Processing styrene polymers and copolymers by injection molding

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2. Styrene polymer and copolymer product range

The following is a brief survey of the styrene polymer and copolymer product range. The aim of this publication is to provide the processors of our products with information of both a general nature and specific to the various products in relation to injection molding machines, molds and processing.

2.1 Composition of styrene polymers and copolymers

Styrene polymers and copolymers are materials capable of being processed by thermoplastic transformation. Figure 1 shows the BASF styrene polymer and copolymer product range.

Crystal polystyrene (PS) and polybutadiene – modified polystyrene (high-impact polystyrene or HIPS) are the main focus of the styrene polymer family.

Styrene copolymers contain, in addition to styrene (S), other monomers in the principal polymer chain. Styrene-acrylonitrile copolymers (SAN, trade name Luran®) form most important representative and basic building block of the entire copolymer product class.

Luran® SAN is a rigid, hard and heat-resistant thermoplastic which is as clear as glass due to its amorphous structure. In contrast with partially crystalline thermoplastics molded parts produced from SAN or Luran possess high dimensional stability while shrinkage and water absorption are low.

By adding rubbers to SAN either ABS (acrylonitrile-butadiene-styrene, trade name Terluran) or ASA (acylate ester-styrene-acrylonitrile, trade name Luran S) polymers are obtained depending on the type of rubber component employed. Luran S/C is manufactured from Luran S and polycarbonate.

The styrene copolymer range is further supplemented by SBS (styrene butadiene and block copolymers, trade name Styrolux) and MABS polymers (methyl methacrylate-acrylonitrile-butadiene-styrene, trade name Terlux). The chemical names, abbreviations and trade names are shown in Figure 2.

2.2 Product range

2.2.1 General-purpose polystyrene

General-purpose PS is a transparent, colorless material. (Fig. 3) It is hard, stiff and has very good dielectric properties (i.e., it is an electrical insulator). The general-purpose grades are differentiated by the unique combination of stiffness, heat resistance and flowability that characterizes each grade.

Polystyrene, due to its amorphous structure, exhibits high dimensional stability and low shrinkage. It absorbs very little moisture. Polystyrene is easy to process, weld, paint and emboss. Its neutral taste and odor are particularly important when it comes to food packaging applications.

2.2.2 Impact-modified polystyrene

Impact-modified polystyrene is made by polymerizing styrene in the presence of polybutadiene rubber, an elastomer that gives the polymer its impact strength (Fig. 4). The stiffness and impact resistance of impact grades is determined by the amount of polybutadiene present. HIPS is naturally opaque, its surface appearance can range from matte to high gloss.

2.2.3 Styrolux

Styrolux is a styrene-butadiene block copolymer that combines excellent clarity and impact strength. (Fig. 5) Styrolux is universally applicable, is easy to thermform and can be printed, welded and embossed. Also, it absorbs very little water, is physico-logically harmless and gamma-ray sterilizable.

In many applications, Styrolux is mixed with general-purpose polystyrene to custom modify physical properties. A high degree of clarity is realized with high and low styrolux levels when blended with GPPS.

Fig. 1: Product range

Fig. 2: Styrene copolymer product range

Fig. 3: Transparency of clear thermoplastics in %

Fig. 4: Impact resistance of a high impact polystyrene compared to a super high impact polystyrene

Fig. 5: Impact properties of Styrolux 684D and Polystyrene compared
2.2.4 Luran SAN
As a styrene-acrylonitrile copolymer, Luran is both an individual plastic in its own right as well as the basis for some other styrene copolymers (Terluran, Luran S).

The most prominent properties of Luran are:
- outstanding transparency,
- good chemical resistance
- thermal resistance
- high strength
- rigidity (see Fig. 7),
- dimensional stability
- resistance to fluctuating temperatures.

For years Luran has proved to be very effective in numerous applications in the field of household articles and tableware, cosmetics packaging, hygiene and toilet articles as well as for writing implements and office supplies. The Luran color range extends from a large number of transparent and smoky topaz shades through bright solid colors having a high surface gloss.

2.2.5 Terluran ABS
All types of ABS are styrene-acrylonitrile copolymers modified with finely divided butadiene rubber which have high impact strengths and notched impact strengths (even at relatively low temperatures). They are distinguished by high surface gloss, good scratch resistance and good thermostability.

**Terluran “World Grades”:**
Terluran “World Grades” were specially developed for the needs of global customers. They are standard, injection-molding and extrusion grades supplied in light, extremely constant self-colors, in a limited number of standard colors.

2.2.6 Luran S (ASA and ASA/PC)
In contrast with Terluran, the ductile phase in the case of Luran S consists exclusively of an acrylate ester rubber. As a result of this, excellent resistance to UV and heat aging (Fig. 8) is obtained resulting in very good resistance to yellowing. Accordingly, Luran S is primarily suitable for outdoor applications. In addition, it has high resistance to chemicals.

Properties such as flowability, heat resistance or impact resistance are adjusted differentially according to Luran S grade. Processing of Luran S at high temperatures shows that the ASA/PC blend exhibits increased impact resistance and thermostability at comparable rigidity and dimensional stability.

In contrast with polycarbonate chemical resistance is better and processability is distinctly enhanced. A fire-protection grade free of chlorine, bromine and antimony rounds off the product range.

2.2.7 Terlux (MABS)
Terlux is transparent, amorphous thermoplastic based on a MABS polymer. Thus Terlux combines in ideal manner typical ABS properties, such as a balanced relationship between toughness and rigidity, with the transparency familiar from PMMA molding compounds (Fig. 9).

This combination of properties singles out Terlux as a specialty in the field of transparent thermoplastics.
3. The injection molding machine and mold

3.1 The screw injection molding machine

It is customary nowadays to employ screw injection molding machines for the processing of styrene polymers and copolymers. In these machines, the screw assumes the roles of conveying, plasticizing and injection. Other types of machines (e.g. plunger injection molding machines) are now used only for special applications (for the production of marbled effects, for example).

3.2 Injection molding screws

3.2.1 Single-flighted three-section screws

The screw employed in the plasticizing unit affects the properties of the molded part. In certain circumstances the choice of a screw which is unsuitable for the material results in inhomogeneities in the melt (temperature, color distribution, non-uniform melting). As a result of this, the residence time in the plasticizing unit is shortened. This can be advantageous when handling thermally sensitive materials.

What are known as three-section screws have proved to be highly effective in practice for the processing of styrene polymers and copolymers. As the name already indicates this type of screw is divided into three different zones (feed, compression and metering section) each of which has to execute different tasks. Located at the tip of the screw there is additionally a nonreturn valve which during the injection and holding phase prevents backflow of the plasticized melt.

Standard modern screws generally have an effective length of 20–23 D, the length of the feed section being approximately half the length of the screw. The compression and metering sections are of approximately the same length. The pitch is usually 0.8–1 D. The flight depth ratio of the feed and metering sections ranges from 2 to 3. A compression ratio of 2 to 2.5 has proved to be effective for the processing of styrene polymers and copolymers in injection molding applications. The flight depths recommended by BASF for three-section screws are shown in Figure 11 as a function of the screw diameter.

In the flight depths illustrated in Figure 11, a distinction is made between standard screws and shallow-flighted screws. Shallow-flighted screws pick up less material, and as a result of which the residence time in the plasticizing unit is shortened. This can be advantageous when handling thermally sensitive materials.

3.2.2 Other screw geometries

Standard or universal screws, such as the three-section screw, are still encountered most frequently in practice and even today still cover a large portion of the spectrum of requirements and materials. In recent years, however, applications have increasingly appeared in which higher demands are imposed on the quality of the melt, than can be provided by a three-section screw. This may be encountered, for example, in critical product formulations and also in in-plant coloring using master batches or pigment concentrates. In order to achieve the required homogeneity, additional shearing and/or mixing parts as well as barrier zones can be and are employed.

Common to all the shearing and mixing parts are the basic principles of screw clearance and the division and recombinination of the melt stream. The Maddock and spiral shear sections together with the toothed disk or diamond pattern mixing section are primarily employed (Fig. 12). Furthermore, in a pilot plant trial good results were obtained with the Twente mixing ring (TMR), a combination of nonreturn valve and mixing part, developed by the University of Twente in the Netherlands (Fig 13) and available commercially in North America.

Using this system in contrast with two other shear and mixing sections studied in parallel, molded parts free from streaks were producible especially in the case of critical colors and low-concentration pigment pastes.

These mixing and shearing sections should be designed as far as possible to be pressure-neutral. This design keeps the material throughput, minimizes wear and avoids detrimental effects on the melt temperature.

![Fig. 10: Plasticizing unit with three-section screw](image)

![Fig. 11: Flight depths for three-section screws](image)

![Fig. 12: Three-section screw with shear and mixing sections](image)

![Fig. 13: Twente Mixing Ring](image)
3.3 Screw tip, nonreturn valve

The designs of the tip of the screw and nonreturn valve are important for the troublefree flow of the melt in the plasticizing unit.

A constant melt cushion and long holding pressure times can only be maintained by means of nonreturn valves. The clearance between the cylinder and nonreturn valve should lie between 0.02 and 0.04 mm (Fig. 15) at the operating temperature. In order to avoid any back pressure from the melt, the flow cross sections in the different regions (A, h, and H) must be of the same size.

The screw tip has to be designed in a manner to promote flow (Fig. 15). The angle \( \alpha \) at the screw tip and nozzle inlet should be the same so that as little melt as possible can settle in the melting, an effect which must be prevented. The minimum precondition for qualitatively flawless parts is that the maximum possible metering stroke and the effective length of the screw have a limited ratio to one another (i.e., for example, that the maximum metering stroke for a screw 20 D long should be restricted to 3 D).

The more air drawn in due to enlarged metering or injection strokes, the more difficult it is for this air to escape again to the hopper and not to move into the space in front of the screw. Indrawn air which is included in the melt and gets into the mold causes streaking in the molding, an effect which must be prevented. The minimum precondition for qualitatively flawless parts is that the maximum possible metering stroke and the effective length of the screw have a limited ratio to one another (i.e., for example, that the maximum metering stroke for a screw 20 D long should be restricted to 3 D).

Larger shot volumes are achieved at low cost and by structurally simple means like enlarging the metering length. Enlargement of the metering length has the consequence that the effective screw length shortens. This can result in unmelted material and inhomogeneities in temperature. A further risk with larger metering length is that even more air can be drawn in, especially during injection.

3.4 Injection nozzle

3.4.1 Open nozzles

Due to flow-related advantages, open nozzles (Fig. 16) allow simple cleaning and rinsing as well as rapid change of materials and colors. In order to prevent thermal damage, the opening of the nozzle bore should be at least 3 mm wide. The angle at the nozzle inlet should be the same as that of the screw tip.

The use of shut-off nozzles allows the injection nozzle to be retracted during plasticization. As a result of this, the transfer of heat between the temperature-controlled injection nozzle and the cooler mold is cut off.

Shut-off nozzles are also advantageous when operations must be conducted with elevated back pressure and unwanted stringing is to be avoided. Mechanically or hydraulically operated needle shut-off nozzles are highly suitable for styrene polymers and copolymers (Fig. 17). By comparison with open nozzle systems shut-off nozzles suffer from the disadvantage of higher-pressure losses.
3.5 Injection mold / Molded part design

3.5.1 Sprue design
In the design of injection molds for styrene copolymers, care should be taken that runners and gates are of an adequate size. Flow resistance during injection and holding has to be kept as low as possible. Undersized gates can cause streaking, charring due to shear and devolatilization. Premature solidification of the melt in the sprue frequently results in sink marks in the molded part since the contraction in the volume of the melt during the holding pressure phase cannot be compensated for. If gating is placed in regions of thin wall thickness, volume contractions in the thicker regions can no longer be compensated for since the thin walls freeze earlier. Gating in this way generally results in more distinct sink marks.

3.5.2 Design of molds and wall thicknesses
The wall thickness needed is determined by the requirements for strength and rigidity as well as for an economical cycle time for the component. In Figure 19, the effects of wall thickness, melt and mold surface temperatures are shown for an amorphous and a partially crystalline product. The maximum ... It is evident that the wall thickness of the molded part plays the dominant role in determining the setting time.

In order to prevent or reduce sink marks, gating should be placed as close as possible to the region of the greatest wall thickness because here the holding pressure can act for the longest time.

3.5.3 Venting
Molds must also be vented. When the two mold halves close, a volume of air is trapped in the mold cavity. During injection ... the plastic. In extreme cases, the mold cannot be filled. The removal of the trapped air is accomplished using vents.

3.4.3 Directions for installing the injection nozzle
In order to ensure troublefree demolding of the molded part, care has to be taken during installation of the nozzle that the radius of the nozzle head is always smaller than that of the sprue bushing the mold. The diameter of the nozzle bore must always be smaller than the diameter of the runner of the sprue bushing (Fig. 18).

A thermocouple for measuring the melt temperature should be installed in all nozzle structures. This provides the processor with evidence of the melt temperature actually prevailing in the space in front of the screw (Figs. 16 and 17).
For prototype work where a small number of parts will be produced, lead/zinc alloys are often used. These materials are inexpensive, can be cast into near net shape, and often remelted and reused. The lead and zinc are not alloyed, and this family of materials is not suitable for high production applications. When these materials are used, the lead is lost, which results in a material with excellent physical properties, primary tensile strength, and surface toughness when used at temperatures above 80°C (175°F).

While there are many materials that production molds can and have been made from including aluminium alloys, bronze, and stainless steel, the most common materials are usually made from hard chromium due to the improved surface finish when polishing and photo etching is required. Stainless steel is the most common because it is the easiest to machine, is typically used because of improved surface finish when polishing and the excellent wear resistance when metal is sheared. Hard chromium plating is often used on the tooling, which provides wear resistance and improves the tooling and surface finish when photo etching is required.

The cooling rate of the part is affected by the material of construction. Aluminium and beryllium copper can conduct heat twice as fast as tool steel and four times as fast as stainless steel. For prototype work where a small number of parts will be produced, lead/zinc alloys are often used. These materials are inexpensive, can be cast into near net shape, and often remelted and reused. The lead and zinc are not alloyed, and this family of materials can be cast into near net shape with remelting and reuse. When these materials are used, the lead is lost, which results in a material with excellent physical properties, primary tensile strength, and surface toughness when used at temperatures above 80°C (175°F).

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A rising temperature control profile is employed when residence times are relatively long. This permits relatively gentle fusion of the material. The initially rising temperature profile which then falls on approaching the nozzle is used primarily for open nozzles in order to prevent the melt running out or to prevent stringing. The aim of all temperature profiles has to be the setting of that melt temperature in the space in front of the screw which is required for processing. By means of the thermocouple fitted in the nozzle head, the actual melt temperature can be measured and the temperature profile of the band heaters together with the rotary speed of the screw can be corrected.

4.3.1. Special product-specific characteristics

BASF polystyrene products should be processed between 180 and 270ºC (356 - 518ºF). Temperatures above 280ºC (536ºF) and long residence times can cause thermal degradation.

A number of molded article properties can be controlled by adjusting the melt temperature (Fig. 25).

While processing is done in the upper temperature range, residence times should be short in order to prevent yellowing of or damage to the material. Furthermore, when high processing temperatures and/or long residence times are used the temperature of the first band heater (close to the hopper) should be set a little lower. This will prevent premature melting of the pellets in the feed section.

4.3.2. Effect of processing temperature on mechanical strength

Depending on which product is being processed, the processing temperature has a greater or lesser effect on mechanical strength (notched impact strength, see Fig. 26). Particularly noteworthy is the impact strength maximum of Terluran GP 22 at 260ºC (500ºF).

Luran S

By comparison with Terlux, the Luran S and Luran S/C grades exhibit higher stability to temperature and processing. Nevertheless when processing is carried out in the upper temperature range, care should be taken to keep residence times as short as possible in order to prevent any thermal damage to the material. This may be recognized in the case of bright colors by a change in color, usually towards a somewhat lighter shade.

Styrolux

Styrolux feeds easily in the barrel. The temperature profile should increase gradually in the direction of the screw tip. The feed zone should be set a little lower. This will prevent premature melting of the pellets in the feed section.

PS/HIPS

Terluran

Styrolux

Luran S

Luran S/C

Terlux

180 190 200 210 220 230 240 250 260 270 280 290 300

Melt temperature (°C)

Fig. 24: Processing temperature ranges for styrene copolymers

4.3 Melt temperature

Apart from a few exceptions, styrene polymers and copolymers can be processed over a broad range of melt temperatures.

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Styrolux

Styrolux feeds easily in the barrel. The temperature profile should increase gradually in the direction of the screw tip. The feed zone should be set a little lower. This will prevent premature melting of the pellets in the feed section.

The maximum processing temperature for Styrolux is 250ºC. Above this temperature, the rubber component of Styrolux starts to crosslink, causing poorer melt flow and haze in the molded article.

Luran

Especially when processing lightly colored, transparent Luran formulations, changes in the shade of the finished part can occur when the melt is subjected to excessive thermal stress. This effect, peculiar to SAN materials, can only be prevented by processing under gentle conditions.

Terlux ABS

At melt temperatures above 260 ºC (500ºF), particularly in the case of long residence times of the material in the cylinder or high heat production through shear, products containing polybutadiene can suffer a decrease in impact strength due to thermal damage.

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Terlux ABS

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Fig. 25: Instrumented impact of high impact polystyrene vs. melt temperature and injection speed

100 300 400 500 600 700 800 900 1000 1200 above

400 500 600 700 800 900 1000 1100 1200

200 300 400 500 600 700 800 900 1000

2000 2200 2400 2600 2800 3000

180 190 200 210 220 230 240 250 260 270 280 290 300

Melt Temperature (°C)

Injection Speed (m/sec)

Impact Force (kN)

Fig. 26: Notched impact strength as a function of processing temperature
4.4 Mold surface temperature

The surface temperature of the mold is among the most important parameters in the injection molding process. Figure 27 presents BASF’s recommendations for the mold surface temperatures. Apart from surface quality, (gloss and weld line marks) the effective mold surface temperature also affects the mechanical properties, weld line strength and the dimensional tolerances of the molded part (Fig. 29). Locally different mold temperatures result in different rates of cooling of the molding and hence in differences in shrinkage caused by cooling and in warpage.

In general a higher mold surface temperature brings about slower freezing of the melt. Shrinkage can be compensated for with longer cooling times resulting in lower residual stresses.

Figure 28 shows the effect of the mold surface temperature (MST) on the surface gloss of a molding made from Terluran 967 K. Increasing the mold surface temperature from 30°C to 60°C (86°–140°F) resulted in the case of a test mold with an appropriately polished surface in an increase in gloss of 24 % (melt temperature 230°C).

However, in the case of Terluran, a high melt temperature in combination with a low injection rate and low mold surface temperatures can result in distinct deterioration of the surface gloss. Increasing hold pressure and mold temperature can have a significant effect on peak force (Fig. 29).

4.5 Peripheral screw speed

The rotary speed of the screw can be selected in such a way that the time available in the cycle for plasticization is utilized to the greatest possible extent. As Figure 30 shows the peripheral screw speed \( V_u \) should be about 0.2 m/s and as far as possible, even in intensive use, not exceed 0.3 m/s. When using a screw having a diameter of 80 mm for example, this corresponds to a speed range of 48 to 72 rpm.

4.6 Back pressure

In order to prevent air intake and to produce a sufficiently homogeneous melt, it is necessary to work with back pressure. In doing so, the level of back pressure should as much as possible, but not exceed a hydraulic pressure of 10 bar (150 PSI). A back pressure which is too high results in excessive heating by friction and thus in an uncontrolled and generally excessive processing temperature. This can result, for example, in thermal damage to the melt and consequently in considerable losses in the quality of the molded part.

At a higher injection speed, the pressure requirement rises and the demands on mold venting become more stringent. In the case of a relatively cold melt, there is a danger of damage to the melt and of higher stresses in the molding.

4.7 Injection pressure / Injection speed

A good molding surface can be achieved by filling the mold uniformly. To prevent the injection speed from falling below the desired value throughout the injection process, a high injection pressure has to be set. A drop in the injection rate at the end of the injection phase indicates that the injection pressure is too low or the target speed is too high.

Marked differences in wall thickness while the injection speed remains the same result in nonuniform filling of the mold and hence in flow marks. If necessary, the injection speed has to be varied in steps or the component geometry has to be revised.

Especially in the case of thin-walled moldings, high injection speeds should be chosen. As a general rule, high injection speeds result in a higher melt temperature and a higher surface gloss (Fig. 28). They bring about improvements in flowability and especially in the case of glass-fiber reinforced product improvements in surface quality. High injection speeds give rise to a more uniform solidification process. In many cases, weld lines are less visible and the impact strength of the products is enhanced.
4.8 Holding pressure / Holding pressure time

The holding pressure is intended to compensate for the shrinkage of the solidifying plastic. For this purpose it is important that the changeover to the holding pressure occurs exactly at the volumetric filling of the cavity.

Depending on the geometry of the component, voids and sink marks can be very largely balanced out by choosing an appropriate holding pressure value and a holding pressure time. On account of their amorphous structure, the holding pressure times for styrene polymers and copolymers are distinctly lower than for partially crystalline polyamide for example.

4.9 Cooling time

The criterion for an optimum cooling time is the demolding of the injection molded part without any lasting or subsequent deformation of the component. The cooling time can be determined for many geometries with the aid of computer programs.

4.10 Shrinkage and warpage

The shrinkage of a component is determined both by the nature of the material as well as by the processing conditions and the geometry of the molding (shape of the molding, wall thickness and position of sprue). Interactions among these factors make it difficult to predict the exact shrinkage.

Accordingly, the shrinkage values set out in the material data sheets apply only to the specified processing and mold surface temperatures and the geometry used for the component. At the same time, a distinction has to be made between the values for free and impeded shrinkage parallel and at right angles to the direction of flow of the melt.

At 0.3–0.7%, the free shrinkage of amorphous materials is smaller by a factor of three or more than that of partially crystalline plastics which is 1–3%. Figure 32 shows the values of free shrinkage for the processing temperatures in question. These were measured on a 110 x 110 x 2 mm (4.3” x 4.3” x 0.08”) plaque.

Shrinkage also affects molded parts in two ways other than part dimensions, namely sink marks and voids. Both of these molding problems are caused by the shrinkage of the hot melt as it cools on the inside of the molded part. In the case of sink marks, as the polymer cools and shrinks, material is pulled away from the wall of the part, creating a depression in the surface of the part. Voids occur from the same root cause, shrinkage of material on the inside of the part; but in this case, the walls have frozen solid and cannot be pulled away from the walls. As the material shrinks and volume decreases, a void is created on the inside of the part. Correction of both of these problems requires increased packing of the molded part to compensate for the shrinkage. Often, mold design changes are required to avoid thick sections in the part and minimize shrinkage to acceptable levels.

The processor can control shrinkage substantially by selective changes in the holding pressure and in the maximum effective holding pressure time up to the gate sealing point. The aim should be to compensate for the contraction in volume occurring during the freezing process for as long as possible by feeding melt through the holding pressure and holding pressure time.

A high mold surface temperature affects the cooling rate of the molding and thus prolongs the possible duration of action of the holding pressure. On the other hand, the injection speed and melt temperature have only a minor influence on the course of shrinkage.

Shrinkage in the molding is generally caused by differences in shrinkage in the direction of flow transversely to flow and also by different wall thicknesses in the component. Since the holding pressure acts for very much longer close to the sprue than far from it, the different shrinkage along the component can also give rise to warpage.

The processor has the possibility of controlling warpage of the component by means of differential temperature control on the two halves of the mold as well as by means of partial temperature control of individual parts of the mold.

Fig. 31: Relationship between fracture energy and holding pressure

![Fig. 31: Relationship between fracture energy and holding pressure](image)

Terlux 567K
Melt temperature = 250°C
Mold temperature = 60°C
Wall thickness = 1.5 mm

600 bar 800 bar

Fracture energy (Mx)

0 10 20 30

A B C

0.3–0.7% 0.4–0.7% 0.4–0.7%

Fig. 32: Processing shrinkage * of styrene copolymers

![Fig. 32: Processing shrinkage * of styrene copolymers](image)

<table>
<thead>
<tr>
<th>Material</th>
<th>Shrinkage Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luran</td>
<td>0.3–0.7%</td>
</tr>
<tr>
<td>Terlux</td>
<td>0.4–0.7%</td>
</tr>
<tr>
<td>Luran S</td>
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<tr>
<td>Luran S/C</td>
<td>0.5–0.7%</td>
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<tr>
<td>Terlux</td>
<td>0.4–0.7%</td>
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</tbody>
</table>
5.1 Multicomponent injection molding with styrene and styrene copolymers

The multicomponent injection molding technique makes it possible to selectively combine different products having their own specific properties in a molding. Stylene copolymers in combination with different thermoplastics and thermoplastic elastomers are also highly suitable for this special process in injection molding technology.

The processes combined under the generic heading of multicomponent injection molding include injection molding. Here, two plastic melts are prepared in different units and injected one after the other through a gate into the mold cavity. The result is a skin or a core component (material which flows after the first component). A molding with a sandwich-like structure is produced (Fig. 35).

If, for example, they do not adhere adequately to one another, delamination of the layers can result in a reduction of functionality or serviceability. On the basis of experience, styrene copolymers undergo comparably good bonding to one another. On the other hand, a materials combination involving styrene copolymers with polypropylene for example is not recommended.

A increasing number of new applications are produced by a further multi-component injection molding process, sandwich injection molding or over-molding. In this process, pre-moldings produced out of the first component are first manufactured. On completion of the setting time, these are covered in part with at least one further product (Figs. 36 and 37).
5.2 Internal gas pressure process

The internal gas pressure process (IGP), also known as gas assist, was developed in the middle of the seventies. It has been used on a large scale only since the middle of the eighties.

The principle of the IGP method is the selective production of cavities at points in the molding having great wall thicknesses by the injection of inert gas – nitrogen as a rule – into the cavity partially or completely filled with plastic melt. The gas can be introduced by injection needles both via the machine nozzle as well as via a gas nozzle installed directly in the mold. In principle, all thermoplastics used in conventional injection molding, i.e. including styrene polymers and copolymers, can be processed by IGP. Figure 38 shows an example of this.

Depending on the type of plastic molding to be produced, a choice can be made between the inflation method and the blowing out method.

The decision whether to use IGP or conventional injection molding is substantially determined by the mold geometry. In order to make optimum use of the advantages of the IGP method, it is necessary to start thinking differently as early as the design of the component and the mold. The factors affected are: position and layout of the sprue, design of wall thicknesses, use of ribs and diversion points for the melt.

The following advantages relative to conventional injection molding come to the forefront when the IGP method is used.

- Greater design freedom in the development of the molding.
- Simpler, more suitable injection molds.
- A great level of integration, i.e. the production of one part instead of two or more individual parts which subsequently have to be assembled.
- Prevention or minimization of sink marks.
- More uniform shrinkage, lower internal stresses and less warpage on account of the uniform distribution of gas pressure in the molding.
- Optimization of weight or material consumption while the rigidity of the molding is relatively high.
- Reduction of cycle times.
- Use of machines having a lower clamping force.

On the other hand, the following disadvantages can occur.

- Gas spreading and the hollow space formed is not predictable. Appropriate computer simulations, such as FEM programs for example, can provide indications.
- The gas spreading, size of the hollow space and the resultant residual wall thickness can only be affected within certain limits by the process parameters such as melt temperature, mold surface temperature, gas pressure and gas delay time.
- Additional resources are needed to carry out the process. These include gas pressure generator and pressure control modules, process gas and injection nozzles.
- Patent situation (license fees).
- Injection molds must be made with great precision and be perfectly balanced – this applies especially to multicavity molds – in order to ensure uniform spreading of the gas.

All injection molding machines commonly available on the market are suitable for the IGP method.

The manufacturers of gas systems supply different systems, such as Airmould, Airpress, Cinpress, Gain, etc. Some systems or variants of the process are protected by patents. For that reason, the processor should obtain comprehensive information about the patent position before starting technical utilization.
Plastics Line of the BASF Corporation

**Products of BASF Corporation**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Terluran®</td>
<td>Acrylonitrile/butadiene/styrene copolymer (ABS)</td>
</tr>
<tr>
<td>Luram® S</td>
<td>Acrylonitrile/styrene/acrylate copolymer (ASA, ASA + PC)</td>
</tr>
<tr>
<td>Luran®</td>
<td>Styrene/acylonitrile copolymer (SAN)</td>
</tr>
<tr>
<td>Terlux®</td>
<td>Methyl methacrylate/acrylonitrile/butadiene/styrene copolymer (MAS)</td>
</tr>
<tr>
<td>Crystal PS</td>
<td>Polystyrene</td>
</tr>
<tr>
<td>Avantra®, high-impact PS</td>
<td>Styrene/butadiene polymer (HIPS)</td>
</tr>
<tr>
<td>Styroeblend®</td>
<td>Blend based on styrene/butadiene polymer (HIPS blend)</td>
</tr>
<tr>
<td>Styrolux®</td>
<td>Styrene/butadiene block copolymer (S/B/S)</td>
</tr>
<tr>
<td>Ultradur®</td>
<td>Polysulphone terephthalate (PBT, PBT + ASA)</td>
</tr>
<tr>
<td>Ultraform®</td>
<td>Polyphenylene (PSM)</td>
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<tr>
<td>Ultramid®</td>
<td>Polyamides (PA-6, 66, 6/10, 6/6T)</td>
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<tr>
<td>Ultrasone® S</td>
<td>Polyisulphone (PIS)</td>
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<tr>
<td>Styropor®</td>
<td>Expandable polystyrene (EPS)</td>
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<tr>
<td>Neopor® P</td>
<td>Expandable polystyrene (EPP)</td>
</tr>
<tr>
<td>Neopor® E</td>
<td>Extruded rigid polystyrene foam (EPE)</td>
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