Rigid-flexible joints in injection molding technology

Technical Information

BASF

The Chemical Company

- Short cycle times and a small number of processing steps have a positive effect on unit costs and hence on competitiveness.
- Accordingly, special procedures, such as the multicomponent injection molding process, are increasingly gaining acceptance.
- The following explanatory details present an overview of composite injection molding. Particular attention is devoted to joints between rigid and flexible plastics.
- Adhesion between the various components is a key topic.

The integration of function and design plays an increasingly important role today in product development for plastic parts. This often requires the use of several materials. Increasing pressure on costs, moreover, demands that assembly and joining operations be cut out. Special methods in injection molding technology, such as the multicomponent process, offer an all-round cost-saving solution for this purpose.

Increased component functionality

There are numerous reasons favoring the use of multicomponent injection molding.

By integrating sealing and insulating functions in components the main savings are in assembly costs. Process reliability is also increased since the handling and bonding of often extremely flexible seals is dispensed with.

Optical functions can be integrated in the component by combining differently colored, even transparent or light transmitting components (viewing windows, lettering, design for day/night use, etc.). The two-component technique is often employed simply for aesthetic reasons.

Apart from the optical features of components, great attention is now being paid to haptics – the capability of a material to feel good to the touch. In tools (Fig. 1) and also in household appliances such a soft-touch surface additionally affords security against slippage.

The combination of high-grade special products in areas of the component which are subjected to high load stresses together with standard products in areas exposed to less stress provides, in some cases, substantial cost advantages. This, however, applies mainly to rigid-rigid combinations.

Multicomponent injection molding

To date the term multicomponent injection molding has not been used without ambiguity. Apart from composite injection molding it also encompasses assembly and sandwich injection molding.

Two-shot molding or overmolding means injecting a flexible or rigid plastic around, on or over an usually rigid base structure.

In assembly injection molding nondetachable joints which can move relative to one another are produced. These nondetachable joints are used for the production of toys (e.g. Playmobil, toy monkey, Company Geobra Brandstätter, Fig. 2) or smallest parts (e.g. watch movements). In contrast with composite injection molding this requires that the materials used are completely incompatible with regard to adhesion and have matching shrinkage behavior.

Sandwich injection molding allows the production of molded parts built up in multiple layers. These consist of a skin and a core component. This procedure has the advantage that many combinations of plastic materials, including the use of recycled material, are possible.

Conventional injection molds can be used for sandwich injection molding since both materials are injected through the same gate. The interaction of the two injection units is much more difficult to regulate but this will not be elaborated upon in this technical information.

This technical information for experts focuses on the composite injection molding of hard and soft plastics. Assembly injection molding and sandwich injection molding are identical in terms of the mold and machine technology.

Fig. 1: Hammer drill made by the Bosch company (Ultramid® B3EG7 + TPE-S)

Fig. 2: Toy monkey (Ultramid® + Ultradur® + Ultraform®)

Machine technology

As a rule a multicomponent injection molding machine differs from the conventional machine only in that it has one or more additional injection units. The arrangement of the units relative to one another is dependent on the availability of space, mold design and accessibility (e.g. for handling devices). Layout plans in which the main unit is positioned centrally in standard manner are also suitable for the production of parts which consist of only one material.

Mold technology

All multicomponent mold techniques have a common factor. First of all the preform composed of the first component is injected in one cavity. This is then supplemented by further components by freeing up volumes in the subsequent cavities. This can be done with or without movement of the preform. Multicomponent molds can basically be classified as transfer, rotary or sliding split molds (see Fig. 3) /1/.

In the transfer technique the preform is transported into the finished part injection station by means of a handling device. In this case it is also possible to work with two conventional injection molding machines. This application concept also offers a high degree of design freedom, since it is possible in principle to alter the contours of the core.

The preform is ejected completely. Here, however, short term shrinkage presents a problem for centering the preform in the cavity for the finished part. Utmost precision is required in dimensioning the cavity for the finished part in order to guarantee that the preform can be inserted and fixed exactly in place /2, 3, 4/.

This procedure is recommended for processing thermoplastics in combination with elastomers. Here good thermal separation is important in order to prevent the thermoplastic from melting once more at the high mold temperatures required for cross-linking the elastomer.

Rotary molds include cube techniques, turntable, indexplaten and capstan-type molds. The principle of operation of rotary molds allows the simultaneous production of the preform and finished part. Rotary molds also allow excellent centering of parts since the preform shrinks onto the core. However, in contrast with the transfer technique, it is difficult to alter the contours of the core /2, 3, 4/.

In the case of turntable molds one half of the mold is turned completely. This is usually the ejector side. While this is happening the preform remains in the cavity and is transported into its final injection position by turning the machine turntable.

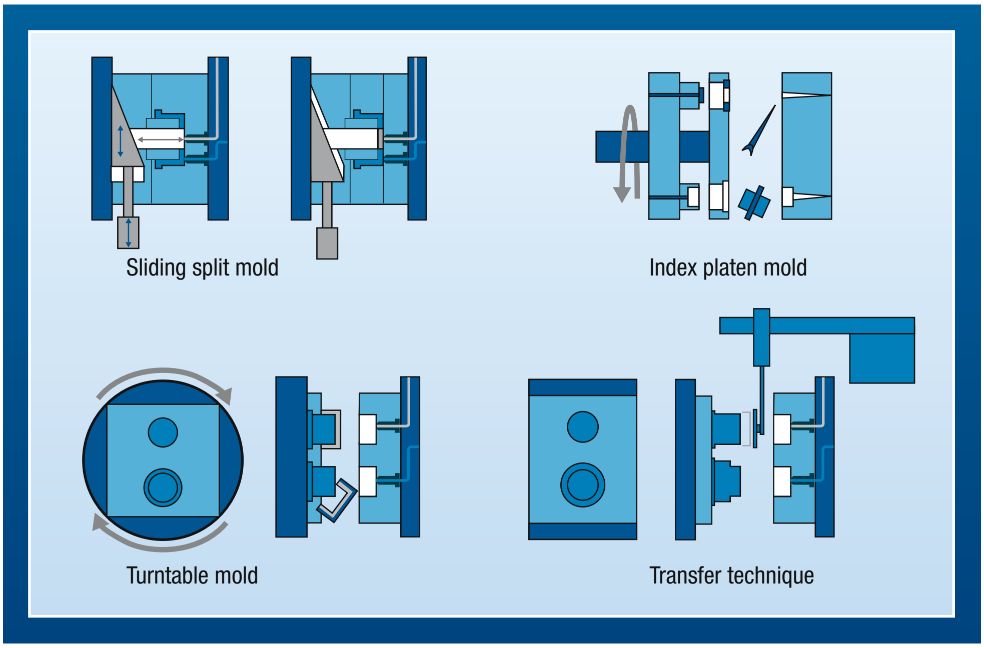

Fig. 3: Mold technologies for multicomponent injection molding

The acquisition of a turntable for the injection molding machine proves cost-effective when different multicomponent molds are used frequently /2, 3, 4/.

In index platen molds a mold plate together with the preform is lifted off by a machine ejector or a core puller while the mold is open, turned and retracted again. With the capstan-type mold this occurs only with part of the mold plate. These two mold concepts make it easier to carry out a core-related alteration of the molding than is possible with a turntable /2, 3, 4/. In the three-plate technique, the middle mold plate can be rotated vertically by 180°, which allows gating from two sides. If the middle plate is configured as a cube, additional work steps such as, for example, the insertion of films or printing, can be performed at two additional stations.

The use of sliding split molds or core-back molds offers a cost-effective alternative. In contrast with the types of molds described so far, in this case the preform and finished part are both molded in the same mold cavity. The cavity for the finished part results when a sliding split is pulled and enlarges the cavity of the preform. Such a sealing split can both isolate a part of the mold cavity (barrier split) or alternatively form the latter completely (opening core). Since sliding split molds work sequentially, the disadvantage in this case is longer cycle times in comparison with rotary molds. Shrinkage of the preform can also be a problem. Rapid injection of the second component, however, increases bonding strength. The central position of the cavity also results in minimization of the required clamping force.

Nonuniform opening pressures on the mold due to the off-center cavity, as is the case with rotary molds, and wear of the parting line caused by this does not occur here.The absence of lubricating films and deposits on the parting surface of the split is very important /2, 3, 4/.

Regardless of the type of mold, however, some general design guidelines for rigid-flexible joints should be observed.

- If possible, the finished part should be ejected via the rigid component. Otherwise the surface of the ejector should be adapted to the shore hardness of the flexible material.
- Drafts of up to 2° should be provided for the flexible component. The "suction cup" effect on the walls of the mold can be counter acted by sand blasting the surface to a roughness of approx. 25 µm.
- Since high injection speeds have generally proved advantageous during composite injection molding, good mold venting should be provided /4/.

Flexible components

In most cases, thermoplastic elastomers are selected as the flexible component for rigid-flexible joints. However, conventional elastomers are also used.

Thermoplastic elastomers (TPE) are materials in which elastomeric phases (the flexible component) are incorporated into the thermoplastic (the rigid component). Depending on the manner of incorporation a distinction is made between block copolymers and polymer blends with separate phases. The advantages by comparison with cross-linking elastomers are ease of processing with short cycle times, the possibility of coloring with bright colors and the recycling of sprue and reject parts. The disadvantages are the tendency to creep at relatively high elongation, as well as limited elastic recovery at higher temperatures. Table 1 provides an overview of the types of TPE.

Table 1: **Thermoplastic elastomers – an overview of types**

Block copolymer	Elastomer blends
■ Styrol types (TPE-S) ■ Polyurethanes (TPE-U) – on polyether basis – on polyester basis ■ Polyether esters (TPE-E) ■ Polyether amides (TPE-A)	■ Uncross-linked thermoplastic polyolefine (TPE-O) ■ Cross-linked thermoplastic polyolefine (TPE-V))

Fig. 4: Two-component plate

Combinations of materials

The choice of a combination of materials is determined in the first instance by the function of the part and its field of application. In the case of the multicomponent method, however, three aspects should be considered while the application is still at the development stage.

- **Processing compatibility** relates to the temperature of the melt and of the mold in injection molding. If the melt temperature of the second component is too high, the fringes of the preform melt again. This can result in deformation of the preform. That is why in most cases the flexible component with the lower melting point is injected after the more rigid thermoplastic.
- **Compatibility of properties** relates, among other things, to the modulus of elasticity, the coefficient of thermal expansion and the shrinkage characteristics of both components. Great differences in properties can give rise to high internal stresses in the molding during the cooling. Apart from warpage of the part this can also cause cracks to form at the boundary surface of the composite.
- **Compatibility of adhesion** means the ability of plastic materials to form a mutually adhesive bond with one another. To explain adhesion various theories have been advanced which will be considered in greater detail in the next section /5/.

The phenomenon of adhesion

The best known theory is the diffusion theory which assumes the interpenetration of macromolecules in the boundary layers. In this case the bonding strength is determined by the depth of penetration of the molecules. A good diffusion layer is obtained through a high melt temperature and a sufficiently long contact time.

There are further theories which propose interactive forces of an electrostatic nature as the cause of adhesion. Physical bonding is caused by polar linkages or van der Waals forces in the boundary layer. For such a bond to be durable, surface tension is essential; the surfaces of both components must thoroughly moisten each other.
The theory of mechanical adhesion describes the penetration of one component into the pores or capillaries in the surface of the other. This leads to the development of mechanical interlocking.

Currently it is assumed that adhesion arises from the superimposition of mechanical, physical and chemical mechanisms /6, 7, 8/.

Effects on adhesion

The strength of bonding is greatly affected not only by the chemical composition of the polymers (e.g. similar polarity) but also by process parameters, such as temperature, time and pressure. In order to examine the adhesion of two materials, two-component test plates (Fig. 4) are injection-molded. These are then processed into tensile test specimens (type 5A, Fig. 5).

To start with the first half of the plate is made in the first injection unit of the two-component machine. This is the rigid component in rigid-flexible combinations. After the cooling time for the first product the sliding split is pulled, which frees the second half of the cavity. In this way the melt of the second component then injected can now come into contact with the first half of the plate. If both materials have compatibility of adhesion a plate composed of two different plastics results.

Since there is no standardized method at present for testing adhesion in two-component injection molding the bonding in the two-component plate was measured by tensile tests in line with ISO 527.

The maximum stress and elongation at break were taken as the measure of the bonding strength of the joint. Rigid-flexible joints are frequently subjected to peel stresses which are usually more critical than simple tensile stresses. For this reason, during the production of the two-component plate, the soft component can also be injection-molded onto the hard component, thus creating a material overlap. This overlapping area is made into a strip which is then subjected to a peel test based on the roller peeling test DIN EN 1464. Apart from mechanical characteristics, the nature of the break can also provide information about the quality of the bond. The following break patterns are distinguished.

- Adhesion break: Both components detach completely from each other without residue.
- Cohesion break: The failure does not occur at the boundary layer but entirely in one of the components.
- Combination break: Adhesive as well as cohesive failure occurs in this case.

Fig. 5: Two-component tensile bar

Even if flexible components of very low shore hardness have poor mechanical characteristics, very good adhesion can still be assumed if cohesion break or combination break occurs. The wide array of different TPE types and the various effects of the processing parameters as well as the influence of the design of the molded parts and of the molds only permit a qualitative evaluation of the adhesion characteristics (Table 2).

Table 2: **Overview of adhesion of various TPEs to selected BASF plastics**

TPE-Type	**TPE-U**		**TPE-S**			**TPE-S / TPE-U**	**TPE-V**
BASF plastics / Basis	Polyester	Polyether	SBS	SEBS	SEPS		
Ultradur® B 4300 G6	+			0			–
Ultradur® B 4500	0	–		+			
Ultradur® B 4520	–	–	0	–			
Ultradur® S 4090 G4	+	–		+			
Ultraform® N 2640 Z6	+	–					
Ultraform® S 2320 003	–	–					
Ultramid® A3K	+	+		++	--	--	–
Ultramid® A3WG6	++			++			
Ultramid® A3ZG6			-	+		–	
Ultramid® B3K	++	++					
Ultramid® B3S	++	+	--	++	--	–	–
Ultramid® B3EG6				++			
Ultramid® B3WG6	++	++		++			
Ultramid® B3ZG6	++	++		+	--		–
Ultramid® T KR 4355 G5	–	–		–			–
Ultramid® T KR 4365 G5	0	0		–			–

++ very good adhesion, + good adhesion, o adhesion, – little adhesion, -- no adhesion

If no bond is formed between a desired pairing of materials, the possibility exists to employ positive and non-positive connections. In this case, splits and cores are systematically employed to create openings and undercuts in the pre-molded part. During the subsequent overmolding, the second component flows around or through these openings and undercuts. Depending on the application, this variant can make high technical demands of the mold and can thus be cost-intensive.

Another way to improve the bond between two materials is a plasma pre-treatment. In this process, the pre-molded part is irradiated with plasma – a gas consisting of electrically charged particles – and this modifies the surface of the part. The second component is injected-molded onto it immediately after the treatment. During the plasma treatment, the incorporation of oxygen into the surface causes the formation of functional groups that bring about an improvement in the adhesion /9/. The adhesion of Ultradur® to TPE-U, for instance, can be rendered very strong by means of a plasma treatment.

Applications

The fields of application of rigid-flexible joints are extremely diverse, so that two-component applications are commonly found to a greater or lesser degree in every sector of industry (Table 3).

Injection-molded seals make up a large proportion, since two-component injection molding makes production not only less costly but also more reliable. Examples from the automotive industry include a cover made by the Mecaplast company for a Renault engine (Fig. 6). In case of a triangle mirror base the injected seal has in addition to its sealing properties the function of preventing rattling noises. The seal on a gearshift lever guide affords protection against contamination and has acoustic advantages.

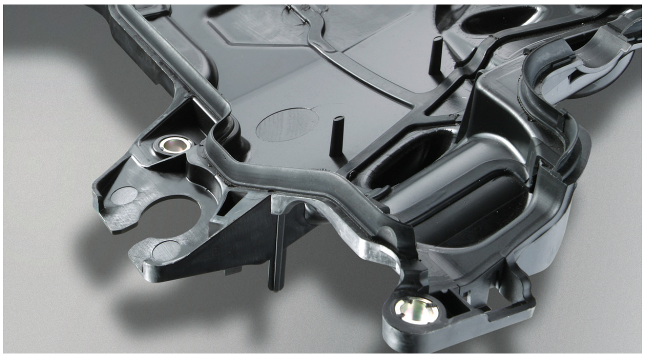

Fig. 6: Engine cover for a passenger car (Ultramid® B3GM24 + Elastollan® C85 A15 HPM)

Table 3: **Fields of application for rigid-flexible joints**

Automotive:	Electrical:	Packaging:	Sport/Leisure:
■ Door lock module with seal ■ Gearshift lever guide with seal ■ Cowling with sealing lip ■ Air vent seal ■ Door threshold cover strip ■ Multi-switch end pieces ■ Handbrake cover ■ Wind deflector ■ Door bellows	■ Seals on plug connectors ■ Knobs for electric cookers ■ Switch housing with seal ■ Electric shaver ■ Switch cover ■ Electric toothbrush ■ Handles for power tools	■ Bottle caps with molded seal ■ Disposable 5 L tin kegs ■ Sealing cap for cosmetic packaging	■ Diving – fins, eyeglasses ■ Handle sheats ■ Toys ■ Suitcase wheels

Further reading

The following references, quoted in part above, provide further insight into the possibilities of multicomponent injection molding.

/1/ Kuhmann, K., “Prozess- und Materialeinflüsse beim Mehrkomponentenspritzgießen” (Effects of processing and materials in multicomponent injection molding), Dissertation, University of Erlangen-Nuremberg, 1999.

/2/ Steinbichler, G., “Werkzeuge für Sonderverfahren” (Molds for special processes) in “Erfolgsfaktor Spritzgießwerkzeug” (The injection mold as success factor), VDI Verlag, Düsseldorf, 1994, pp. 128-170.

/3/ Langenfeld, R., “Werkzeugtechnik beim Mehrkomponentenspritzgießen” (Mold technology in multicomponent injection molding) in “Mehrkomponentenspritzgießtechnik 2000” (Multicomponent injection molding technology), Erlangen, April 2000, pp. 42-64, VDI Verlag, Düsseldorf, 2000.

/4/ Derks, M., “TPE Hart-Weich-Verbindungen” (TPE rigid-flexible joints), Kunststoffe 88 (1998) 7, pp. 962-968.

/5/ Brinkmann, S., “Verbesserte Vorhersage der Verbundfestigkeit von 2-Komponenten-Spritzgießbauteilen”, (Improved prediction of the bonding strength of two-component injection molding), Dissertation, RWTH Aachen, 1996.

/6/ Jaroschek, C., “Spritzgießen von Formteilen aus mehreren Komponenten” (Injection molding of parts made of several components), Dissertation, RWTH Aachen, 1994.

/7/ André, V., “Polymerschmelzen an Grenzflächen – Charakterisierungsmöglichkeiten und offene Fragen” (Polymer melts at boundary surfaces – Methods of characterization and open questions) in “Mehrkomponentenspritzgießtechnik 2000”, Erlangen, April 2000, VDI Verlag, Düsseldorf, 2000, pp. 65-81.

/8/ Wu, S., “Polymer Interface and Adhesion”, Marcel Dekker Inc., New York, 1982.

/9/ Lommatsch, U. “Vorbehandeln mit Plasma bei Atmosphärendruck” [Plasma pre-treatment at atmospheric pressure], MO-Metalloberfläche [Metal Surface] 57 (2003)

/10/ Jaeger, A., “Neues vom Mehrkomponenten-Spritzgießen” (The latest about multicomponent injection molding), Kunststoffe 89 (1999) 9, pp. 85-89.

/11/ Jaeger, A., “Verbinden mehrerer Komponenten beim Spritzgießen” (Joining several components in injection molding), Hanser-Seminar “Dekorative und funktionale Teile im Spritzgießverfahren” (Decorative and functional parts by the injection molding method), Darmstadt, October 1997.

/12/ Jaroschek, C., “Overmolding heute – spritzgegossen und schon montiert” (Overmolding today – ready-assembly by injection molding), Hanser-Seminar “Spritzgussteile mit dekorativen Oberflächen” (Injection-molded parts with decorative surfaces), Wiesbaden, 1998.

/13/ Rothe, J., “Sonderverfahren des Spritzgießens” (Special methods in injection molding), Kunststoffe 87 (1997) 11, pp. 1564-1580.

/14/ Steinbichler, G., “Mehrfarben- und Mehrkomponententechnik” (Multicolor and multicomponent techniques), Kunststoffe 86 (1996) 3, pp. 318-320.

/15/ N.N., “Kernzug oder Drehtisch” (Core puller or turntable), Plastverarbeiter 49 (1998) 7, pp. 70-72.

/16/ Ehrenstein, G.W., “Spritzgießen von PA6/TPU-Verbunden” (Injection molding of PA6/TPU composites, Kunststoffe 86 (1996) 9, pp. 1264-1267.

/17/ Molter, W., Pollmann, M., “Hart und weich nebeneinander” (Rigid and flexible alongside one another), Kunststoffe 85 (1995) 6, pp. 817-820.

/18/ Kunze, H.-J., “Zwischen Elastomer und Thermoplast” (Between elastomer and thermoplastic), Plastverarbeiter 3/2000, pp. 72-75.

Selected Product Literature:

- Ultramid® – Product Brochure
- Ultramid® – Product Range
- Ultradur® – Product Brochure
- Ultradur® – Product Range
- Ultraform® – Product Brochure
- Ultraform® – Product Range
- Ultrason® – Product Brochure
- Ultrason® – Product Range
- Ultramid®, Ultradur® and Ultraform® – Resistance to Chemicals
- Ultrason® – Resistance to chemicals

Note

The data contained in this publication are based on our current knowledge and experience. In view of the many factors that may affect processing and application of our product, these data do not relieve processors from carrying out own investigations and tests; neither do these data imply any guarantee of certain properties, nor the suitability of the product for a specific purpose. Any descriptions, drawings, photographs, data, proportions, weights etc. given herein may change without prior information and do not constitute the agreed contractual quality of the product. It is the responsibility of the recipient of our products to ensure that any proprietary rights and existing laws and legislation are observed. (May 2014)

Please visit our websites:
www.plasticsportal.com (World)
www.plasticsportal.eu (Europe)

Additional information on specific products:
www.plasticsportal.eu/name of product
e. g. www.plasticsportal.eu/ultraform

Request of brochures:
PM/K, F204
Fax: +49 621 60-49497

If you have technical questions on the products, please contact the Ultra-Infopoint:

Ultra Infopoint
+49 621 60-78780
ultraplaste.infopoint@basf.com

PME 1413 TE