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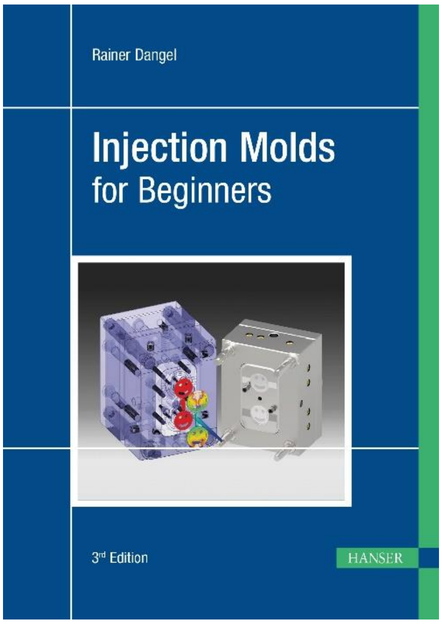

Sample Pages

Injection Molds for Beginners

Rainer Dangel

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Preface to the Third Edition

First of all, I would like to thank my readers warmly. The success of this work has shown that its creation was a valuable exercise. The extensive feedback I have received over the years has been consistently positive. The English edition, like the German edition, was well received and it was a pleasure to see it being sold around the world. Also in China and India, it is used in companies and training institutions. The popularity of the book is also the reason that the book has, since the second edition, been printed in color, and that the third edition appears now.

Of course, I was asked several times how a mold maker came up with the idea to write such a book. How does he find the time and where does the comprehensive knowledge come from?

The motivation to write a book can be manifold. My motivation was to write a small manual for the distribution of machining centers for mold making. The sales department of my employer at the time should understand what mold making is, what it does, which components are to be manufactured and from which materials the individual components are made. At first, I wanted to use existing documents and publications. But I came to realize that there was nothing suitable at this level for beginners or newcomers. Then the only thing left was to create something of my own.

After completing the small manual, they were all gone after a few days. Not only the sales department but also other interested parties tried to get hold of one. So, what could be more obvious than making a large work from this book? Especially since, as already mentioned, there was nothing comparable on the market. At first, time constraints meant that the project ran more and more behind schedule. Then a long, serious illness gave me the time that I then used. Over 2500 hours of work and about 40 tool designs and revisions of designs had to be accomplished. Including all corrections, this project took considerably more than half a year.

In order to make the new, larger book understandable for everyone, the idea came to me to always use the same plastic part as the basic concept. It should be as simple as possible and concentrate on the essentials. This gave me the possibility to build up the level of difficulty of the plastic part stepwise, and to explain the there-by-arising changes simply. That is to say, the central thread throughout the whole book should be uncomplicated and understandable.

About 45 active years in mold making, including more than 23 years as an independent entrepreneur and now as a project manager, consultant, and lecturer, have given me the necessary knowledge and experience. My education as a mold maker began in the summer of 1976. I went through the entire technological change from the hand-operated milling machine to NC technology to today's 5-axis simultaneous machining. The first mold designs were made with India ink on the drawing board, moving on via a simple 2-D CAD program, to the full 3-D CAD system in 1995.

The change over the decades was not only in the technology of the production of the injection molds, but also in the necessary shift from a handicraft business to an industrial company. Today the customers of the mold maker are almost exclusively industrial companies. Certifications, creation of processes, Industry 4.0, environmental protection, and sustainability are keywords that have occupied the mold making industry in recent years.

When I wrote and illustrated the first and second editions, I did not have a simulation program for evaluating plastic parts. The information in the book was therefore based on my experience. Today I have this kind of simulation program and I was able to confirm all the information I had written in the books with real simulations. The theme of simulation is also the main optimization part of this third edition.

I hope you enjoy reading this book and look forward to your feedback.

Rainer Dangel, July 2023

Foreword to the First Edition

German die and mold 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 molds 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 molding 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 mold 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 mold making. In a very clear way, he combines theory with practice, always focusing 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 Molds 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).

The Author

Rainer Dangel began his education as a mold maker from 1976 to 1980. Even as a young, skilled worker, he recognized the possibilities to make a difference in this technically ambitious profession. The foundation of his career was completed with the master craftsman's diploma in mechanics at the age of 23.

His self-employment began in 1987. The initially small CNC milling shop for mold components developed over the course of a few years into a modern, technically high-quality specialist company for the production of injection molds for a wide variety of requirements. The first 3-D CAD CAM system was installed in 1995 and used successfully. All production possibilities of a modern mold making shop were now part of the offer.

Rainer Dangel has made it his task to actively practice and constantly develop and perfect the mold making process. In 2006, the company founded its own plastic injection molding shop in order to expand the process chain to the finished plastic part. With certification according to DIN EN ISO 9001:2008 in 2008, his company was able to serve different industries. Among other things, plastic parts for the automotive industry could be tested and approved according to the VDA (VDA = Association of German Automobile Manufacturers). In the generally economically difficult year 2010, he closed his mold making shop.

Subsequently, Rainer Dangel was for several years the team leader of the Technology Center at Gebr. Heller Maschinenfabrik GmbH in Nürtingen, Germany, and was responsible for customer support in mold and tool making.

Today Rainer Dangel is again active in the field of mold making, as a consultant. He works in two main areas: project management from part development to mold design through tool making to the start of production of plastic parts; and training and special education in mold making in general, and in the machining, milling in particular.

The author's passion is milling; he is proficient in all types of processing up to the programming and milling of 5-axis simultaneous processing.

Acknowledgments

I would like to express a heartfelt thank you to my colleagues at the Association of German Tool and Mold Makers (VDWF) for the support during the development of this book. Special thanks to Prof. Dr.-Ing. Thomas Seul, President of the VDWF, for the foreword.

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Finally, I would like to thank the Translation Management department at Meusburger Georg GmbH & Co. KG, Wolfurt, Austria, for their expert translation of my original German text into English. Achieving a high-quality translation of a specialist technical book is no trivial task, and for this the professional support of Meusburger is most warmly acknowledged.

Contents

1 Introduction

“Where do all these plastic parts actually come from? Who makes them and how are these plastic components even manufactured?” These are questions that hardly anyone asks. “What are those little curls on or in the plastic part, what are they for? Then there is a small spot that looks as if something was cut or torn.” These are all characteristics that are visible on each part and arise in the manufacturing of plastic parts. For this manufacturing technique, besides an injection molding machine and plastic granulates, an injection mold is needed.

Review your day and think about how many plastic parts you held in your hand, and then you can imagine that firstly there is an incredible number of injection molds and secondly the diversity of injection molds there must be in a variety of industries, applications, or life situations.

> For each plastic part which is manufactured there is the corresponding injection mold. There are at least as many injection molds as different plastic parts, worldwide. Nevertheless every injection mold is unique and there is an unimaginable number which increases every day.

Or to put it in a different way, imagine yourself in the kitchen, bathroom, office, or sitting in the car. Now imagine all of the plastic parts gone. What remains? Not much is left that is not made of plastic.

In concrete terms: Let’s start early in the morning. Before even getting up you hit the alarm button. You already have had the first contact with a plastic part. It continues when you brush your teeth. Today’s toothbrushes are, although this is not easily recognizable, manufactured with very complex and complicated injection molds. The conventional toothbrushes with automatically inserted brushes are the simpler version. However, for manufacturing an electrical toothbrush, two different plastics are injected one after another in the injection mold in a very complicated procedure in order to make the rotating brushes in the small brush enclosure.

Hair dryers, coffee machines, tea kettles, refrigerators, stoves, and ovens are just a few consumer goods used in daily life. Opening the door of your car, you again have contact with plastic parts. Without injection molds, the interior of a car is unimaginable. Seats, steering wheel, switches, buttons, handles, levers, blinds, instruments, covering, trays and so on, a countless number of injection molds are used for the manufacturing of a vehicle.

Plastics surround us in the immediate vicinity of our workplace, whether it is in the workshop, in the office or in school. It doesn't matter what you hold in your hand or use, again it's plastic parts. A computer, a keyboard, whether it is on the machine or on the desk. Everywhere there are things made of plastic, in different colors, contours, shapes, and degrees of hardness—from hard and stable printer housings to the soft and flexible protective covers for the mobile phone.

Last but not least, a child's room! Almost all children's toy boxes are full of toys made from plastic: toy blocks, board game figurines, racetracks, puppets, game consoles, etc. Plastic parts, no matter what we do or where we are, accompany us the whole day. Plastic parts are everywhere, and without them a normal life would be inconceivable.

The list goes on and on. Everyone goes through their day, consciously or unconsciously in contact with plastic parts, but no one thinks about their origin, even though there is a huge worldwide industry behind them. Not only are there manufacturers of injection molds all over the world but also large corporations that manufacture the machines for the production of the plastic parts and very large chemical companies that constantly develop and produce new plastics for different applications. Millions of people are at home in this inconspicuous world.

Through the constant development of ever improving high-quality plastics the application possibilities continue to increase. Sheet metal parts made of steel or aluminum are gradually replaced by plastic parts. Brackets made of metal used for fixing cables, fuel lines, containers, or the like in a car's engine compartment are replaced today by high-strength plastic parts.

Further evidence that this development will certainly continue is the progress in the production of bioplastics. To put it simply, for bioplastics, the petroleum used normally as raw material is replaced by biologically derived material. These oils are extracted from renewable raw materials and are also biodegradable. So far there have only been a few applications that were often only explored by scientific facilities. The whole thing is still in the stages of development. However, if only from the sustainability point of view, bioplastic is predicted to have a bright and important future.

The most significant advantage of plastic parts is that after manufacturing or the injection process a ready-to-use piece comes out of the injection molding machine. The manufacturing time for such a component is only a few seconds. This also has an impact on the much lower cost per piece. But now we come back to the contents of this book—the success of this whole process depends on a high-quality injection mold.

2 Mold Types

2.1 Simple Open/Close Mold

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

The entire motion sequence is called an injection cycle or just cycle. It begins with a closing of the injection mold. When it is closed, a liquid, hot plastic mass is injected into the injection mold 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 mold reaches a certain stability. The injection mold opens and the finished, still-warm plastic parts are ejected from the injection mold. When all of the movements are finished, the process starts again. For the outside observer, the machine opens and closes again and again.

> In using the term “liquid plastic”, one is referring to plasticized plastic. Plastic pellets are heated and plasticized, which means they become soft and capable of flowing. In this consistency, the plastic can be injected into the injection mold. Depending on the type and kind of plastic pellets, this vary from being highly viscous to having a water-like viscosity.

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

The open/close mold is the simplest of all injection molds. 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 mold.

Figure 2.1 shows the demolding direction of a simple open/close mold. 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 mold in such a way that when opening the mold on the injection molding machine it is not damaged or destroyed.

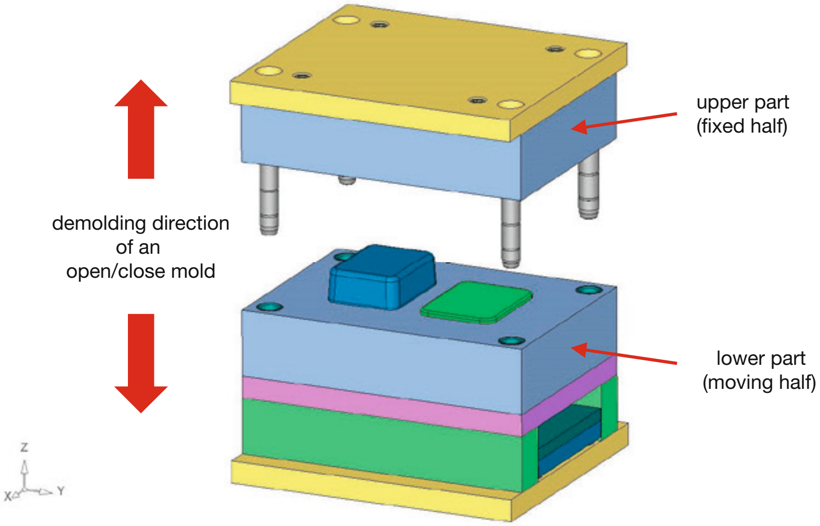

Figure 2.1 Demolding direction

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

A plastic part can have elements such as side openings, latches and clips, laterally protruding edges or pipes. For the demolding of these elements, moving components—called slides or inserts—are designed for the mold. In a secondary demolding direction, these elements called undercuts can be removed from the mold 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 mold can look.

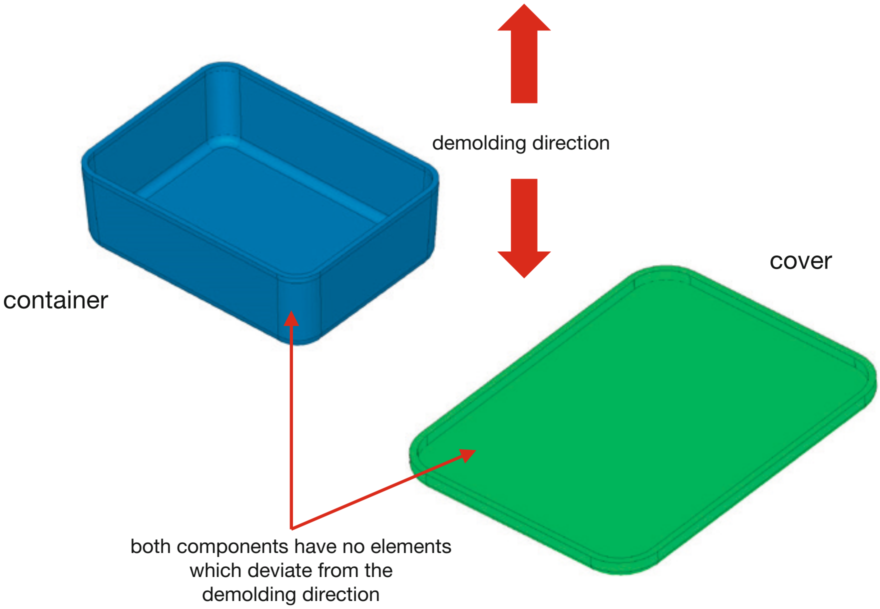

Figure 2.2 Parts for an open/close mold

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 mold 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 demolding direction.

In Figure 2.3, the additional sleeves in the container and the stepped bores in the cover are shown. The demolding direction remains the same.

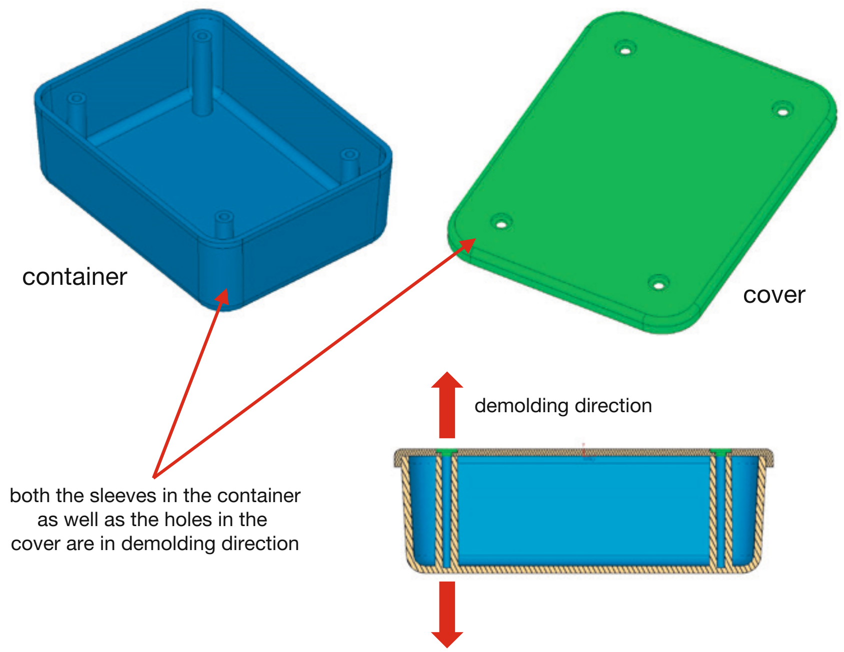

Figure 2.3 Parts for the open/close mold with additional elements

2.1.1 Classic Structure of an Open/Close Mold

The upper part (fixed half) and the lower part (moving half) are made up of several plates and risers. Via the integrated guides, that is, bolts in the fixed half and the bushes in the moving half, the mold closes precisely.

The **fixed half** consists of the clamping plate and the cavity plate. The guide bolts are installed in the cavity plate. The guide bolts are provided at the back end with a collar, which is embedded in the cavity plate. Against the slip out of the guide bolts the clamping plate is screwed tightly with the cavity plate. The cavity plate is fixed to the mold plate via another fitting diameter at the guide bolt.

The **moving half** of a classic open/close mold is made up of the mold plate, possibly a backing plate, the risers and the lower cavity plate. The ejector set is between the risers. The guide bushes are also provided with a collar here and mounted in the cavity plate. They are secured in the moving half through the risers, which are attached, like the fixed half, via the back fitting diameter of the guide bush. The risers are again installed with the clamping plate and with the additional guide sleeves. Everything is screwed tightly together with long screws from the clamping plate through to the mold plate. This guarantees that all components are aligned and tightly connected. Ejectors are the moving parts in the injection mold that eject or expel the plastic part after opening the mold. Ejectors are usually round pins which are installed in the ejector set. The small rings mentioned at the beginning which are usually visible on the plastic part are the imprints of these ejectors.

In Figure 2.4 several longitudinal and cross sections through an injection mold are represented so that the classic structure of an open/close mold can be seen.

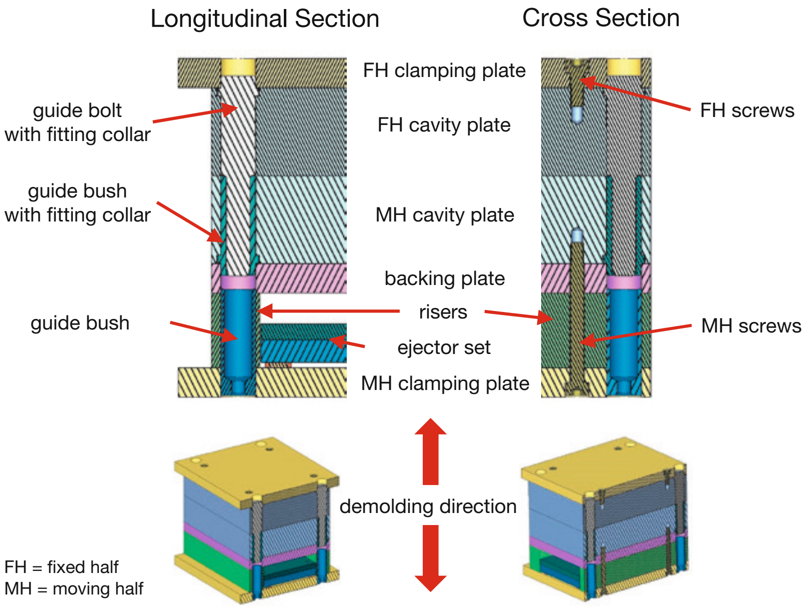

Figure 2.4 Section through a mold structure

> The accuracy of fit in a mold is extremely important. Without precise guiding and fixing of both mold halves they can move radially.

2.1.2 Guiding Elements

The guiding elements in an injection mold are very important. They ensure that both mold halves are already centered while closing against each other. Except in special solutions, guide bolts are built into the fixed half and guide bushes are built into the moving half. The tolerances between the cavity plates and the guide bolts and bushes are so small that they are installed with a light press fit.

The fixed half with the guiding bolts fits exactly, free of play, into the guide bushes of the moving half. Only in this way is it guaranteed that both sides fit together on top of each other precisely and repeatedly. If this were not the case, the mold halves could move radially, which among other things can lead to different wall thicknesses in the plastic parts. This is also called mold offset.

Figure 2.5 shows what can happen when the guiding elements of an injection mold are not exactly aligned.

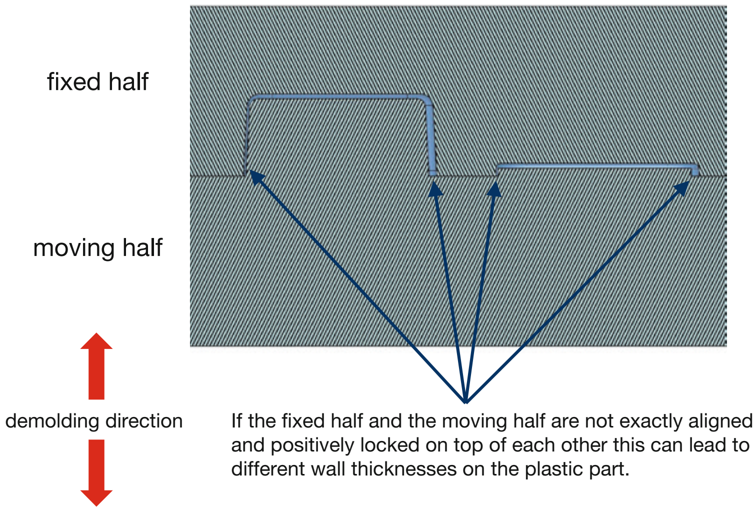

Figure 2.5 Mold offset through insufficient guiding

> Here are a few comparisons to get an idea of how important the accuracy of the guiding is. The tolerances between the bolt and the plate have to be so accurate that some light strikes are required when installing the bolt in the plate. If the bolt is just 0.006 mm too thick, it will be very difficult to install.
>
> The tolerance between the guiding bolt and the guiding bush is even smaller. The difference between free-of-play movement and getting jammed is a maximum of 0.004 mm in diameter.
>
> If the center distance between the guiding elements of the plates in the upper part and the lower part differs by more than 0.02 mm it is difficult for the mold to close.

Anti-rotation Protection

Today nearly all injection molds are rectangular. For this reason normally four guiding elements are installed, one in every corner. To prevent a false (rotated) assembly of the fixed half and the moving half, one of the guides is smaller or bigger than the other three.

In Figure 2.6 the fixed half of a mold is displayed: three guide bolts with diameter (⌀) 18 mm and one guide bolt with ⌀ 20 mm. This should prevent a false (rotated) assembly of the fixed half on the moving half.

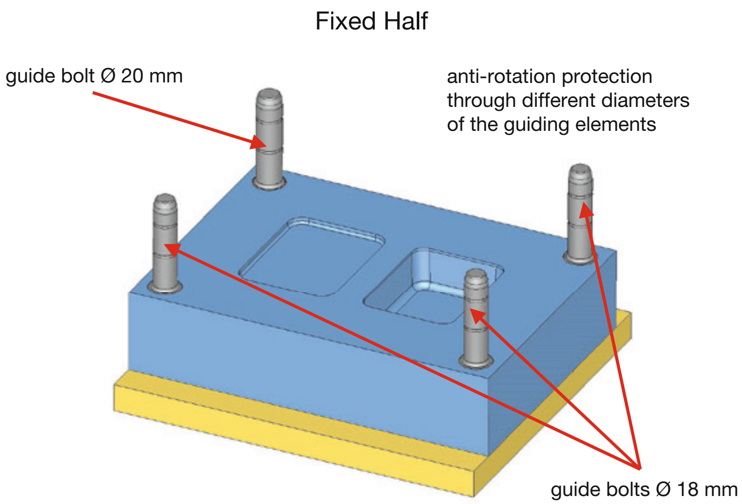

Figure 2.6 Anti-rotation protection in mold making

The following is important for the length selection of the guide bolts: Before the mold contours of the two halves approach, the guides must already fit into one another. If the guides are too short, the mold contour could be damaged during the closing action of the mold halves.

In Figure 2.7 it is clearly visible that the guides are already sliding into one another before both sides can have contact.

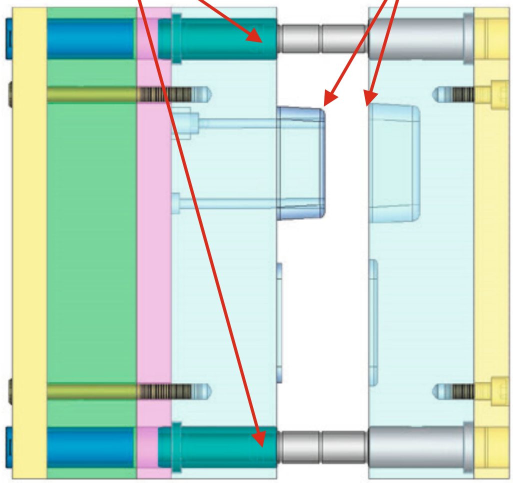

Figure 2.7 Length selection of guiding elements

2.1.3 Backing Plate

These are not used very often in a very simple injection mold. They are installed when a complex cooling, a core pin or additional components that have no space in the cavity plate or pass through the cavity plate and should be held by the backing plate, are required in an injection mold.

In Figure 2.8 a core pin is shown which is installed in the cavity plate and is held by the backing plate.

The use of a backing plate has more functions and advantages here. One of the advantages is that the backing plate is installed under the cavity plate and is level. Therefore all the components which are attached to the backing plate are geometrically determined and on the same level. A further advantage is the manufacturing costs. To achieve a similar fixing of such a core pin, an additional installation of another cover from below would be necessary. A possibility here is a small built-in cover plate or a set screw which fixes the core pin.

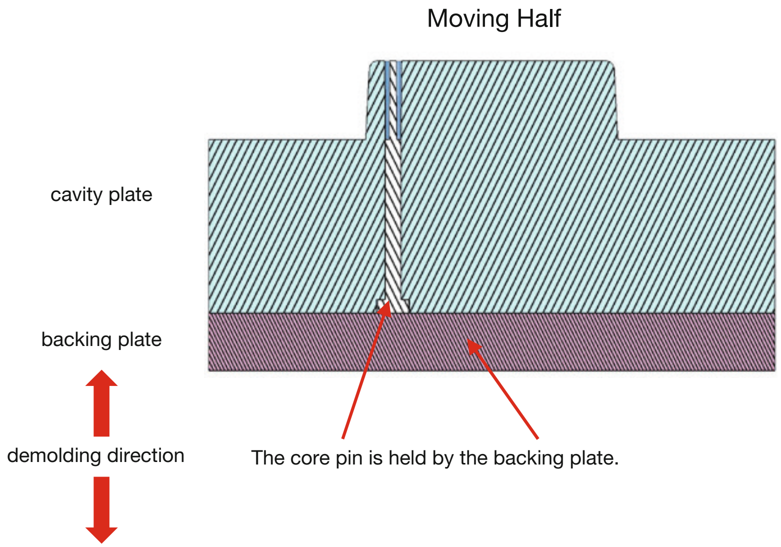

Figure 2.8 The backing plate fixes and holds the core pin

Both alternatives cause higher production costs. If they are used several times in a mold, it makes sense to install a backing plate.

In Figure 2.9 two possible alternatives for the fixing of core pins are shown.

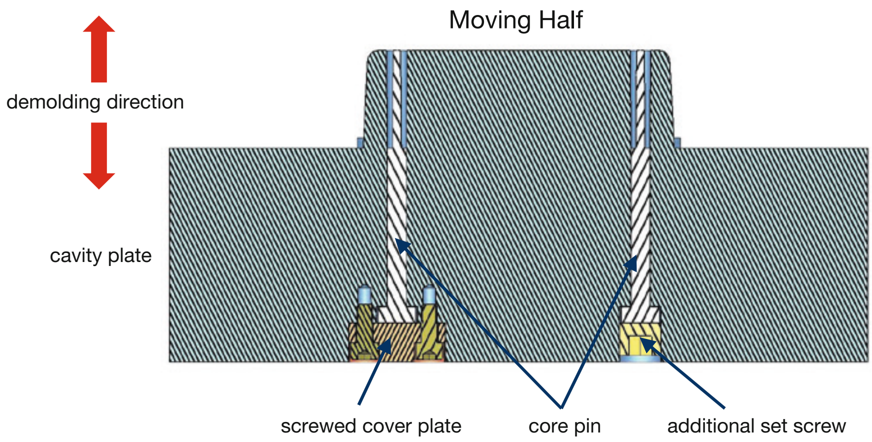

Figure 2.9 Alternatives for fixing

Further additional and basic designs, functions, elements and components of an injection mold are discussed individually in the following sections of this book.

2.2 Molds with Moving Elements

Almost everything that makes an injection mold complicated and expensive originates from the geometry of the subsequent plastic parts. Therefore attention should already be paid in the planning and design of this plastic part that everything that should later contain the plastic part is also to be realized in the injection mold. This is often a big challenge in the development, that is, the design of plastic parts. When design and technology meet, sometimes one has to compromise.

2.2.1 Undercut

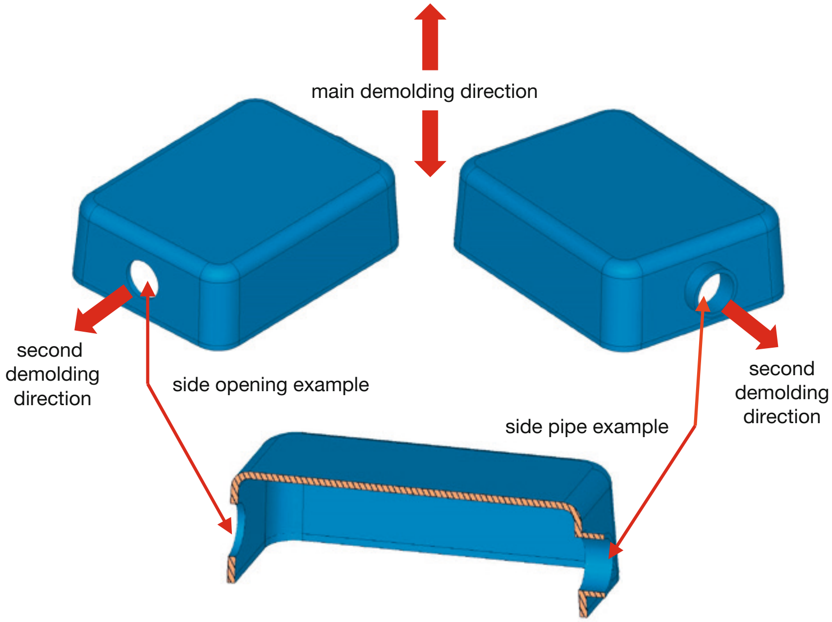

Figure 2.10 Additional demolding directions

The next level of difficulty in plastic parts is elements which cannot be demolded in the main demolding direction like in an open/close mold. These elements, which are troublesome during demolding, are called undercuts. They need to be released or demolded in an additional demolding direction. For this purpose moveable components, such as slides, core pins, ejectors for inclined ejection units or inserts, are used in the injection mold. They support the plastic piece so that it can be better demolded and ejected.

In Figure 2.10 two possible elements, a side bore hole and a side pipe, are seen on our component. Both elements are an undercut on the plastic part and must be released via the second demolding direction. Only this way can the plastic parts be ejected from the mold without damage. For these two examples slides are used to do this.

2.2.2 Slide

When implementing these side openings the open/close mold becomes a mold with slides. Slides are moving components inside the injection mold. One or more parts of the mold contour are incorporated into these slides. The slide itself moves away from the plastic part during or after the opening of the mold in an additional demolding direction. Through this movement the undercuts are released before the plastic part is ejected from the injection mold. 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 mold without damage after the ejection.

In Figure 2.11 the slide for demolding the side opening on our container is shown. In the front area of the slide a part of the mold contour of the plastic part is incorporated. The round surface in front has contact with the fixed insert when the mold 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.

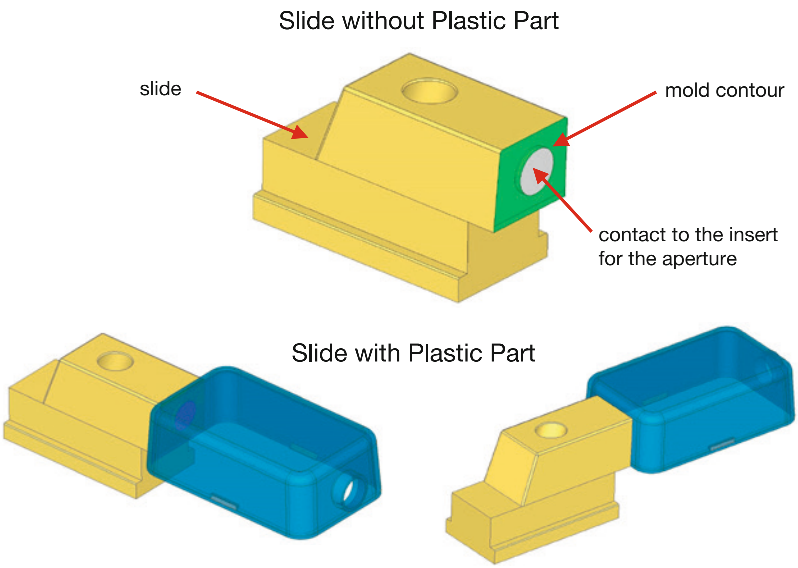

Figure 2.11 Slide with and without plastic part

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 mold. 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 mold. The front part of the inclined pin submerges in the moving slide. When the mold opens in the main demolding direction, through the resulting movement this inclined pin moves the slide in an additional demolding direction. There are additional details in Section 4.2.

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

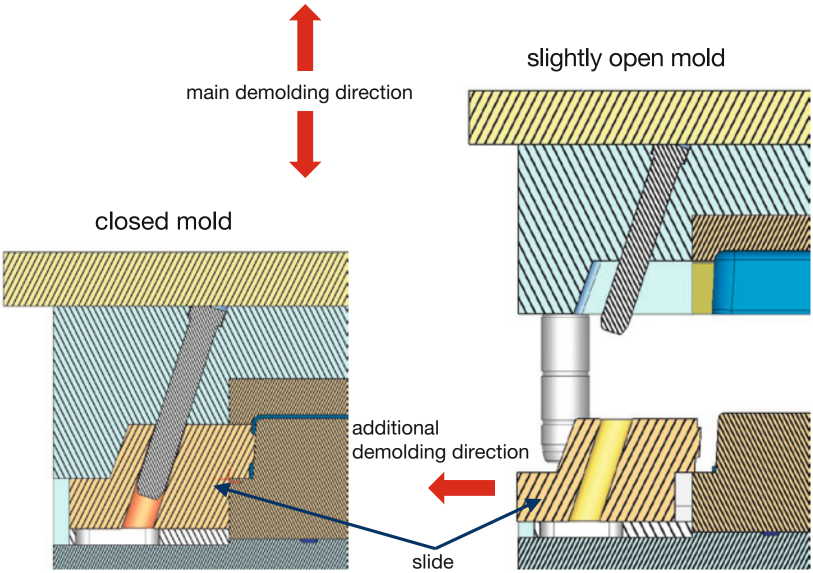

Figure 2.12 Closed and slightly open mold

2.2.4 Latch, Clip Lock

Even a very small and harmless looking clip or catch can have a major impact on the design and on the cost of an injection mold.

The simplest application is a clip for snapping the cover onto the container. Clips or catches are also used to connect several plastic parts or to fix them together in an entire assembly group. The assembly of plastic parts has to be done very fast today and if possible automated. The use of such clip connections on plastic parts has, among others, the advantage that they can be quickly and easily installed without further hand tools.

For the size, type, complexity and also for the costs of an injection mold, it can be very important if the clip is attached outside or inside of the plastic part. This should be considered during the planning of the plastic part. If the clip or latch is outside of the component, it is in the demolding direction and thus there is no undercut. Consequently, it is demoldable without further action.

Figure 2.13 shows both variations of a latch, inside and outside. The outer latch is open above, thus enabling a problem-free demolding. The inner latch is not open in the demolding direction. It will be damaged or even torn away during ejection. Consequently, one must think of how to prevent this.

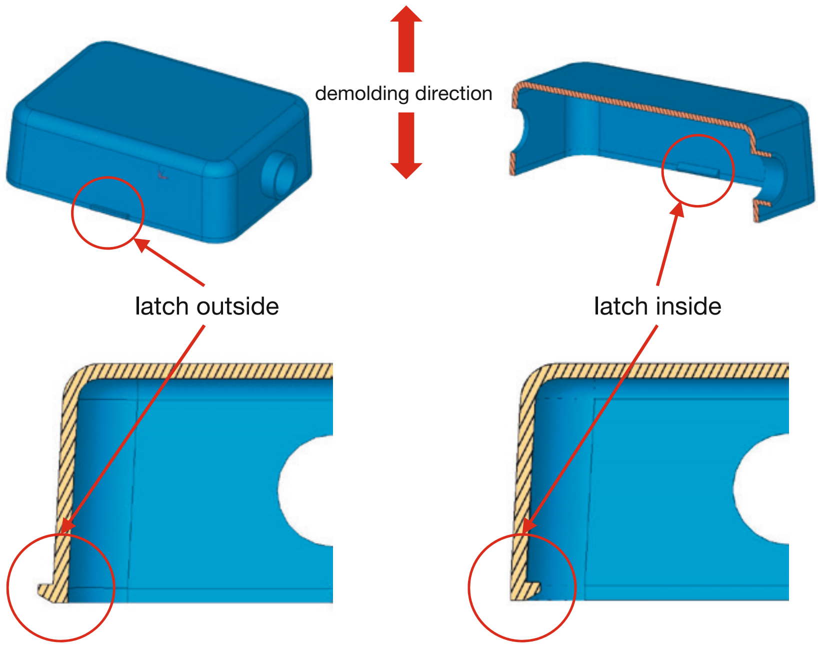

Figure 2.13 Outside and inside latch

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