,35	1,15	0,45
Crastin® T805	toughened	PBT GF30	110-130	2-4	250	240-260	80	30-130	0,85	0,25	1,15	0,35

Injection molding recommendations for Crastin® PBT

	Description	Denomination	Drying temperature	Drying time	Melt temperature optimum	Melt temperature range	Mold temperature optimum	Mold temperature range	Molding shrinkage ISO 294-4 (2 × 60 × 60 mm) ⊥	‖	Annealed ⊥	‖
			°C	h	°C	°C	°C	°C	%	%	%	%
Low warp grades												
Crastin® LW9020	low warpage	PBT blend GF20	110-130	2-4	250	240-260	80	30-130	0,65	0,35	0,9	0,55
Crastin® LW9030	low warpage	PBT blend GF30	110-130	2-4	250	240-260	80	30-130	0,65	0,25	0,95	0,4
Crastin® LW9130	low warpage	PBT GF30	110-130	2-4	250	240-260	80	30-130	0,65	0,25	1	0,4
Crastin® LW9320	low warpage	PBT blend GF20	110-130	2-4	260	240-260	100	30-130	0,65	0,4	0,85	0,5
Crastin® LW9330	low warpage	PBT blend GF30	110-130	2-4	260	240-260	100	30-130	0,6	0,25	0,85	0,4
Crastin® S0653	low warpage	PBT GF20	110-130	2-4	250	240-260	80	30-130	1,55	1,8	2	2,25
Unreinforced flame retardant grades												
Crastin® S660FR	V-0 @ 0,25 mm, high flow	PBT	110-130	2-4	250	240-260	80	30-130	2,0	2,05	2,5	2,6
Crastin® ST830FR	V-0 @ 0,85 mm, super tough	PBT	110-130	2-4	250	240-260	80	30-130	1,3	1,7	2,0	2,3
Glass reinforced flame retardant grades												
Crastin® SK652FR1	flame retarded, V-0 @ 0,81 mm	PBT GF15	110-130	2-4	250	240-260	80	30-130	1,5	0,65	1,7	0,8
Crastin® SK655FR1	flame retarded, V-0 @ 0,40 mm	PBT GF30	110-130	2-4	250	240-260	80	30-130	1,35	0,30	1,55	0,45
Crastin® SK662FR	flame retarded, V-0 @ 0,30 mm	PBT GF15	110-130	2-4	250	240-260	80	30-130	1,1	0,65	1,35	0,75
Crastin® SK665FR	flame retarded, V-0 @ 0,30 mm	PBT GF30	110-130	2-4	250	240-260	80	30-130	0,95	0,65	1,2	0,4
Thoughened glass reinforced flame retardant grades												
Crastin® T841FR	flame retarded, toughened	PBT GF10	110-130	2-4	240	240-260	80	30-130	1,15	0,7	1,5	0,9
Crastin® T843FR	flame retarded, toughened	PBT GF20	110-130	2-4	240	240-260	80	30-130	1	0,4	1,25	0,5
Crastin® T845FR	flame retarded, toughened	PBT GF30	110-130	2-4	240	240-260	80	30-130	1	0,3	1,3	0,35
Low warp flame retardant grades												
Crastin® LW9320FR	flame retarded, low warpage	PBT blend GF20	110-130	2-4	260	240-260	100	65-130	0,75	0,45	0,95	0,5
Crastin® LW9330FR	flame retarded, low warpage	PBT blend GF30	110-130	2-4	260	240-260	100	65-130	0,6	0,2	0,9	0,3
Crastin® LW685FR	flame retarded, low warpage	PBT GF30	110-130	2-4	250	240-260	80	30-130	1,0	0,75	1,15	0,9
High CTI FR												
Crastin® HTI668FR	high tracking	PBT (GP + M) 45	110-130	2-4	250	240-260	80	30-130	0,85	0,45	1,1	0,6

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