Injection molding

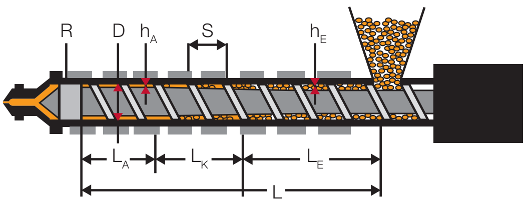
Injection molding is the most important method for processing Ultraform®. Ultraform® can be processed on all commercial molding machines provided that the plasticizing unit has been correctly designed.

Injection unit

Three-section screw

The usual single-flighted, three-section screws are suitable for the injection molding of Ultraform®. In modern machines the effective screw length is 20 - 23 D and the pitch is 0.8 - 1.0 D. The tried and tested geometry for three-section screws is shown in Fig. 16. Feed and fusion of the granules is substantially determined by the temperature control on the barrel and the depth of the screw flight. Recommended flight depths for different screw diameters are set out in Fig. 21. When using shallow-flighted screws the plasticizing power is somewhat lower than in standard screws. They pick up less material than deep-flighted screws. However, gentler fusion, shorter residence times in the barrel and better homogeneity of the melt are achieved. This yields advantages for the quality of molded parts made from Ultraform®.

Processing in degassing screws is inadvisable.



D	outer diameter of the screw		
L	effective screw length	20 - 23	D
L_E	length of the feed section	0.5 - 0.55	L
L_K	length of the compression section	0.25 - 0.3	L
L_A	length of the metering section	0.2	L
h_A	flight depth in the metering section		
h_E	flight depth in the feed section		
S	pitch	0.8 - 1.0	D
R	non-return valve		

Fig. 20: Screw geometry – terms and dimensions for three-section screws for injection-molding machines

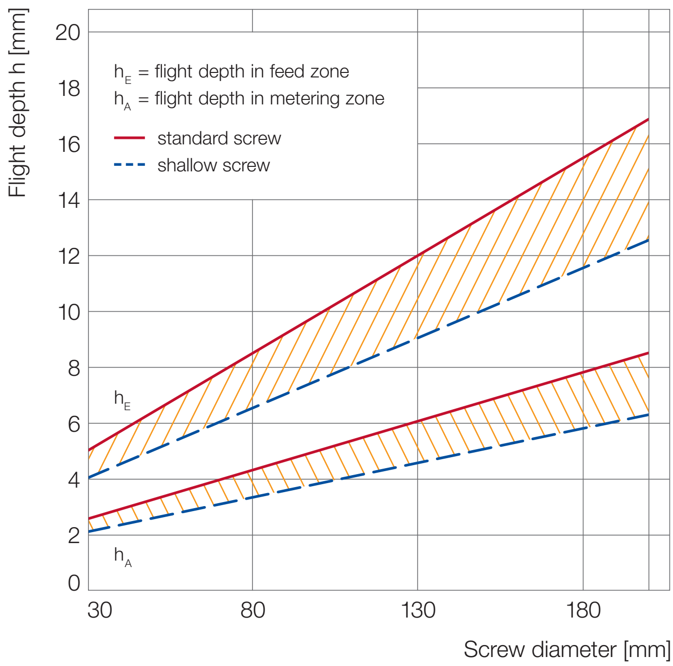


Fig. 21: Screw flight depths for three-section screws in injection-molding machines

Injection nozzle, non-return valve

An open injection nozzle is generally adequate for the injection molding of Ultraform®. Apart from its simple design ensuring smooth flow, this type of nozzle has the advantage that any gaseous decomposition products formed as a result of thermal damage can escape without pressure build-up. This can arise when residence times are unintentionally long, at high melt temperatures, during stoppages or other interruptions.

A shut-off nozzle prevents outflow of the melt during plastication and when the nozzle is retracted from the mold. Spring-loaded needle shut-off nozzles are particularly suitable for this purpose. For optimum production the screw should also be fitted with a non-return valve to prevent the melt flowing back over the screw flights during the injection and holding pressure phases.

A non-return valve is the only way to achieve a melt cushion and a holding pressure acting on the melt.

Protection against wear

When glass-fiber reinforced Ultraform® is processed, hard-wearing plasticizing units, e.g. bimetallic barrels and hardened screws, screw tips and non-return valves, should be used.

Injection mold

Gate and mold design

All know types of gate, including ante-chamber and hot runner systems, can be used for the injection molding of Ultraform®. The relevant construction guidelines for the design of gates and molds for injection-molded parts made from thermoplastics also apply to Ultraform®. Runners and gates must not be too small.

Due to the low melt viscosity, surface contours are reproduced extremely accurately. Accordingly, the inner surfaces of the mold must be impeccably machined. The same applies to the mold parting surfaces. The parting line must not cause flash formation but must ensure adequate venting of the mold.

It is important that there is a good seal between the cooling water circuit and the mold cavity, otherwise entry of water may result in solutions which corrode the mold.

Use of metal inserts

Metal inserts can be encapsulated without any trouble. They should, however, be preheated to 80 - 120 °C before insertion in the mold so that no internal stresses arise. The metal parts must be free of grease and be knurled, grooved or similar to ensure good anchorage. Care has to be taken that the metal edges are well rounded.

Loudspeaker grills

Mold temperature control

A well thought-out and effective temperature control system is of special importance since the temperature of the mold has a major impact on the surface finish, shrinkage, warpage and tolerances of the moldings. The temperature control should be designed in such a way that the same temperature prevails in all shaping parts of the mold.

The temperature regulation should be selected in such a way that the same temperature is present in all of the shaping areas. In special cases, it can sometimes be necessary to systematically select divergent temperatures. Thus, for instance, the warpage of the molded parts can be influenced to a certain extent by systematically selecting different temperatures in the mold halves. This is only possible with separate circulation systems.

As with all partially crystalline thermoplastics, it is also the case with Ultraform® that the mechanical properties of an injection-molded article are determined in part by the degree of crystallinity. The crystallinity increases as the mold temperature rises. The hardness, stiffness and strength increase as the mold temperature rises (Fig. 22). The toughness values (Fig. 23) behave in precisely the opposite way.

Generally speaking, it is sufficient to regulate the temperature within the range from 60 °C to 90 °C. Precision parts require mold temperatures between 90 °C and 120 °C. If there is a need for especially high dimensional stability, the mold temperature should be set at least as high as the temperature at which the molded part will be used later on.

In order to avoid heat losses, it is recommended that insulation be fitted between the mold and platen.

Processing by injection molding

Processing temperature

As a rule melt temperatures of 180 °C to 220 °C are sufficient. Complex molds with long flow paths and thin walls may in exceptional cases require temperatures up to 230 °C. Higher processing temperatures involve the risk of thermal degradation. This is prevented if the production conditions allow a high shot rate and hence a correspondingly short residence time of the melt in the injection molding cylinder.

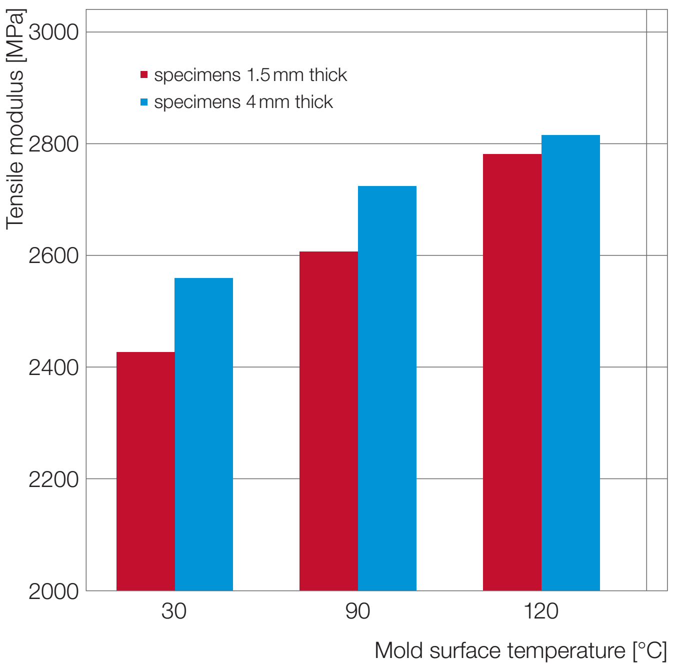


Fig. 22: Ultraform® N2320 003 – influence of the mold surface temperature on the stiffness of tensile bars with different thickness

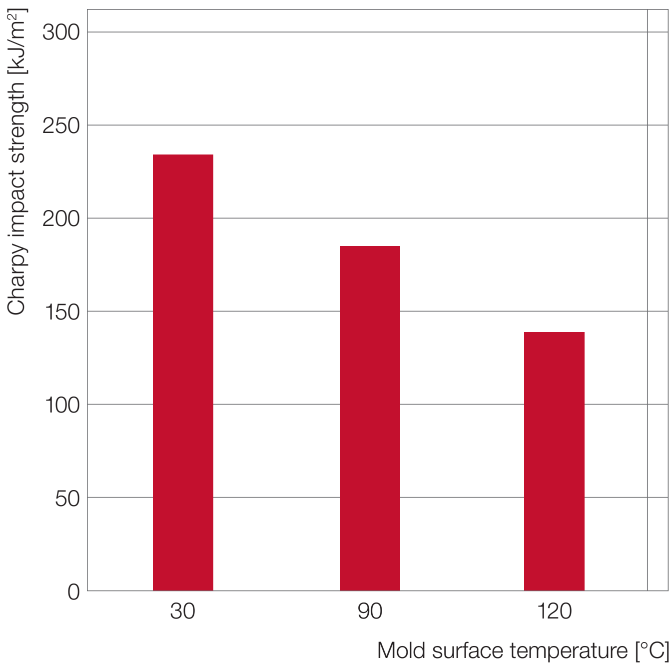


Fig. 23: Ultraform® N2320 003 – influence of the mold surface temperature on the charpy impact strength (ISO 179/1eU)

Continuous measurement of the melt temperature is recommended. Use of a needle shut-off nozzle affords a good opportunity of doing this because a thermocouple can be readily accommodated in this nozzle.

The individual heater bands in the injection molding machine can frequently be set to the same temperature. If cycle times are long, the first heater band (near the hopper) should be set to a slightly lower temperature to prevent premature melting of the pellets in the feed zone.

Feed characteristics
Ultraform® is drawn in without problem by standard screws (Figs. 20, 21). The screw geometry, screw speed, back pressure and temperature control at the barrel determine the feed behavior of the granules and their plastication.

The cooling possible in most injection molding machines in the region of the hopper allows adjustment of the feed behavior if required. In special cases, a dropping temperature profile (e.g. 220 °C to 205 °C) has to be set from the hopper to the die for Ultraform® N2310 P.

The peripheral speed of the screw should not exceed 0.3 m/s.

Mold filling
The quality of the finished parts also depends on the speed at which the mold is filled. A filling rate which is too high promotes alignment of the molecules and results in anisotropic mechanical properties. On the other hand a filling rate which is too low yields parts with poor surface finish.

Particular care has to be taken that air in the mold cavity can escape easily at suitable points when injecting the melt, so that burn marks due to compressed air (Diesel effect) are not produced. An insufficient ventilation of the mold increases mold deposits. Fig. 24 shows a well-tried system for ventilation.

When material accumulates, the formation of voids is counteracted by making the holding pressure sufficiently high and the holding pressure time sufficiently long so that the contraction in volume occurring on cooling of the melt is compensated. The precondition for this is a sufficiently large and well sited gate so that the melt in this region does not solidify too early before the end of the holding pressure time and as a result seals the still plastic molding in the interior against the holding pressure of the melt.

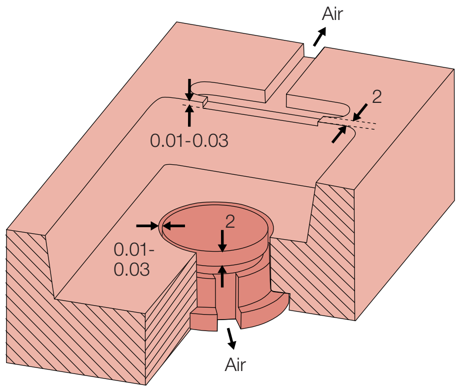


Fig. 24: Mold venting system

Flow characteristics

Ultraform® H4320, the high-molecular-weight resin with the highest viscosity, is a preferred material for extrusion. It is also suitable, however, for the production of particularly tough injection-molded parts having relatively thick walls (> 3 mm).

Ultraform® N2320 003 is the standard grade for moldings of normal wall thickness (> 1.5 mm) and flow paths which are not too long. The free-flowing Ultraform® S2320 003 is recommended when the walls are thinner and the flow paths longer.

Ultraform® W2320 003 and the especially easy-flowing Ultraform® Z2320 003 are available when due to the upper processing temperature limit complete filling of the mold with Ultraform® S2320 003 is no longer possible.

The flow characteristics of these grades as a function of the wall thickness as revealed by the spiral flow test are shown in Fig. 25. Although this test is not standardized, it nevertheless allows a practice-based assessment. The flowability or the flow path of a product depends not only on the processing parameters, such as injection pressure, injection speed, melt and mold temperature, but also on the design of the mold and of the machine. Fig. 26 provides an overview of how flow depends on the melt temperature. Despite having good flow properties, Ultraform® injection molding grades do not tend to form flash.

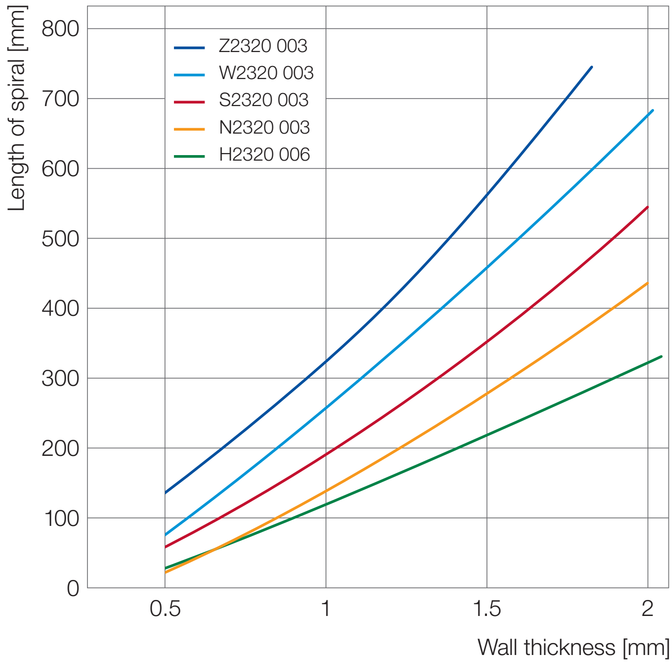


Fig. 25: Flowability as a function of wall thickness (spiral flow test). Machine: 1300 kN, screw diameter: 30 mm, mold: test spirals, injection pressure: 1200 bar, melt temperature: 210 °C, mold surface temperature: 80 °C

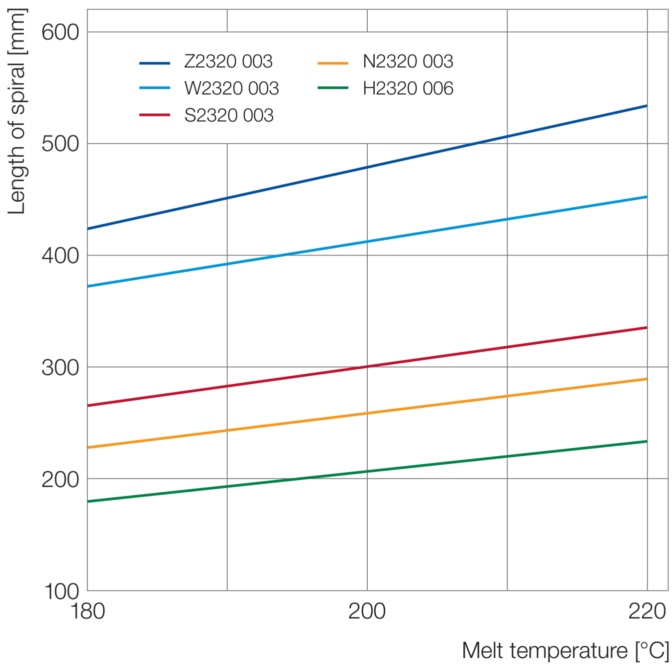


Fig. 26: Flowability as a function of melt temperature. Machine: 1300 kN, screw diameter: 30 mm, mold: 1.5 mm test spirals, cycle time: 20 s, injection pressure: 1000 bar, mold surface temperature: 80 °C

Processing speed
Factors governing the processing speed in injection molding are on the one hand the time it takes for the melt to cool from the processing temperature to the setting temperature, and on the other hand the rate of solidification, which in the case of semicrystalline thermoplastics is closely related to the rate of crystallization.

In the case of thin-walled parts the processing speed is mainly determined by the rate of crystallization, while for thick walls it is principally determined by the rate of the plastic's heat conduction.

The Ultraform® grades are characterized by high solidification rates and are therefore exceptionally suitable for the economic production of thin-walled parts.

Demolding
Ultraform® can be readily demolded. Even with high mold surface temperatures it has no tendency to stick to the mold walls. The drafts in injection molds are normally 1 to 2 degrees. Smaller drafts are possible for Ultraform® as a result of the high contraction in volume. However, the ejector or stripper plates must have a large contact area.

The general rule is that the ejector pins should not be too thin relative to the part, otherwise the moldings are damaged by indentation of the ejector pins when cycle times are short or the mold temperature is high.

The mold cooling channels should be designed in such a way that the molding is cooled as uniformly as possible and as a result can solidify largely free of warpage.

Shrinkage and aftershrinkage
Shrinkage is defined as the difference between the dimensions of the mold and those of the molding at room temperature. It is normally determined 24 hours after production and expressed in percent (ISO 294-3/4). As accurate a prediction as possible of the anticipated shrinkage is important, especially for the mold maker.

The dimensions of the mold must be designed in such a way that moldings with the desired final dimensions can be produced. Although shrinkage is primarily a property of the material, it is additionally determined by the shape and wall thickness of the injection-molded part and by the processing conditions (mold surface temperature, melt temperature, holding pressure, injection speed, position and size of the gate). The interaction of these different factors usually makes it very difficult to predict shrinkage exactly. The test box as depicted in Figure 27 has proven its suitability for ascertaining the practice-relevant shrinkage dimensions. Usually the length A is evaluated as the measure of the shrinkage of the bottom of the box.

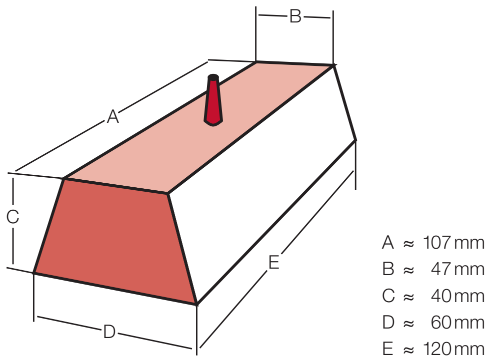


Fig. 27: Test box

The greatest influence on the shrinkage comes from the temperature of the mold surface and from the wall thickness of the molded part. Figure 28 shows this dependence with reference to test boxes having wall thicknesses of 1.5 mm, 5 mm and 8 mm. It can be seen that shrinkage increases rapidly as the mold temperature rises. Here the mold temperature is always to be taken as the measured surface temperature and not the temperature of the temperature control medium.

With reference once more to the test box having a wall thickness of 1.5 mm, Fig. 29 shows the dependence of shrinkage on holding pressure. Higher holding pressures partially compensate for shrinkage.

Other factors, such as the melt temperature or the injection speed for example, do not affect the shrinkage of Ultraform® to any great extent. It only increases slightly as the melt temperature rises and the injection speed falls.

Over time the dimensions of injection moldings may alter slightly owing to temperature-dependent and time-dependent post-crystallization and also in small measure to the relaxation of internal stresses and alignments.

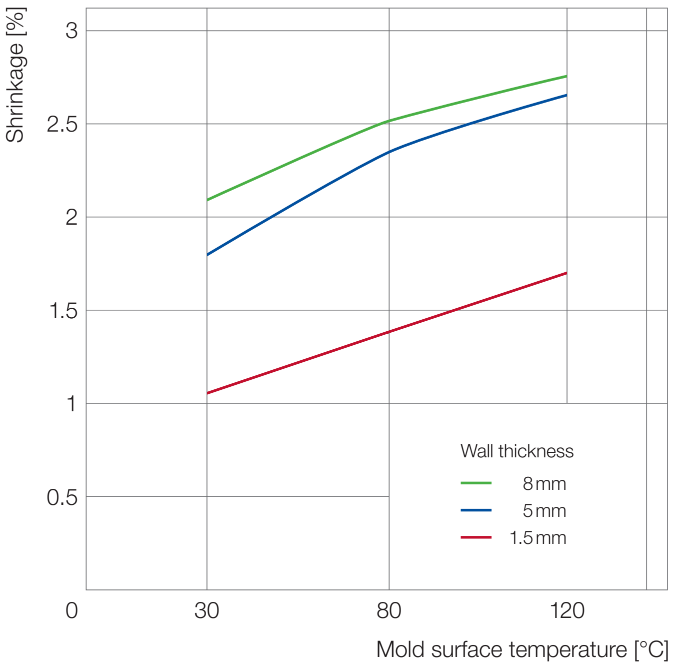


Fig. 28: Shrinkage of test boxes molded from Ultraform® N2320 003 one hour after molding (distance A)

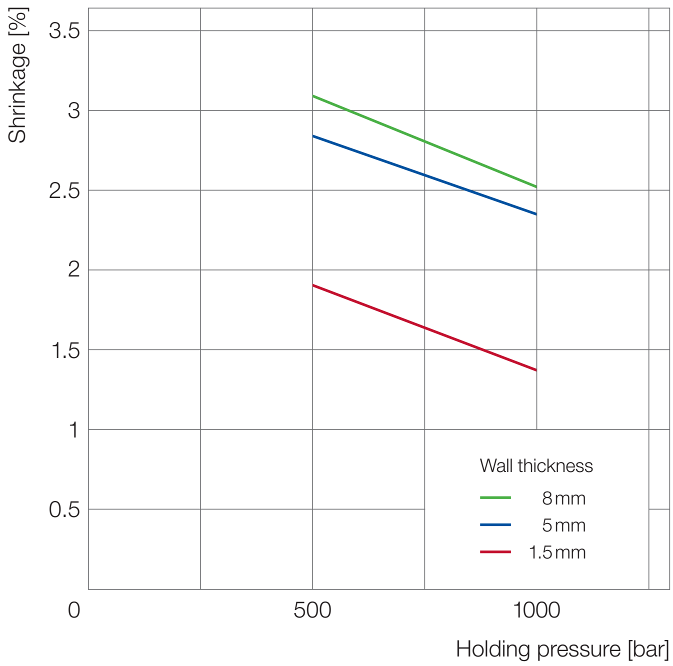


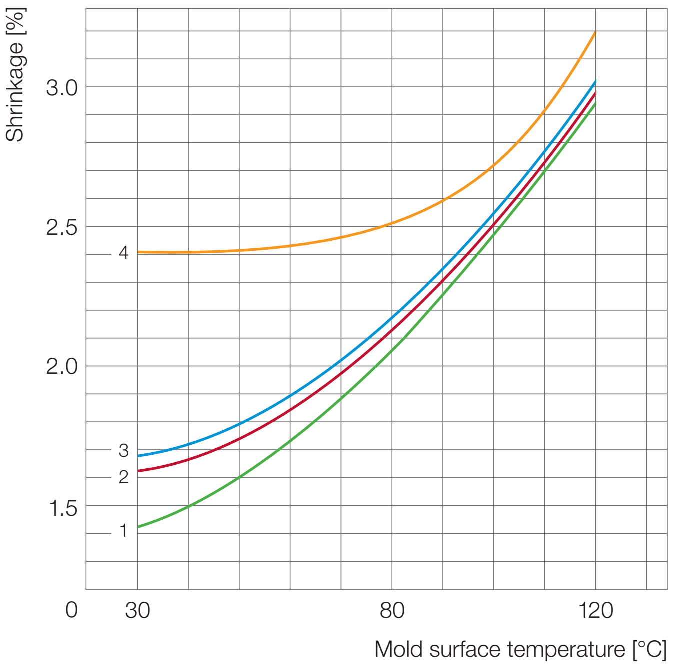
Fig. 29: Shrinkage of test boxes molded from Ultraform® N2320 003 one hour after molding (distance A)

Fig. 30 shows the shrinkage measured on the test box after an hour (Curve 1), 14 days and 60 days (Curves 2 and 3). The parts were stored at room temperature. Aftershrinkage, i. e. the increase in shrinkage due to postcrystallization, is visible from the curves. Curve 4 shows the shrinkage of the same parts after 24 hours at a temperature of 120 °C.

Tempering is worthwhile when injection-molded parts made from Ultraform® are to be exposed to relatively high temperatures in later use. The tempering anticipates the change in dimensions otherwise to be expected as a result of postcrystallization. As Fig. 30 shows, however, tempering can be dispensed with when injection molding is carried out at high mold temperatures.

Shrinkage of the glass-fiber reinforced Ultraform® N2200 G53 is substantially smaller than that of the unreinforced grades. However, due to the orientation of the glass fibers, the shrinkage is anisotropic. Depending on the shape, gate position and processing conditions, this can cause warpage of the moldings.

By contrast, the mineral-filled Ultraform® N2720 M63 is largely characterized by isotropic shrinkage. Fig. 31 shows shrinkage parallel and perpendicular to the direction of flow for free shrinkage of unreinforced, glass-fiber reinforced and mineral-filled Ultraform®.



Curve 1 Processing shrinkage 1 hour after production
Curve 2 Shrinkage after 14 days at room temperature
Curve 3 Shrinkage after 60 days at room temperature
Curve 4 Shrinkage after tempering for 24 hours at 120 °C

Fig. 30: Shrinkage and aftershrinkage of Ultraform® N2320 003 as a function of mold temperature, time and temperature determined on the basis of a box having a wall thickness of 1.5 mm. Machine: 1300 kN, mold: test box with walls 1.5 mm thick, melt temperature: 210 °C, holding pressure: 500 bar, dimension measured: A = 107 mm

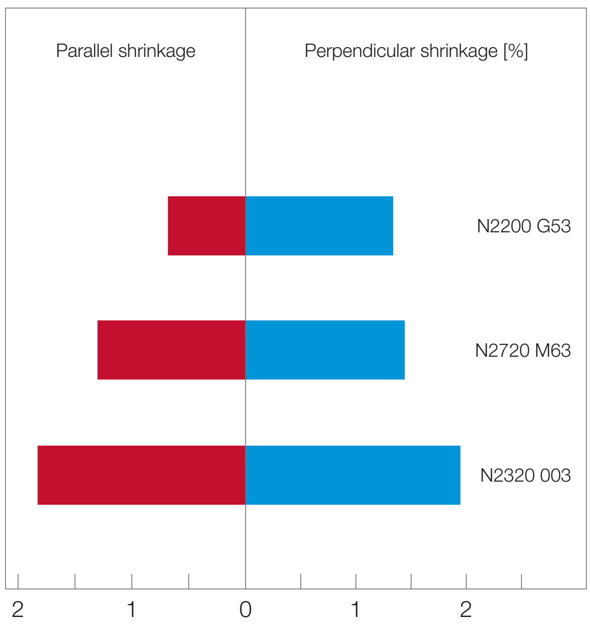


Fig. 31: Shrinkage of unreinforced, glass-fiber reinforced and mineral-filled Ultraform® parallel and perpendicular to the direction of flow for free shrinkage determined for sheet measuring 110 · 110 · 2 mm; melt temperature: 200 °C, mold surface temperature: 80 °C