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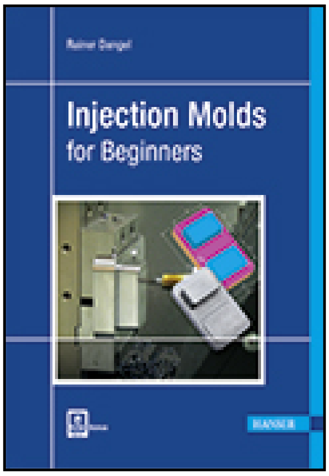

Sample Pages

Rainer Dangel

Injection Moulds for Beginners

Book ISBN: 978-1-56990-631-6

eBook ISBN: 978-1-56990-632-3

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Dangel

Injection Moulds for Beginners

Rainer Dangel

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Hanser Publishers, Munich Hanser Publications, Cincinnati

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Distributed in the Americas by:
Hanser Publications
6915 Valley Avenue, Cincinnati, Ohio 45244-3029, USA
Fax: (513) 527-8801
Phone: (513) 527-8977
www.hanserpublications.com

Distributed in all other countries by:
Carl Hanser Verlag
Postfach 86 04 20, 81631 München, Germany
Fax: +49 (89) 98 48 09
www.hanser-fachbuch.de

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© Carl Hanser Verlag, Munich 2016
Editor: Mark Smith
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Coverconcept: Marc Müller-Bremer, www.rebranding.de, München
Coverdesign: Stephan Rönigk
Typesetting: Kösel Media GmbH, Krugzell
Printed and bound by Hubert & Co GmbH, Göttingen
Printed in Germany

ISBN: 978-1-56990-631-6
E-Book ISBN: 978-1-56990-632-3

Foreword

German die and mould making is a brand with global significance. The reasons for this are diverse, but the industry's secrets to success can certainly be attributed to smart design with a great deal of know-how, top performance production engineering and quality related criteria. One major aim of this book is to disseminate this philosophy to a wider, English-speaking readership.

Rapid implementation of innovations through close information exchange between all parties is planned for the future. Injection moulds today already play a key role in modern production engineering in the manufacturing industry. Visions of the future such as the "smart factory" in the context of injection moulding now offer the chance to raise the energy and resource efficiency of the production process to a new level with intelligent management and network flexibility. But the basis for this is a solid knowledge of the basics of engineering and manufacturing processes in mould making. The above-mentioned topics can only be implemented based on this knowledge and wealth of experience. And this is exactly where this technical book from Rainer Dangel comes in. What is required for bringing a product into shape?

In the book the author didactically as well as technically breaks new ground in the field of technical literature for injection mould making. In a very clear way, he combines theory with practice, always focussing on the following questions: "What is this product relevant for? What needs to be solved technically for which product specifications?" And, regarding the method of the manufacturing implementation: "How and with what can I fulfil the product requirement within the scope of the design and also the manufacturing process?" Through Mr. Dangel's technical expertise which he established and developed over many years, it quickly becomes clear when studying the book that the practical implementation of the described has great significance. Basic knowledge and solutions are holistically considered. Advantages and disadvantages are presented and discussed. The wealth of 35 years of experience, beginning with training as a tool maker to the master craftsman's diploma then to owning a private company flows through this technical book.

"Injection Moulds for Beginners", the title of this book, hits the bull's eye and old hands who think it is no challenge to them might be taught a lesson!

Prof. Dr.-Ing. Thomas Seul

Vice rector for Research and Transfer at the Schmalkalden University of Applied Sciences and President of the Association of German Tool and Mold Makers (VDWF).

Contents

2 Mould Types

2.1 Simple Open/Close Mould

The open/close mould got its name from its easy movement and function when the injection mould for machining of the plastic parts is clamped onto an injection moulding machine. The injection mould or the injection moulding machine opens and closes without any further necessary movement taking place in the injection mould.

The entire motion sequence is called an injection cycle or just cycle. It begins with a closing of the injection mould. When it is closed, a liquid, hot plastic mass is injected into the injection mould under pressure. Now a certain amount of time must pass before the liquid plastic has cooled and solidified and the plastic part in the injection mould reaches a certain stability. The injection mould opens and the finished, still-warm plastic parts are ejected from the injection mould. When all of the movements are finished, the process starts again. For the outside observer, the machine opens and closes again and again.

The direction in which the injection mould or the injection moulding machine opens and closes is called the main demoulding direction. All movements of the injection moulding machine, the injection moulds and the moving parts in the injection mould run in this axial direction. Depending on the component there can be additional demoulding directions. This is described in Section 2.2.

The open/close mould is the simplest of all injection moulds. As a result it is often the cheapest. Already in the planning and designing of plastic parts, efforts are made so that the plastic piece can be produced with this type of injection mould.

Figure 2.1 shows the demoulding direction of a simple open/close mould. Both upper part (fixed half) and lower part (moving half) open and close in an axial direction. The plastic part has been designed for being produced with this specific mould in such a way that when opening the mould on the injection moulding machine it is not damaged or destroyed.

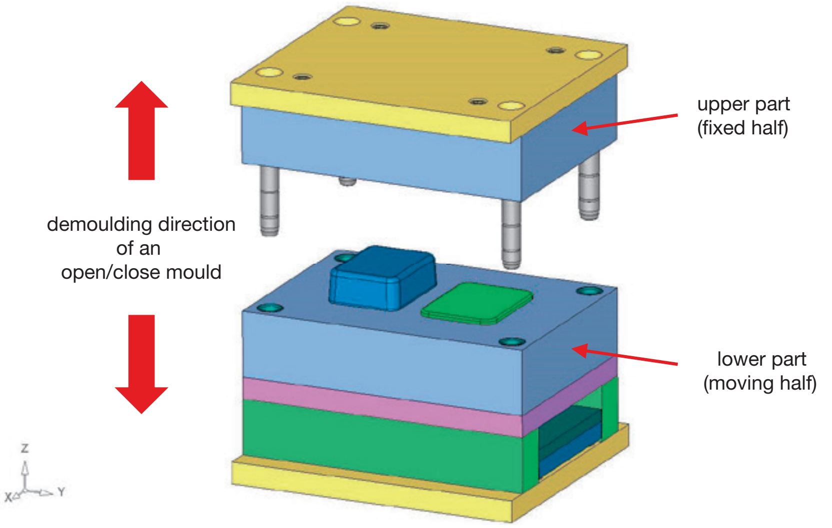


Figure 2.1 Demoulding direction

The plastic parts which are to be produced with such an injection mould have no structural elements which deviate from the main demoulding direction. Cup-shaped or flat parts, for example, are manufactured with this type of mould.

A plastic part can have elements such as side openings, latches and clips, laterally protruding edges or pipes. For the demoulding of these elements, moving components—called slides or inserts—are designed for the mould. In a secondary demoulding direction, these elements called undercuts can be removed from the mould without damage. More on this in Section 2.2.

The previously mentioned "expanding" parts container and cover is shown in Figure 2.2 to illustrate how such plastic parts produced in an open/close mould can look.

Here already is the first addition to container and cover. To connect the two and be able to close the container, a sleeve is introduced in every corner of the container and, aligning to the sleeve, a stepped bore is introduced in the cover. Now you can screw down the cover on the container with four screws.

Both the size of the injection mould as well as the open and close technique do not change despite these additions to the plastic parts. The additional elements are also in the demoulding direction.

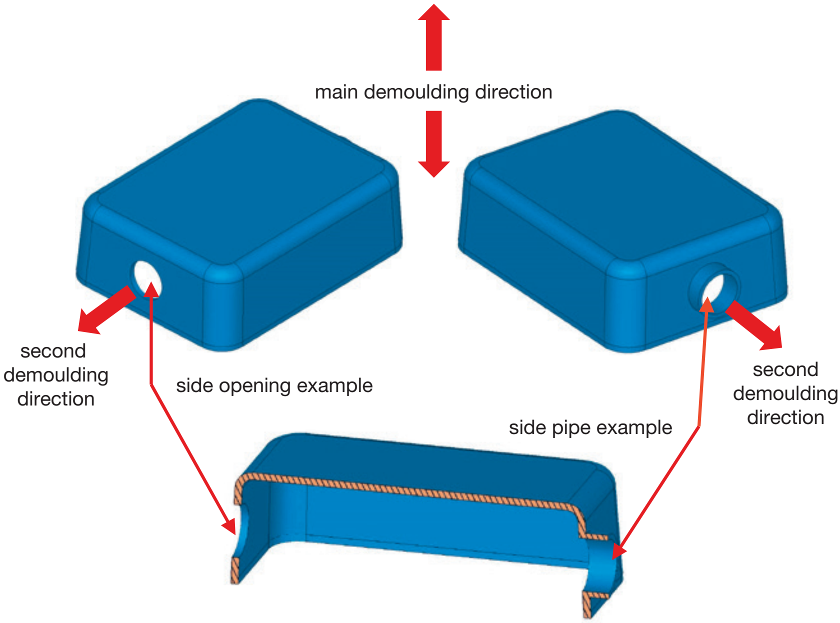


Figure 2.10 Additional demoulding directions

2.2.2 Slide

When implementing these side openings the open/close mould becomes a mould with slides. Slides are moving components inside the injection mould. One or more parts of the mould contour are incorporated into these slides. The slide itself moves away from the plastic part during or after the opening of the mould in an additional demoulding direction. Through this movement the undercuts are released before the plastic part is ejected from the injection mould. The required path is calculated and defined in advance. It must be large enough so that the plastic piece drops out of or can be removed from the injection mould without damage after the ejection.

In Figure 2.11 the slide for demoulding the side opening on our container is shown. In the front area of the slide a part of the mould contour of the plastic part is incorporated. The round surface in front has contact with the fixed insert when the mould is closed and is injected. During injection, this contact prevents that the plastic covers this spot and thus forms the bore holes in the plastic part. In technical language, this contact point is also called an aperture.

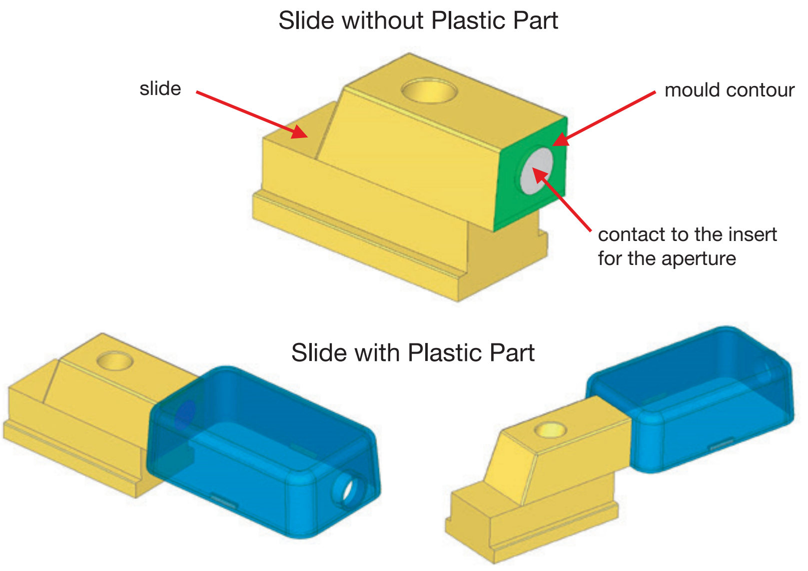


Figure 2.11 Slide with and without plastic part

2.2.3 Slide Operation

To move this slide there are two possibilities. The first possibility is that the slide is connected with a hydraulic cylinder which is in turn screwed tightly to the injection mould. The slide is moved via this cylinder. For this solution the cylinder covers a clearly defined distance. It is bought and installed as a standard part. Find out more in Section 4.2. The second option is the forced control through an inclined pin. The pin is installed with a defined inclination on the fixed half of the injection mould. The front part of the inclined pin submerges in the moving slide. When the mould opens in the main demoulding direction, through the resulting movement this inclined pin moves the slide in an additional demoulding direction. There are additional details in Section 4.2.

Figure 2.12 displays the closed mould on the left and the slightly open mould on the right. On the slightly open mould the inclined pin has moved the slide in an additional demoulding direction to the end position.

In Figure 2.20 the injection mould for the cover with external thread is shown. The slides are open and are force-controlled by means of inclined pins. The overall contour is incorporated in the slide. The distance covered by every slide is half the width of the plastic part plus a few millimetres safety margin. Note also the size of the injection mould in relation to the size of the plastic part.

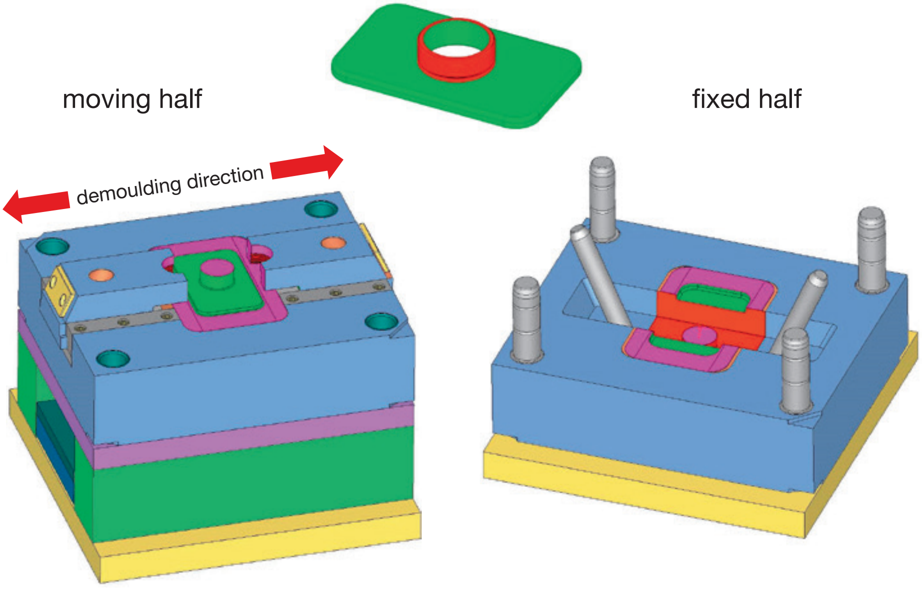


Figure 2.20 Mould for cover with external thread

In Figure 2.21 the slide with all functional surfaces is displayed. Right in the front there is the split line surface in the middle of the injection mould, where both slides and the mould contour—where the thread geometry belongs—meet. In addition, the inclined hole is shown in which the inclined pin for moving the slide is immersed. On the sides the slide guides, in which the slides are embedded and are driven in the demoulding direction, are displayed.

Only exception: the contour of the thread *lies* in the mould and is right in the main demoulding direction. The threaded plug in the top left corner of Figure 2.19 is such a plastic part. It is produced with an open/close mould.

For all types of de-spindling, it must be ensured that the plastic part does not rotate during de-spindling with the turning of the mould core. Often the parts that have an internal thread are round parts. Through serrations on the outer surface or a polygon or small catches on the bottom edge, the twisting can be prevented. This is not a problem for our rectangular cover.

In Figure 2.22 the plastic part is shown with the mould core which is injection moulded with the thread.

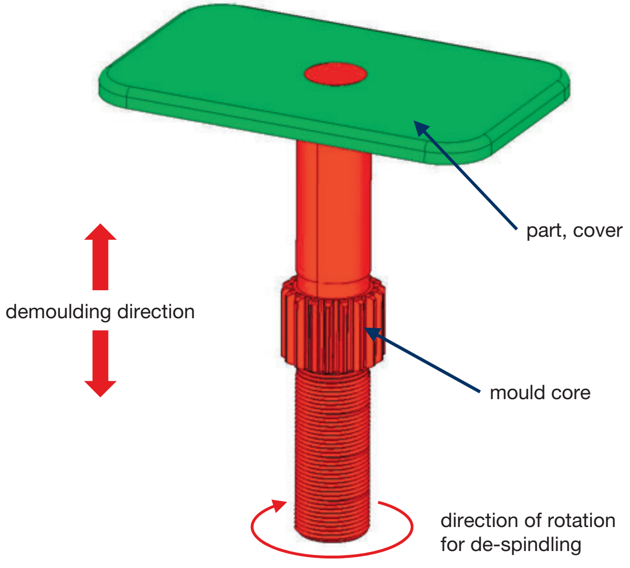


Figure 2.22 Plastic part with mould core

2.3.3 Drive Types for De-spindling

2.3.3.1 Hydraulic Unscrewing Unit

The hydraulic unscrewing unit is an additional device that either is screwed onto the injection mould or to the machine. It is connected to the injection moulding machine and driven and regulated from this. It can either be electrically or hydraulically operated. These unscrewing units are highly flexible in their handling. They can be used for demoulding threads which are on the fixed half or the moving half or on the split line face. The unscrewing unit produces the screwing movement and drives either a small gear or the mould core directly. Unscrewing units can be obtained in different types and options from the manufacturers of standard mould components or manufacturers of injection moulding machines.

injection moulding machine (moving half 2 in Figure 2.35). This hot runner is only the feeder for the plastic. In the middle section the hot runner with the distributor which fills the entire cavity with plastic is located. In the split line between fixed half 2 and the moving half 2 (see Figure 2.35) there is a transfer point for the plastic. Through the opening and closing of the mould this transfer point between the two hot runners is separated and connected again once in every cycle.

In Figure 2.36, a hot runner system has been integrated in the mould. The transfer point can be seen in the split line 2 (see Figure 2.35). The plastic is injected centrally through the machine nozzle.

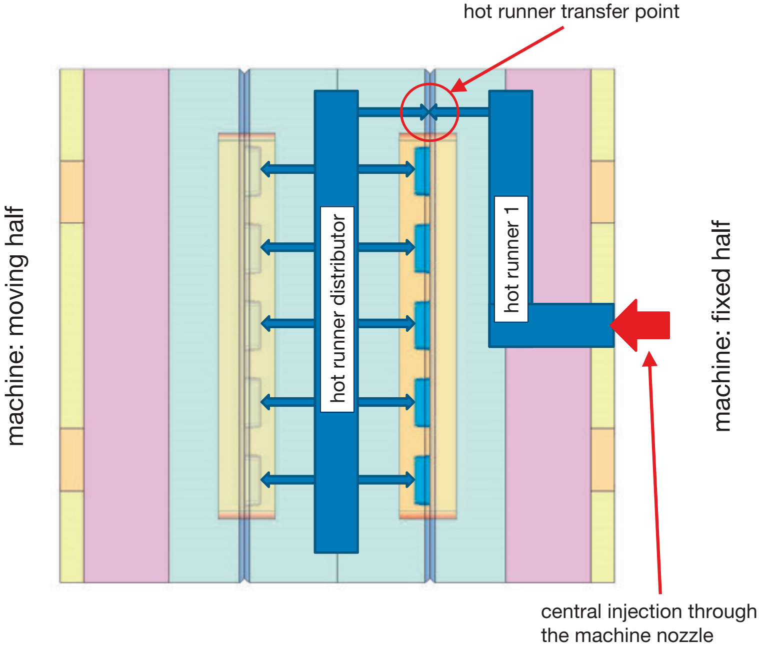


Figure 2.36 Stack mould with hot runner

2.5.3 Opening and Closing

The mould is clamped as usual to the injection moulding machine: with a clamping plate on the left to the moving half machine plate and with a clamping plate on the right on the fixed half machine plate. The central part of the mould is held in the centre by the guiding between the two moving halves. For this special case, in some machines there are sliding guides on the machine base and the central part is supported with a guide shoe.

In Figure 2.37 the injection mould is clamped on the machine. The central part is supported on both sides by the guide shoe.

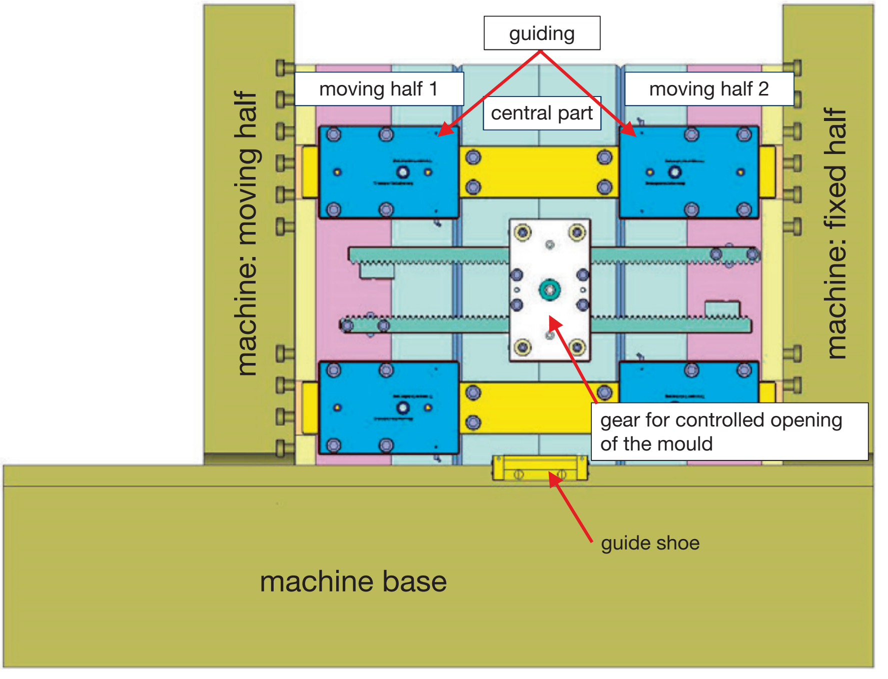


Figure 2.37 Injection mould installed on the machine

When opening and closing, the machine or the injection mould covers a certain distance, in our example 400 mm. The central part is controlled through the gear and travels half the distance, that is, 200 mm, and the opening width is the same for both split lines.

Figure 2.38 illustrates the situation for an open mould. The machine has travelled 400 mm and the opening width of each split line is 200 mm. Therefore there is enough space for the finished plastic pieces to fall from the mould.

For an even better visualisation of this concept, a three-dimensional view of the open injection mould with gear and external guiding is displayed in Figure 2.39.

Examples of an Economic Efficiency Calculation:

Requirements for a plastic part over the entire service life of 100,000 pieces.

- Cost for the 1-cavity mould: $20,000. The price per part produced with the 1-cavity mould is $0.50/piece. 100,000 pieces x $0.50 results in an overall cost for the parts of $50,000. Together with the mould costs, a total of $70,000 is calculated over the entire service life.
- In contrast, the 2-cavity mould costs $30,000 but because two parts instead of one part comes out of each machine in every cycle the price per part is only $0.30/piece. If you sum up the costs for the 2-cavity mould, the overall cost for the parts is $30,000 and the overall cost for the mould is $30,000, which together makes $60,000.

  Result: This calculation shows that with a 2-cavity injection mould, a total of $10,000 can be saved over the entire service life.

In Figure 3.18 two examples of moulds are displayed: the 2-C mould and the stack mould, comparing their complexity and the output quality.

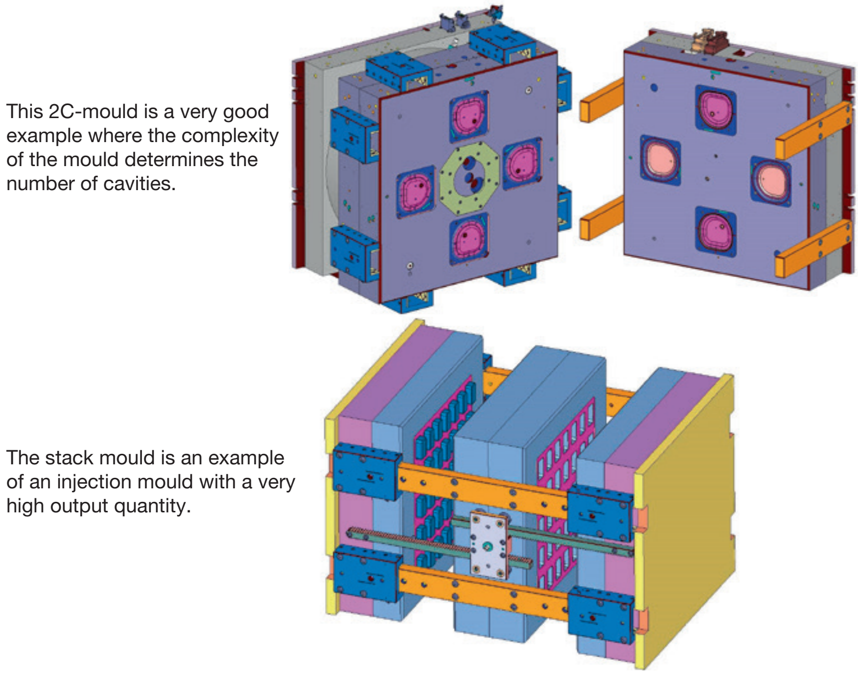


Figure 3.18 2-C mould and stack mould

3.4 Material Selection for Injection Moulds

The selection of the right materials for the construction of an injection mould is defined and influenced by many different conditions and factors.

Output Quantity

One of most important factors is the output quantity over the entire service life of the injection mould. For a sample mould used for injecting only 100 pieces, it can be sufficient to make the mould out of aluminium. For this purpose there is a special aluminium with higher strength for the mould making.

Table 3.2 The following tables contain material specifications for injection moulds. [Source: Meusburger GmbH, Wolfurt]

3.3547 (AW-5083)	DIN: AlMg 4.5 Mn EN: ISO 5083 AFNOR: A-G4.5MC UNI: 7790	Si - 0.40 Fe - 0.40 Cu - 0.10 Mn - 0.70 Mg - 4.40 Cr - 0.15 Zn - 0.25 Ti - 0.15	≤ 290 N/mm² (depending on thickness)	**Aluminium alloy**	Plates for mould bases and jigs
3.4365 (AW-7075)	DIN: AlZnMgCu 1.5 EN: ISO 7075 AFNOR: A-Z5GU UNI: 9007/2	Si - 0.40 Fe - 0.50 Cu - 1.60 Mn - 0.30 Mg - 2.40 Cr - 0.23 Zn - 5.60 Ti - 0.20	≤ 540 N/mm² (depending on thickness)	**Aluminium zinc alloy** high-strength, hardened	Plates for mould tools and dies with increased requirements on strength

If the mould is designed for an average quantity of for example 100,000 pieces, a better quality of material is required. For example, the mould frame is made from pre-toughened tool steel 1.2312.

1.2312	DIN: 40 CrMnMoS 86 AFNOR: 40 CMD 8.S AISI: P20+S	C - 0.40 Si - 0.40 Mn - 1.50 Cr - 1.90 Mo - 0.20 S - 0.06	≈ 1080 N/mm²	**Tool steel** alloyed and pre-toughened, good cutting properties	Plates for mould tools and dies with increased requirements on strength

The inserts and slides can be made out of hot-work steel 1.2343.

1.2343	DIN: X 38 CrMoV 51 AFNOR: Z 38 CDV 5 UNI: X 37 CrMoV 51 KU AISI: H11	C - 0.38 Si - 1.00 Mn - 0.40 Cr - 5.30 Mo - 1.20 V - 0.40	≈ 780 N/mm²	**Hot-work steel** high-alloy	Moulding plates and inserts for plastic injection mould tools
1.2343 ESU (ESR)	DIN: X 38 CrMoV 51 AFNOR: Z 38 CDV 5 UNI: X 37 CrMoV 51 KU AISI: H11 ESR	C - 0.38 Si - 1.00 Mn - 0.40 Cr - 5.30 Mo - 1.20 V - 0.40	≈ 780 N/mm²	**Hot-work steel** suitable for mirror polishing, electro-slag remelted, high-alloy	Moulding plates and inserts for die casting (Al, Mg, Zn etc.) and plastic injection mould tools

If the quantities are in the millions, all of the plates and inserts are made of a through-hardening material, e. g. 1.2767 for the cavity plates.

1.2767	DIN: 45 NiCrMo 16 AFNOR: 45 NCD 16 UNI: 40 NiCrMoV 16 KU AISI: ≈ 6F7	C - 0.45 Si - 0.25 Mn - 0.40 Cr - 1.35 Mo - 0.25 Ni - 4.00	≈ 830 N/mm²	**Steel for through hardening** special alloy suitable for polishing, with high resistance to pressure and good flexural strength	High-performance cavity plates and inserts; cutting and bending inserts for high compressive loads

Surface

The quality of surface on the draft angle is also of high importance. No matter which machining method the surface was produced by, under a microscope they all look like a mountainous landscape.

Milling: Very often the milling direction is 90° offset to the demoulding direction. This results in a stair-like milled profile over the entire surface and causes the formation of burrs resembling barbed hooks. The demoulding becomes more difficult. Such milled surfaces must be re-treated. The most common post treatment is the polishing of the surface. In doing so it is polished in the demoulding direction.

In Figure 3.34 the insert for our mould "container with cover" is milled.

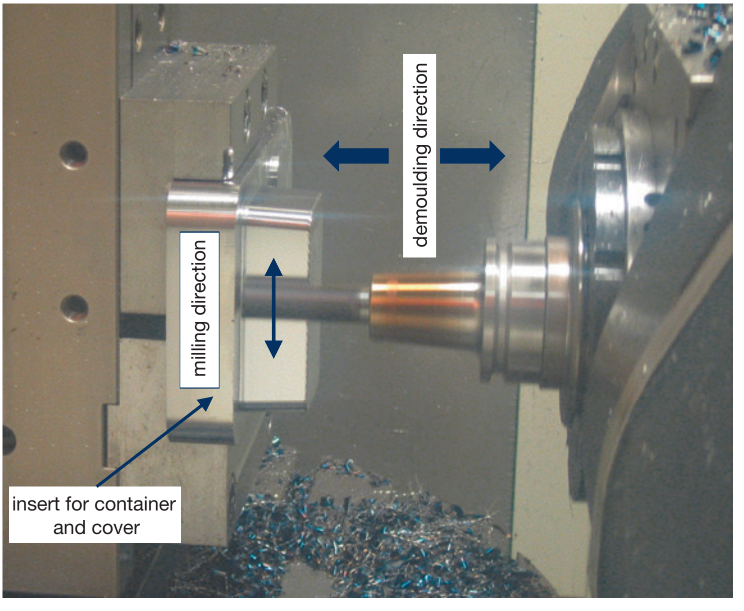


Figure 3.34 Milling insert [Factory picture: Gebr. Heller Maschinenfabrik GmbH, Nürtingen]

EDM: Surfaces produced by EDM—which is used, for example, to make ribs—are uniform but rough. Depending on the settings of the EDM machine the surface becomes more or less rough. The rougher the surface, the harder the demoulding. Like the milled surface, an EDMed surface must also be re-treated. Polishing also helps here.

Wrong Side

If the orientation and the position of the component were incorrectly assessed, it is possible that the plastic part sticks to the fixed half. Or the already described vacuum is stronger than expected. There are many reasons why the part sticks to the *wrong side.*

In Figure 3.68 the different filling of both cavities can be seen. The cover fills up sooner than the container. The flow line is shifted further inside the container.

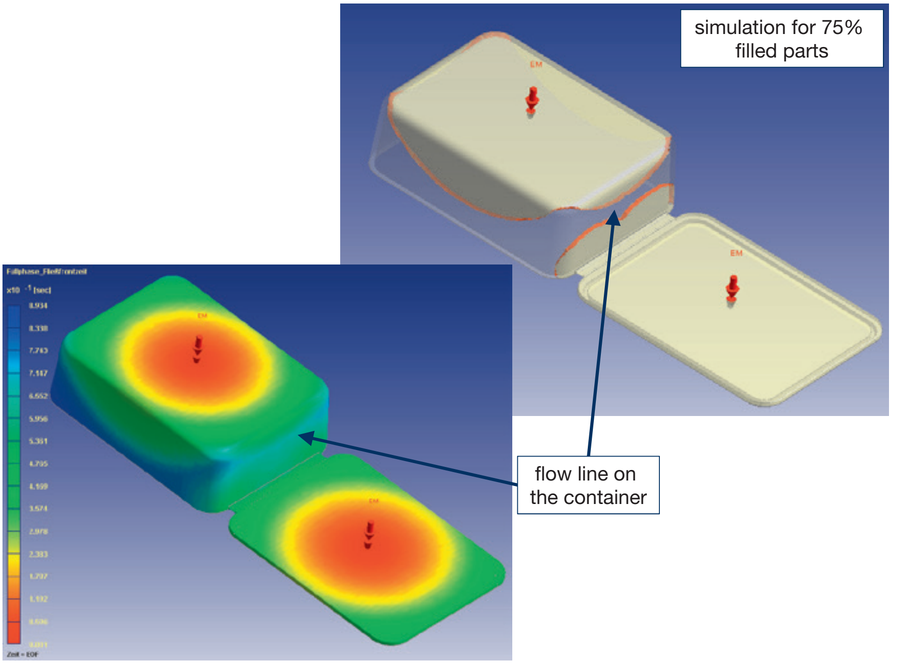


Figure 3.68 Filling with delay [Simulation: Cimatron GmbH, Ettlingen]

Another very important option results from the time delay control of the needles for very long and thin plastic parts. If these parts are injected uniformly with a hot runner distributor system with for example six open nozzles, five flow lines result. If the same part is filled with needle valve nozzles it could look like this: The first nozzle opens and fills the first portion of the cavity. If the melt front is over the second nozzle, it opens and injects into the flowing melt. This continues until the part is completely filled. The exact procedure must be determined through a filling analysis on the machine. Flow lines are avoided or minimised.

In Figure 3.69 the design of a hot runner system with needle valve nozzles is pictured.

In Figure 3.70 the elements of a hot runner system with needle valve nozzles is pictured. The heating is not additionally described here; it is analogous to the manifold in Figure 3.66.

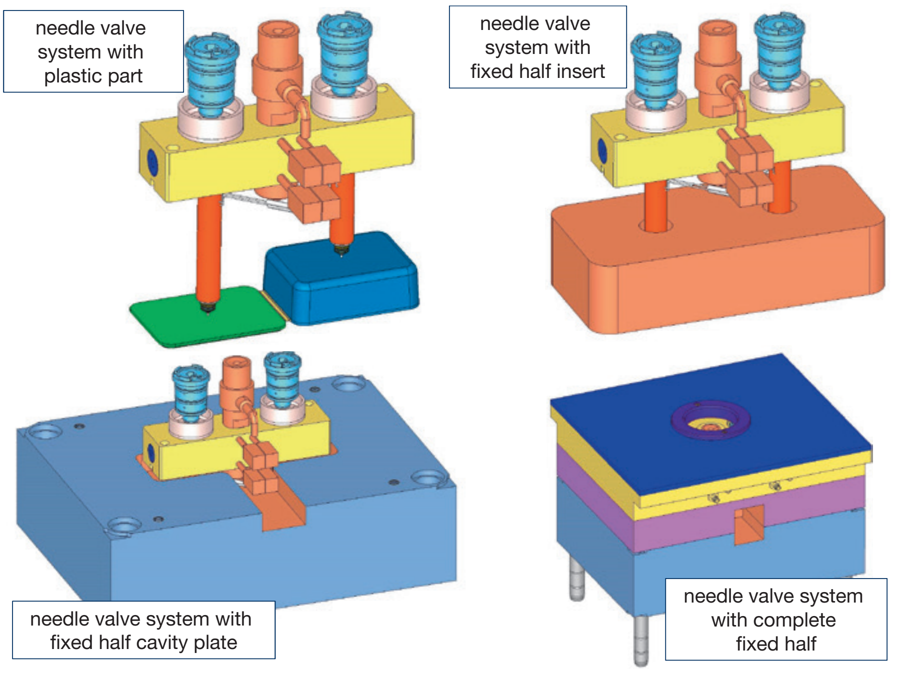


Figure 3.69 Design of a mould with needle valve system
[Source: CAD-Data, PSG Plastic Service GmbH, Mannheim]

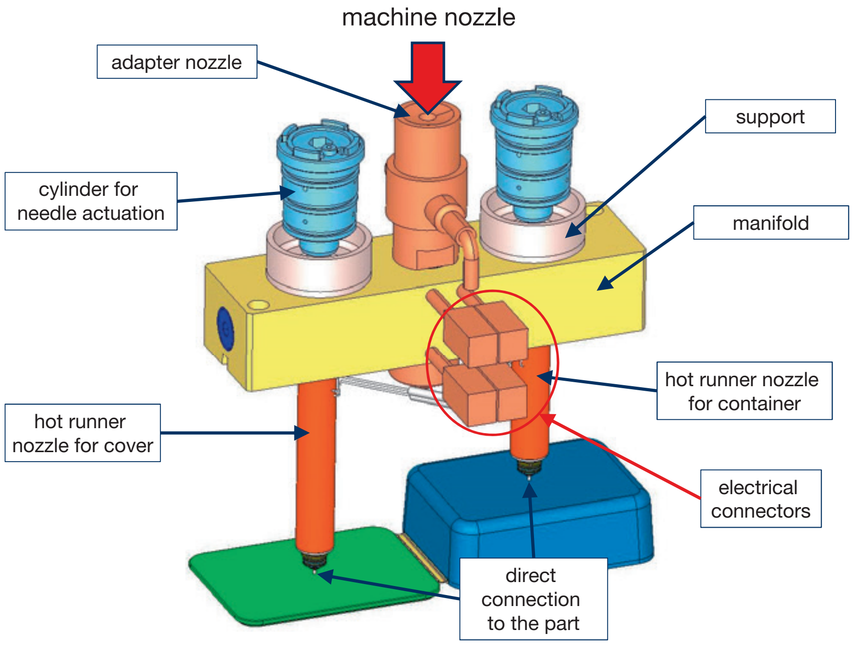


Figure 3.70 The elements of a hot runner system with needle valves
[Source: CAD-Data, PSG Plastic Service GmbH, Mannheim]

4.2.2.2 Split Line on Slide

If the mould contour is on the slide then the split line is circumferential to the mould contour. The split line must be tight but also serve as ventilation.

For the split line on the slide the same rules as for the general split lines in Section 3.8 apply.

There is an additional decisive factor for the slide. The slide or the split line of the slide moves forward and backward in the guiding. The problem there is the level split line at the bottom. With every movement the slide touches the level split line face. Because of the distance it must cover it can be that it moves beyond the edge of the moving half insert. During retraction in the mould the slide runs over the outer edge of the insert with the front edge of the split line. Over time this edge on the slide is damaged and a burr forms.

To avoid this, at this split line there should be a small ramp similar to the draft angle on the side of the slide.

> A split line on the slide should always be designed so that at the last moment of closing the injection mould it has contact with the opposite side.
> During opening it is reversed: it should be immediately free. Split lines that slip along the opposite side will not last very long.

In Figure 4.12 two slides from our container are displayed. On the big slide a circumferential split line is drawn. The inclined ramps are seen at the bottom of both slides.

In Figure 4.13 the real situation is shown on the injection mould. The lead-in chamfer is shown on the slide and in the insert. The slide has first contact with the insert when the injection mould is totally closed.

The same applies for slides which are installed on the lower half of the mould split line. Such a slide, in addition to the inclined ramp below (see Figure 4.12), also needs a lateral ramp or lead-in chamfer. Through this lateral lead-in chamfer the split line between the slide and the insert is sealed. Because of the inclined split line, the slide has first contact with the insert just before the slide is in the first end position. On our container with cover from the integral hinge section there is now a lateral catch which must be demoulded below the main split line. The catch is an undercut and therefore needs a slide.

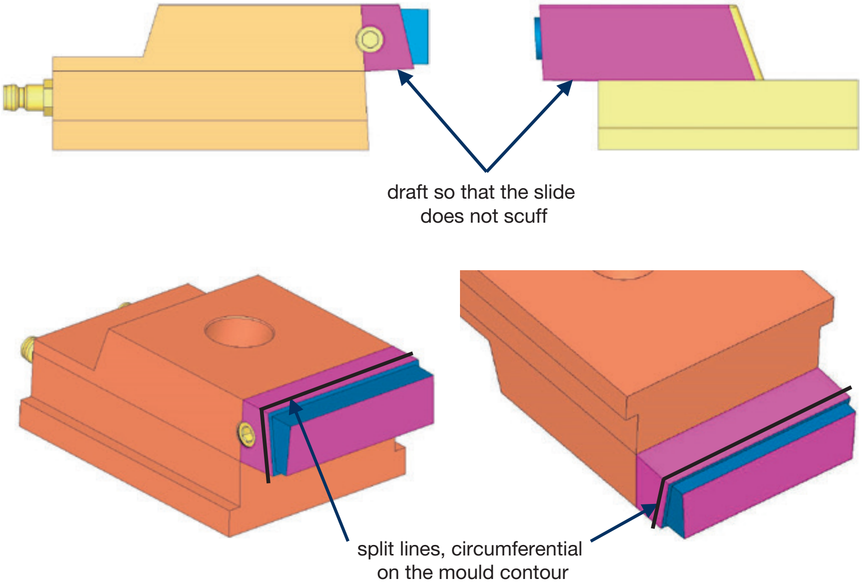


Figure 4.12 Slides with split lines and ramps

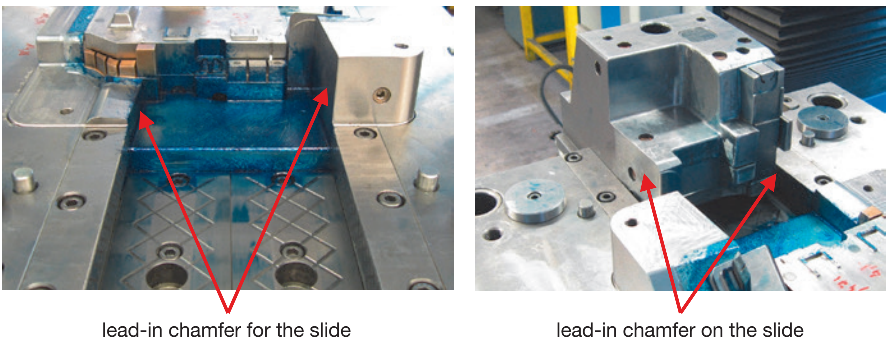


Figure 4.13 Slide and insert with lead-in chamfer [Factory picture: Formenbau Rapp, Löchgau]

In Figure 4.14 the lateral ramp and the ramp below are shown. Also for this slide it is important that the contact between the slide and the insert takes place at the very last moment.

4.6.3 Graining

A treatment proven for decades to generate a structured surface on plastic parts is graining, or texturing, by etching. With this procedure a variety of surfaces can be produced, such as leather appearance, textile appearance, geometrical structures or also EDM structure.

For graining by etching, the inserts or cavity plates with mould contours are covered on all points which should not be textured with an acid resistant adhesive. The desired texture is inserted as a foil in the mould contour and covers the rest of the parts. The acid etches the clear areas. The textured surface is cleaned and sandblasted. The foils are inserted again etching and sand blasting is repeated. The procedure is repeated several times until the final structure is achieved. The covered positions are freed again and the mould is finished. What is here relatively simply described is actually a complicated and elaborate process which demands time.

Since these structures are very deep the rules for the draft angle must be noted.

In Figure 4.63 a leathery texture and a grained EDM texture, which is generally known, are shown.

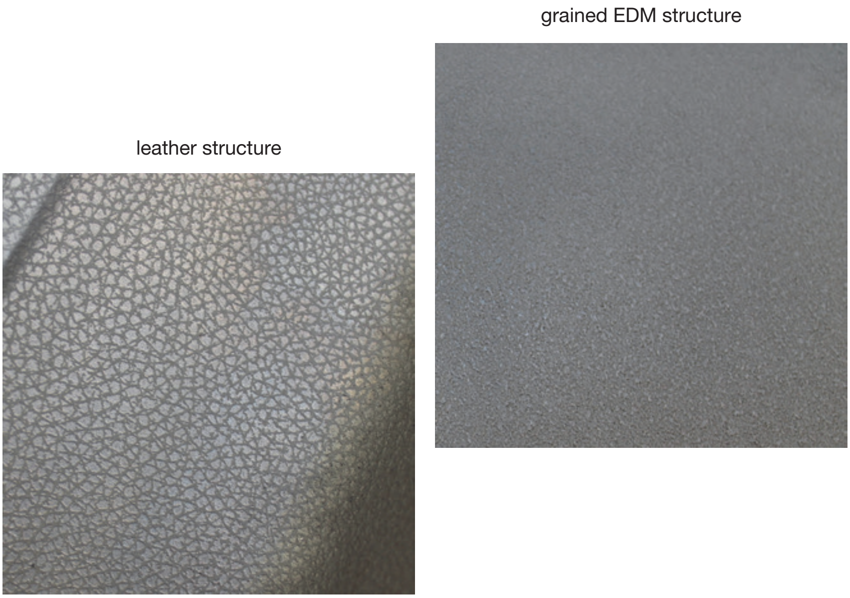


Figure 4.63 Different grained textures [Source: Reichle GmbH, Bissingen-Teck]

Example: Surface

Another example is the surface of the plastic part. As described in Section 4.6, the type of surface must be clarified with the customer at the beginning of the work.

Depending on the surface the preliminary work must be adjusted accordingly. If the surface is EDMed later, not too much effort and time are required in finish-milling.

If the surface is mirror polished subsequently, the EDMed surface is not a good working surface. Through EDM the microstructure on the surface is changed. During high gloss polishing this EDM scale must be completely removed or otherwise no shiny surface can be produced.

If in the planning for the construction of an injection mould the entire process chain is kept in mind and all steps are planned and communicated at the beginning of the project, then mistakes are minimised considerably. It is better to invest in precise planning at the beginning than to pay for costly rework or corrections later. In Figure 6.1 the process chain in mould making is graphically displayed. There are processes that depend directly on each other but there are also processes that are independent. In any case it is important to know the steps and how they are related to each other.

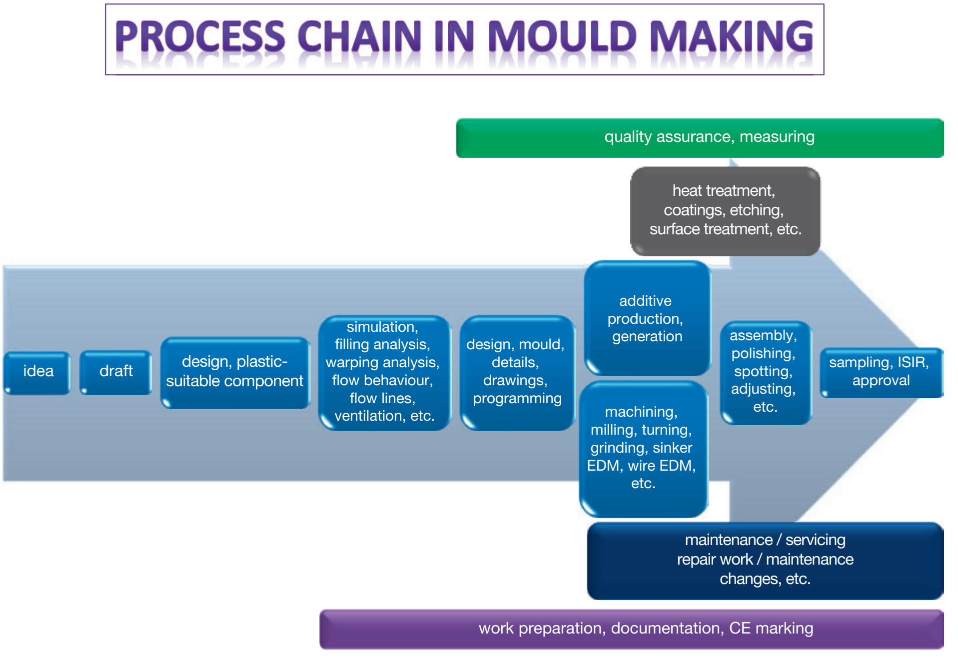


Figure 6.1 Process chain in mould making

6.2 Quality Assurance

Quality assurance (QA) is more than, for example, checking the quality of an insert or measuring its width. Although this is also a part of quality assurance it is just a small part.

Mission Statement, Vision

Every company should define a mission statement or vision. These are goals the company wants to reach in an agreed time period, usually a calendar year. These goals are different depending on the company. For example, a 5 % increase of turnover or the reduction of error rate to 0.5 %, increasing the spindle hours in the milling department by 10 %, acquiring new or specific customers, or being active in a new industry, etc.

Achieving these goals must not be left to chance.

Example: Reducing the Error Rate

Let's look at the example of reducing the error rate. Errors always involve time and money. It's not about looking for someone to blame. Possibly a process was defined falsely and could not be processed differently. If an error occurs, different mechanisms must be set in motion. What happened, why did it happen, and what can we do to assure it does not happen again?

- What happened? The ejector is too short.
- Why did it happen? The measurement carried out with the calliper was incorrect.
- What can we do to ensure that it does not happen again? Introduce an audit for measuring equipment or change the testing cycle of the measuring equipment.
- Of course the ejector must be remade but this is only a logical consequence.

What is described above must be an automatic process in which the hours, the value, and the costs incurred are determined. If the goal is the reduction of the error rate then the basis for the reduction must be known.

Description of Recurring Processes

In mould making, recurring processes and tasks are frequent. To maintain control of a company, it is necessary that the processes or tasks are described. This of course only applies for essential processes. It does not include, for example, how to find the way to the cabinet where the ejectors are kept. A sensible description of a process can for example say: each ejector has to be measured. At the beginning of the work, the measuring equipment must be checked with a gauge or calliper and the result recorded. The ejectors must be labelled; the measured dimensions must be off the list or written down.

The effort for following the process described is not much more than if this work would be excursively done. Even without process, a list of ejectors is needed, the measuring equipment must be available, and the ejectors must be labelled according to their length.

Assured Quality

If such processes are complied to then quality is ensured over a long period. Quality should never be left to chance.

A very important aspect of quality assurance is that every employee should follow the same process. Thus the quality is consistent and secured for the entire company.

The quality assurance is a live system. Its effectiveness must be constantly reviewed and checked. Insufficient processes must be expanded and too strict guidelines relaxed. Changes of the tasks, the environment, the techniques and so one must be adapted to the changing descriptions and conditions.

Consistent Quality Assurance

The list of the defining processes and procedures can be continued indefinitely at this point. Starting from the offer of the customer's ordering process, the process planning, the definition of the individual process steps from the procurement and the production to the dispatch of the product, it is important that the systematic quality assurance is understood.

Often the quality assurance is regarded negatively by a company as an additional cost factor. Of course this approach is wrong. By implementing consistent quality assurance and defining procedures and processes, mistakes are avoided, procedures are improved and simplified, and much becomes more transparent and clearer. The costs saved with the right quality assurance are higher than the costs incurred by it.

A company's success must never be left to chance!

Standards:

Different industries require different standards.

- The standard VDA 6.1 is applied in the German automotive industry.
- Suppliers who supply parts to the automotive industry, parts for driving vehicles must meet the standards of the ISO/TS 16949.
- The general standard which applies to mould making is the EN ISO 9001:2008.
- A guiding principle which must be valid everywhere is:

  Quality is when the customer comes back and not the injection mould.

6.3 Fits and Play in the Mould: What Must Fit?

The design of an injection mould is precision work. Precision in mould making not only means accurate adherence to tolerances, but also coordination of components, which must fit among themselves. In mould making there are press fits, loose fits, fits which must run smoothly and free of play, or fits where the parts are assembled with a very light hammer strike. The scope includes everything that belongs to the theme precision. The measurable difference between something installed free of play which can be moved manually or something that was built in with light hammer strikes is minimal. The difference between them is only a few µm. Hereinafter, the components and their fits or accuracy of fit are described.

Guiding in the Plates

Guide bolts and guide bushes are assembled in the plate with light hammer strikes. It is also not a problem if they are pushed into the holes by hand. However the bush or the bolt must not be installed with hard hammer strikes. It is important that oil is used during every installation. If the bush or the bolt is jammed, the guiding is defective. If the bush is installed too tight in the guide, it could be compressed and then the bolt would not move any more in the guide bush.

Inclined pins can also be installed with a light hammer strike or by hand. They may not wobble or have play. Inclined pins must also absorb radial forces. If they have play, the hole becomes bigger over time and there is always more play, until the inclined pin breaks.

In Figure 6.2 the bushes, bolts, and inclined pins in the cavity plates are shown.

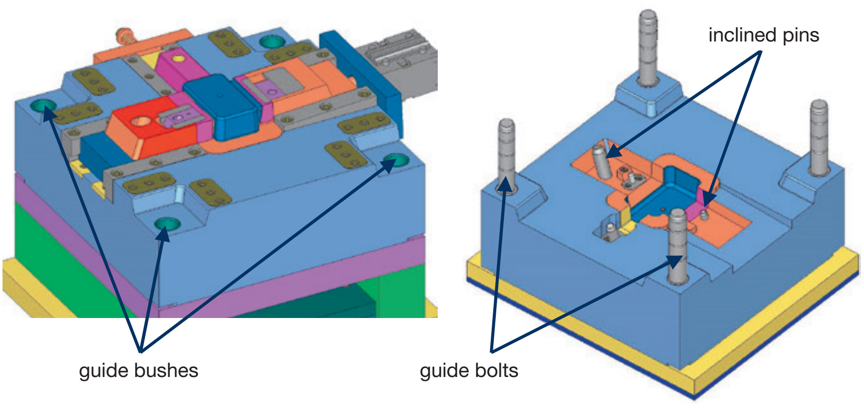


Figure 6.2 Guide bushes, guide bolts, and inclined pins

Inserts in Cavity Plates

The bigger the insert the more difficult it is to install in the cavity plate. The difference in the fit should not be larger than 0.02 mm. The insert should be mounted with very light strikes. The surfaces of the insert must be lubricated with oil so that the insert cannot fret during installation.

If the inserts are larger or the accuracy of fit must be < 0.02 mm, tapered alignment strips are recommended. The designer must decide what is better here. The possibilities for how an insert can be installed in-house also play a role. If a crane is available, by which the insert can be inserted evenly in the pocket, it is still possible for large inserts. For an installation by hand the limits are significantly lower.

In Figure 6.3 on the left an insert with tapered alignment strips on two sides is displayed. Through these alignment strips it is ensured that the insert is always installed at the same position. The injection mould has a length of 800 mm. On the right, an even insert which is inserted in the plate with the help of a crane is displayed. The play between cavity plate and insert is 0.02 mm. Note: the injection mould is 1000 mm long.

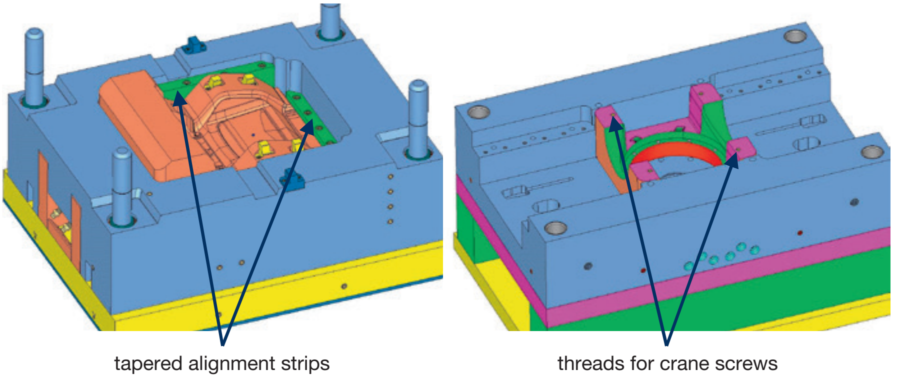


Figure 6.3 Installed matching inserts

Slide in Guiding

Slides must run smoothly. As already described in Section 4.2, the guiding of the slide is separated from the mould contour. It is also due to the play and the fact that the slide must run smoothly that the slide should have a conical ramp in the area of the split line face. The slide may have play in its guiding. Depending on the size of the slide, 0.02 to 0.05 mm is allowed. Only when the mould closes and the slide is in its end position, the slide must fit without play.

A very important aspect is the cooling of the mould. If the slide has too little play and the mould is operated at high temperatures, the slide may get jammed due to the different thermal expansion of slide and cavity plate.

A fundamental solution for temperature differences would be that the slide in the guiding has some play laterally and above. Therefore, as discussed in Section 4.2.2.3, an additional guiding rail is used in the middle. As a consequence, the slide can extend in all directions; however, it stays in the right position, and does not get jammed.

For the slides in Figure 6.4 the slide bodies with their guiding are at a certain distance from the mould contour. They may have a light play of 0.02 to 0.03 mm in this area.

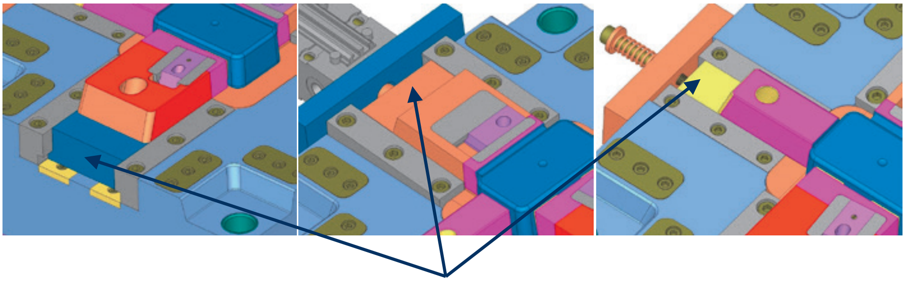


Figure 6.4 Three slide situations, slides must run smoothly

Ejectors

If the ejector has play, a burr forms on the plastic part; this is the brief summary for the ejector. The ejector must also move smoothly, without play or wobbling. The flash which may form when an ejector is used only needs a very thin gap between the insert and the ejector. Between moving smoothly and jamming there is 0.003 mm to 0.005 mm for an ejector.

For an ejector it is also important that the front of the mould contour is sharp edged. Every chamfer or radius forms a flash on the plastic part.

For inclined ejectors which move through the plate or the insert inside a cylindrical hole, the same applies as for the round ejectors. They must move smoothly but without play. The inclined ejectors or contoured ejectors, which are moved over a rod, are conical and are adjusted without play.

The only exception is the push back pin. It has nothing to do with the mould contour, and therefore it can have up to 0.1 mm play.

In Figure 6.5, the round, contoured and inclined ejectors are displayed.

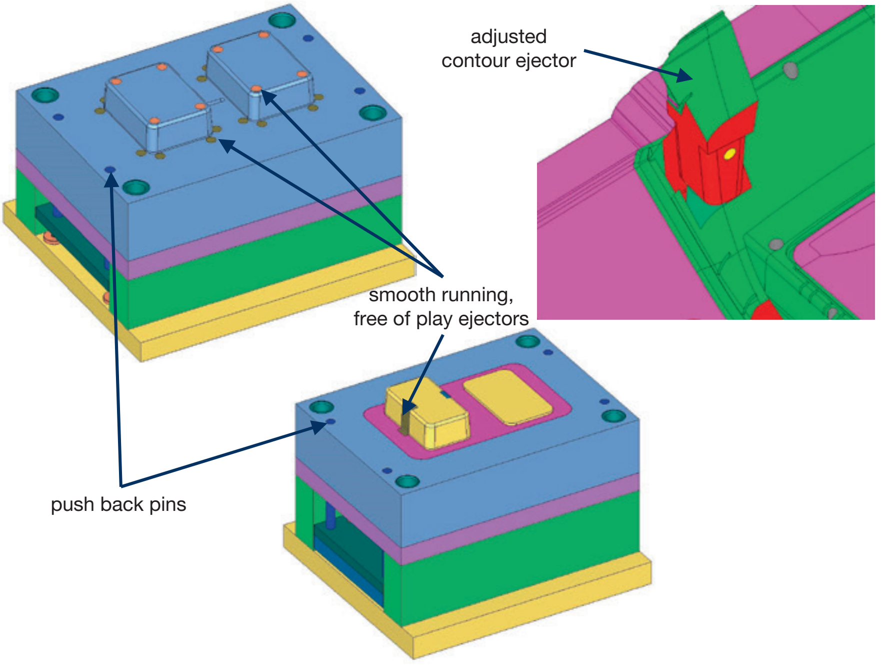


Figure 6.5 Installed ejectors and push back pins

Dowel Pins

Dowel pins are installed when the components or other elements need to be exactly attached or fixed in a position. They are designed by the tolerance as press fits. Dowel pins may be driven into the holes with light hammer blows.

> Before the dowel pin is driven into the hole, it should be clear whether or not it will be dismantled again.

If the dowel pin is mounted in a blind hole, a pin with thread should be used. Or the possibility of being able to introduce a small hole for dismantling the dowel pin from the opposite side should be checked.

In Figure 6.6 a core which is installed in a slide is displayed. A tightly fitting dowel pin can be seen in the core. The dowel pin fixes the core in the slide and thus the core is secured against twisting.

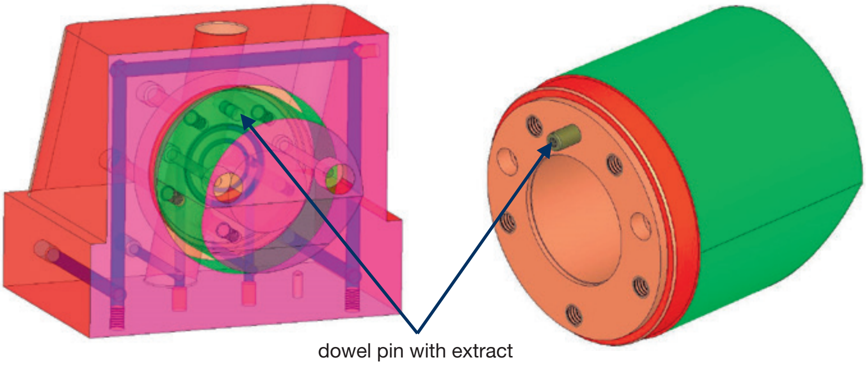


Figure 6.6 Permanently installed dowel pin

■ 6.4 Heat Treatment

In modern mould making, the heat treatment is an important factor for the success or failure of an injection mould. There are always more new mould steels with their corresponding heat treatments. The quality of the moulds, especially their longevity, is driving this trend.

Nowadays hardened steel blocks are available from material manufacturers. The advantage of these is that the heat treatment has already taken place and one can fully rely on the geometry of the component: there is no warping to be considered because of the geometry. The disadvantage is that, due to the hardness, the subsequent machining is more complicated and the hardened steel costs more. It must be carefully considered here what is better or cheaper.

As already discussed in Section 6.1 on the process chain, the heat treatment should be considered from the beginning and ongoing in the planning and process preparation of an injection mould. This already begins during the selection of the appropriate material. The material defines the procedure before, and the procedure defines the material.

Does an insert have to be annealed between one machining step and another because there was an extensive or inhomogeneous machining of the insert or large cavity plate? Are they hardened or nitrided? How is the roughing of an insert done when it is through-hardened, or nitrided? Are there corners, fillets, ribs, etc. considered during the planning? These are questions that need to be considered already during the planning.

Types of Heat Treatment

Heat treatment refers to any method which changes the microstructure or the surface by effect of heat and possible additives. The following addresses the most common heat treatments for mould making. In Figure 6.7 a simplified representation of the time/temperature chart during hardening or annealing is displayed.

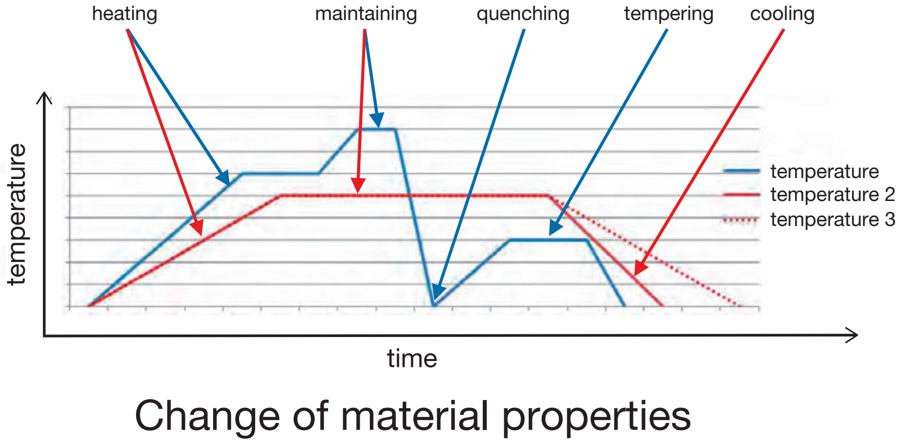


Figure 6.7 Time/temperature chart of heat treatment
[Source: Werz Vakuum-Wärmebehandlung GmbH, Gammertingen-Harthausen]

6.4.1 Annealing

The technically simplest method is the annealing: heating, maintaining, cooling. This procedure releases tension, which is caused either by the manufacture of the steel or through the first processing, by changing the microstructure. This method is used mainly for the manufacturing of plates and standard parts. Or, if a large insert has been subject to extensive machining, then through the annealing the tension caused by the machining is released from the workpiece.

However, annealing is also used for further applications.

- Normalising: irregularities in the microstructure are eliminated (normalised).
- Soft annealing: the microstructure is transformed to achieve a better machinability of the material.
- Solution annealing: improves the corrosion resistance in stainless steel.
- Stress-relieving heat treatment: as already described to release tension in the workpiece.

The temperatures for the individual procedures range from 550 °C to over 1000 °C.

6.4.2 Hardening

An already old-established method for the hardening of components is *carburising* or *case-hardening*. The surface layer of steel with little carbon content is hardened by this method. In the past, components would be placed in a box with a special coal. The box with the mould components went into the hardening furnace and was heated. The carbon transferred from the coal to the component and thus hardened the outer surface layer. In modern hardening furnaces carbon in the gaseous state is conducted into the combustion chamber of the furnace during the hardening process. In the furnace the entire process of the carburising, quenching, and tempering can be processed in one run. The carburised outer layers have a thickness of 0.1 to 4 mm. Steel which is suitable for case-hardening or carburising has a carbon content of 0.1 to 0.3 %.

Steel with more than 0.3 % carbon content is *through hardened.* The through hardening steel is heated under vacuum to a temperature between 800 and 1080 °C depending on the type of material. This temperature is maintained over a defined period depending on material and thickness. Afterwards, it is quenched and tempered several times. Depending, again, on material and tempering temperature, the desired hardness is reached. The through hardening steel is not only hardened on the surface but, like the name suggests, a uniform hardness is reached over the entire component. The hardening under vacuum has several advantages. The two most important are the very low warping and the oxidation-free, bright surface. The vacuum hardening is more environmentally friendly compared to the other methods.

As discussed several times, the heat treatment must be planned. This especially applies to vacuum hardening. If this is not the case, it may cause disastrous hardening errors. The reason is not the false hardening but the false preparation of the workpiece.

In Figure 6.8, the workpieces which during or after the hardening cracked or became deformed and unusable are displayed.

In Figure 6.9 several errors during the preprocessing of the workpiece are displayed. How the workpiece should be properly prepared is also shown.

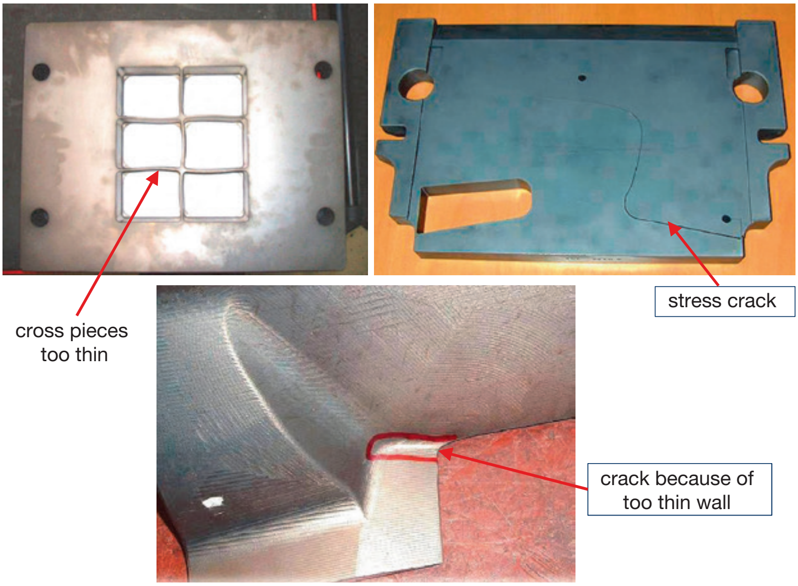


Figure 6.8 Errors during preprocessing before hardening
[Source: Werz Vakuum-Wärmebehandlung GmbH, Gammertingen-Harthausen]

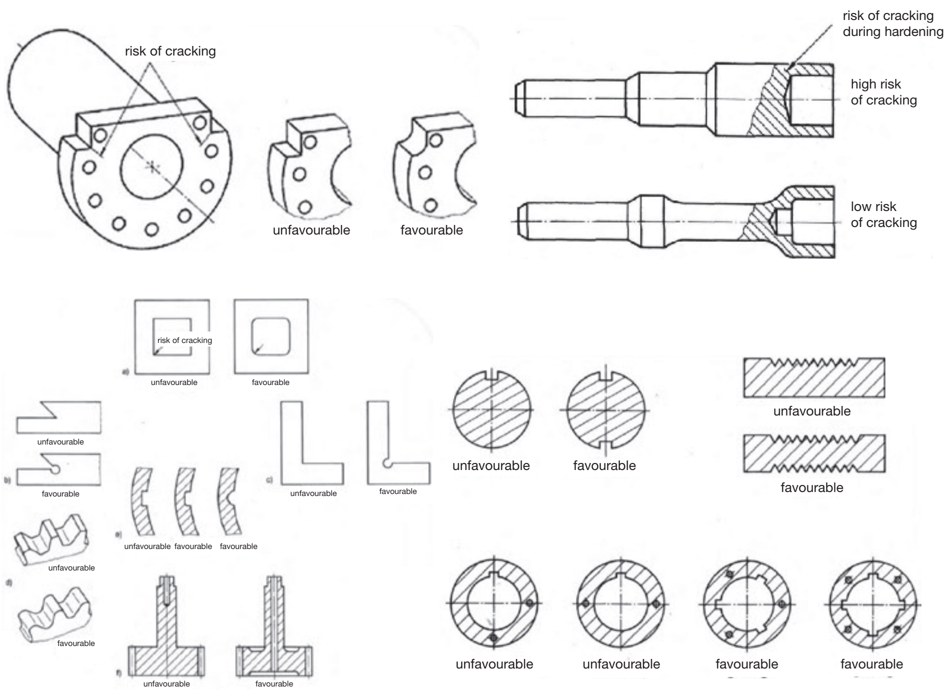


Figure 6.9 Examples of correct and false geometries
[Source: Werz Vakuum-Wärmebehandlung GmbH, Gammertingen-Harthausen]

Steel

Steels suitable for vacuum hardening are:

- high-alloyed tempered and mould steel
- cold-work and hot-work steel
- high-speed steel
- powder metallurgical steel
- corrosion-resistant steel

In Figure 6.10 the specific material grades and the percentage frequency of use for hardening is displayed.

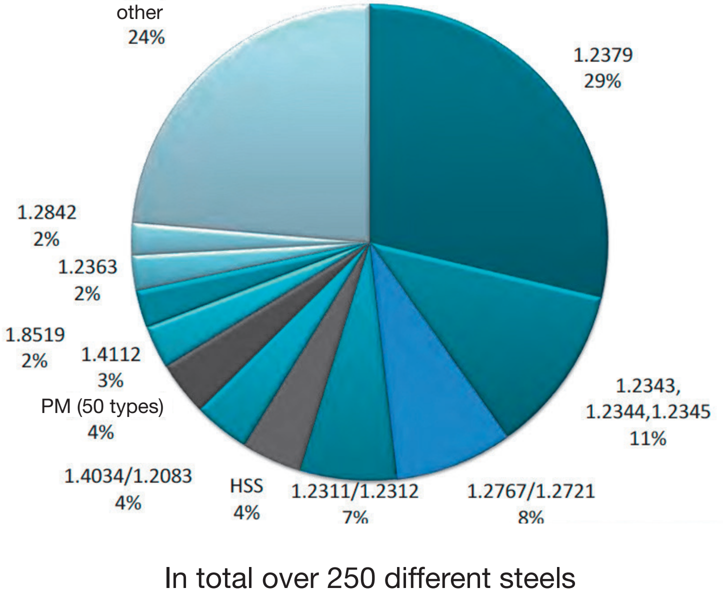


Figure 6.10 Materials for vacuum hardening
[Source: Werz Vakuum-Wärmebehandlung GmbH, Gammertingen-Harthausen]

6.4.3 Nitriding

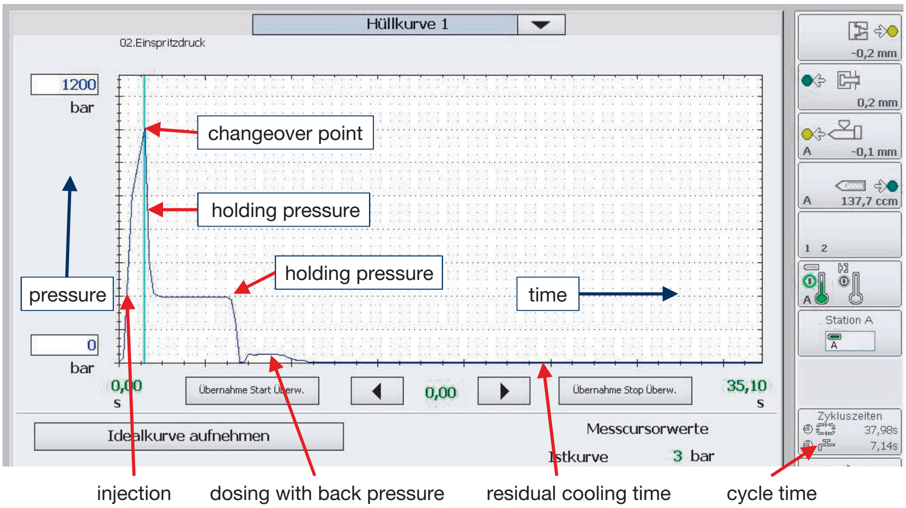
A now common method in mould making is plasma nitriding. During plasma nitriding a nitrogen gas atmosphere is diffused into the surface zone of the workpiece, which is made out of ferrous material. The temperatures during plasma nitriding are at a maximum of 600 °C. Therefore the warping of the workpiece is extremely low. This is also the decisive advantage over the hardening process.

All ferrous materials, including cast iron and sintered material, can be plasma nitrided.

melt cushion remains in the screw. It should be the same after each cycle. This is ensured by the back pressure.

The volume of the screw should be in proportion to the weight of the plastic part; a complete filling of the screw in theory is sufficient for three to five plastic parts. If the volume of the plastic part is so large that the melt in the screw is not sufficient for at least three pieces, the melt cushion is too small, the plasticizing of the granulate is not completed and therefore the injection process is unstable. With too much melt, the material is too long in the hot screw and runs the risk of being thermally damaged. This may cause the plastic to decompose or to form gases.

In Figure 7.6 an entire injection process is displayed in a timeline.



Picture 7.6 Complete cycle in process
[Source: Friedrich Heibel GmbH Formplast, Heuchlingen]

7.1.4 Forces Acting in the Mould during the Injection Process

During an injection process, different, partly extreme pressures and forces act on an injection mould. Already during injection there is the injection pressure and then the holding pressure. For corresponding projected areas the cavity pressure can open a mould, that is, the closing force of the machine is not sufficient, or the mould becomes so deformed that it bends in the centre when the split line is opened.

As already addressed, with high-viscosity plastic this can happen already during injection, that is, even before the holding pressure comes into effect at the change-over point.

Compared with the finished (prefabricated) part, a generated core has still some allowance on it so the finished contour can be produced.

The advantages of laser sintering are:

- Time saving: Only a few hours after the design, the core can actually be held in hand, no matter how complex it is.
- Flexibility: Modifications of the design data and production of variants can be integrated in the original process and quickly implemented after a sampling.
- Quality: With the laser more complex moulds can be generated than with traditional methods. This can improve the quality of the products.
- Productivity: The installation of conformal cooling systems in injection moulds enables the reduction of the production cycle times.
- Cost reduction: As a general rule, laser sintered inserts from original material last longer than conventionally produced inserts. In connection with the aforementioned factors this results in clear cost benefits.

Figure 9.22 displays a core on the laser machine on the left, with some powdery material on the right of the core. The right shows the finished, mirror polished mould core and the produced plastic parts.

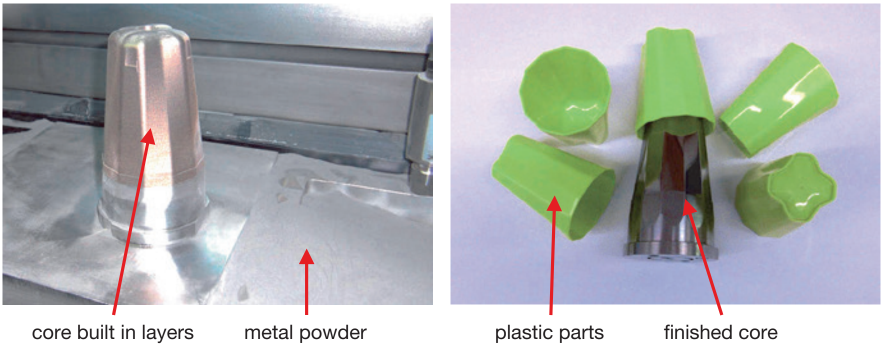


Figure 9.22 Raw material and finished core [Source: bkl-lasertechnik, Rödental]

9.6.2 Vacuum Soldering

Like laser sintering, vacuum soldering belongs to the recent technologies in mould making. The soldering itself is a long-established practice for connecting materials. The trend towards conformal cooling was a motivation for the development of this method.

During vacuum soldering several individual parts are soldered together with a solder. In practice it can look like this: many layers of steel are laid one above the other. A soldering foil or solder paste is placed between two layers. Depending on

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