BOY®
Spritzgiessautomaten

Processing of Thermoset Materials

Processing of thermoset materials on BOY injection moulding machines

1. Thermoset moulding compounds

1.1 General

Thermoset material are used when high surface hardness, resistance to solvents and good heat resistance are required. These materials are still display a high modulus of elasticity even at high temperatures. The surface resistance of thermoset mouldings is such as to prevent electrostatic charging.

Due to their exothermal cross-linking reactions, thermoset materials can be processed in shorter cycle times than thermoplastics when the wall thickness exceeds approx. 4 mm. The moulding shrinkage can be reduced and even eliminated with low-profile formulations.

1.2 Classification

The mould compounds to be processed must be formulated in such a way as to permit processing on an injection moulding machine. A number of thermoset compounds are available on the market today which can be injection moulded without difficulty. The most important thermosetting moulding compounds are classified in the following main groups.

1.	Phenol-formaldehyde resin	PF
2.	Urea-formaldehyde resin	UF
3.	Melamine-formaldehyde resin	MF
4.	Unsaturated polyester resins	UP
5.	Eposy resins	EP
6.	Polyamides	PI
7.	Diallyl phthalate resins	DAP
8.	Furane resins	FF
9.	Phenacrylate resins	PHA

The general term “aminoplastics”is also used to refer to thermosetting synthetic resins and mould compounds based in amino groups and formaldehyde. These compounds display light fastness and colourless. They are basically identical with the urea compounds and melamine resins, as well as with the moulding compounds produced from these materials.

Thermoset moulding compounds generally contain a variety of fillers and reinforcing materials. A distinction is made between organic and inorganic fillers.

a) Inorganic fillers

Inorganic fillers ensure high heat resistance, good tracking resistance, high mechanical strength and low shrinkage, but make a high density inevitable. A compromise must be found between uniform distribution of the filler and high mechanical strength. The types or filler and their particle shape are as follows: mineral powder, asbestos in the form of chopped fibres, glass in the form of continuous strands and mica in the form of platelets.

b) Organic fillers

Organic filler are lighter than inorganic fillers, thus yielding a lower density. They readily absorb water. These fillers take the following forms: wood flour as powder, cellulose as chopped strands, textile fibres as continuous strands and shredded fabric as platelets.

The DIN standards governing thermoset materials associate each resin with precisely defined fillers, which are indicated in the numerical code for the moulding compound. This numerical code also specifies features typical of the material, the resin base, the resin content and the colour.

The designation with code numbers is explained in the following tables. The resin content of a moulding compound has a decisive effect on its flow ability.

The types used most frequently have a resin content between 40% and 60%. The moulding compound with the lowest resin content yields the best mechanical value but is more difficult to process. However, a number of special types are also available with additional fillers, such as graphite, for specific application conditions.

Härtbare Formmassen	DIN-Kurzz. 7728[1]	Vernetzungsreaktion, Spaltprodukte b. d. Vernetzung, Verarbeitungsdruck	Typ (Nr. nach DIN), Füllstoffe, mögliche Verarbeitung 53479[1]	Dichte g/cm^3 53455[1]	Zugfestigk. N/mm^2 53457[1]	E-Modul N/mm^2	Obere Anwend.-temp. (kurzzeitig) °C 53458[1]	Wärmeformbest. (n. *Martens*) °C 53472 bzw. 53495[1]	Wasseraufnahme mg bzw. %
Phenoplaste	PF	Kondensationspolymerisation des Phenol-Formaldehyd-Harzes bei 140 bis 180°C[2], Wasserabspaltung, ab 160°C auch geringe Formaldehydabspaltung, P: 150–800 bar; SP: 500–2000 bar; SG: 800–2500 bar	unverstärkt	1,25	25–40	3000			0,3–0,4%
			Typisierung nach DIN 7708.2						
			Gruppe I:						
			31 (Hm) P, SP, SG	1,4	25	6000–8000	140	125	<150
			Gruppe II:						
			85 (Hm/Zs) P, SP, SG	1,4	25	6000–8000	140	125	<200
			51 (Zs) P, SP, SG	1,4	25	4000–8000	150	125	<300
			83 (Bf, kurz/Hm) P, SP	1,4	25	6000–9000	140	125	<180
			84 (Bsch/Zs) P, SP	1,4	25	6000–9000	140	125	<150
			71 (Bf) P, SP, (SG)	1,4	25	6000–9000	140	125	<250
			74 (Bsch) P, SP	1,4	25	7000–10000	140	125	<300
			75 (Ks) P, SP, SG	1,4	25	6000–8000		125	<300
			Gruppe III:						
			12 (As, kurz) P, SP, SG	1,8	20	9000–15000	160	150	<60
			15 (As, lang) P, SP	1,8	20	8000–15000	160	150	<130
			16 (As -schnur) P, SP	1,8–2,0	25	9000–16000	170	150	<90
			Gruppe IV:						
			11.5 (M, elektr. hochwertig) P, SP	1,85	15	6000–15000	160	150	<45
			13 (Gl) P, SP	1,9	20	7000–12000	160	150	<20
			13.5 (Gl, elektr. hochwertig) P, SP	1,9	20	7000–12000	160	150	<20
			30.5 (Hm, elektr. hochwertig) P, SP, SG	1,4	25	6000–8000	140	100	<200
			31.5 (Hm, elektr. hochwertig) P, SP, SG	1,4	25	6000–8000	140	125	<150
			51.5 (Zs, elektr. hochwertig) P, SP	1,4	25	4000–8000	150	125	<300
			Gruppe V:						
			13.9 (Gl, ammoniakfrei) P, SP	1,9	20	7000–12000	160	150	<20
			31.9 (Hm, ammoniakfrei) P, SP, SG	1,4	25	6000–8000	130	125	<150
			32 (Hm u. a. organ. Füllstoffe) P, SP, SG	1,4	25	6000–8000	130	125	<150
			51.9 (Zs, faserig, ammoniakfr.) P, SP	1,4	25	4000–8000	130	125	<300
			52 (Zs) P, SP	1,4	25	6000–8000	150	125	<100
			52.9 (Zs, harzimprägniert) P, SP	1,4	25	6000–8000	130	125	<100
Aminoplaste	UF	Kondensationspolymerisation des Harnstoff-Formaldehyd-Harzes bei 140 bis 150°C[2], Wasserabspaltung P: 150–800 bar; SP: 500–2000 bar; SG: 1000–2500 bar	Typisierung nach DIN 7708.3						
			Gruppe I:						
			131 (Zs) P, SP, SG	1,5	30	6000–10000	100	100	<300
			Gruppe IV:						
			131.5 (Zs, kurzfaserig) P, SP, SG	1,5	30	6000–10000	100	100	<300
	MF	Kondensationspolymerisation des Melamin-Formaldehyd-Harzes bei 130 bis 165°C[2], Wasserabspaltung, je nach Stoffmengenverhältnis auch Formaldehydabspaltung P: 150–800 bar; SP: 500–2000 bar; SG: 1000–2500 bar	Gruppe I:						
			150 (Hm) P, SP, SG	1,5	30	6000–7000	110	120	<250
			Gruppe II:						
			153 (Bf) P, SP, SG	1,5	30	8000–10000	100	125	<300
			154 (Bsch) P, SP, SG	1,5	30	8000–10000	100	125	<300
			Gruppe III:						
			155 (M) P, SP	2,0	15	8000–12000	140	130	<200
			156 (As) P, SP, SG	1,8	20	10000–13000	140	140	<200
			157 (As + Hm) P, SP, SG	1,7	25	8000–10000	130	140	<200
			Gruppe IV:						
			152 (Zs, kurzfaserig) P, SP, SG	1,5	30	8000–10000	110	120	<200
			Gruppe V:						
			152.7 (Zs, für Lebensmittelgebrauch) P, SP, SG	1,5	30	8000–10000	110	120	<200
Amino-/Phenoplaste	MP	Kondensationspolymerisation des Melamin-Phenol-Formaldehyd-Harzes bei 140 bis 165°C[2], Wasserabspaltung P: 150–800 bar; SP: 500–2000 bar; SG: 1000–2500 bar	Typisierung nach DIN 7708.3						
			Gruppe I:						
			180 (Hm) P, SP, SG	1,5	30	7000–10000	110	120	<180
			Gruppe IV:						
			181 (Zs) P, SP, SG	1,6	30	6000–7000	110	120	<150
			181.5 (Zs, elektr. hochwertig) P, SP, SG	1,6	30	6000–7000	110	120	<150
			182 (Hm + M) P, SP, SG	1,6	30	6000–8000	130	120	<120
ungesättigte Polyester	UP	Propfcopolymerisation von Styrol auf ungesättigten Polyester (aus unges. Maleinsäureanhydrid, arom. Phthalsäureanhydrid und aliphat. Propylenglycol) + Initiator (Härter) 1. Kalthärtung: Redoxpolymerisation ab 0 bis 35°C unter Zugabe eines Beschleunigers (drucklos) 2. Hitzehärtung: Polymerisation bei 80 bis 110°C[2] P: 100–400 bar; SP: 300–800 bar; SG: 300–1000 bar	unverstärkt	1,22–1,27	30–55	3000–4800			0,15–0,6%
			Typisierung nach DIN 16911:						
			801 (GF >6 mm) P, SP	1,8	25–30	13000		125	<100
			802 (GF ≤3 mm) P, SP, SG	2,0	30–40	10000		140	<45
			803 siehe 801, 804 siehe 802 jedoch mit besseren elektrotechnischen Eigenschaften						
			UP-Harzmatten typisiert nach DIN 16913:						
			830/830.5 (GF-Matte) P, SP	1,8	40	9000			<100
			832/832.5 (GF-Matte) P, SP	1,8	80	12000			<100
Epoxydharze	EP	Kettenmoleküle aus 1-Chlor-2,3-Epoxypropan und aromatischen Dihydroxyverbindungen, Vernetzung der Kettenmoleküle mit Epoxyendgruppen (Additionspolymerisation als Stufenreaktion) 1. Kalthärtung ab Raumtemperatur mittels Kalthärter (z. B. Polyamine) 2. Warmhärtung bei 80 bis 110°C[2] mittels Warmhärter (z. B. Dicarbonsäuren und deren Anhydride). P: 100–500 bar; SP: 300–800 bar; SG: 800–1800 bar	unverstärkt	1,20–1,22	35–55	3500			0,1–0,5%
			nicht typisiert:						
			Granulat (GF + M) P, SP, SG	1,8	60	13000		120–130	10
			Plättchen (30%GF + M) P, SP	1,75	100	16000		120	14
			Stäbchen (60%GF + M) P, SP	1,78	140	25000		110	10
			EP-HM-CF (70–75%CF)	1,55	900	150000			
			EP-HF-CF (70–75%CF)	1,5	1250	110000			
			EP-Aramid (70–75% Aramidfasern)	1,38	1380	60000			

Abkürzungen:

P: Pressen
SP: Spritzpressen
SG: Spritzgießen

[1] zugrunde gelegte Norm
[2] Massetemperatur

As:	Asbest
Bf:	Baumwollfaser
Bsch:	Baumwollgewebeschnitzel
CF:	Kohlefaser
GF:	Glasfaser
Gl:	Glimmer
Hm:	Holzmehl
M:	mineral. Füllstoffe, Gesteinsmehl
Zs:	Zellstoff
Ks:	Kunstseidenstränge
HM-CF:	Hochmodul-Kohlenstoff-Faser
HF-CF:	hochfeste Kohlenstoff-Faser

1.3 Properties of thermoset materials

All thermoset materials display a number of properties, which must be considered particularly positive, such as the following:

1. High mechanical strength
2. High modulus of elasticity
3. High surface hardness
4. Good heat resistance
5. Resistance to tracking and arcing
6. Resistance to fuels, oil and brake fluids, etc.

Depending on the requirements to be met, a preliminary selection can be made on the basis of the following summary:

a) High heat resistance

Moulding compounds based on phenolic resin, special melamine or polyester resins and above all polyamides can be used for such applications. The heat resistance can be improved in particular by reinforcement with inorganic fillers.

b) Electrical properties

Moulding compounds based on polyester, epoxy resin and DAP (diallyl phthalate) should be used to meet high electrical properties, particularly the dielectric constant.

c) Price

When listed in ascending order, the price rises between 7 and 9 times the initial value, from phenolic resin through urea resin, melamine resin, polyester resin and epoxy resin to DAP resin compounds.

d) Low density

Organic fillers must be used in order to achieve the lowest possible density. A higher filler content also leads to higher density.

e) Low after-shrinkage

The after-shrinkage of epoxy, polyester and DAP resin compounds is lower than that of other thermoset materials. The after-shrinkage can be reduced by increasing the content of inorganic fibre fillers.

f) Low shrinkage

UP and DAP moulding compounds display low shrinkage and this can be reduced still further by increasing the content of inorganic fibre fillers.

g) Mechanical strength

Coarsely structured compounds display high mechanical strength.

h) Tracking resistance

The best tracking resistance is obtained with chopped-strand inorganic fillers in melamine or polyester resin.

i) Light fastness

Melamine, urea, polyester resin or DAP moulding compounds should be used high requirements are imposed with regard to the light fastness. The dyestuffs used also have an effect.

2. Processing of thermoset materials in general

The main features characterizing the processing of thermoset materials are described below as it differs fundamentally form that of thermoplastics:

Thermoplastics melt in heat and solidify when cooled. Their plastic state depends solely on the temperature. From the granules to the injection mouldings, the shaping process is roughly speaking a physical process and can be repeated several times.

The thermosetting compound also melts in heat at first, but then a chemical reaction takes place and the compound cures. The material cannot subsequently be remolten. This process is irreversible. Temperature and pressure conditions must be maintained precisely during plasticization so that this process can be controlled when injection moulding thermoset materials. On account of this requirement, the additional equipment needed for processing thermoset materials basically comprises:

1. a specially formed screw,
2. a fluid-heated plasticising cylinder and
3. a nozzle which can be released particularly quickly.

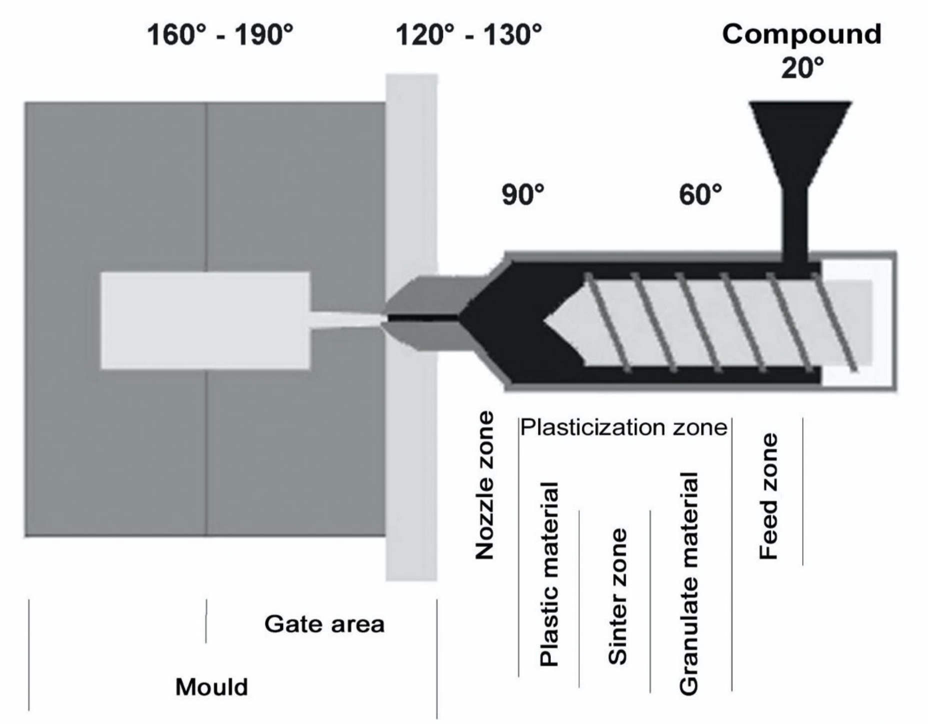
The geometric conditions of the screw play an important part. The flight depth of the feed zone is an important factor. Coarse-grained material can only be fed in with difficulty if the flight depth of the screw is too shallow in the feed zone. Excessively deep flights, on the order hand, result in uneven heating and plasticization. There is no transition zone here, such as that found on a screw for thermoplastics. Transition less or slightly degressive screw are usually used for modern thermoset materials. The ratio of length to diameter is smaller when processing thermosets than for thermoplastics. L/D rations between 12 and 15 are common.

Heating of the plasticising cylinder is a point of particular importance, since the temperature must be controlled precisely. Since and frictional energy must be dissipated, it is advisable to use a fluid to control the cylinder temperature, as fluids can also dissipate energy. This cannot be done with electric heating, Oil is a suitable medium for temperature control. Water can also be used when operating with cylinder temperatures of less than 80 °C. The flow rate and temperature of both media are controlled via a temperature regulator.

The screw tip and nozzle are designed to ensure flow conditions. Local accumulations of residue must be avoided in all cases. Under no circumstances should a slug of cured moulding compound remain in the nozzle, as it would enter the mould first with the next shot or clog the nozzle completely. The nozzle can rapidly be unscrewed from the cylinder with a hexagon socket so that it can be cleaned without delay when faults occur. The cylinder can be emptied after removing the nozzle.

The schematic drawing of the injection moulding machine is made up for sections: feed zone, plasticization zone, nozzle zone and mould. the plasticization zone is additionally subdivided into three areas.

The moulding compounds is transferred from the feed hopper and the nozzle zone by the rotary movement and simultaneously plasticized. During the rotary movement, the screw retracts until sufficient material has accumulated in front of the nozzle to produce the required moulding.



Cycle times

Thermoset moulding compounds can be processed on screw injection moulding machines in particularly short cycle times, such as generally cannot be achieved with conventional presses and transfer moulding presses. Since the compound to be injection moulded is preheated and plasticized in the machine and is therefore immediately ready for injection into the mould, it can be heated to high temperatures so that it rapidly curses in the mould. Higher mould temperatures can also be used in many cases, thus accelerating the curing process.

The optimum cycle time largely depends on the time required for the compound to cure without voids. The shorter curing time permitted by injection moulding is particularly advantageous when producing thick-walled mouldings, for the time required for the material to cure any disadvantages when producing parts with different wall thickness.

Another advantage of injection moulding machines is that it is no longer necessary to meter, pellet and preheat the moulding compound in separate operations.

The cycle time for injection moulding thermoset compounds basically comprised the times actually required: to close the mould, advance the injection unit, inject the melt, cure the moulding-i.e. the curing time-open the mould and remove the moulding. Curing generally accounts for the largest part of this time sequence. However, it should also be mentioned that in exceptional cases, i.e. poor feed performance, more time may be required for delivery and plasticization than is available for the minimum curing time. In such cases, the mould must remain closed until the plasticising phase ends and the cycle time is then determined by the plasticzing time instead of by the minimum curing time.

The time required for a moulding to cure depends on several factors. The nature of the moulding compound is one factor of importance. Polyester compounds generally cure more rapidly than melamine resins and these usually cure more quickly than phenolic resin compounds. There are also differences as regards the curing rate within this overall group.

The flow properties of the moulding compound also play an important part. The harder the flow, the more quickly the compound normally cures. Compounds with such a hard formulation must naturally be processed with great care, since the slightest fault in the machine sequence can cause the melt to harden in the cylinder.

The curing time can be reduced still further by intensive plasticization in the metering phase, although this also entails a high risk of operational faults due to premature hardening of the material in the cylinder.

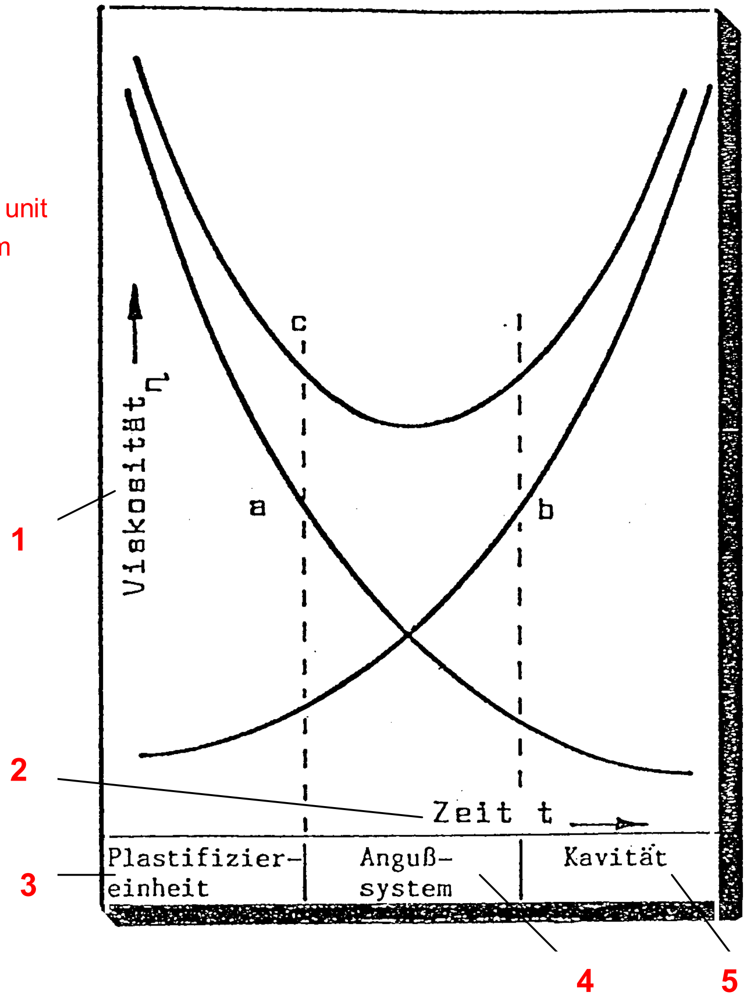
a – Viscosity decreases as material heats up

b – Viscosity increases due to chemical reaction

c – Real viscosity

c = a+b

1 Viscosity
2 Time
3 Plasticization unit
4 Gating system
5 Cavity

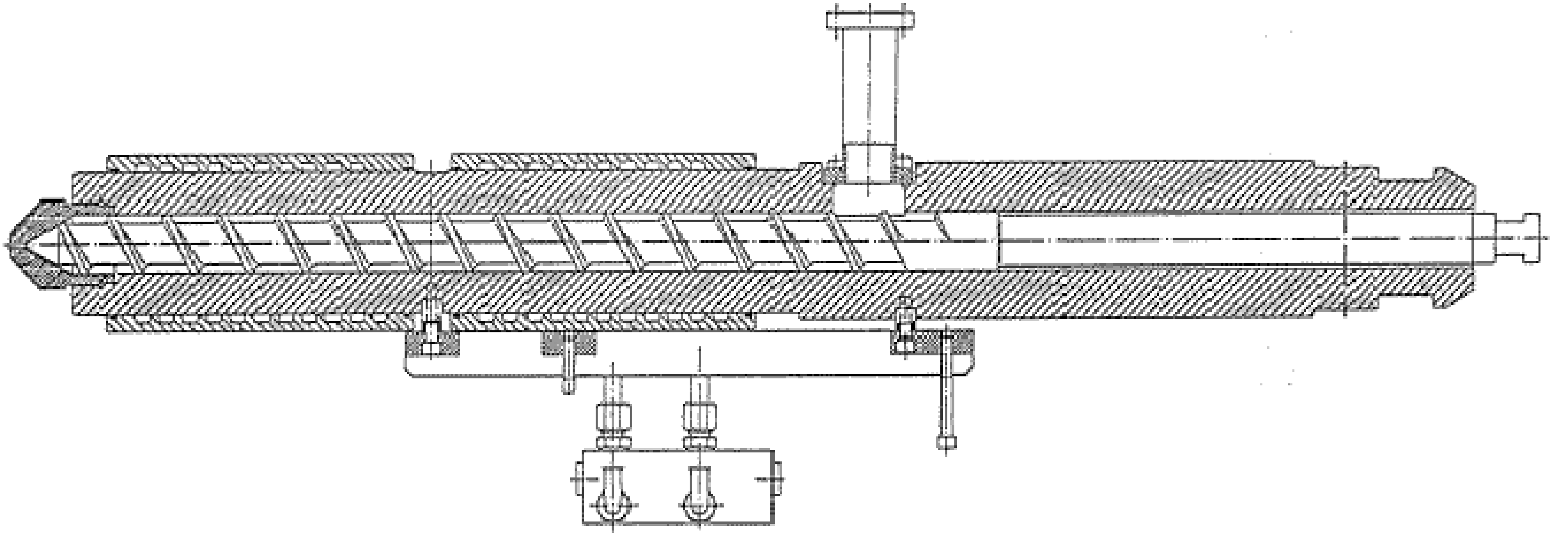


Qualitative viscosity profile during the cross-linking reaction

The dwell time in the respective areas does not correspond to the time axis, but should merely be considered as a function of the viscosity.

The cross-linking reaction should be 80% complete when demoulding the parts. The mouldings are then normally sufficiently hard to avoid damage when demoulded. The reaction continues outside the machine due to the high temperature of the moulding.

Plasticising unit for processing of thermosets



	BOY 22	BOY 35		BOY 55		BOY 90	
	220-52	350-52	350-92	550-79	550-205	900-205	900-370
Screw diameter	24	24	28	28	32	32	42
Max.stroke volume (theoretical) ccm³	36	36	58,5	58,5	96,5	96,5	214,7
Max. spec. Injection pressure bar	1455	1455	1577	1351	2127	2127	1724

Nozzle

The nozzle is designed in such a way to avoid dead spaces in which material can accumulate and harden.

The material must not be allowed to absorb too much frictional energy during the injection process. The nozzle bore and thus the entire nozzle must consequently be kept very short.

The nozzle has an external thread and is screwed directly into the cylinder with a hexagon socket so that it can be removed quickly in order to clean the cylinder. Particular care must be taken to ensure that the sealing face between nozzle and cylinder is absolutely clean when fitting the nozzle. Even minute residues of material prevent it from fitting correctly so that moulding compound cam enter the gap. The constant changes of pressure during the injection moulding process destroy the sealing faces of nozzle and cylinder within a very short period of time, thus leading to the formation of dead spaces and accumulations of material. Utmost cleanliness must be ensured when fitting the nozzle.

Storage

Thermoset moulding compounds should be stored closed in their original containers at a temperature of approximately 10-25° C. Generally, a storage time of 6-9 months should not be exceeded, especially for fast curing compounds as the flow-cure-ratio may exhibit some change after this time.

When compounds are stored at a temperature lower than 10° C, it is recommended that the moulding compound be moved to the processing area 12-24 hours prior to processing, to warm to room temperature.

Should any portion of the compound leak from a bag, it should, under no circumstances, be filled back into the container, in order to eliminate any contaminations during processing. Following these requirements should insure optimal conditions for homogenous processing.

Material Preparation

In contrast to many technical thermoplastics, thermoset moulding compounds should not be pre-dried, because they are chemically reactive systems. It is recommended that the original package be climatized 6-12 hours in the processing area before production.

Processing with Injection Method

Injection moulding machines
Thermoset moulding compounds may be processed on all standard injection moulding machines equipped with a thermoset unit. Standard screws for thermosets with a compression of 1:1.2 may be used. The L/D ratio is usually 15-19. The cylinder should be equipped with a minimum of two separately regulated heating zones.

Barrel temperature, melt temperature

The following cylinder temperatures apply to almost all thermoset moulding compounds:

feed section 65-90° C
nozzle section 90-110° C

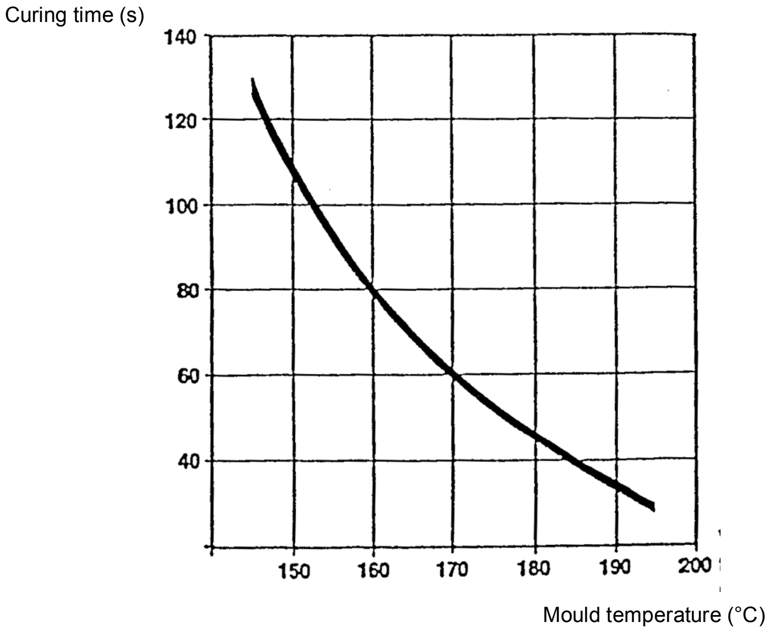
A mass temperature (during continuous processing) of 110-120° C at the nozzle is required to maintain a homogenous moulding compound.

Mould Temperature / Curing Time

A mould temperature in the area of 165-190° C is required for processing. The final curing time is basically depended on mould temperature.

Moulding compounds are homogeneously and consistently heated when filling the cavity in injection processing; therefore, wall thickness does not play as great a role in curing speed as in the compression procedure.

Curing time in relation to mould temperature



Back Pressure

Specific back pressure should come to about 40-100 bar, to keep feeding fluctuations as low as possible.

Screw Speed

Screw speed should not be higher than 130 rpm (with a screw diameter of 40 mm). The moulding compound may cure, even at a short cycle interruption, because of the higher friction. Plastification delay should be utilised so that holding time in the cylinder is not too long.

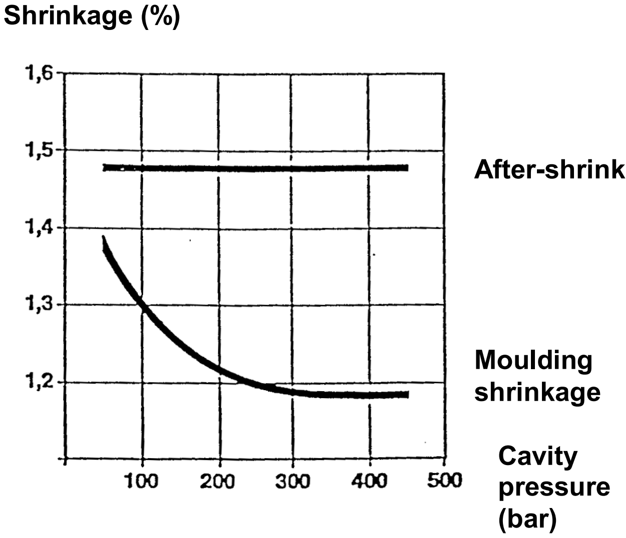
Injection Pressure

Specific injection pressure for thermoset moulding compounds lies between 900-2200 bar, depending on flow- cure- ratio and gate type.

Cavity Pressure

Cavity pressure of at least 200 bar is generally required at the end of flow path for optimal densification of moulded parts. This is also shown in the dependence of shrinkage, especially mould shrinkage, on the cavity pressure. Insufficient densification caused by too low cavity pressure leads to a sharp increase in mould shrinkage of a moulded part.

Shrinkage as function of cavity pressure
(set via shot volume)



Holding Pressure / Holding Pressure Time

Switching from injection to holding is not required, due to working without a cushion (otherwise cure of the moulding compound in the cylinder may be expected).

Switching is commonly programmed by screw position. Depending on the part, the screw position should lie between 2-10% of the metered volume when switching.

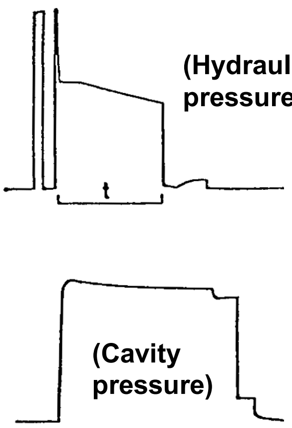
The cavity pressure curve is the most exact method of determining required holding time. Internal mould pressure decreases sharply when holding time is insufficient. If, after a sufficient holding time, the curing of the moulding compound is advanced enough; internal mould pressure will remain constant after holding pressure is switched off.

Holding pressure times for thermoset moulding compounds lie between 8-18 s, depending on flow- cure- ratio and gate type.

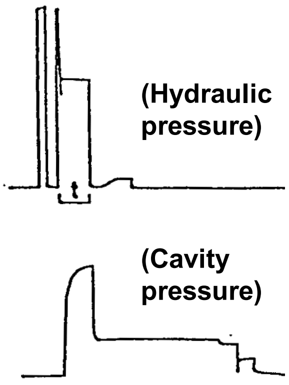
Holding pressure time may already be contained in curing time, depending in the type of injection machine.

Internal mould pressure as function of holding pressure time

correct holding
pressure time (t)



holding pressure
time too short (t)



Cycle Interruption

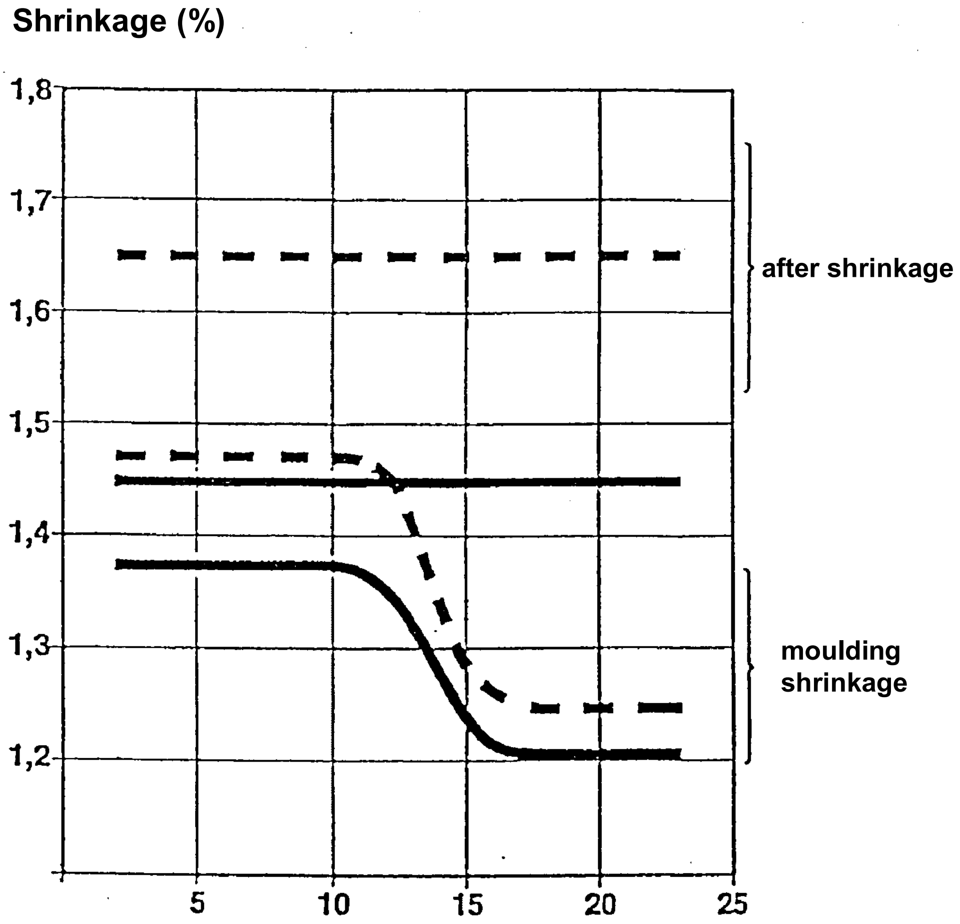
When a cycle interruption is much longer than a normal processing cycle, it is possible that the machine compound in the cylinder has already hardened. In this case the cylinder has not be cleared after removing the nozzle.

Shrinkage

Besides shrinkage values determined according to DIN 53464, we measured shrinkage on injection moulded test specimens and parts ourselves to obtain values close to common conditions (mostly injection compounds). Test showed that, to some extent, clear differences exist.

Working with a de-gassing program also decreases shrinkage values considerably

Shrinkage as function of holding time
(---) with venting
(.....) without venting
T_{wz} 170°C; t_C = 35s



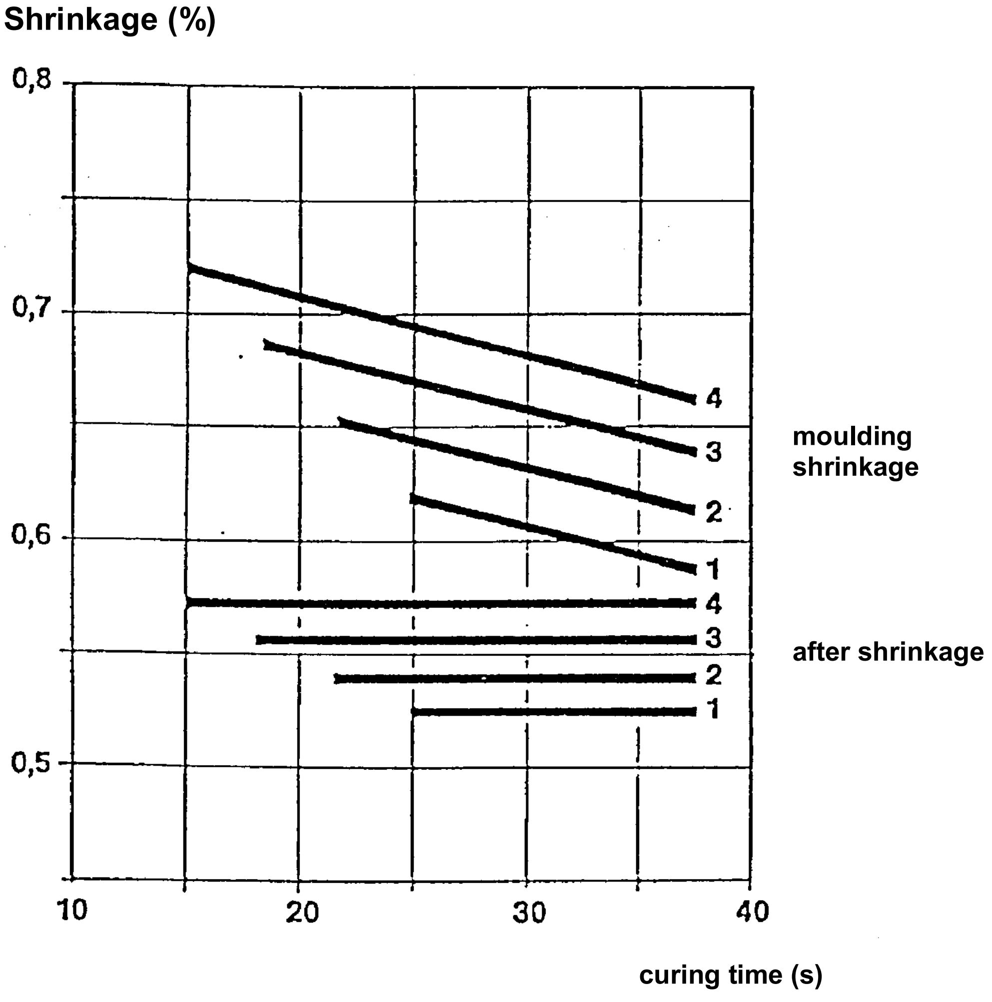
holding pressure time

Changes in curing time and mould temperature have different influence on shrinkage. Mould shrinkage increases with rising processing temperature but decreases, on the other hand, with increased curing time.

Post shrinkage is mostly dependent on mould temperature and different curing times have nearly no effect.

Shrinkage as function of curing time at different mould temperatures

1 - T_M = 155° C
2 - T_M = 165° C
3 - T_M = 175° C
4 - T_M = 185° C



Moulds

Sprue and Runner Systems

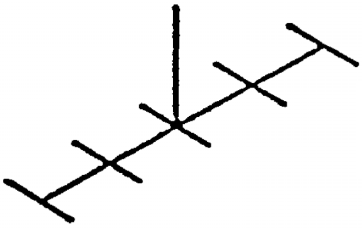
Sprues should be constructed with a round cross-section or a rounded trapezoidal shape and must have will polished surface adequate demoulding.

In a normal situation a runner diameter of a gated wall thickness S+1,5 mm is adequate.

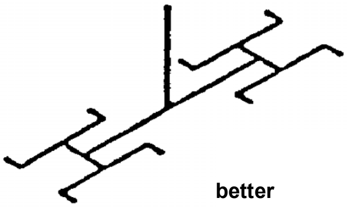
Varying flow distances lead of different curing rates. Most of the time the result is that cavities with the longest flow distance cannot fully densify (decreased mechanical properties, increased shrinkage) or cannot be filled completely. When using multi-cavity moulds, a flow design with equal flow lengths to each cavity should be considered.

Runner systems for multi- cavity moulds

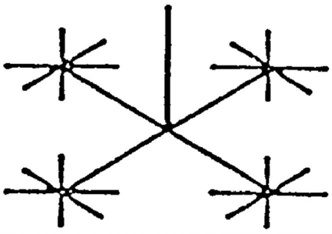
Balancing different flow path lengths by modifying diameters should be avoided, if at all possible. Varying pressure in individual cavities cannot be balanced with relatively short flow distances.



Not so good, different flow distances



better



8 cavity

24 cavity

If possible, cavities with different volumes should not be combined within one injection mould.

Gates: -Sprue gate
- Pinpoint gate
- Fan gate
- Tunnel gate

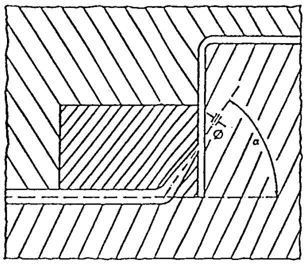
are up to today’s technical standard for thermosets.

Tunnel gates may be used for small parts with wall thickness up to 3 mm.

The injection angle should be about 45°-50°. With an angle less than 45°, there is a risk that the sprue will tear off when demoulding and block the gate. When processing mineral filled products increased wear from abrasion in the gate area may be expected. It is recommended that the gate area of a mould be designed as an insert to allow easy replacement.

Gate diameter should be 1.0-2.5 mm.

Tunnel gate



Ø= 1,0 – 2,5 mm
α = 45 –55°

The use of a tunnel often is not possible with flat pieces. Injection into a supporting pin or supporting rip allows fully automatic production. The support pin may be left on the part or removed during further processing.

When injection moulding directly with a sprue gate, moulded parts with large surface tend to break. This effect is caused by strong fibre orientation.

It should be noted that when sprue gates are used, moulded parts with large surfaced injected by a direct gate tend to tear, because of strong fibre orientation

Moulded parts should be produced with the injection compression method when this type of gate is used.

For pinpoint a film gating the same construction rules apply as for thermoplastics.

Mould Steel

Hardened steel has proven to be the best material for mould cores used for processing MF and MPF moulding compounds.

Table 27 includes two types of steel with properties resistant to wear (1.2767 and 1.1279).

A corrosion resistant type material no. 1.2083 has proven to be suitable.

We recommend that mould plates be made from material no. 1.2312, belonging to the group of tempered mould steels, which need no hardening and have high compressive strength.

Gate inserts may be made of Ferrotitanium to extend their lifespan.

Tool steels for the plastic processing

Werkstoff-	DIN-	Richtanalyse (Gew. %)							
Nr.	Bezeichnung	C	Si	Mn	Cr	Mo	Ni	V	S
1.2162	21 MnCr5	0.21	0.25	1.25	1.20				
1.2764	X19NiCrMo4	0.19	0.25	0.40	1.25	0.20	4.0		
1.2767	X45NiCrMo4	0.45	0.25	0.40	1.35	0.25	4.0		
1.2083	X42Cr13	0.42	0.40	0.30	13.00				
1.2379	X155CrVMo121	1.55	0.30	0.30	12.00	0.70		1.0	
1.2312	40CrMnMoS86	0.40	0.40	1.50	1.90	0.20			0.06
1.1730	C45W3	0.45	0.30	0.70					

Mould Tempering

Insulated plates between mould and machine supporting base are indispensable in maintaining constant mould temperature (thickness 8 mm). This reduces mould heating time and prevents excessive stress on machine parts, such as bearings and joints.Suitable insulation plates made from compression resistant materials with low moisture absorption are available from standard mould manufacturer.

Cartridge heaters, available from standard manufacturers, have proven best for maintaining high mould temperatures and even temperature distribution.

Placement of heat cartridges should follow the same guidelines as placement of cooling channels for thermoplastics, to insure even temperature on the mould surface. If equations of the heat cartridge manufacturers are used to determine the required heat output*, a heating up time of 60 minutes should be considered. When specific heat output is too high, inadequate temperature distribution takes place. Different rates of heat expansion may cause mould damage. Control thermal couples should be placed near the cavities.

It is recommended that continuous be used. When the desired temperature is reached the mould is supplied with as much energy as needed to maintain a set temperature. Two point regulators each switching the set heat output off and on, cause large deviations in the mould surface temperature and therefore effect the quality of the moulded part.

It is recommended the injection and the ejection side each have a separate regulation system. Varying metal mass and thermal conductivity (ie. ejector system) may cause variation in mould temperature on injection and clamp halves and lead to mould damage.

*f.e. $P = \frac{m.c.\Delta}{f}$

P = power (W)
M = weight of mould (kg)
c = specific heat (w.h/kg.K)
ΔT = temperature difference (K)
t = heating time (h)

Demoulding Angles

A demoulding angle of 0.5° is sufficient for flat cavities. For cases and long cores, a demoulding angle of 1° to 2° should be used, if the part's dimensional tolerances allow.

Cores should be polished in direction of demoulding to avoid unnecessary demoulding force.

Degassing

Because a degassing program can not be used in all cases, vents must be appropriately placed at the end of the flow path, so that air may easily escape from the cavities.

Vents can be made 0.02 – 0.05 mm deep and about 3-5 mm wide, depending on the product and the flow ratio. Degassing vents must be polished to insure adequate demoulding of the flash. Degassing can be aided by proper placement to the ejectors.

Jointing / Printing

In contrast to amorphous thermoplastics, MF and MPF moulding compounds can not be properly glued. Screw may be used to connect such moulded parts. Special thermoset screw, as well as basic calculations, are available from the product's manufacturer.

All thermoset types can be printed on. The tampon printing system is preferred. Instructions concerning the types of printing links, as well as the accelerator, may be obtained on request.

Waste Disposal / Recycling

Waste from all thermoset types, which has not been cured should be disposal of as special waste. Local regulations are to be observed.

Principally, the use of regrind, ground sprue mixed into fresh moulding compounds, is technically possible. A change in the properties of parts made from such reground moulding compounds can not be excluded. Therefore, tests and measurements are necessary to safeguard against variations this process might create.

Health and Safety Aspects

An exhaust system over the mould should be used when processing thermoset moulding compounds.

Parts of the skin which come into contact with MELOPAS moulding compounds should be washed with soap and water.

Further health risks are not known at this time.

Remedying faults

by correctly setting the variable machine data

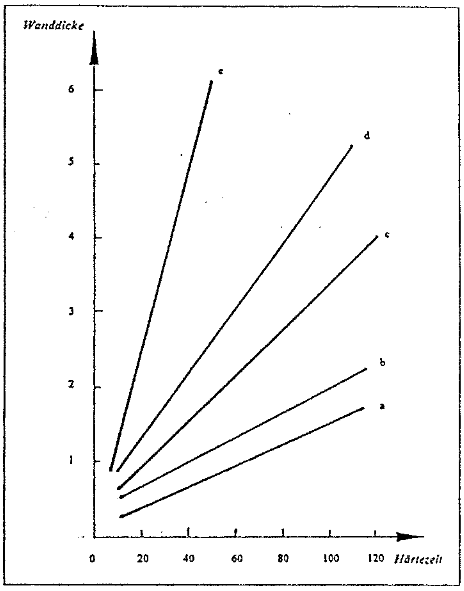
Fault	Cause	Remedy
Moulding not full	Injection pressure too low	Increase injection pressure
	Metered quantity too small	Increase metered quantity
	Holding pressure too low	Increase holding pressure and time
	Melt not yet sufficiently plastic	Increase back pressure. Increase temperatures on cylinder and screw. Increase injection rate.
	Melt overcured in cylinder	Reduce dwell time in cylinder. Set end of plasticizing time = end of curing time.
	Inadequate venting	Use “venting” program
Part damaged when demoulded	Curing time yet ended	Increase the curing time Demould part more slowly
	Tension inside the moulded part	Reduce injection pressure and holding pressure
Sprue torn off	No separation of material between mould and cylinder	Lift off nozzle after time-lag
	Sprue not sufficiently cured	Increase curing time Slightly increase mould temperature on gate side

Fault	Cause	Remedy
Screw does not retract	Back pressure does not build up	Increase screw speed, check supply of material and infeed Use agitator or suffer if necessary
Melt emerges between nozzle and sprue bush	Poor contact	Check centering of nozzle, radius and contact
Moulding compound too hot (opposite steps can be taken if moulding compound too cold)	Back pressure too high	Reduce back pressure
	Temperatures too high	Reduce temperatures in general
	Injection rate and pressure too high	Reduce injection rate and pressure
	Screw speed too high	Reduce speed
Uneven metering	Screw speed too high	Reduce speed
	Back pressure too low	Increase back pressure
	Irregular infeed of material	Check supply of material, use agitator and suffer if necessary
	Screw worn down	Replace screw
Excessive flash	Metered quantity too large	Reduce metered quantity
	Mould does not close	Increase closing pressure
	Injection pressure too high	Reduce injection rate, injection pressure and holding

Fault	Cause	Remedy
Parts distorted	Injection speed too low	Injection material more quickly
	Parts distorted during demoulding	Eject parts more slowly
	Curing time too long or too short	Set correct curing time
Sink marls on moulded part	Holding pressure too low	Increase holding pressure and time. Increase injection pressure. Increase nozzle contact time.
	Metered quantity insufficient	Increase metered quantity
Weld marks at join of material	Material at flow front already cured excessively	Viscomatic application
Moulding porous and partly scorched	Injection pressure too low	Increase injection pressure
	Back pressure too low	Increase back pressure
	Inadequate venting	Use “venting” program
	Mould temperature too high	Reduce mould temperature
	Metered quantity slightly too small	Increase metered quantity
	Cylinder and screw temperature too high	Reduce temperatures Back pressure profile

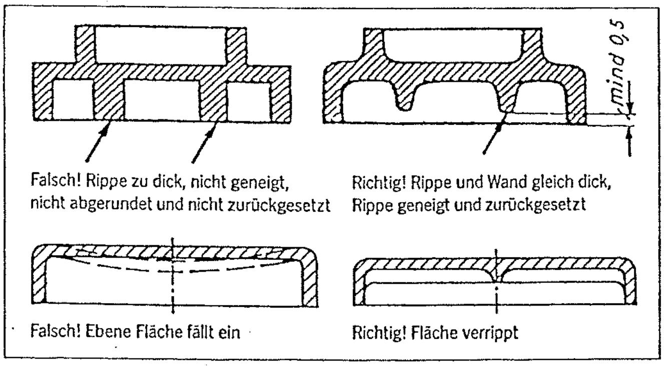
Fault	Cause	Remedy
Clouding, light – dark discoloration	Major temperature differences between mould and cylinder	Reduce the temperature differences
Brown marks on aminoplastics	Air trapped in the plasticized melt	Increase back pressure
Surface dull and patchy	Injection pressure too low	Increase injection pressure, holding pressure and time
	Inadequate venting	Use “venting” program
	Metered quantity too small	Adjust metered quantity
Mouldings blistered	Material not sufficiently cured in places	Increase curing time, temperatures and pressures Back pressure profile
Excessive shrinkage	Material not sufficiently compacted	Increase injection pressure, holding pressure and holding time
	Excessive temperature differences between melt and mould	Reduce mould temperature
	Cross-linking reaction not complete	Increase curing time

Wanddicke
- a: Pressen mit kalter Formmasse
- b: Pressen mit Ofenvorwärmung
- c: Pressen mit HF-Vorwärmung
- d: Spritzpressen
- e: Spritzgießen



Abhängigkeit der Härtezeit von der Wanddicke bei verschiedenen Verarbeitungsverfahren

Verrippungen



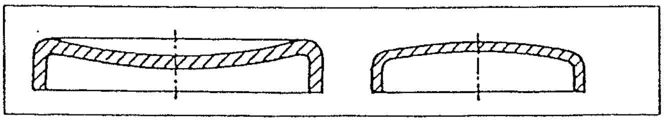
Falsch! Rippe zu dick, nicht geneigt, nicht abgerundet und nicht zurückgesetzt

Richtig! Rippe und Wand gleich dick, Rippe geneigt und zurückgesetzt

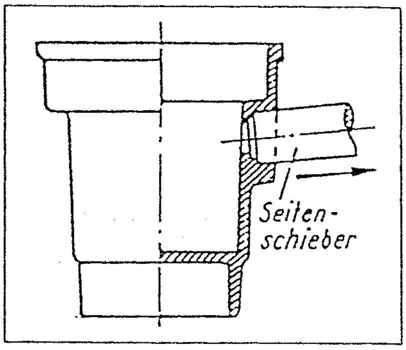
Falsch! Ebene Fläche fällt ein

Richtig! Fläche verrippt

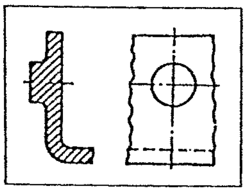
Fläche betont nach innen oder außen gewölbt



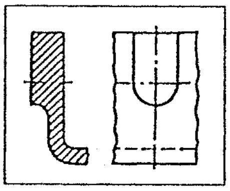
Hinderschneidungen



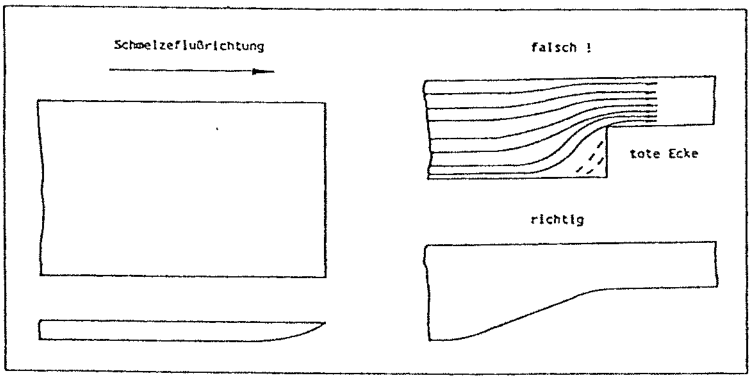
Hinterschneidung (Durchbruch) durch Seitenschieber hergestellt



Ungünstig! Seitliches Auge nur mit Seitenschieber ausführbar

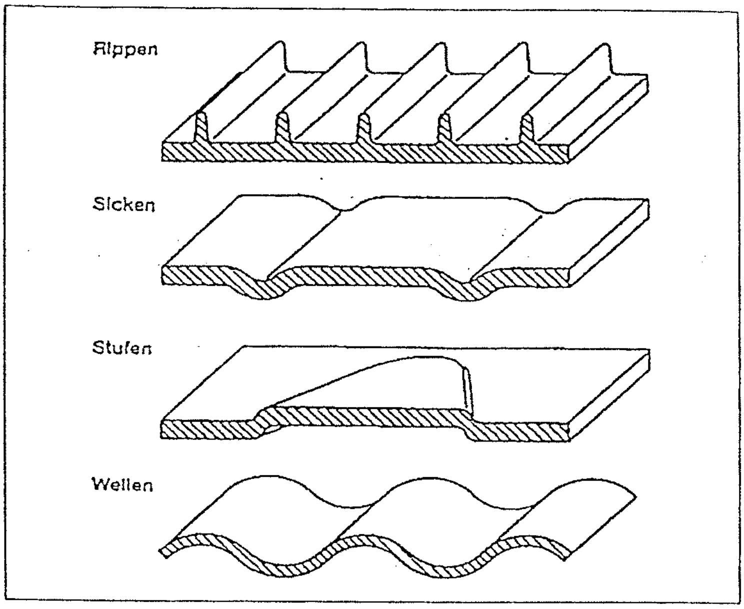


Günstig! Bis zur Oberkante durchgehendes Auge vermeidet Hinterschneidung; einfach herstellbar

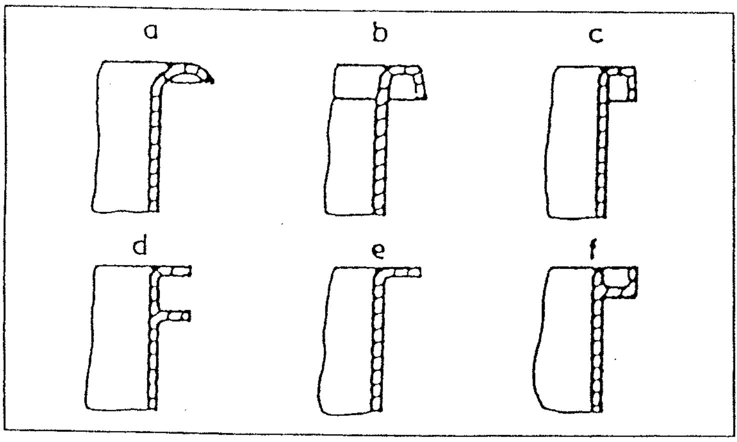


Progressive Wanddickenverjüngung am Fließwegende

Wanddickenübergang

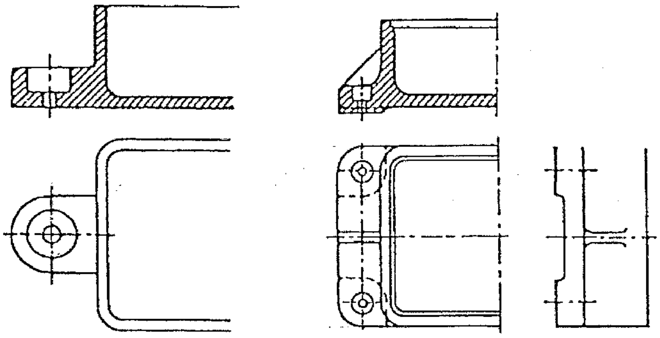


Profilierung von Flächen



Randprofilierungen

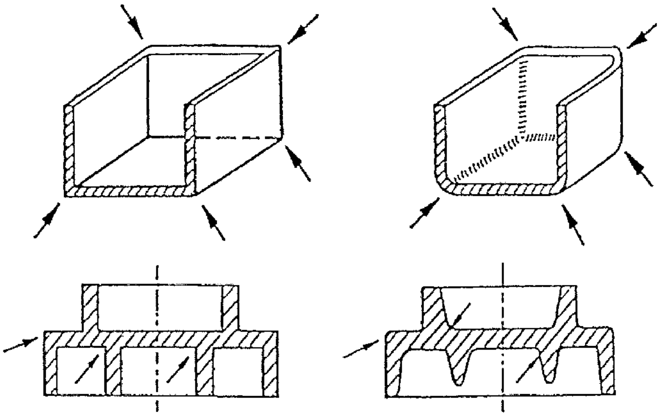
Befestigungsaugen bei ebenen Auflageflächen



Falsch! Schroffe Übergänge und ganzflächige Auflage

Richtig! Allmähliche und abgerundete Übergänge, Verstärkung durch Rippen, richtige Ausbildung der Auflage

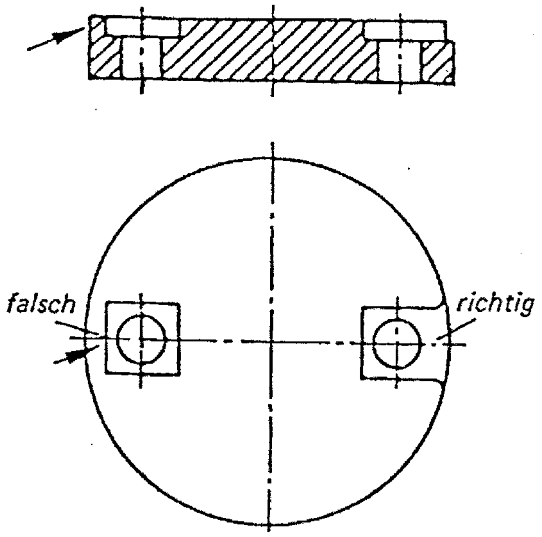
Konturgestaltung



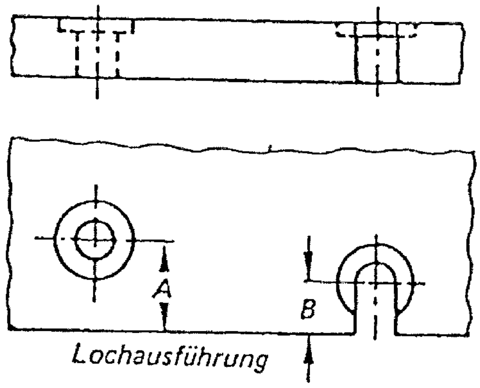
Falsch! Scharfe Außen- und Innenkanten

Richtig! Abrundungen der Außen- und Innenkanten

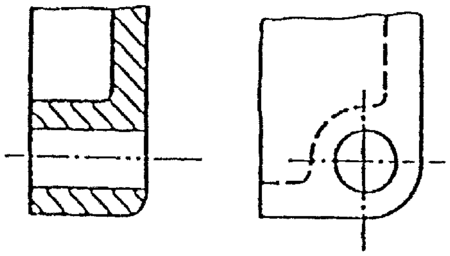
Durchbruchgestaltung am Formteilrand



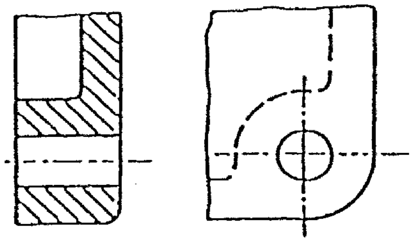
Links falsch! Aussparung bricht leicht aus.
Rechts richtig! Aussparung bis zum Rand durchgeführt



A: Bei genügender Entfernung vom Rande
B: Bei kleiner Entfernung vom Rand (Schlitzloch)

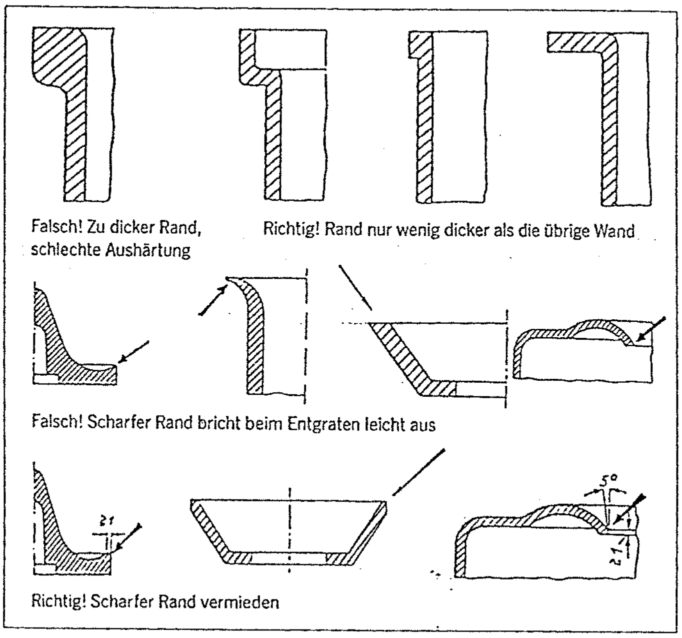


Falsch! Zu geringe Randdicke am Loch



Richtig! Genügende Randdicke

Randgestaltung

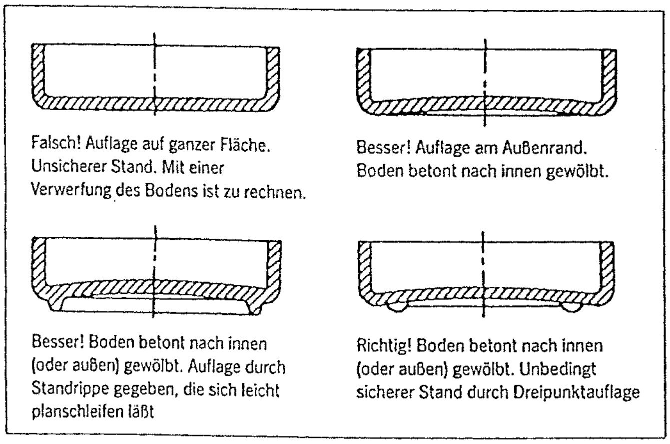

Falsch! Zu dicker Rand, schlechte Aushärtung

Richtig! Rand nur wenig dicker als die übrige Wand

Falsch! Scharfer Rand bricht beim Entgraten leicht aus

Richtig! Scharfer Rand vermieden

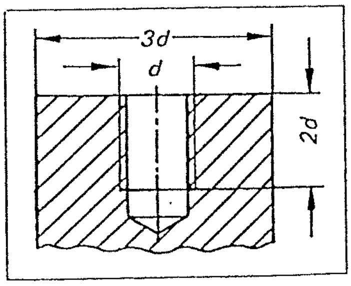
Standflächen


Falsch! Auflage auf ganzer Fläche. Unsicherer Stand. Mit einer Verwerfung des Bodens ist zu rechnen.

Besser! Auflage am Außenrand. Boden betont nach innen gewölbt.

Besser! Boden betont nach innen (oder außen) gewölbt. Auflage durch Standrippe gegeben, die sich leicht planschleifen läßt

Richtig! Boden betont nach innen (oder außen) gewölbt. Unbedingt sicherer Stand durch Dreipunktauflage



Eingeformte Gewinde