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Injection molding of ZX-100

General data

ZX-100 has been developped for the production of ductile objects which are not especially subjected to high temperatures. Due to its good flow properties it permits the molding of complicated objects with long flow distances. Depending on the processing conditions and especially the mold temperature, ZX-100 can be processed to injection molded parts of crystal or amorphous structure. Owing to the fact that numerous properties are determined by the crystal consistency, the choice of one of both possibilities depends on the demands on the end product.
ZX-100 can principally be processed on every machine type. However, we recommend the use of injection molding machines with a screw plasticizing unit and in fact especially singe-screw machines in consideration to the required homogenity.

Screw

The geometry of the screw is decisive for the extraction and plastication of the granulate. A three-section screw with a L/D-relation of about 15 and a flight depth ratio of 1:2, which is mainly used for polyamides has been well-established in the process of ZX-100.

Screws with a so-called constantly increasing root diameter like those employed for the processing of PVC are not suitable here, because they can cause interruptions of the granulate transport, which could only be avoided by means of very high barrel temperatures. Such high barrel temperatures, however, hold the danger of thermal degradation of the material, which leads to brittle products. The screws must be equipped with a back flow valve in order to avoid the backflow of the melt during the process of injection and holding pressure.

Barrel

In order to achieve an optimum result high temperature fluctuations must be avoided during the injection process. Therefore the temperature of the heating elements must be controlled precisely by means of an effective measuring and control system.

Processing guidelines

Generally a high injection pressure is required for the injection molding of ZX-100. The barrel must therefore be calculated with regard to maximum pressures.

Nozzle

For the processing of ZX-100 we recommend the use of a shut-off nozzle. In case of working with machines with a decompression control you may also use an open nozzle. When using shut-off nozzles, hydraulically driven nozzles should be preferred, but spring caps are also suitable, provided that the spring is resistant to high temperatures (300°C) and installed outside.

By means of a generously dimensioned nozzle aperture (3mm or more) a premature solidification of the melt can be avoided as well as pressure loss is reduced. We recommend to detach the nozzle from the mold plate after injection and refill, in ordert o limit the heat exchange between the injection nozzle and the mold to a minimum.

Feed hopper

During processing the feed hopper must be well closed to ensure that the material is kept dry and free of dust.

Shot weight

In order to guarantee a well-dimensioned and weight-wise reproducibility of the molded parts, it is important to avoid a fully utilization of the shot weight of the machine. We recommend to use a machine with a maximum shot weight, which is 30 to 50 % higher than the weight of the injection molded parts.

Moisture content of the granulate

The granulate supplied in a humidity protective and airtight packaging shows a very low moisture content and therefore does not require predrying. Dry granulate has the tendency to absorb humidity from the air.

The moisture absorption is very low (maximum 0.2-0.3 %), but also a slightly increased moisture content may cause problems in processing and can spoil the injection molded part. Therefore you must make sure that the granulate is always kept dry.

The following precautions have to be taken:
- do not open the canisters until using the material;
- open canisters must be well closed immediately after removal;
- cool stored canisters must be put into the processing room timely (at least 12 hours before use), in order to avoid that atmospheric humidity condenses on the cold granulate surface.
- always keep the feed hopper well closed.

Humid granulate can be dryed in a vacuum dryer or hot air oven at temperatures of 120-140 °C. The layer hight should not exceed 2 mm.

Drying times

in the vacuum dryer 3 to 6 hours,
in the hot air oven 5 to 7 hours.

Waste recycling

When recycling the waste, always pay attention to an especially careful dehydration before processing. We recommend to blend only small doses of waste (up to 15 %) with fresh material.

Barrel temperatures

ZX-100 requires a slight temperature gradient difference, which means that the barrel temperature is at its highest on the feed hopper and slightly decreases near the injection nozzle.

The following temperature settings have frequently been well-established in practice:

zone 1 (feed hopper side):	275°C
zone 2:	270°C
zone 3:	265°C
nozzle:	260°C

However, it can be necessary to adapt the temperatures, because the temperature setting also depends on the article (wall thickness, flow distance) and on the injection molding machine.

The most favourable temperature control must be determined in preliminary tests. Temperatures exceeding 300 °C should be avoided due to danger of thermal degradation. In order to keep the granulate from early melting, the feeding head in the cylinder must always be cooled.

Mold temperature

As already mentioned at the beginning, ZX-100 can be processed to parts with crystal or amourphous structure.

The mold temperature depends on the requested structure of the molded parts. An optimum crystallization can be achieved at a mold temperature of 130°C, whereas for an amouphous structure the mold temperature must be kept below 50°C.

ZX-100 has the tendency to crystallize on slow transition from a liquid to a solid condition.

An amorphous structure can only be achieved, when the material has been cooled down as soon as possible. Therefore the fluid material must be extruded into a cold mold. Then it solidifies so quickly that a sufficiently rigid injection molded part is being produced already after a very short cooling time, which can be ejected without any danger of deformation. Pratically no molding shrinkage can arise.

A completely amorphous structure as well as a good rigidity can be achieved at a mold temperature below 50°C. At higher temperatures the rigidity considerably decreases very quickly and demolding problems can occur due to deformation of the injection molded part. Therefore always pay attention to the following basic rule: for amorphous injection molded parts the mold temperature (determined by flow distance and wall thickness) should be below 50°C.

For the manufacture of amorphous injection molded parts special types of ZX-100 have been developped, which restrain crystallization. However, in case of thick-walled parts (more than 5 to 6 mm) sometimes a crystallization point cannot be avoided due to the immense heat content of the material.

Injection pressure and injection rate

A high injection pressure is necessary as a rule in order to guarantee a good mold filling and to avoid shrink marks. It should be about 1000 to 1200 bar, but it may also be higher or lower depending on flow distance and wall thickness.

In order to avoid an early solidification of the melt during the mold filling action also a high injection rate is necessary in most cases. In this case you must carefully pay attention to a good deaeration of the mold, because otherwise the danger can arise, that compact air leads to signs of charring. Especially thin-walled objects require a high injection rate.

Holding pressure and holding pressure time

During solidification of the melt in the mold a considerable shrinkage arises. Holding pressure and holding pressure time must therefore provide an adequate adjustment. A holding pressure which has about 40 to 60 % of the injection pressure leads in most cases to a perfect injection molded part. Whereas a too high holding pressure can cause internal stress to the product and must therefore be avoided. The holding pressure time should not be calculated too short. In practice, the holding pressure time should from case to case be determined in preliminary tests (for example by weighing the injection molded part). Shrink marks or voids are often consequences of a too short holding pressure time. With an increasing wall thickness also the holding pressure time must be extended.

Screw speed and dynamic pressure

In order to prevent an excessive heat evolution, a high screw speed as well as a high dynamic pressure must be avoided. Just in case the melt temperature increases too high despite minimum screw speed, we recommend to increase the temperature of the second heating zone (seen from the feed hopper). So the frictional heat is reduced and the temperature of the material drops.

The application of a low dynamic pressure already supports the homogenity of the melt.

Clamping force

Before starting injection molding of molded parts with an amorphous structure, the mold clamping pressure must be tuned to the injection pressure and the requested surface finish of the molded part.

The production of molded parts with a crystal structure requires a higher mold clamping pressure, because the material solidifies more slowly due to the relatively high mold temperature.

Feeding

It is recommendable to adjust the feeding in that way, that there is always a little „melt cushion“ in front of the screw, which, however, should not be too small considering the reproducibility of the melt and the weight of the injection molded part. Whereas a too big melt cushion can cause a high loss of pressure and may therefore lead to an insufficient top feed of the mold.

Molding cycles

The cycle time of ZX-100 lies within a normal scale; it certainly depends on the required cooling time, which is determined by the wall thickness of the injection molded part and the mold temperature. In any case it should be guaranteed by means of a suitable machine, that the dwell time inside the melt barrel does not exceed ¼ hour.

Production breakdown

In case of a necessary break in production the following rules must be followed:

- if the break is less than 15 minutes, the temperature setting must not be changed. It is enough to flush the barrel thorougly, until it is completely loaded with fresh melt, before resuming the production.

- after a long breakdown the barrel should be emptied first and then flushed thoroughly, for example with polyethylene (PE). The barrel temperatures must respectively be reduced.

Material change

When replacing ZX-100 by another thermoplastic material, we recommend to flush the barrel thoroughly with high-density polyethylene (PE) or polypropylene (PP). The replacement of any thermoplast by ZX-100 does not cause any problems in general. Most materials can easily be displaced by ZX-100.

Safety precautions

The processing of ZX-100 does not require any special safety precautions. The usual precautions are absolutely sufficient. Also after long machine stoppage no excessive gas production arises. Moreover, the gases are not toxic and do not represent an explosive hazard.

Examples for molding conditions

In chart 1 the optimum molding conditions are compared by means of injection molding test pieces. Certainly, these molding conditions cannot be applied to any article just like that, however they may be used as guide lines. Only the injection molded part itself can always be used as a scale.

General data

The determination of the processing conditions starts from the following criterions:
a) a smooth molded part with a constant weight and without any shrink or void marks;
b) automatic ejection.

Machine data

screw: diameter: 30 mm

compression rating:	1 : 1.7
diameter of nozzle aperture:	3 mm
maximum end volume:	54 cm3
clamping force:	500 kN
typical application:	gear cut belt pulley

chart 1 / processing conditions for ZX-100, example

ZX-100		
mold temperature	20	°C
barrel temperature zone 1	275	°C
barrel temperature zone 2	270	°C
barrel temperature zone 3	265	°C
nozzle temperature setting	100	%
injection pressure	1200	bar
holding pressure	600	bar
dynamic pressure	36	bar
screw speed	130	r/min
injection time	0.9	s
holding pressure time	15.6	s
cooling time	5.9	s
total cycle time	26.3	s
Product weight	32.3	g

Molding shrinkage

During injection molding the solidification of the melt inside the mold causes a considerable volume shrinkage. In order to limit this shrinkage to a minimum, most possible liquid material is refilled during the solidification process. The material quantity, which must be extruded into the mold in order to equalize the shrinkage, depends on different factors. One of the most important factors is the wall thickness of the injection molded part.

Thick-walled objects cool down more slowly, which leads to a higher crystallization and therefore to shrinkage. In order to be able to refill the most possible material quantity it must be worked with bigger gates when dealing with thick-walled objects. Because a bigger gate does not freeze so quickly and so the holding pressure remains longer effective.

The wall thickness, the gate design as well as the gate size are the most important factors, which influence the molding shrinkage. Furthermore, also the melt and the mold temperture play a role, although the influence of the melt temperature to the molding shrinkage is extremely low, as practice has shown. Whereas the influence of the mold temperature is considerably bigger, but also the mold temperature does not play an essential role when processing ZX-100.

In chart 2 the molding shrinkage of ZX-100 showing different wall-thicknesses and types of gates is compared.

The chart also shows the difference between longitudinal and transverse shrinkage. Longitudinal shrinkage means the shrinkage in flow direktion of the melt, whereas transverse shrinkage means the shrinkage perpendicular to the flow direction.

chart 2 / shrinkage allowance of ZX-100 (product and mold measured at 20°C)

tm1(°C)	wall thickness	gate	wall thickness	gate

		2 mm film gate	B	4 mm film gate	C
longitudinal shrinkage (%)					
ZX-100	20	0,35	0,30	0,40	0,30
transverse shrinkage (%)					
ZX-100	20	0,20	0,15	0,25	0,15

tm1 = mold temperature

Mold design

The mold design requires the general guidelines for injection molding.

Polished molding tools are necessary in order to achieve a possibly glossy surface on the injection molded part. A good deaeration is absolutely important, because otherwise flame signs can occur. When working with heated molds, we recommend the arrangement of a sufficient isolation between molding tool and adapter plates. This can be achieved by means of asbestos sheets with a high compressive strength. This supports the homogenity of the mold temperatures and shortens the heating time considerably.

Gate design

* The feed point should preferably be located at the thickest point of the article. It is important that the flow distances have the same length in all directions. When dealing with articles with a wall thickness exceeding 3 mm a complete gate must be located, which means the cross-section of the gate should have about ¾ of the thickest wall thickness.

* The feed channels should preferably have a round or trapezoidal cross-section, which is tuned to the shape and the wall thickness of the injection molded part.

* The sprue should be kept as short as possible and should show a draft of minimum 30.

* The number of ejector pins or ejector sheets should not be too small and the mold parting lines should be generously dimensioned. This especially applies for molds and crystal articles.

* Pay special attention to mold venting.

* A sufficient number of cooling channels must be provided and should possibly be arranged near the mold surface and symmetrically around the mold cavity (ies).

* In general, pin gate leads to satisfactory injection molded parts, when processing ZX-100.

Safety precautions

The processing of ZX-100 requires the normal safety precautions. Special precautions are not necessary. Also after a long dwell time inside the barrel at high temperature, no gas production arises (no danger of explosion, no toxic fumes).

Processing faults and remedies

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faults	cause	remedy
- incomplete injection molded part	- material feed too low - resistance too big	- increase feeding - increase barrel temperature - increase mold temperature - extend diameter of feed channels and gates - improve mold venting - increase nozzle temperature - increase injection pressure
	- cooling of the melt too quick	- increase barrel temperature - increase mold temperature - increase injection rate
- void or shrink marks	- insufficient top feed of the mold	- increase feeding - increase injection rate - increase holding pressure - extend holding pressure time - increase mold temperature - extend diameter of sprue, feed channels and gates - transfer gate - shorten flow distance by means of several feed points
- weld lines	- insufficient confluence of two or more melt streams	- increase injection pressure - increase injection rate - increase mold temperature
	- bad venting	- improve venting - transfer gate
- brown discoloration	- oxidized material	- clean barrel and nozzle - remove „dead“ corners - reduce barrel temperature - reduce dwell time of the melt inside the barrel - remove fusion throug contaminants
- silvery strips	- humid granulate	- dry granulate or use new material
	- melt temperature too high	- reduce barrel temperature - reduce screw speed - reduce dynamic pressure
	- dwell time of the material too long	- shorten cycle time
- black stains	- combustions due to compact air in the	- improve venting - reduce injection rate

	mold cavity	- reduce injection pressure
- deformation on ejection	- bad detachment	- increase draft of the product - locate or improve aeration - change arrangement of the ejector pins or increase number of ejector pins - extend cooling time
	- inadequate rigidity	- extend cooling time - reduce mold temperature
- deformation after ejection	- internal stress	- remove possible temperature differences inside the mold - better polish surface of the mold - increase barrel temperature - increase mold temperature - reduce differences in wall thickness - reduce holding pressure - extend cooling time
- warped parts		- provide constant temperature control of the molding tool - use regular wall thicknesses if possible
- flash	- inadequate clamping force	- increase mold clamping pressure - reduce barrel temperature - reduce injection and holding pressure - secondary finishing of mold closing surfaces
- unusual brittleness of the injection molded part	- clearance too big between the movable parts of the mold	- reduce clearance, also between the ejector pins
	- humid granulate	- dry granulate or use new material
	- thermal degradation	- reduce barrel temperature - shorten cycle time - use machine with lower plasticating capacity
- lamella formation		- increase gate diameter
- streaking		- increase mold temperature - reduce injection rate - round off edges - increase gate diameter

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If necessary, we kindly ask you to contact our applicational department.