htl bildung mit zukunft	**HÖHERE TECHNISCHE BUNDES - LEHR- UND VERSUCHSANSTALT ST. PÖLTEN**
	Abteilung: **Wirtschaftsingenieurwesen** Ausbildungsschwerpunkt: **Betriebsmanagement**

DIPLOMARBEIT

5YHWIM – Reife- und Diplomprüfung 2009/10

Thema	Entwicklung, Konstruktion und Realisierung eines PVC- Spritzgussteils innerhalb eines europäischen Projekts in Zusammenarbeit mit europäischen Schulpartnern.
Aufgabenstellung	- Konstruktion und Entwicklung - Produktentwicklungsprozess innerhalb eines Projekts - Dokumentation des Projektes - Fertigungsverfahren: Spritzgießen und die Spritzgusstechnik - Kunststofftechnik: Werkstoffe - Formkonstruktion und Berechnung - Kalkulation und Kostenrechnung - Projektsprache: Englisch, Diplomarbeit in englischer Schrift und Sprache - Projektevaluierung

Kandidaten	**Betreuer**
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Schriftliche Kooperationsvereinbarung liegt vor:
Budget:
Bedeckung durch: HTL St. Pölten, Leonardo- Projekt

Geplante Verwertung der Ergebnisse:
Erfolgreiche Teilnahme an einem europäischen Schulprojekt und Produktion eines PVC- Spritzgussteils.

Erklärung

Die unterfertigten Kandidaten / Kandidatinnen haben gemäß § 34 (3) SchUG in Verbindung mit § 22 (1) Zi. 3 lit. b der Verordnung über die abschließenden Prüfungen in den berufsbildenden mittleren und höheren Schulen, BGBl. II Nr. 70 vom 24.02.2000 (Prüfungsordnung BMHS), die Ausarbeitung einer Diplomarbeit mit der umseitig angeführten Aufgabenstellung gewählt.

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Die Abgabe der vollständigen Diplomarbeit hat bis spätestens

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DIPLOMARBEIT

Titel der Diplomarbeit:

Entwicklung, Konstruktion und Realisierung eines PVC- Spritzgussteils innerhalb eines europäischen Projekts in Zusammenarbeit mit europäischen Schulpartnern.

Verfasser:	**Martin M. PFANNHAUSER,**	**Matthias WIELAND**
Katalog-Nr.:	**10 / 5 YHWIM,**	**12 / 5 YHWIM**
Schuljahr:	**2009/2010**	
Höhere Lehranstalt:	**Wirtschaftsingenieurwesen - Bertiebsmanagement**	
Beurteiler:	**Direktor OStR Dipl.-Ing. Johann Wiedlack, Prof. Dipl.-Ing. Dr. Egon Zveglic, Dipl. Päd. Bernd Gutmann**	

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Preface

The present diploma thesis was elaborated from September 2009 to May 2010 during an EU- project, the so called “European CNC-Network-Moulding for Europe”. It was a great honour for us to attend a “LEONARDO DA VINCI, Education and Culture Lifelong Learning Programme”. We are sure that we have gained a lot of experience during the project meetings and by working together with students from other European schools. This experience will help us in our future professional life.

The topic of the diploma thesis, “Product development, implementation and production of a plastic injection moulded part in liaison with European schools”, contains the key of our education. The diploma thesis made high demands on us, but much more important was the intellectual benefit.

Our special thanks go to our advisers Prof. Dipl.-Ing. Dr. Egon Zveglic for his extensive mentoring of our work, technical assistance and supply of major documents, especially to our Headmaster OStR Dipl.-Ing. Johann Wiedlack for supporting us with literature, and also to Dipl. Päd. Bernd Gutmann for his project mentoring during the meetings and giving advice in regards to the injection mould constructions.

Further, we are fall of gratitude to Dipl. Päd. Günther Amstätter- Zöchbauer, Michael Winkler and Markus Walzer, whose assistance during the project meetings and also during our work helped us to achieve the objectives of our diploma thesis at the department of industrial Management at the College of Engineering, Arts and Crafts in St. Pölten.

St. Pölten in May 2010

Martin M. Pfannhauser, Matthias Wieland

Contents

1 Situation

1.1 Introduction

At the beginning we want to explain the EU- Project "European CNC-Network-Moulding for Europe"[1]. It is an European LEONARDO project and an educational lifelong learning programme sponsored by the European Union. LEONARDO projects are targeted to build a European network between schools and to give students the possibility to broaden their mind in their education programme.

The topic of this LEONARDO project is called "European CNC-Network-Moulding for Europe". In this project 6 schools from 5 different countries are attending part:

- **Austria:** HTL St. Pölten[2], HTL Fulpmes[3]
- **Germany:** BBS TGHS Bad Kreuznach[4]
- **Spain:** Salesians de Sarriá Barcelona[5]
- **Portugal:** CENFIM Trofa[6]
- **Turkey:** M.Rustu Uzel Industrial Vocational High School Gaziantep

[1] http://mould.cnc-network.eu/index.htm Stand: 04.02.2010
[2] www.htlstp.ac.at Stand: 04.02.2010
[3] www.htl-fulpmes.ac.at Stand: 04.02.2010
[4] www.bbstghs.de Stand: 04.02.2010
[5] www.salesianssarria.com Stand: 04.02.2010
[6] www.cenfim.pt Stand: 04.02.2010

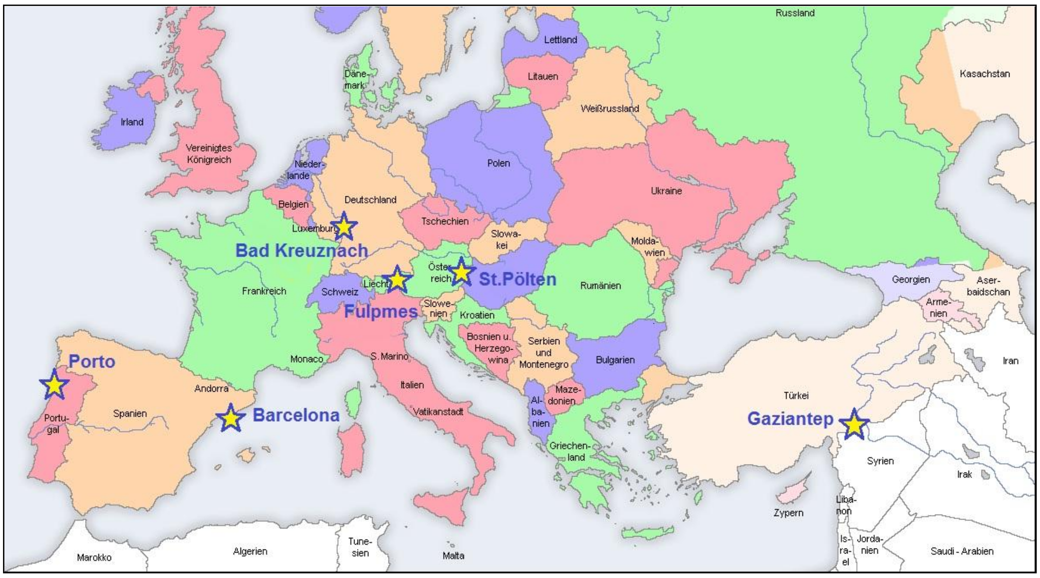

Figure 1: EU- map with the participanting schools

1.2 Project: Moulding of Europe

1.2.1 Technical Project

As the project suggests it is a technical project. Five European schools and one school from Turkey are dealing with. The requirements for the participating schools are to design and produce a key fob in cooperation of the schools. In seeing that, every participant school should have a stake in the project work and should be recognized in the key fob.

The second requirement is to produce the key fob with the manufacturing process of injection moulding.

1.2.2 Communicative Project

The second important point of this “LEONARDO DA VINCI, Education and Culture Lifelong Learning Programme” is the chance to liaise with foreign students and create a network with them, but also to see other cultures and parts of the European Union. And so the key fob should typify the cooperation of the European Union.

Concerning the cooperation between the schools there will be 6 meetings, one at each school. At these locations the attending students will work for the project objectives, but also see other countries and their culture.

Concerning the communication in the LEONARDO project there will be a forum[7] and Moodle- platform[8] in the internet. The language is also a very important

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[7] http://mould.cnc-network.eu/forum/index_forum.htm Stand: 29.01.2010

[8] http://mould.cnc-network.eu/moodle/index_moodle.htm Stand: 29.01.2010

point in this project, because the students will improve their language skills and broaden their mind in the use of technical English.

After the meetings and project work the Moodle- platform, which contains information about injection moulding and final exams about this topic should provide teachers with information for their students.

1.3 Objectives

The goal of this European project is to cooperate in production and in a product development process, which starts with the design of the key fob, then goes on with the construction of the injection mould, the manufacture of the injection mould and at last the production of a key fob with an injection moulding machine.

This will be realized after 6 meetings, which are at each partner school.

1. Meeting - Spain, Barcelona:
It was about brainstorming and setting guidelines. The guidelines were to design a key fob or a puzzle.

2. Meeting - Turkey, Gaziantep:
The project members decided on draft and construction. They selected a cube, which could be used as a key fob.

3. Meeting - Austria, St.Pölten:
The meeting was about the construction and design of the key fob. At the end it should be a cube with a click-system and 12 logos on each face.

4. Meeting - Germany, Bad Kreuznach:
The issue was about moulding assembly, producing a prototype and the modifications for the future. Another point was to finish the workshop drawing for the cavity inserts.

5. Meeting - Portugal, Porto:
There were talked about the construction of the injection mould, the runners and gates, the cooling and the designs of the logos. The plastic material was selected. Another point was the fitting of the cavity inserts in the form platen.

6. Meeting - Austria, Fulpmes:
That was the last point of the project work. It was about the production and the parts assembly. 1200 key fobs were produced and assembled in Fulpmes. The project tools, like the Leonardo- forum and the Moodle- platform were supplemented.

2 Theory of Injection Moulding

2.1 Injection Moulding Machine

2.1.1 Description of Injection Moulding Machines

For the description of injection moulding technique the European Committee of Machinery Manufacturers for the Plastics and Rubber Industries worked out a guideline, which is called EUROMAP.

In the figure below you can see an injection moulding machine.

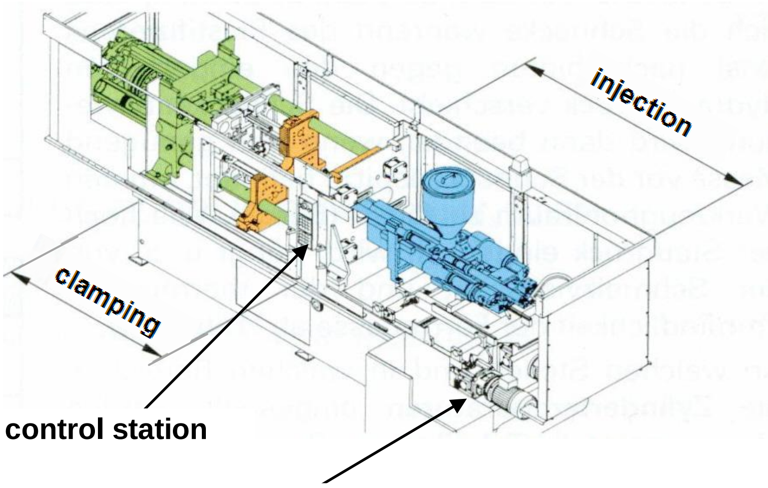


Figure 2: Injection moulding machine [9]

Normally the injection moulding machine is subdivided into 2 parts the injection unit with the descriptive parameter **injection volume [cm³] at 1000 [bar] injection pressure** and the clamping unit with the descriptive parameter **clamping force [kN].** In the EUROMAP 1 below you can see the description guidelines for injection moulding machines.

The classification in EUROMAP:

1. **General**
2. **Design features**

   2.1 Clamping unit

   2.2 Injection unit

3. **Technical data**

---

[9] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, p 125

3.1 Clamping unit ➔ **Clamping force**

3.2 Injection unit ➔ **Injection volume [cm³] at 1000 [bar] injection pressure [kN]**

3.3 Drive

4. Dimensions, weight

EUROMAP 1:

A description of injection moulding machines includes data on design features and technical data for further explanation. The list below should be used for technical documents of all kinds as guideline and reference should be made to the details to be considered when assessing the injection moulding machine.

The EUROMAP size indication gives an indication of the size and capacity of an injection moulding machine and should therefore be mentioned in all documents, indicating the EUROMAP recommendation, together with the type designation.

		Explanation	Unit
1.	**General**		
1.1	Type designation	to be established by the manufacturer	
1.2	EUROMAP size indication	consits of the sizes by which the injection moulding machine is identified: these are the clamping force in kN and the calculated injection piston (or screw) displacement in cm³ (related to an injection pressure of 1000 bars). In a horizontal clamping unit, the clamping force in kN is identified by a suffix H. In the case of a vertical clamping or injection unit, the corresponding numerical value is supplemented by a suffix V. Where there is injection into the separating plate, in the horizontal clamping and injection unit, suffix L is added to the numerical values. If two injection units are provided, the calculated displacement in cm³ of the second unit must be linked to the numerical value for the calculated displacement (stroke volume) in cm³ of the first injection unit by a stroke (/). **Examples:** 17800 H - 16170 3430 V - 3750 600 V - 35/60	
1.3	Application	e.g. general use, special application; for thermoplastics, thermoplastics containing expanding agents, duromers, rubber	
2.	**Design Features**		
2.1	**Closing unit**		
2.1.1	Position	e.g. horizontal, vertical, pivoted	

2.1.2	Design	e.g. toggle linkage, direct hydraulic	
2.1.3	Guide	e.g. 2/3/4 columns	
2.2	**Injection unit**		
2.2.1	Position	e.g. horizontal, vertical, pivoted, displaceable	
2.2.2	Design	e.g. piston, piston with plasticizing screw, reciprocating screw	
2.2.3	Injection drive	e.g. electromechanical, hydraulic, pneumatic	
2.2.4	Screw drive	e.g. electromechanical, hydraulic	
3.	**Technical Data**		
3.1	**Clamping unit**		
3.1.1	Maximum closing force	determined according to EUROMAP 7	kN
3.1.2	Nominal opening force	determined according to EUROMAP 8	kN
3.1.3	Opening stroke	for maximum mould height	mm
3.1.4	Maximun distance between the platens		mm
3.1.5	Mould height	maximum/minimum for direct hydraulic closing, the minimum height only may be indicated	mm
3.1.6	Size of the clamp-ing platens width x height	see EUROMAP 2	mm x mm
3.1.7	Clear distance between columms		mm
3.2	**Injection unit**		
3.2.1	Piston or srew dia-meter		mm
3.2.2	Injection pressure	maximum value	bar
3.2.3	Calculated injetion unit	cross-sectional area x stroke of piston or screw	cm^3
3.2.4	Piston or screw stroke		mm
3.2.5	Effective screw lenght	lenght of the srew calculated form the front of the feed throat opening to the end of the screw flights in the srew forward position; may be shown as the ratio of the effective scre lenght to the diameter	mm
3.2.6	Available (installed) injection power	for eletrical, pneumatic, or hydraulic inejction drive of the psiton or screw (see EUROMAP 4)	kW
3.2.7	Screw speed	from….to….stepless, adjustable in steps	mm^{-1}
3.2.8	Installed drive pow-er for screw	for electrical od hydraulic rotary drive	kW
3.2.9	Number of heating/ cooling zones on the barrel (cylinder)		
3.2.10	Installed barrel (cy-linder) heating power		kW

3.2.11	Plasticising flow rate	see EUROMAP 5	g/s
3.2.12	Injection flow rate	see EUROMAP 5	g/s
3.3	**Drive**		
3.3.1	Drive power of the hydraulic pump		kW
3.3.2	Working pressure of the hydraulic pump or pneumatics		bar
3.3.3	Dry cycle time	is determined to EUROMAP 6	s
3.3.4	Specific energy consumption	see EUROMAP 5	Ws/g
3.3.5	Total installed po-wer		kW
4.	**Dimensions, Weight**		
4.1	Dimensions	lenght x width x height	mm
4.2	Net weight		kg

Table 1: EUROMAP 1 [10]

2.1.2 Components of the Injection Moulding Machine

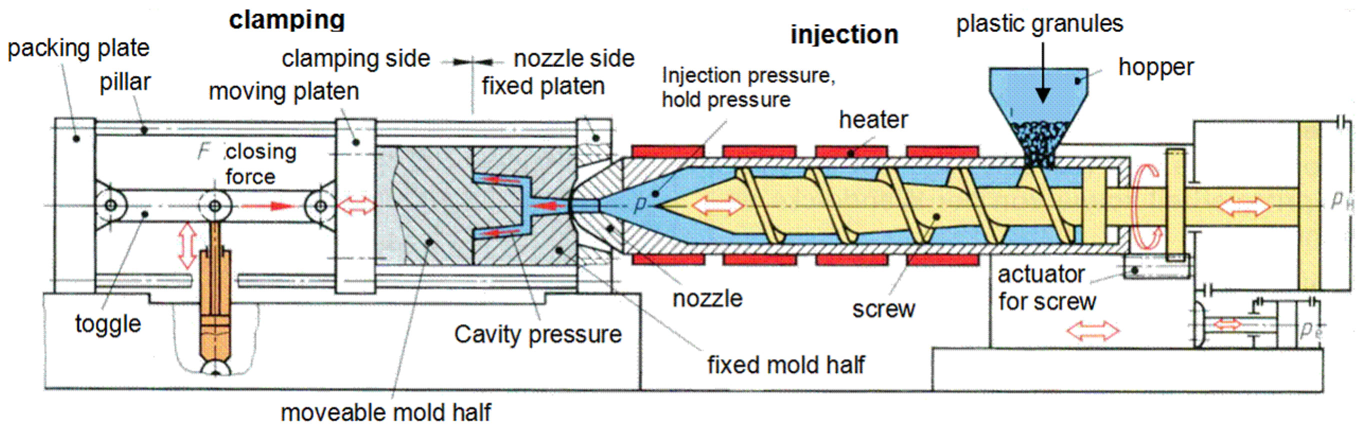


Figure 3: Components of the injection moulding machine

2.1.2.1 Injection Unit

The injection unit has the task of conveying, fusing, homogenizing that means plasticizing the plastic granules and to inject it into the cavity.

[10] www.euromap.org/files/eu1.pdf Stand: 03.03.2010

Here you can see the injection unit with the heating unit around the screw:

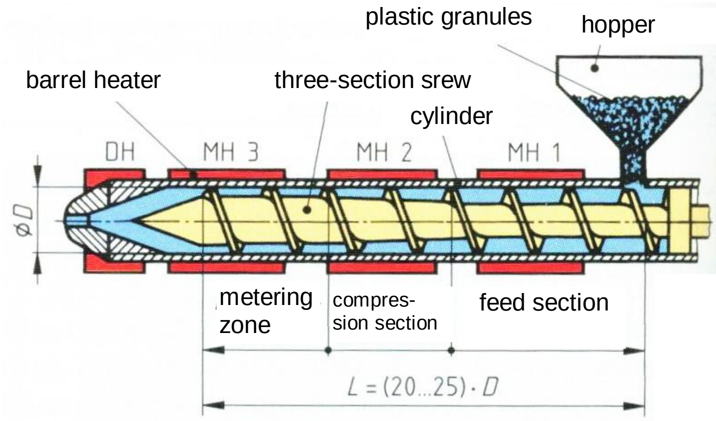


Figure 4: Cylinder temperature for the injection unit

The standard screws for thermoplastics are normally three-section screws.

MH1: feed section

In this zone of the screw the compound will be threaded and aided to the next zone the compression section.

MH2: compression section

In this zone of the screw the compound will be plasticized and compressed. Sometimes there is a unit for venting the compound.

MH3: metering zone

In this zone the compound will be homogenized. During injection a non-return valve before the screw avoids the reflow of the compound. When the screw plasticize new compound for the next work cycle it generates the back pressure between the nozzle and the top of the screw. [11]

DH: nozzle heating

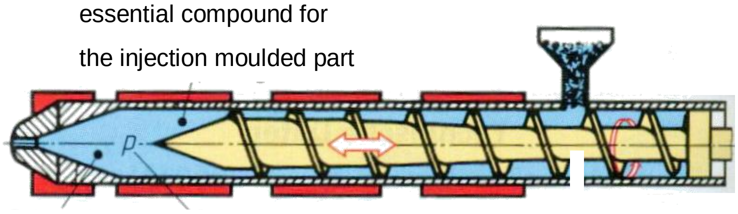


Figure 5: Cause of the back pressure

Screw for thermoplastics:

The screw revolution depends on the screw diameter and the circumferential speed.

The back pressure which is between the nozzle and the top of the screw depends on the melting viscosity and the thermal sensitivity of the compound. When there is enough compound volume to fill the cavity the screw rotation is stopped.

For the injection moulding process a rotating screw actuator is used. The tasks of the screw are to produce frictional heat to plastify the compound (60 % for thermoplastics) and to dose the compound for the next work cycle. After that the screw stops rotating and injects the compound into the mould and then the screw maintains the hold pressure.

For thermoplastics normally standard screws are used, they have a length of 20D – 22D and could be used for all thermoplastics and injection moulding processes, but not for high speed injection moulding. A problem could be requirements for blending colours, but then it is necessary to use special screws.

The non-return valve avoids that the compound flows back into the screw channel during the injection process and hold pressure impact. [12]

Injection nozzle:

The task of the nozzle is to make a closed transition from the injection cylinder to the mould. But there shouldn't be any pressure and temperature losses. A nozzle heater and the move away from the mould after the hold pressure time could be helpful.

Normally the nozzles have got a bow (convex nozzle) and so they are centered and well gasketed. But the nozzle radius must be smaller than the radius of the bushing gate.

If the injection is in the parting line, then it is important to protect the mould from the cotter effect of the convex nozzle.

There are two types of nozzles, the open nozzle and the shut- off nozzle.

[11] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, pp 125-126

[12] Johannaber / Michaeli, Handbuch Spritzgießen, Verlag Hanser, pp 721-777

Open nozzle:

This design will be used when the plastic melting is viscous enough, because it is easy to clean and to flush. The pressure and temperature losses are very low, because the duct is clogged. The nozzle bore is between 3 mm and 8 mm.

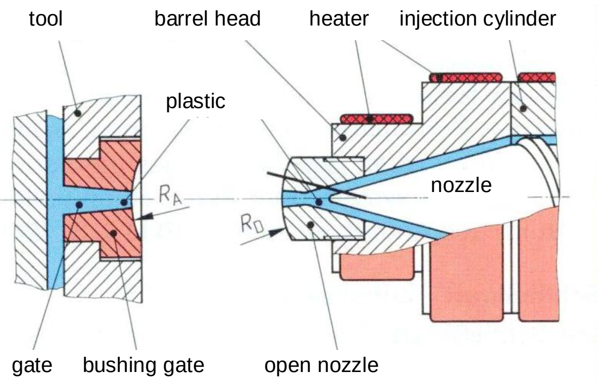


Figure 6: Open nozzle

If the plastic melting has low viscosity, then a shut-off nozzle will be needed.

Shut- off nozzle:

An example of the shut-off nozzle is the slide closure nozzle in the figure below or the transverse needle shut-off nozzle *(Figure 8).* In these nozzles the nozzle aperture will close after each injection process and so the melting cannot effuse.

Shut- off nozzles will close with springs or hydraulically.

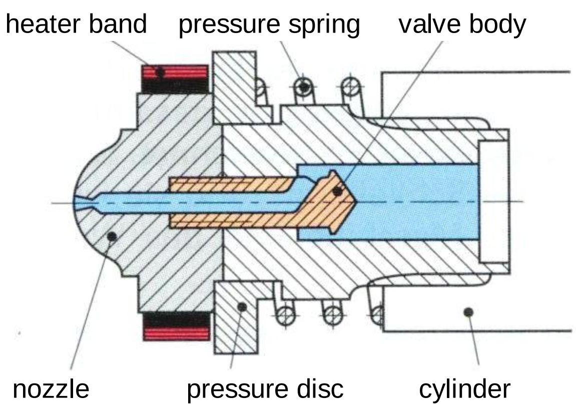


Figure 7: Sliding closure nozzle

This nozzle will be used for a high fluid melting. The nozzle closes after every injection process and restrains the effusion of the melting. The sliding closure nozzle will be operated by a spring or hydraulically and the needle is coaxial to the melting flow-way.

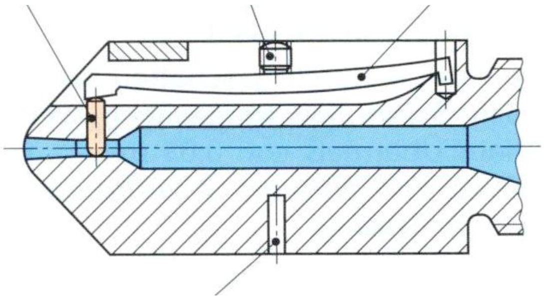


Figure 8: Transverse needle shut- off nozzle

This shut-off nozzle is also used for a high fluid melting. The needle is transverse located to the melting flow-way. The pro of transverse needles like the transverse needle shut-off nozzle is that the needle is closer to the feed bush and so there is no stringing.

2.1.2.2 Clamping Unit

Injection mould machines are marked according to their clamping force in kN. This means the clamping of the injection mould machine is the most important part of the machine and so the distinction is the clamping force.

As example: ENGEL 1000 kN injection moulding machine means a machine with 100 to clamping force.

The clamping unit bears on the moveable and fixed platen at the respective mould halfs. There are two possibilities for the opening, closing and fixing of the mould, it is performed by the mechanical closing *(Figure 10)* or a hydraulic closing *(Figure 12)*.

Mechanical clamping:

The mechanical clamping is often realised with a toggle system, which is hydraulic or electrical operated. The pro of the toggle system is that a hydraulic actuator is smaller than a hydraulic clamping unit, because the force acts on the toggle. Another point is the short closing time and the large opening stroke.

Hydraulic clamping:

The hydraulic clamping is realised with one axial hydraulic actuator or with more symmetric hydraulic actuators. The pro of this system is the easy and precise adjustment of the clamping force. The clamping force is constant, if there is

used an active hydraulic pump. But often the oil column is locked. It is easier to realise.

Another construction concerning the clamping unit is the tie bar-less clamping unit *(Figure 9)*. The bar-less construction of the clamping unit becomes more important in the last years, because the achieveable clamping force of this system increases. The pros are the good accessibility for mould mounting, big and variable mould platen and a good plane parallelism of the closed mould. The energy efficiency is also higher.

In the figure below you can see the different possibilities of clamping units.[13]

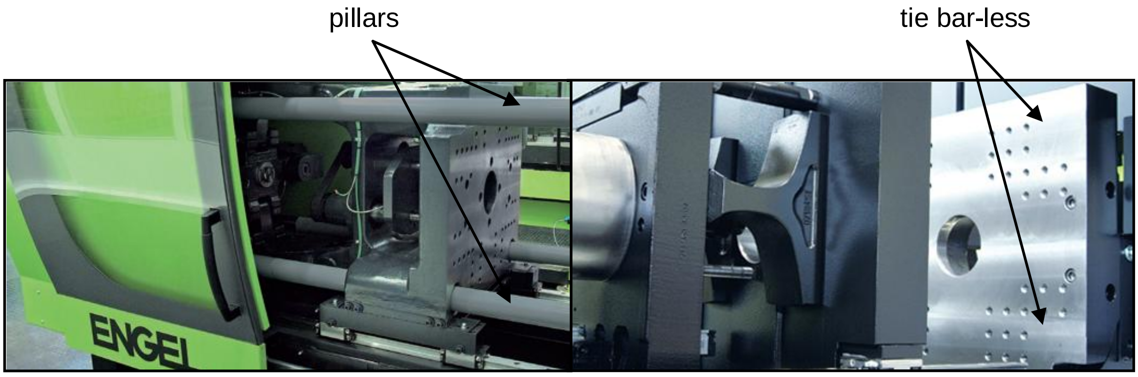


Figure 9: Clamping unit with pillars or tie bar-less

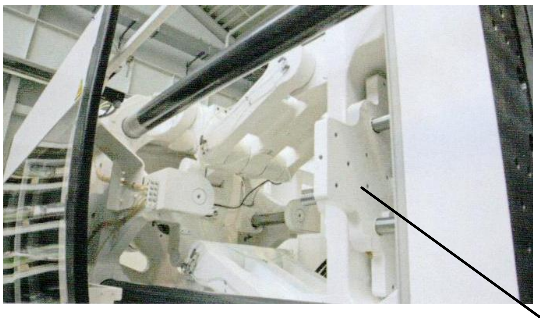


Figure 10: Toggle system

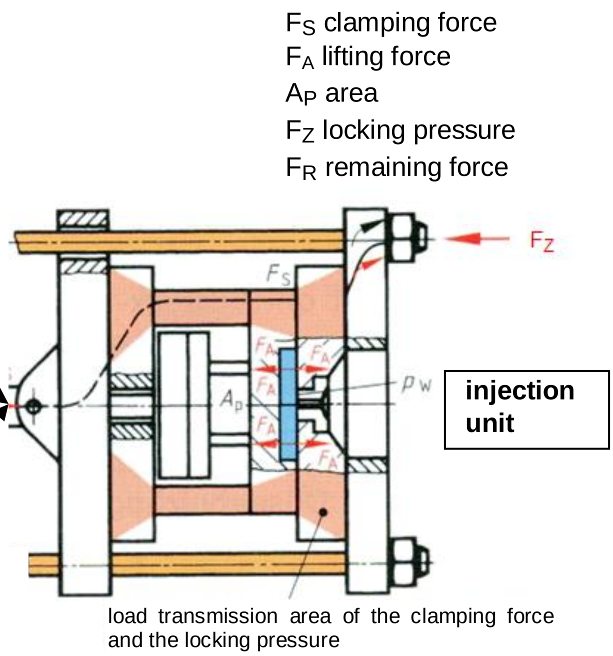


Figure 11: Clamping unit

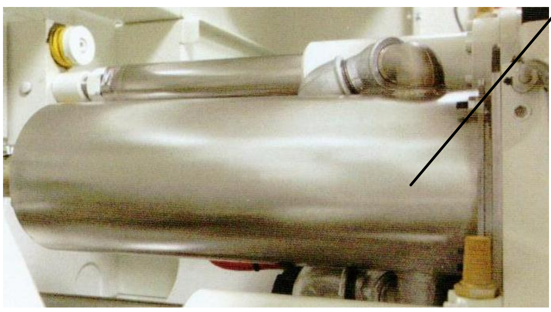


Figure 12: Hydraulic actuator

[13] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, pp 127-128

The clamping force strains and elongates the pillars and presses the mould halfs together. During the injection a lifting force inside the mould results. This force causes a tensile load and elongation of the pillars. The clamping or closing force must be higher than the opening of lifting force inside the mould. It depends on the stiffness of the machine and mould- assembly.[14]

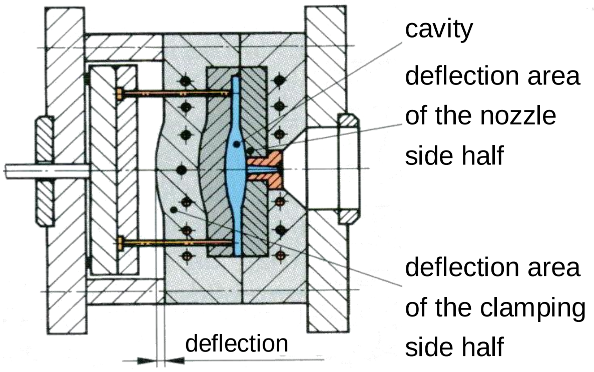


Figure 13: Deflection of the mould halfs

If the lifting force is bigger than the locking pressure, the plastic melting will leak.

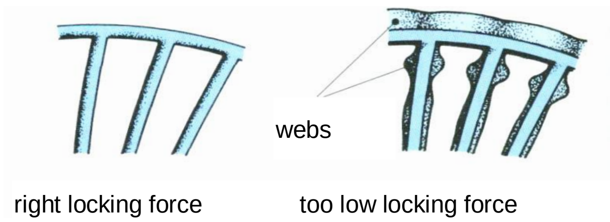


Figure 14: Locking force affects

But the locking pressure should be not too high, because this would effect a deflection of the mould halfs. The areas of the deflection are at the ejector system and the center hole. A support roller could prevent the deflection. The support rollers have an interference of 0,03 mm … 0,05 mm. [15]

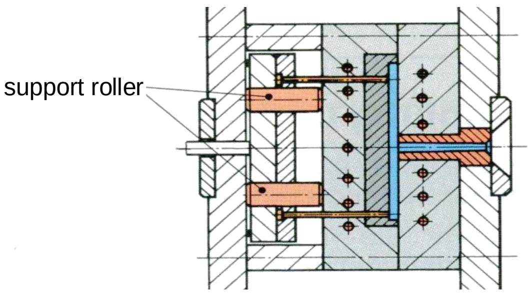


Figure 15: Support roller

[14] Johannaber / Michaeli, Handbuch Spritzgießen, Verlag Hanser, pp 827-831

[15] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, p 128

2.1.2.3 Ejector Unit

You have to divide into mechanical ejectors and hydraulic ejectors. The task of the ejector unit is to eject the moulded part after the opening of the mould. The ejector unit consists of a hydraulic cylinder behind the moveable platen. The plunger of the cylinder is going through the moveable platen. Ejector pins can be coupled with the plunger and so these pins can be ejecting the part after moving the plunger into the direction of the mould.

Often an ejector plate in front of the backing plate is used. On this plate some more ejectors could be fixed. This system is used when more than one ejector is necessary or the ejector isn't centered. Often a pressure spring is used to pull back the ejectors before the mould is closed. Another securing system is to use 4 bigger ejectors, if the pressure spring brakes down. These 4 ejectors are few millimeters longer than the ejectors in the cavity. Another possibility is to secure the ejectors with a position switch.

The ejector system will be specified under the point 2.3 Basics of Mould Design and Construction.

2.1.2.4 Drive Unit

Electrical actuators are in use for injection moulding machines up to 5000 kN clamping force. Above 5000 kN clamping force only hydraulic-mechanical tec-nology is used.

Here you can see the achievement / energy percentage between the parts of a work cycle. [16]

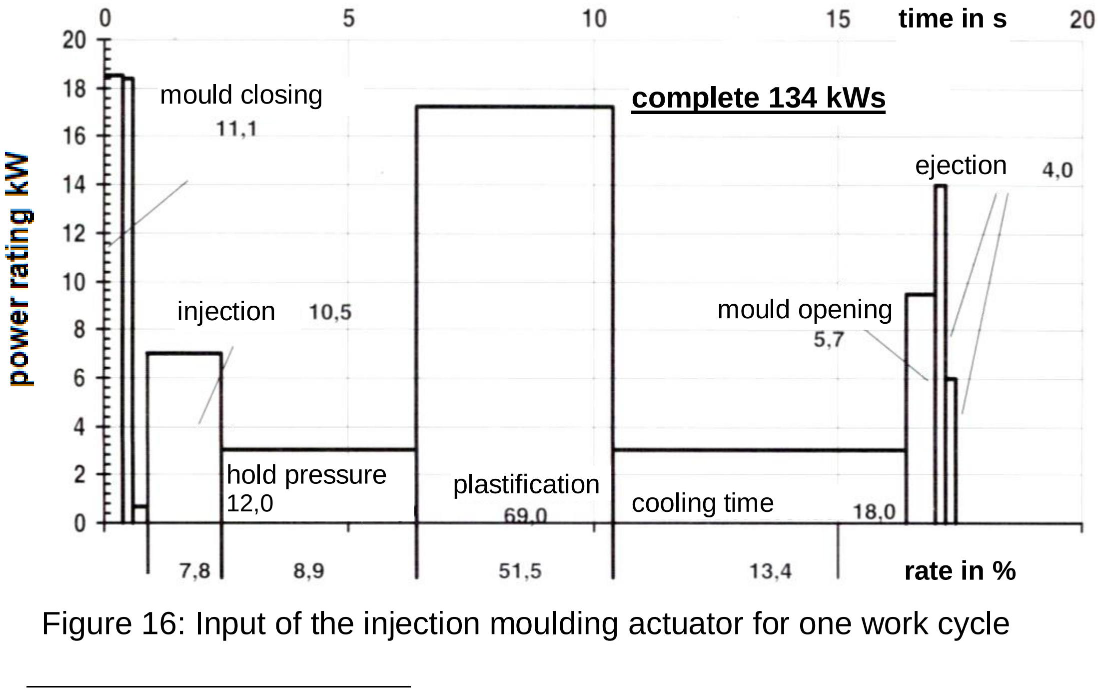


Figure 16: Input of the injection moulding actuator for one work cycle

[16] Johannaber / Michaeli, Handbuch Spritzgießen, Verlag Hanser, p 889

2.1.2.5 Control Unit

The control of the injection moulding machine is electronical and automated. In the picture below you can see the control station, of an injection moulding machine and the second picture shows the menu of the cylinder heating unit with the temperature areas for the screw.

In the production and often in production lines the control of the injection moulding machine is connected with a host system and so the control of the injection moulding- machine, -process and –tool is done by the host system. If there is any error or change in the production process the host system gives a notification.

The control by a host system is also important for the quality management and the documentation of the injection moulding process.

In the figure below you can see a control unit from an industrial injection moulding machine with the cylinder temperature display and its setting parameters. [17]

Figure 17: Control unit

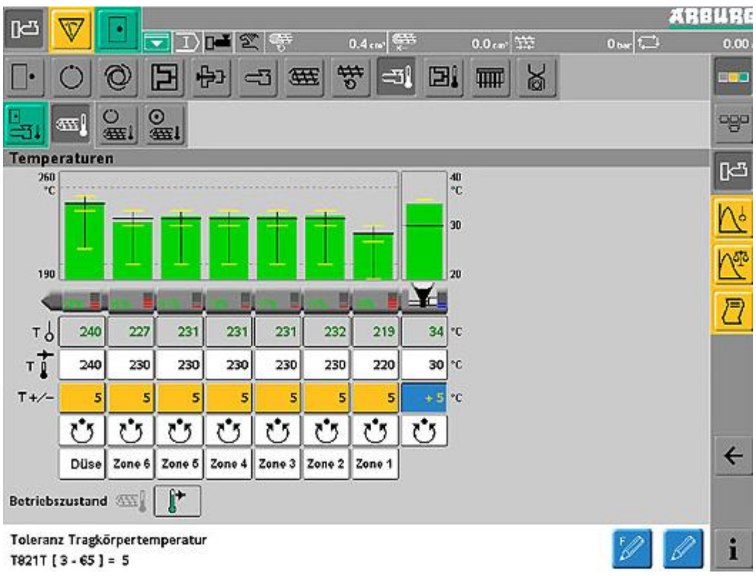


Figure 18: Control unit – cylinder temperatures

[17] www.arburg.de Stand: 09.03.2010

2.2 Injection Moulding Process

In the figure below you can see the place of the injection moulding process regarding the time. The time from one process to the next is called work cycle or section cycle. Here you can see the work cycle for one moulded part, or for one of a mould with cavity inserts.

The process starts with the closing of the mould, then the injection of the compound starts and after the acting of the holding pressure the process goes on with the dose, it means the plastification of the plastic compound and dosage for the next work cycle in the injection unit. The longest time in the work cycle is the cooling time. The injection time and ejection time are very short for example at maximum of few seconds. Between the cooling time and the opening of the mould the back moving and rotating screw plasticizes the new plastic compound for the next work cycle. Then the ejection of the ready moulded part is done.

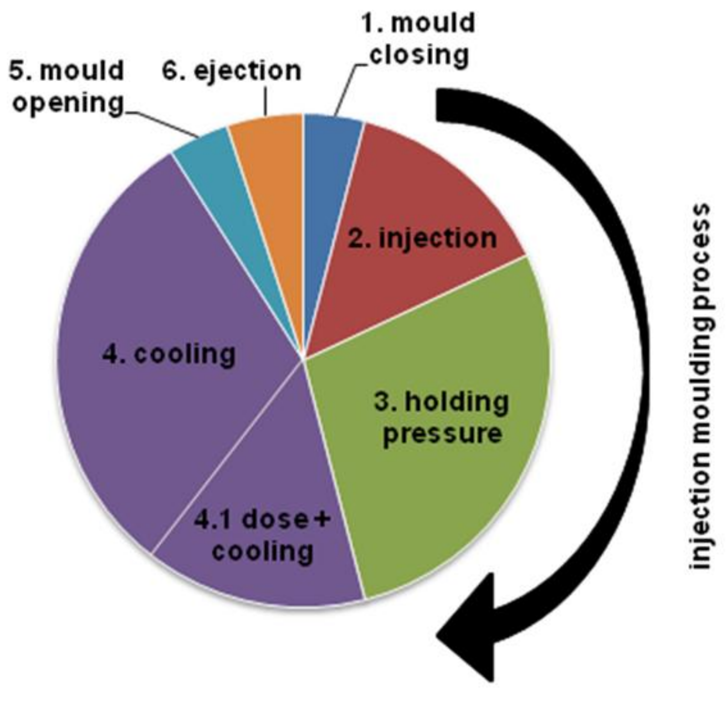


Figure 19: Injection Moulding Process

2.2.1 Closing of the Mould

The closing of the mould is done by the clamping unit. Before the injection the two mould halfs will be closed and the nozzle will be pressed onto the gate of the mould.

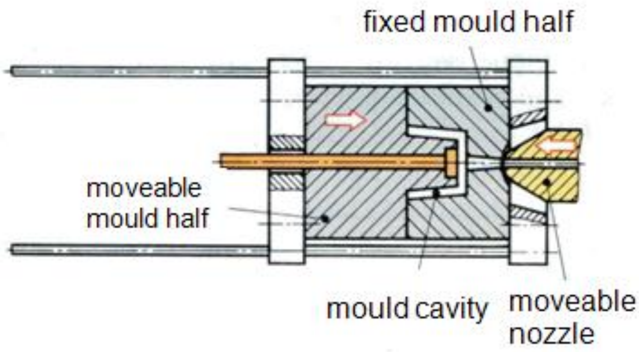


Figure 20: Closing of the mould

The figure below shows the machine characteristic and the mould characteristic. It depends on the elongation of the pillars, the buckling of the mould and the forces, which stress the mould and machine. This means that the elongation of the pillars and the buckling of the mould increase with the height of the forces and so it is necessary to find the ideal clamping force for the injection moulding process.

The clamping force Fs stresses and extends the pillars after the closing of the mould, because it presses the mould halfs together. During the injection of the compound a cavity pressure [cp] develops a lifting force and so this force stresses the pillars too. FA = cp * A

The sum of the forces, which stress the pillars is called locking force. It is bigger than the clamping force and depends on the stiffness of the machine and the mould.

If the lifting force is bigger than the locking pressure, the plastic melting will leak. This is called overmoulding and causes webs.

But the locking pressure should be not too high, because this would affect a deflection of the mould halfs. The areas of the deflection are at the ejector system and the center hole.

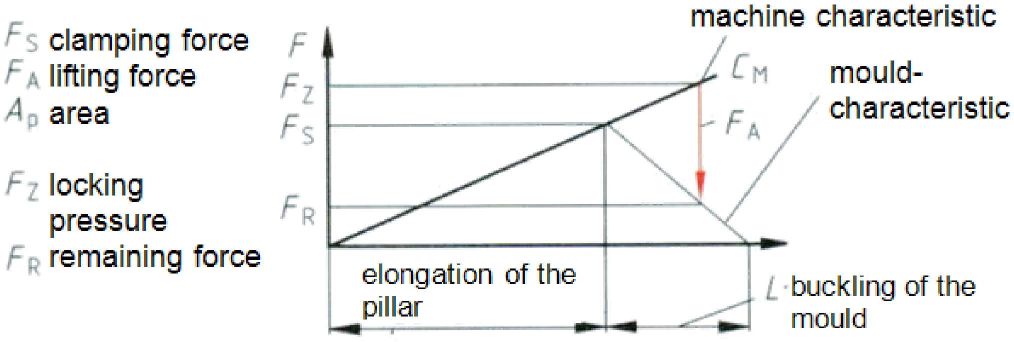


Figure 21: Scope of the clamping- and locking pressure

2.2.2 Injection of the Compound

The injection of the compound is done by the injection unit. The plasticised compound is injected under high pressure into the cavity of the mould.

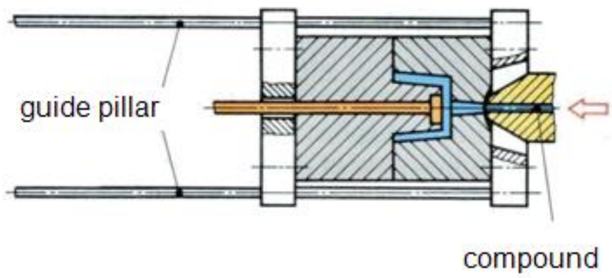


Figure 22: Injection of the compound

In the figure below you can see the march of pressure. The mould cavity pressure is smaller than the injection pressure, because of the flow resistance in the nozzle and in the mould. The injection pressure increases due to compression of the compound (point A to B). When the mould cavity pressure is high enough and the cavity is filled with compound, then the injection pressure will be reduced and called holding pressure. This pressure fills up the decrease in volume, which results from the cooling of the melting. The holding pressure is decreasing by time, because of the cooling of the melting (point C to D).

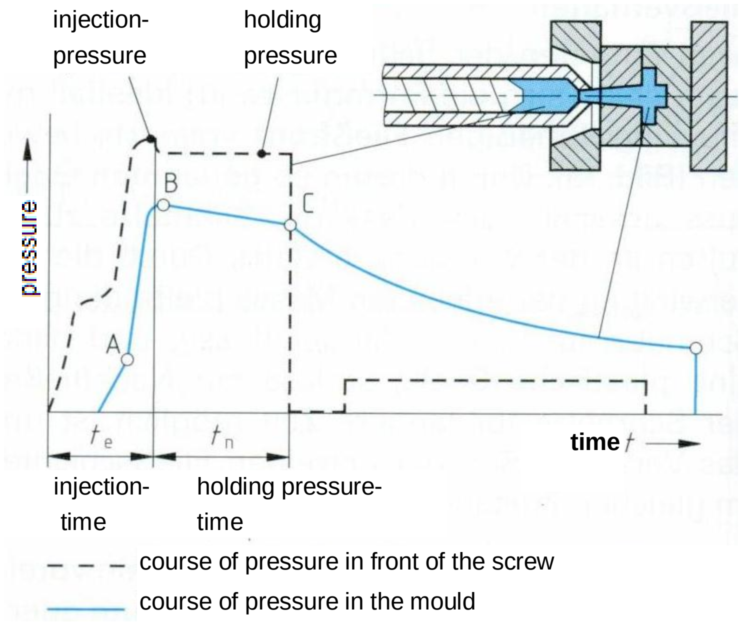


Figure 23: Course of pressure

In the table below you can see the consequences for the moulded part caused by a false injection pressure and injection or filling –speed.

influencing variables		**consequence**
injection pressure	too high	mould cavity pressure high, flash on the part
	too low	mean cavity filling, weak spot in the part
	short action	mean cavity filling, short weight of the parts
	long action	heavy parts, strains in the parts
injection or filling -speed	too high	low molecular orientation, jetting, burns at the part
	too low	bad welding of the melting flow, blowhole, high temperature differences in the compound

Table 2: Influencing variables of the injection- pressure and speed

In the table below you can see the consequences for the moulded part caused by a false holding pressure.

holding pressure	**consequence**	
too low	blowhole	high tolerance variability and shrinkage, low part weight, small part
too short action	low form filling level	
too long action	inefficient	uneconomical, high part weight, big part, high strain in the part and the machine
too high	to small closing force	

Table 3: Influencing variables of the holding pressure

2.2.3 Opening of the Mould

After the injection and cooling down of the compound the mould opens. This opening is done by the clamping unit acting on the moveable mould half.

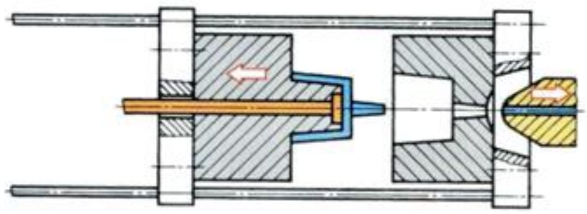


Figure 24: Opening of the mould

2.2.4 Ejection of the Moulded Part

After the opening of the mould the finished moulded part will be ejected by the ejector system. After the ejection a new work cycle could start.

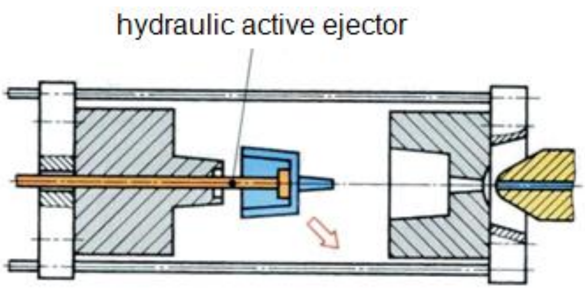


Figure 25: Ejection of the part [18]

[18] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, pp 121-128

2.3 Basics of Mould Design and Construction

2.3.1 DIN / ISO Standard for Injection Mould Devices

There are standardised parts for the mould design and construction, because the devices are matched and so the costs for the mould will decrease. The standard parts are found in the DIN or ISO standard.

The mould making company could choose from ready assembled moulds out of standardized parts or select from the norm parts for its own mould. In the figure below you can see the most important standard parts, which are produced by companies like HASCO. At HASCO you could choose some different standard parts and then you could rework these parts so that they will fit for the assembly of your mould.

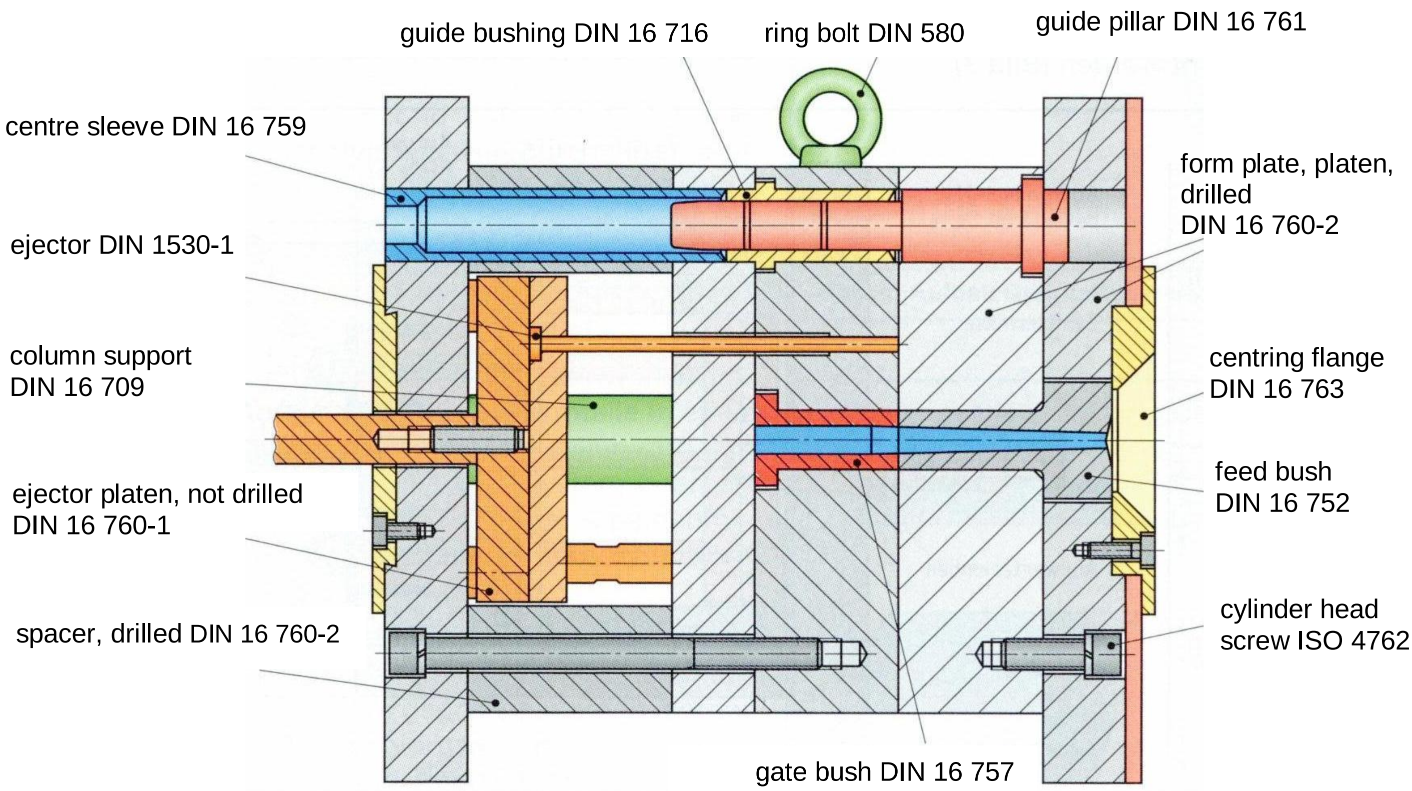


Figure 26: DIN / ISO norm for injection mould devices

2.3.2 Assembly of Injection Moulds

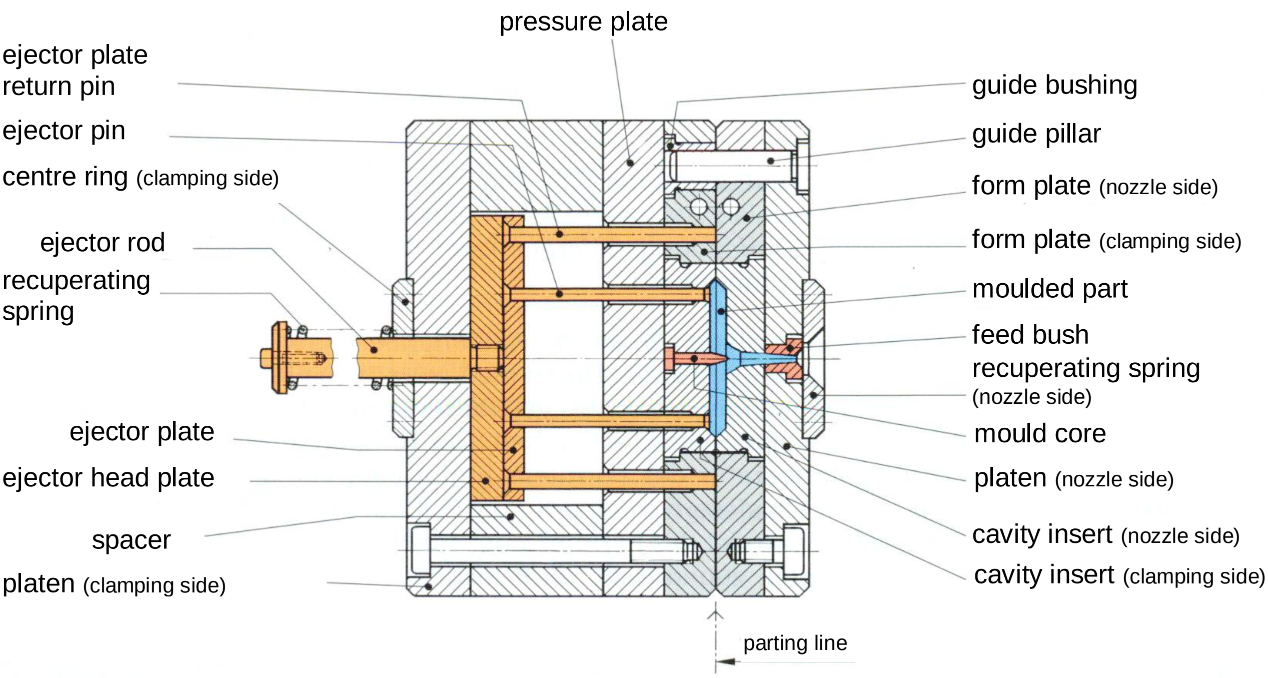


Figure 27: Assembly of injection mould

The multiplicity of injection moulding applications requires on some injection mould applications.

They subdivided according to:

- quantity of cavity inserts
- gating type
- quantity of parting lines
- ejection type

<table>
<tr><th colspan="8">Classification of injection moulds</th></tr>
<tr><td>differentiating factor</td><td colspan="7">mould type</td></tr>
<tr><td>quantity of cavity inserts</td><td colspan="3">single impression mould</td><td rowspan="2"></td><td colspan="3">multi cavity mould</td></tr>
<tr><td>gating type</td><td colspan="3">moulds with setting gates</td><td colspan="3">moulds without setting gates</td></tr>
<tr><td>quantity of parting lines</td><td colspan="2">2-way tool</td><td colspan="3">3-way tool</td><td colspan="2">level-tool</td></tr>
<tr><td>ejection type</td><td>standard- mould</td><td colspan="2">deflector-mould</td><td>slide-mould</td><td colspan="2">split-mould</td><td>screw-mould</td></tr>
</table>

Table 4: Classification of injection moulds

2.3.2.1 2-Way Tool

2-way tools have got a fixed and a moveable form plate. They are the most used standard moulds.

The mould consists of the form-, sandwich plate and platen. The spacer and ejector plate is at the moveable side of the mould. The moveable form plate is fixed with guide bushings, with the sandwich plate and spacer and the moveable platen. The fixed form plate and platen guides the other plates with a pillar guide. In the ejector plate fixes the ejector elements.

This mould will be used for moulded parts, which are easy to eject with ejector pins.

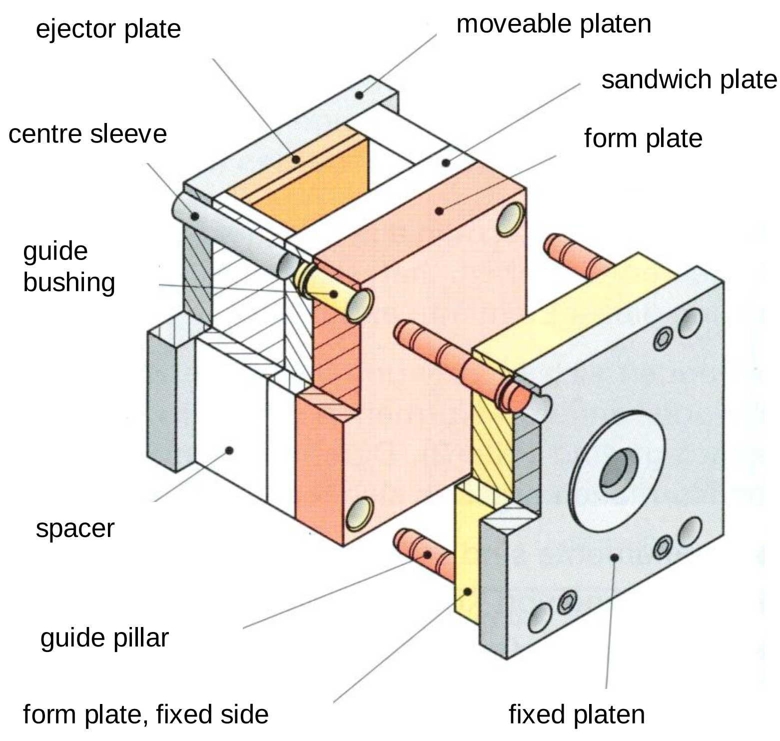


Figure 28: 2-Way Tool

2.3.2.2 3-Way Tool

The difference to the 2-way tool is that the 3-way tool has got three form plates.

The pro of this assembly is that the gates and moulded parts could be separated in the mould. This is possible due the gate plate. All three plates in the middle are able to move and so there are three parting lines. If there is ejection with ejector pins, than there is an ejector plate. Otherwise there is a handling system, like a removal robot.

This mould will be used for moulded parts, which are injected in the middle and will be produced without hot a runner system in cause of the higher costs. Another point could be the separation of the moulded part with the gate.

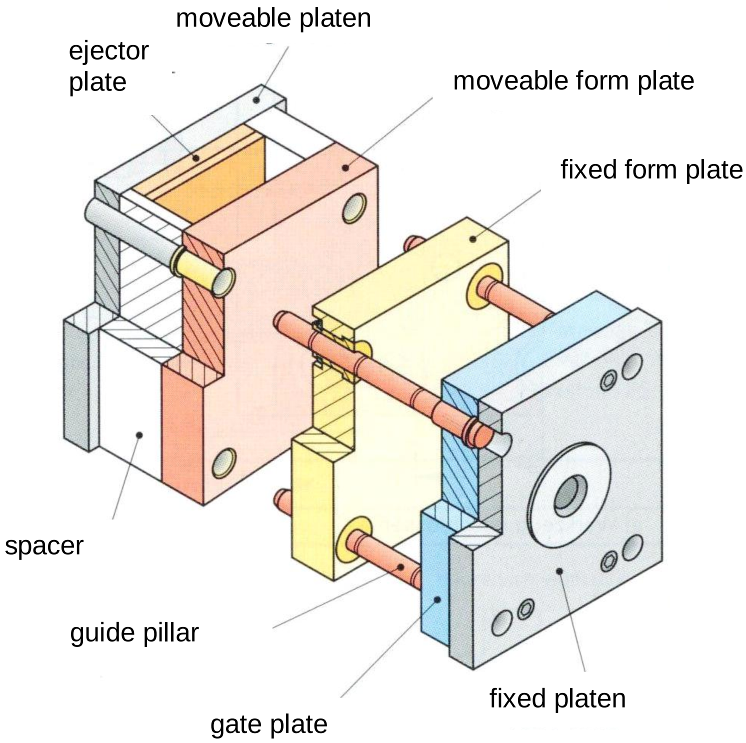


Figure 29: 3-Way Tool

For more complex moulded parts like parts with rotating undercuts a split mould will be used, but this would be exceed the field of this diploma. [19]

2.3.3 Gating System

The gating system has to transport the plastic melt from the nozzle to the cavity insert. Sometimes there are more inserts and so there is a complex gating system. And so the design, the measurements and the gate into the moulded part affect the injection process and the quality of the part.

For a multi cavity mould the gating system normally consists of:

- sprue
- runners
- gate land

[19] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, p 132

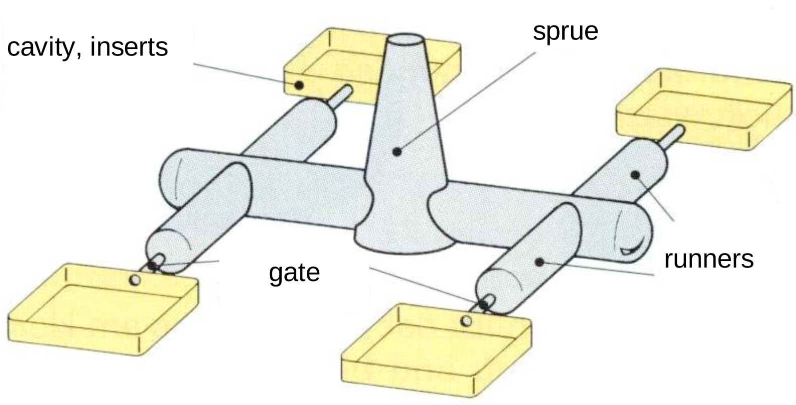


Figure 30: Gating system

The sprue takes the ductile compound from the injection nozzle. For single-cavity moulds the sprue is the whole gating system. This gating system is called sprue gate.

In the multi cavity mould the sprue transports the compound into the runner and the runners transport the compound through the gate into the cavity insert.

Gate type:

1. gates, which stick to the moulded part and have to edit after ejection
2. gates, which are automatically disconnected and have to be remoulded separately
3. gates, which are fluid haven't to eject [20]

Gate Type	
1.	sprue gate, film gate, fan gate, ring gate
2.	tunnel gate, seperation pin-point gate
3.	pin-point gate, antechamber pin-point gate, non gate injection, hot runner distributor

Table 5: Gate type

[20] Menges / Michaeli / Mohren, Spritzgießwerkzeuge, Verlag Hanser, pp 109-113

Sprue gate:

The sprue gate is the easiest and oldest ingate design. The profile is round and connects at its biggest profile. This gate design should always be in the area of the highest section thickness of the moulded part that so the holding pressure can act during the whole cooling time. So there are no volume contractions and bubbles. The sprue gate is often used for rotation-symmetric parts and shouldn’t be at visible surfaces. The con of this gate is the rework after ejection, because the ingate has to be machined off by turning.

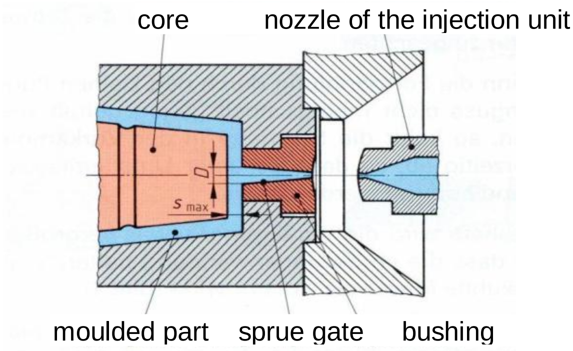


Figure 31: Sprue gate

Antechamber pin-point gate:

During the ejection of the moulded part the antechamber pin-point gate disconnects automatically, so there is no rework necessary and there is no nuisance machining surface. Another pro is the antechamber, because due to it the runners need not to be ejected. If the hole is too small, then the compound freezes in the antechamber and must be taken out. This problem is solved with a bigger antechamber and so the compound at the inner wall of the antechamber acts as an isolator. But the core of the antechamber remains ductile.

Short work cycle times are necessary for a smooth run of this system. Another possibility is to heat the antechamber to keep compound always ductile.

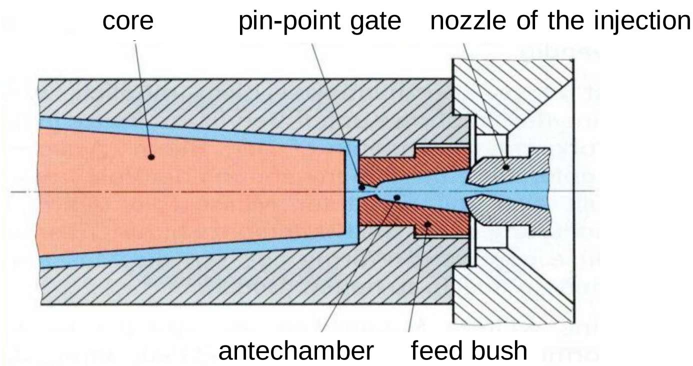


Figure 32: Antechamber pin-point gate

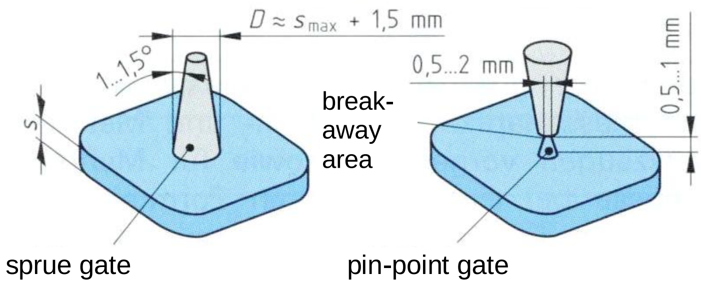


Figure 33: Comparison of a sprue gate and a pin-point gate

Tunnel gate:

The moulded part will be injected laterally, at hidden surfaces or on other smooth points and automatically disconnect from the gating system by the ejection. The disconnecting of the moulded part is possible, because of the cutting edge. But this means that the compound is viscoplastic or during the ejection more or less frozen. Only then the system runs fault-free. Another problem is the high pressure loss and so this gating system is used for small and simple parts in multi cavity moulds. [21]

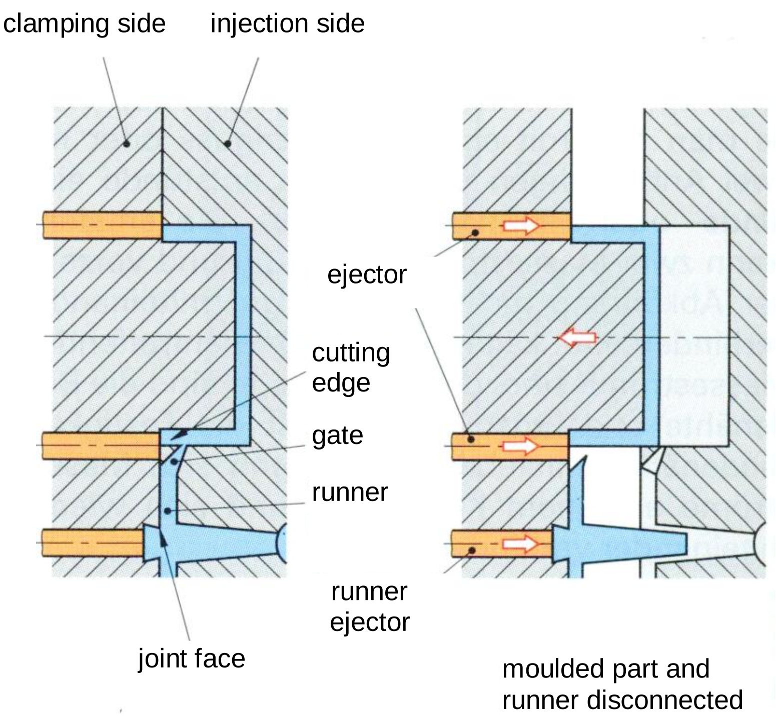


Figure 34: Tunnel gate

[21] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, pp 133-136
Menges / Michaeli / Mohren, Spritzgießwerkzeuge, Verlag Hanser, pp 176-185

Feed bush:

The injection of the compound occurs through the feed bush on the mould side and the nozzle on the side of the injection cylinder. This connection should be tight. This requirement on this connection will be reached by high mechanical stress and abrasion.

Requirements for the feed bush:

- abrasion resistance, that means harden steel
- bending fatigue strength
- the drilling of the nozzle should be 1,5 mm smaller than the drilling of the feed bush

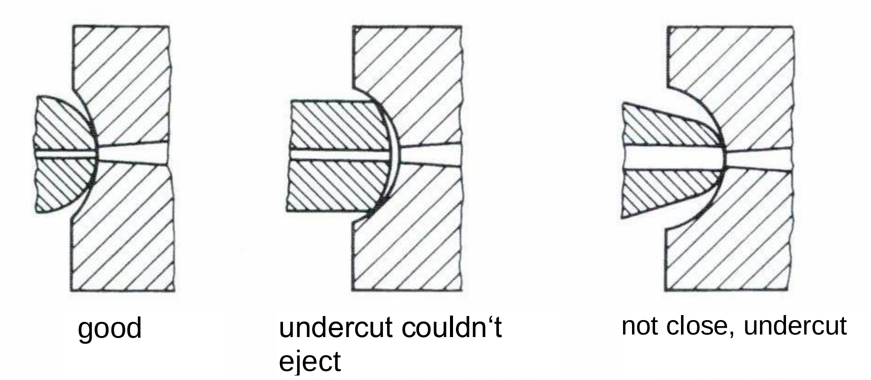


Figure 35: Contact area of nozzle and feed bush

After the feed bush the runner is located. There are three different runner systems:

- normal runner
- hot runner
- cold runner

Normal runner:

These gate runners are in the mould platen and provide the mould parting surface. This runner has got the same temperature like as mould. This means that the runner freezes and has to be ejected in every work cycle. If you work with thermoplastics, the material would be recycled and used as re-granulate.

Hot runner:

These gate runners are in a separate block, which includes the feed bush, the gate runner, the gate and the nozzle.

The temperatures of this block are in the melting range of thermoplastics and so the compound in this block is always ductile. The contact surfaces have to insulate the heat flow from the hot runner area to the injection mould. This means that the contact surfaces are small, a little air gap for insulation and a reflector plate is necessary.

They hot runners are subdivided into outside or inside heating elements.

The pros of hot runner:

- no losing of compound and so less energy- and workinput
- full automatical handling is easier
- better quality of the moulded parts, because the melting is injected into the part at the ideal area
- a high injection- and holding pressure is possible

The cons of hot runner:

- high costs of energy and injection mould
- problem of disruption of compounds with a low thermal consistency
- the breakup of the hot runner and the mould areas around the hot runner is problematic
- compound and colour changes are difficult [22]

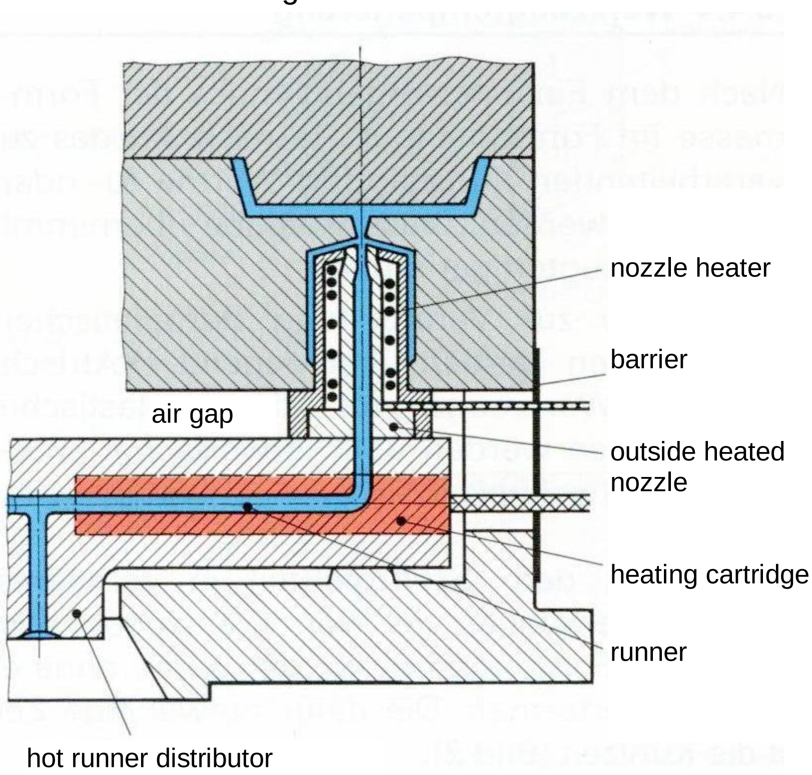


Figure 36: Hot runner mould

[22] Menges / Michaeli / Mohren, Spritzgießwerkzeuge, Verlag Hanser, pp 110-118

Outside heating elements:

Outside heating elements bring the energy from outside into the runner, they are placed around the runner.

Inside heating elements:

Inside heating elements need less energy than outside heating elements, because around the heating element is the isolating plastic melting. This means that a heating element is within the runner.

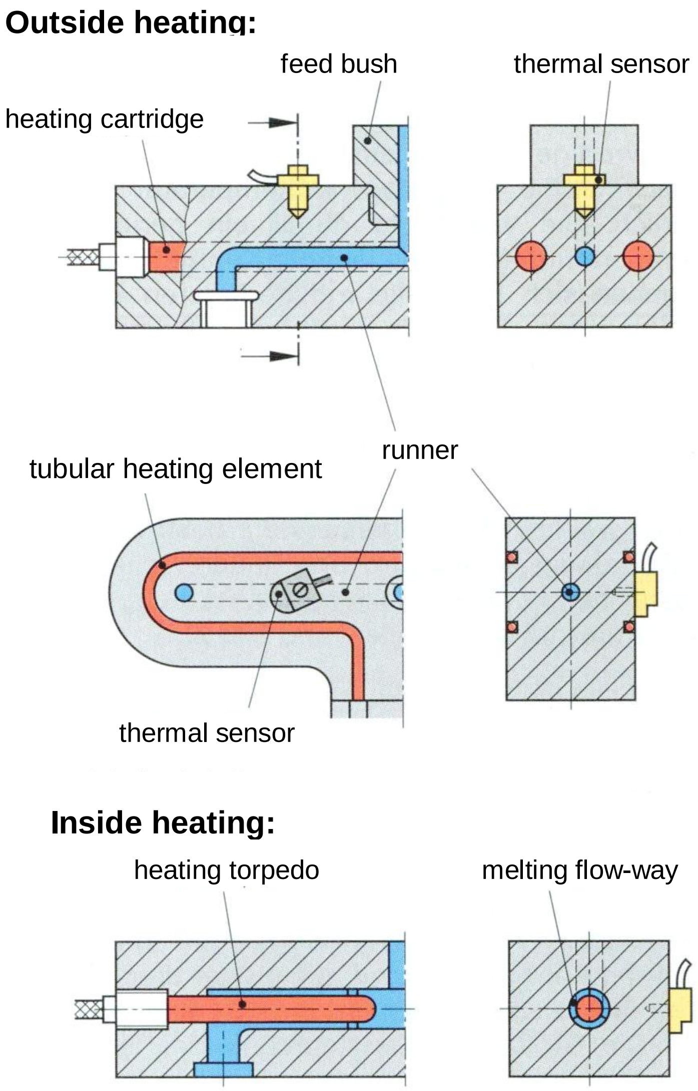


Figure 37: Heating elements

Cold runner:

Analogous to the hot runner for thermoplastics are used the cold runner is used for reacting melts, for example thermosets. The temperature in the cold runner is between 80°C and 120°C. And so the compound doesn't react in the runner.

A problem could be the pressure in the cold runners and the construction costs. Another problem for the viscosity is the temperature difference and so the different viscosity affects the filling of the cavity. [23]

Design of the runner:

Runners connect the sprue across the gate and the cavity with the injection nozzle. The task of the runner is to fill all cavities with the same pressure, at the same time with the same compound.

The cycle begins with the injection of the compound across the nozzle into the runners with high speed. Then the heat dissipation from outer runner wall lets the melting freezes in this area and so the runner becomes a "ductile bore". In this "ductile bore" the melting is hot and could flow into the cavity. After the filling of the cavity the holding pressure acts. The holding pressure is important for the compensation of the shrinkage.

The optimal runner diameter depends on one hand on the compensation task and on the other hand on the economical usage of material. That means if the part is big, then the profile of the runner has to be bigger. A hand rule means that a 1 mm runner is for a part with 1 mm thickness. A big runner profile also affects the filling of the cavity positively, because the flow stress is smaller.

Parameters for gating systems	
part capacity section thickness compound flow resistance surface capacity	loss of heat friction loss cooling time cull volume manufacturing costs mould design

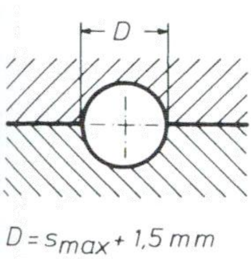
Table 6: Parameters for gating systems

[23] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, p 139
Menges / Michaeli / Mohren, Spritzgießwerkzeuge, Verlag Hanser, pp 110-111

Tasks of the ingates and the runners:

1. injection of the compound
2. in the whole gating system should be the same temperature and same pressure
3. small profile of the runner, but with a good form filling quality
4. proportion of surface to volume should be as small as possible

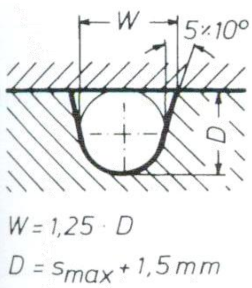
round channel



pros: least surface based on the profile, least cooling, least loss of heat and friction loss, late melting freeze and so a good holding pressure effect

cons: same parts in every mould half and so not so easy to produce and expensive

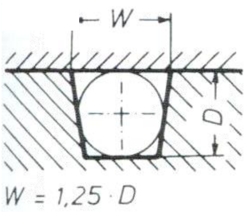
parabolic arc channel



pros: good approach to the round channel, easier to produce, only in one mould half (in the ejection side, because of the ejection
application when slider used relativ to the joint face

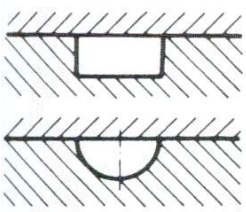
cons: more loss of heat and more cull than in the round channel

trapezoidal channel



alternative solution to the parabolic arc channel

cons: more loss of heat and more cull compared to the parabolic arc channel



bad profiles should be avoided

Figure 39: Design of the runner

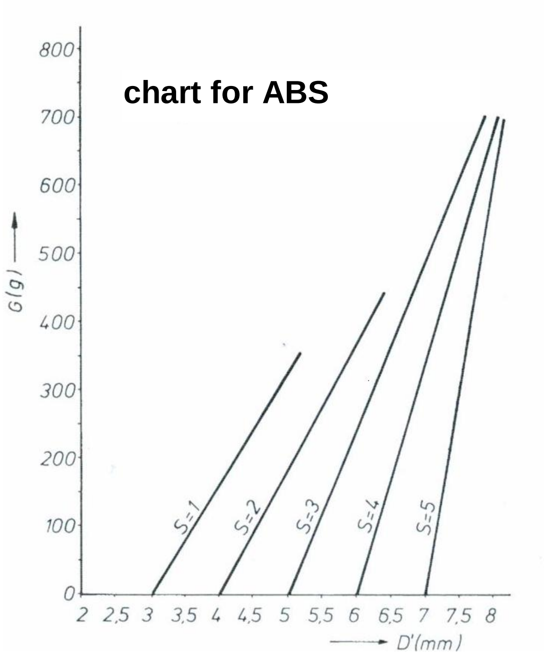


Chart 1: Runner diameter for ABS

Terms:

S: section thickness
D‘: gate diameter
G: weight of the moulded part, depending on a gate in g
L: gate length, depending on the moulded part from the gate distributor to the cavity insert
L_F: coefficient of the gate length

Proceedings:

1. determine G and S
2. determine D‘ in reference of the weigth G
3. determine L
4. determine L_F from Chart 3
5. D=D‘ * L_F

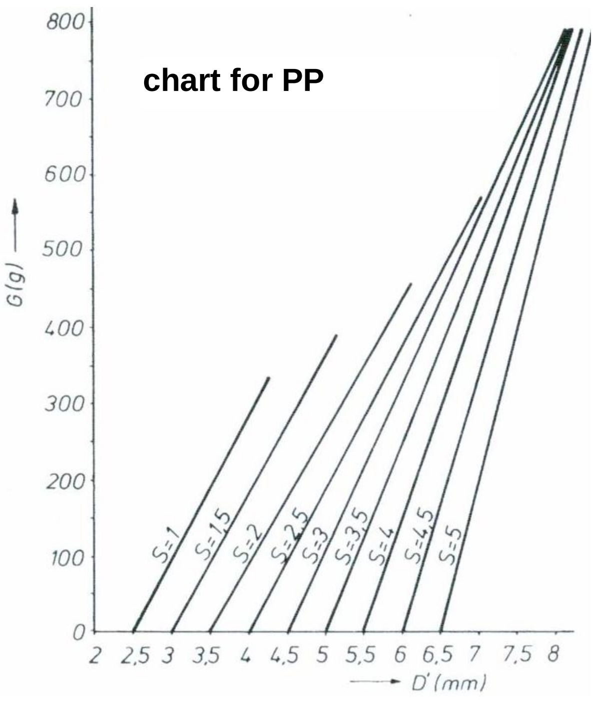


Chart 2: Runner diameter for PP

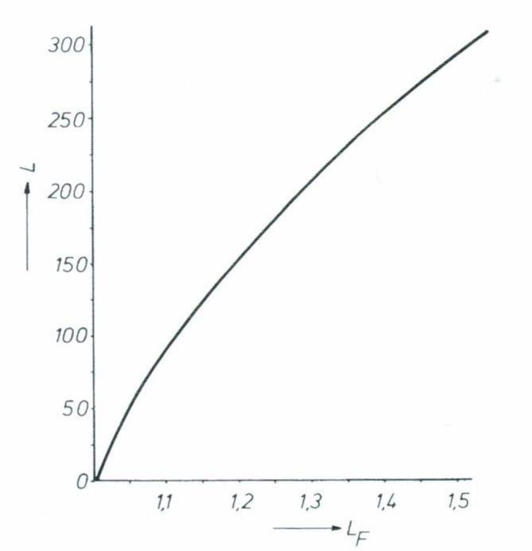
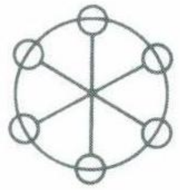


Chart 3: Coefficient of the gate length

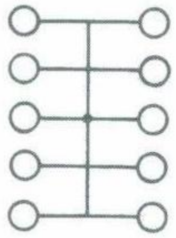
stars allocation



pros: same flow distance to every cavity insert
convenient placing for ejection, especially for work gear spindle

cons: quantity of cavity inserts is limited

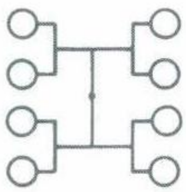
bank allocation



pros: more cavity inserts possible than by stars allocation

cons: unequal flow distances for the cavity inserts
equal form filling only with different channel profiles possible (simulation programms)

symmetry allocation



pros: equal flow distances for the cavity inserts, no gate correction possible

cons: high gate capacity, some cull, fast compound cooling

corrective:
hot runner or insulating runner

Figure 40: Gating system allocation

Before the description from the design of the ingate you should know the material behaviour and orientation during the process in the flow.

The plasticized compound should be injected as fast as possible into the cavity insert. The cause for this requirement is that the pressure and temperature are equal in all areas of the mould. In an ideal case there is a constant structure of the material, a uniform shrinkage behavior and consequently no strains in the moulded part.

With a convenient layout of the influencing variables:

- machine pressure and temperature
- tool pressure and temperature
- attention to the mould instructions

it is possible to achieve optimal injection moulded parts. [24]

[24] Menges / Michaeli / Mohren, Spritzgießwerkzeuge, Verlag Hanser, pp 112-129

Before the injection the molecular orientation of the plastic melting is amorphous and so there are uniform properties everywhere.

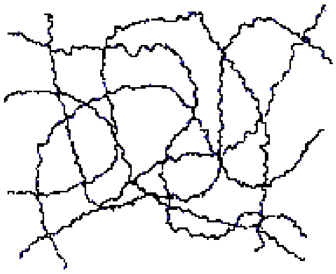
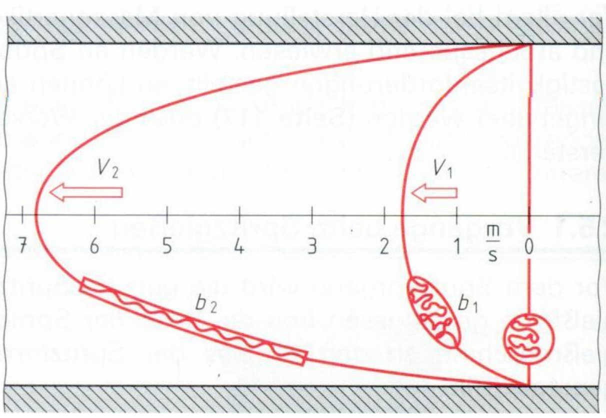


Figure 41: Amorphous molecular orientation [25]

During the injection and the flow of the plastic melting the molecular orientation is changing, because the threadlike molecule will reeve and be stretched in longitudinal direction. The cause for this is the faster material flow in the middle of the mould, generated by the faster cooling of the plastic melting at the border area of the mould. In the middle of the cavity the temperature of the melting is higher and so there is crystalline molecular orientation. At the border area of the mould the molecular orientation is amorphous and this is the cause for a higher shrinkage of the orientation direction than perpendicular. This behavior affects the strains of the moulded parts.



V=0	amorphous situation	b1	low orientation
V1	slow flow speed	b2	high orientation
V2	high flow speed		

Figure 42: Molecular orientation in the flow

[25] www.haha-halbzeughandel.de/Info/Kunststoffe.html Stand 04.01.2010

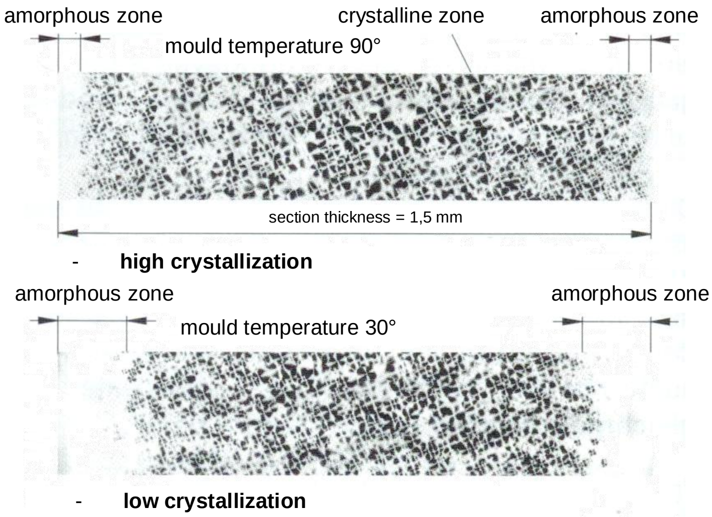


Figure 43: Crystallization in moulded parts

It is possible to treat moulded parts at high temperature (e.g. 140 °C) and assist the after crystallization. This is called tempering.

In the figure below you can see the flowability of the plastic melting when it reaches the cavity insert. In the first figure you can see a constant flow front, which is desired. At first the melting freezes at the wall and this cause insulation and so the melting in the middle remains ductile.

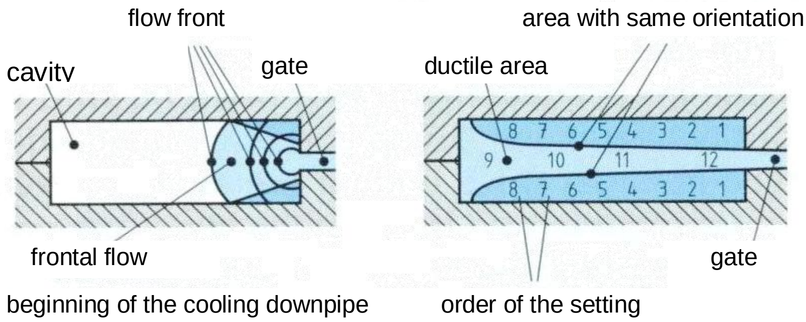


Figure 44: Flow front and cooling downpipe

If the flow front burst, then there is a leading leg or also called “spaghetti”. This is unrequested, because this causes weak spots in the moulded part. In the figure below you can see a leading leg.

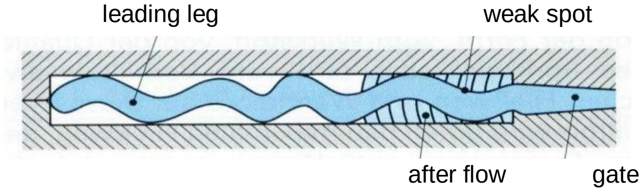


Figure 45: Inappropriate flow characteristics [26]

[26] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, pp 122-124

Design of the ingate:

The gate connects the runner with the injection moulded part. Normally the gate has got the smallest profile in the gating system.

The gates are smaller than the runner. The reason is:

- to disconnect the parts easily from the gating system
- to save the part from the development of flash, which is in the runner
- before filling the cavity the material is sheared and heats the compound
- to change and balance the gating system with further conditioning

Parameters for the ingate	
moulded part	geometrical design section thickness course of demands quality requirements $\frac{\text{flow distance}}{\text{section thickness}} < \alpha$
plastic melting	viscosity temperature flowability fillers shrinkage behaviour
general	distortion joint line release properties separation of the part manufacturing costs

Table 7: Parameters for the ingate

There are three design possibilities for ingates, the pin-point ingate, film ingate and a ribbon ingate. Another possibility is the sprue ingate. The ingate is the smallest profile in the gating system and so during the flow through the ingate there is a resistance. The cause of this is that injection pressure will decrease and the plastic melting temperature will increase markedly.

The requested effects:

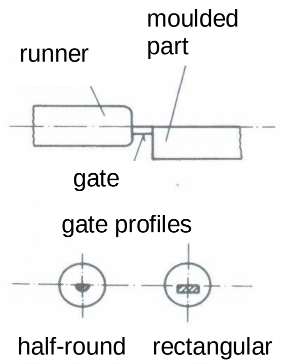
- the plastic melting get a low viscosity and so there is a high form filling rate
- the mould around the ingate gets warmer and so the holding pressure could act longer

The problem of too small ingate profiles are:

- burning of the plastic melting
- too high injection pressure loss

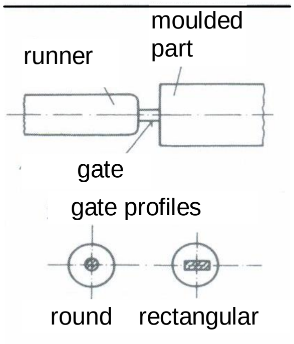
Practically the ingates will be produced smaller than in the construction. After the first injection running and a too small form filling rate the ingates will be re-worked. This balanced the gating system. This means that every cavity will be filled with the same time.

Ingates should have a half-round or a rectangular profile. The best ingate is the rectangular, but the half-round ingate is easier to disconnect from the moulded part.



eccentric ingate

- easy to produce
- easier to eject and to disconnect
- no free jet development



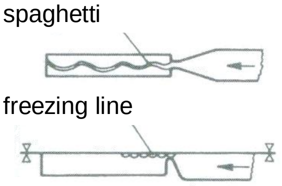
centric ingate

- for low energy- and friction loss a small surface is desired
- round channel is the best solution for this requirement
- difficult production, because of manu-facturing of both mould halfs
- difficult disconnection of the moulded part
- maybe free jet development

Figure 46: Gate profile

You can see the connection to the runner in the figure above, but the problem of this design is that a film, which is developed at the runner barrier, gets into the cavity. This is called platter effect.

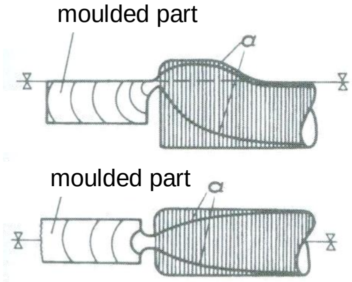
This can be avoided by a design of the “ingate with a bean”. You can see it in the figure below. With this design the plastic melting swells into the cavity.



inconvenient ingates

If the ingates are at the right position there wouldn't be a free jet, like a spaghetti

If the ingate is in one mould half, there would be problems with a cold bodyshell, like a freezing line.



convenient ingates

An ingate with a bean achieves the ductile bore.

Radiuses at the changeover between runner and ingate addict laminary stream and so free jet will be avoided.

Better flow ratio with roundings at the changeover, but this cause a difficult disconnection of the moulded part.

Figure 47: Guidelines for the ingate design

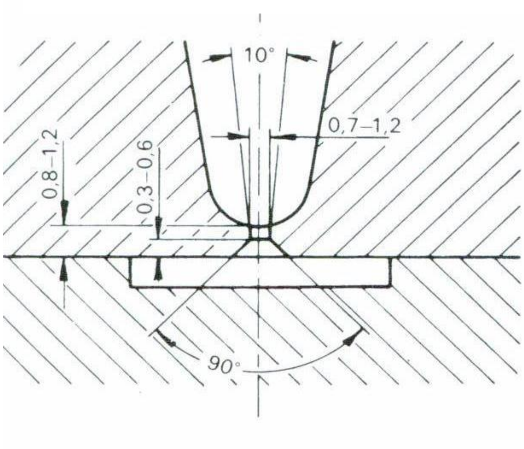


Figure 48: Recommended dimensions for pin-point gates

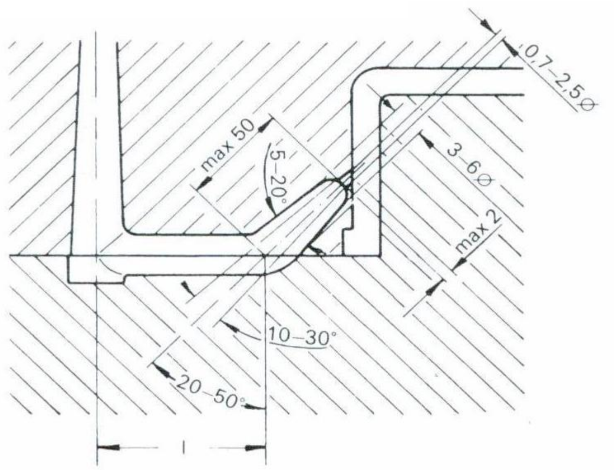


Figure 49: Recommended dimensions for tunnel gates

Location of the ingate at the moulded part:

The position of the ingate must be at the biggest profile of the moulded part, because there is the longest cooling time and so the holding pressure is able to act. If the ingate is at a smaller profile the cooling of the melting is too fast and the injection pressure cannot act and so there are bubbles and a low form filling rate.

The position of the ingate affects the flow course and so the properties of the plastic melting. It also affects the mechanical properties and quality of the moulded part.

The best values of tensile strength and impact strength are in the flow course. At the perpendicular course the stress crack sensitivity is higher and the toughness is smaller.

Here you can see the flow path of different ingate positions:

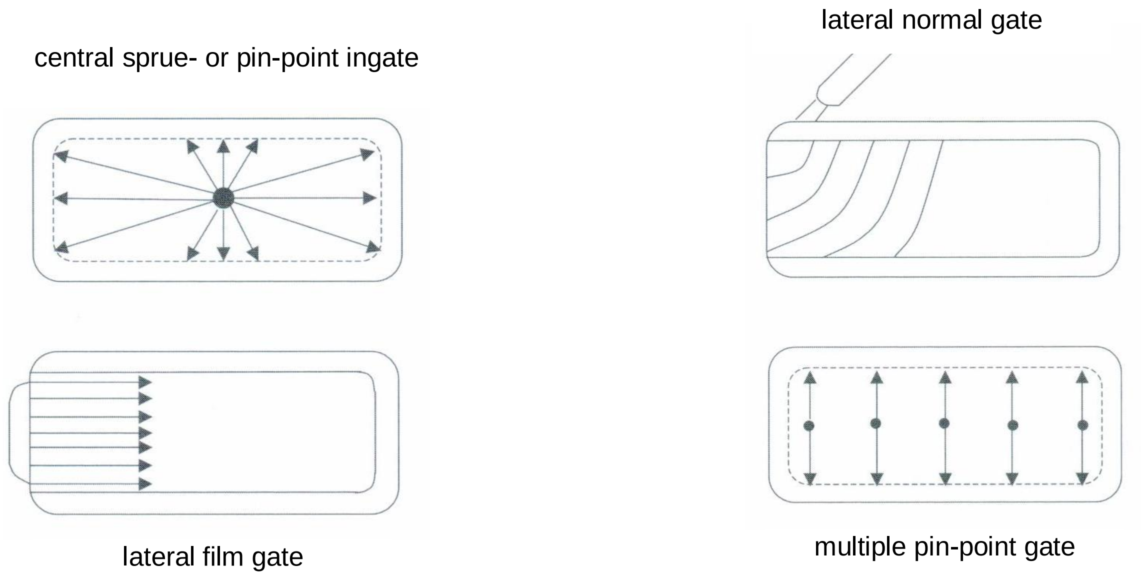


Figure 50: Flow path in moulded parts

In modern injection moulding technology the simulation with computer programs of the form filling was developed.

This helps to simulate the injection moulding process before the mould production and so it is easier and cheaper to construct the mould.

The figure below shows a comparison of a theoretical support-picture and a practical test. This will be reached with different adjustments at the injection moulding machine (injection time, compound bulk, holding pressure, …)

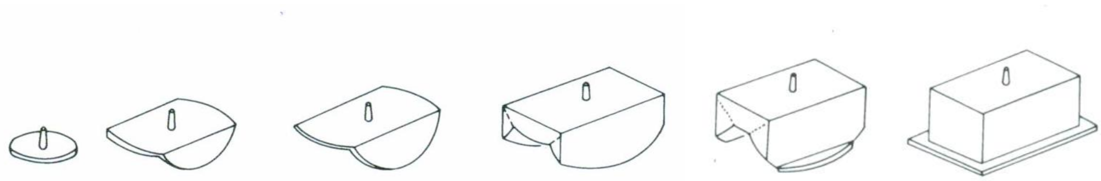
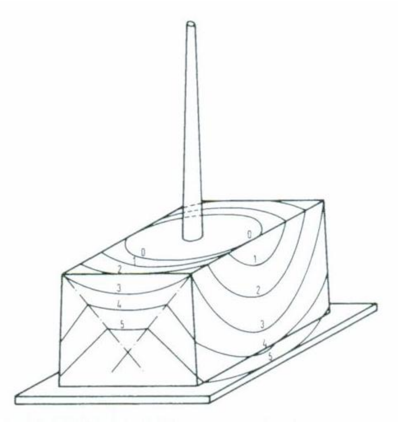


Figure 51: Practical test



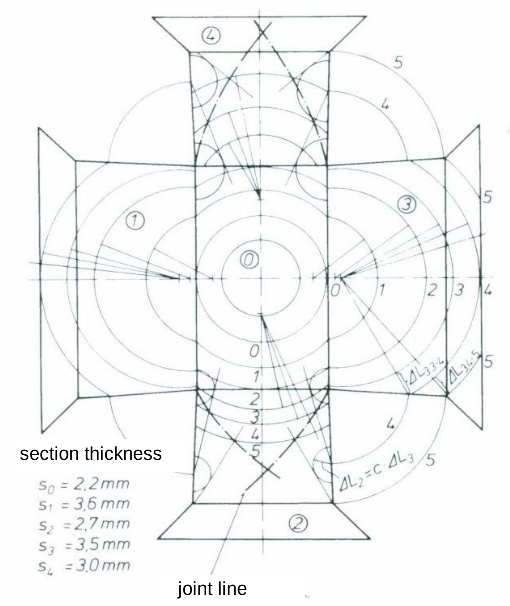


Figure 52: Theoretical support test - simulation

With this theoretical simulation the joint lines and air pockets are able to be identified. Than the injection moulding die construction can be changed and adjusted.

2.3.4 Bleeding

During the injection moulding process and the form filling the mould should be tight. This means that the important areas of the mould are the parting lines at the ejectors, pushers and between the mould halfs. But then there is problem with the form filling because inside the mould there is air which should be removed.

During the injection the air be compressed and the temperature will increase markedly. That causes burnings at the moulded parts and maybe at the mould.

There are two possibilities for bleeding of injection moulds:

- Passive bleeding:

  This bleeding is for simple moulds and a ideal ingate position. The air escape across the parting lines only by the injection pressure. A possibility is to make a further surface finish of the parting areas, for example a rough surface.

- Active bleeding:

  There is a man-made drop of pressure for the bleeding. The pressure drop will be reached by a vacuum construction. The active bleeding is used for plastics with low viscosity. For example: thermosets and elastomeres

Result of deficient bleeding		
results for the moulded part	**results for the mould**	**results for the injection process and machine**
incomplete form filling deficient parts surfaces by textured surfaces air pockets overmoulding burning marks (diesel-effect) high rejections stability lowering	increased mould strain defects at the parting lines high maintenance costs edge-zone softening abrasion corrosion film at the mould mould modifications	higher work cycle time higher pressure demand higher energy demand lower durability higher loss of use irregular process cycle

Table 8: Results of deficient bleeding [27]

2.3.5 Mould Temperature Control

Cooling-down

The cooling of the melting is affected by the temperature of the mould. But the temperature of the mould is adjusted to the type of plastic and it's requirements plus the section thickness of the moulded part.

The cooling time for simple and not ambitious parts are short and the ejection temperature is high. For moulded parts with a short cooling time the shrinkage and distortion is higher than for parts produced with a longer cooling time. A longer cooling time is for parts with high requirements and demands.

If the section thickness is greater and there are more material accumulations in the moulded part, then the cooling time is higher. [28]

Cooling time

The cooling time starts with the filling cycle and ends with the ejection. The cooling time depends on the conductibility of temperature of the plastic material and could be calculated with the result that the cooling time is proportional to the square of the section thickness. [29]

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[27] Menges / Michaeli / Mohren, Spritzgießwerkzeuge, Verlag Hanser, pp 112-129

[28] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, pp 122-125

[29] Johannaber / Michaeli, Handbuch Spritzgießen, Verlag Hanser, p 166

Here are charts for two different plastics:

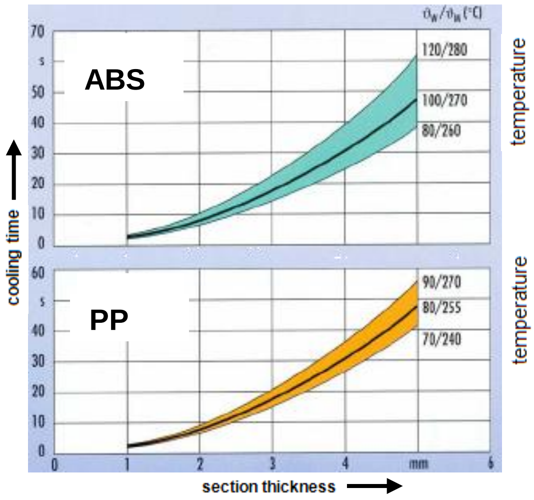


Figure 53: Cooling time - section thickness chart

The cooling time – section thickness charts are supplied by the plastic producer.

After the injection the compound have to cool down or to heat and this is the work of the mould temperature control. Mould for thermosets are electrically heated and moulds for thermoplastics are cooled down with water or oil. [30]

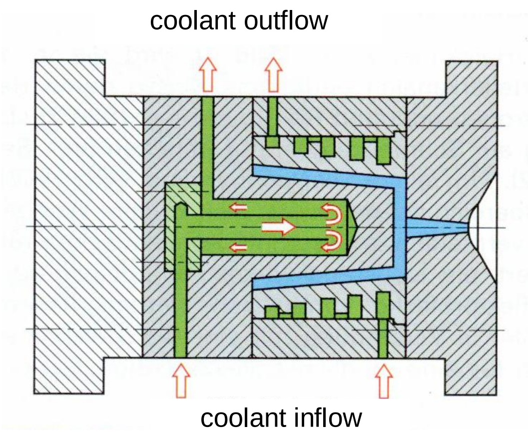


Figure 54: Mould temperature control

The mould temperature control abstract temperature in a short time and so the moulded part is able to eject without deformation. This time is called the cooling time.

30 www.mb.hs-wismar.de/~hansmann/downloads/komplexpraktikum%20Spritzguss/TEIL_1.pdf Stand 05.02.2010

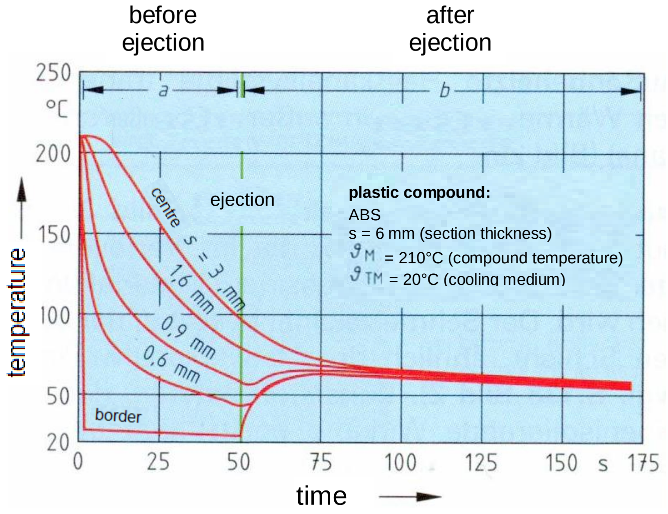


Figure 55: Temperature profile in the injection moulding die

The temperature for the cooling medium for thermoplastics is between 30°C – 130°C and the compound temperature is much higher. The quality of the moulded part depends on the cooling time. Important for a high quality of the moulded parts is the mould wall temperature, because it affects the length of the cooling time and so the residual stress.

The ideal profile for the cooling channel is a rectangle, because the surface is bigger than that of a circle profile and so the cooling effect is better. But there are problems with the resistance, the manufacturing costs and the tightness. And so normally the circle profile is used for cooling channels. The diameter depends on the section thickness of the moulded part. For fast cooling the channels are near to the cavity inserts, but the distance between the channels are smaller and the distance to the cavity insert higher so the cooling is constant.

Cooling channel diameter	
section thickness for the moulded part [mm]	diameter d [mm]
2	8 - 10
4	10 - 12
6	12 - 15

Table 9: Cooling channel diameter

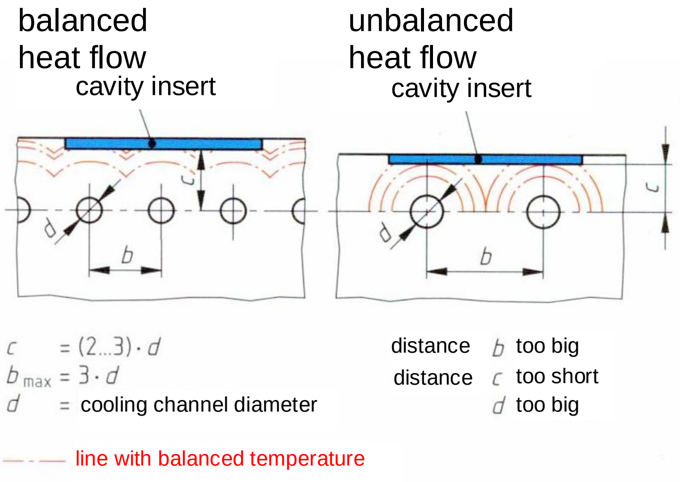


Figure 56: Distance of cooling channels

Serial cooling circuit:

The cooling medium often runs across the hot moulded part and takes up heat. It is possible to make several cooling circuits, because of too long cooling channels.

Parallel cooling circuit:

The cooling is balanced and all channels should have the same flow resistance, because otherwise the channels will get clogged, because of corrosion and other scaling.

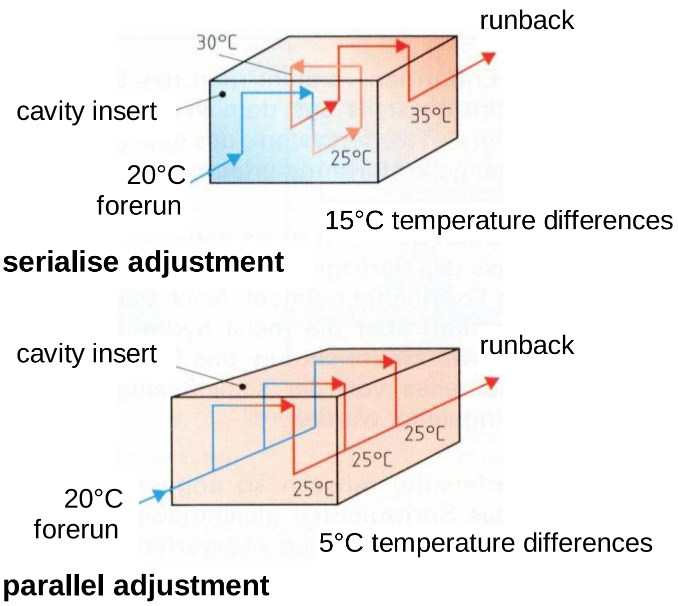


Figure 57: Cooling circuit

Closed cooling circuits are better than open cooling circuits, because at open circuits can come new fouling into the circuit.

The cooling medium should have its lowest temperature at the area with the highest compound temperature. Water is used till 120°C compound temperature and then oil is used. The cooling can be controled with temper devices.

Figure 58 Temper device [31]

2.3.6 Ejection System

After the cooling, freezing of the moulded part and the opening of the mould the part have to be ejected, because normally they don't separate automatically from the cavity. This is provided by an ejector system, which is self acting. Therefore the moulded part has to be placed in the moveable form plate at the clamping side of the mould. This will be realized by undercuts, shrink fitting or with a rough surface of the moveable form plate.

Normally the ejector system is coupled with the opening of the mould, because it is a mechanical system, which is operated with the open pass. So the ejector system slides to the parting line and so the part will be ejected across the ejector pins. If the ejection forces, which are generated from the mechanical opening pass, are too small, than there is the possibility of a hydraulic or pneumatic acting ejector system. The classification of the ejector system depends on the form of the ejector system:

- normal mould
- deflector mould
- slide mould
- split mould
- twist off mould
- separation mould

[31] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, pp 140-142

Another possibility is to take out the moulded parts with roboter arms. Therefore different vacuum or suction systems are useful.[32]

Normal ejector system:

This is a normal ejector system with ejector pins. The location of the ejector pins have to be designed that the ejection of the moulded part is constant. The front side of the ejector has to be adapted to the surface and form of the moulded part. The profile of the ejector shouldn't leave ejector marks on the part, because these marks are problems for the visible- and functional surface.

Another possibility is to use pressurised air, disk ejectors or ring ejectors, if the normal ejector pins are insufficient.

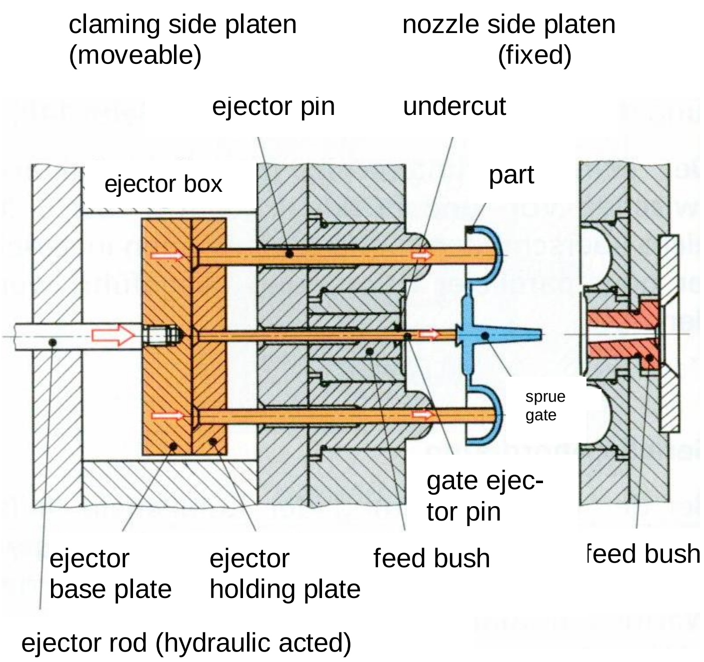


Figure 59: Ejector system

[32] Menges / Michaeli / Mohren, Spritzgießwerkzeuge, Verlag Hanser, pp 435-440

In the figure below you can see other ejector possibilities, if normal ejector pins aren’t suitable.

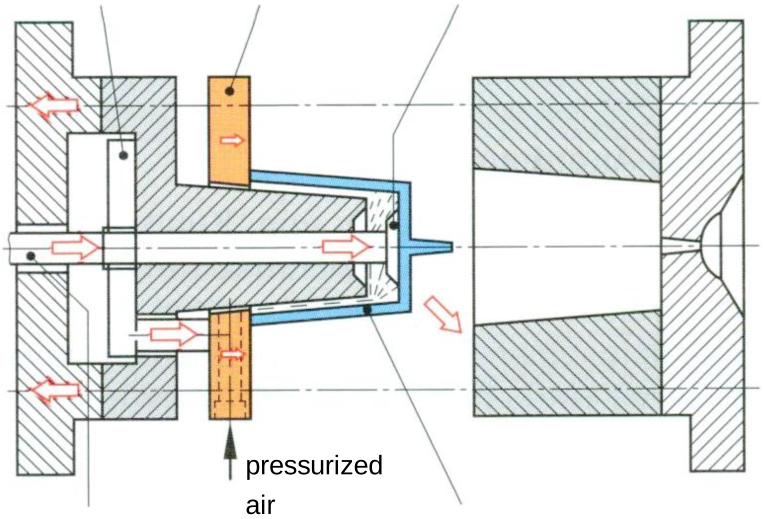


Figure 60: Other ejector elements

The ejection of undercuts is done with slide moulds or split moulds. But another possibility is to eject with the elastic forced demoulding. The requirements therefore are elasticity of the plastic material and a low notch effect or to eject with a higher temperature of the part.

For moulded parts with a screw thread the ejection is done with rotation of the moulded part (external screw thread) or rotation of the core (female screw thread) or with a folding core.

Ejector plates:

The ejector pins, ejector plates and the ejector bush are possible to purchase as standard parts.

The ejector holding plate contains the ejector pins and is moved by the ejector rod. The ejector base plate is bolted down with the ejector holding plate and supports the ejector pins.

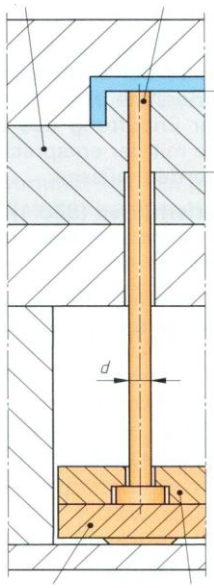
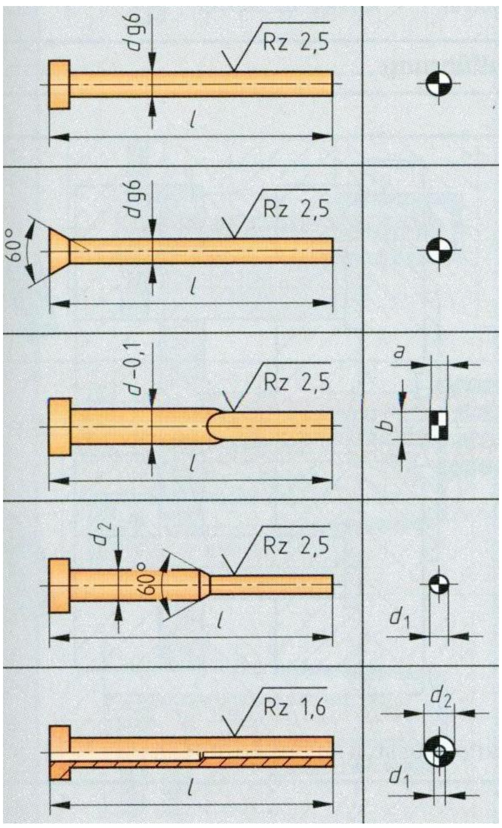


Figure 61: Ejector elements

The ejector pins are standardized in different forms. Normally ejector pins with cylinder heads are used and they are assembled with bottom clearance for balancing the eccentricity, which is caused by the heat strain between the form plate and ejector plate. The proportion between ejector pin and bushing length should be between 1 : 4 and 1 : 8. For small ejector marks, an offset ejector pin is used.

Ejector pin:

drawing **symbol** **application**



ejector pin with cylinder head, for large ejector-strengths and faces
d = 1,5 – 16 mm; l = till 315 mm

ejector pin with conical head, for small and middle high ejector- strengths and faces
d = 1,0 – 12 mm; l = till 200 mm

ejector pin with cylinder head and rectangular offset, for small ejector- strengths and faces
a : b = 1 : 3,8 – 2,5 : 15,5 mm; l = till 400 mm

ejector pin with cylinder head and piston offset, for small ejector marks and small ejector strengths
d_1 = 1 – 2,5 mm; d_2 = 4 – 6 mm; l = till 200 mm

ejector bush with cylinder head, for drillings with core pins
d_1 = 2 – 12 mm; d_2 = 4 – 16 mm; l = till 250 mm

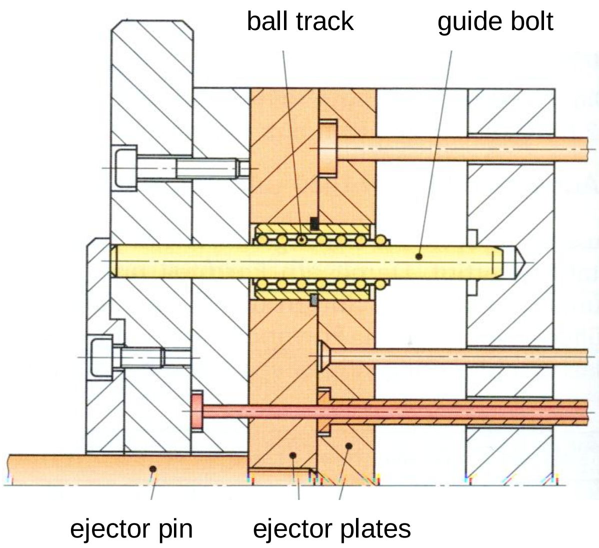
Figure 62: Ejector pin

The number of ejector pins and their diameter depends on to the ejector marks at the moulded part. The ejector location depends on the ejector strengths. The ejector pins often realize the bleeding of the cavity and so they are assembled with standard fits. During the ejection the ejector pins shouldn't be in the cavity, because this creates also ejector marks. The ready length of the pins is recently given at the assembly of the mould.

Ejector bushes are used for ejection of round moulded elements and for shoring core pins. By the closing of the mould the ejector plate return pin brings the ejector pins back into their end position.

The guidance elements should save the ejectors from cant. This is possible with guide bolts with ball tracks or with ball bushes. For small tilting strengths only a guide bush between the ejector plates for the ejector rod is necessary.

In the figure below you can see a ball track of the ejector system.



The ball track saves the ejectors from cant. This is realized with a guide bolt.

2.3.7 Centering and Guidance

The task of the guide unit is to save the mould halfs from backfill and to centering the mould plates. After each opening of the mould the mould halfs have to be in their defined position. Another requirement for the guide unit is the coplanar closing of the mould halfs. This is required for the leak tightness. These requirements will be achieved with a guide unit, like in the picture below.

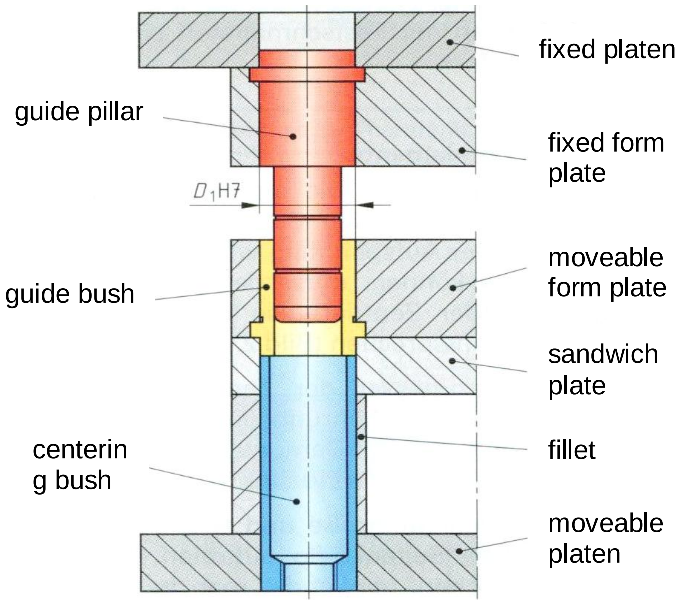


Figure 63: Guide unit [33]

2.3.8 Materials for Injection Moulds

Injection moulds are almost made from steel but they can also be made out of aluminium.

Tools, which should provide a high endurance, are out of steel. There is a wide range of steels which differ in their technological properties. Steels cover a big range of requirements and are cheaper than aluminium. Steels can be combined with other metals to have the reguired properties.

The most important characteristics for materials of injection moulds are:

- economic machining
- trouble-free heat treating
- durability and rigidity
- temperature and abrasion stability
- good heat conductivity
- corrosion resistance

Today these steels are offered consecutively for the production of cavity inserts:

- case-hardening steels
- nitride steels
- full-hardening steels
- tempered steels

[33] Roland Kilgus, Metalltechnik, Verlag Europa-Lehrmittel, pp 155-162

- cold work steel
- martensite hardening steels
- corrosion-resistant steels

Full-hardening steels:

The increase of the hardness is reached with martensite formation after the heating with a fast cooling down. The mechanical characteristics depend on the quenching medium and the rate off cooling down.

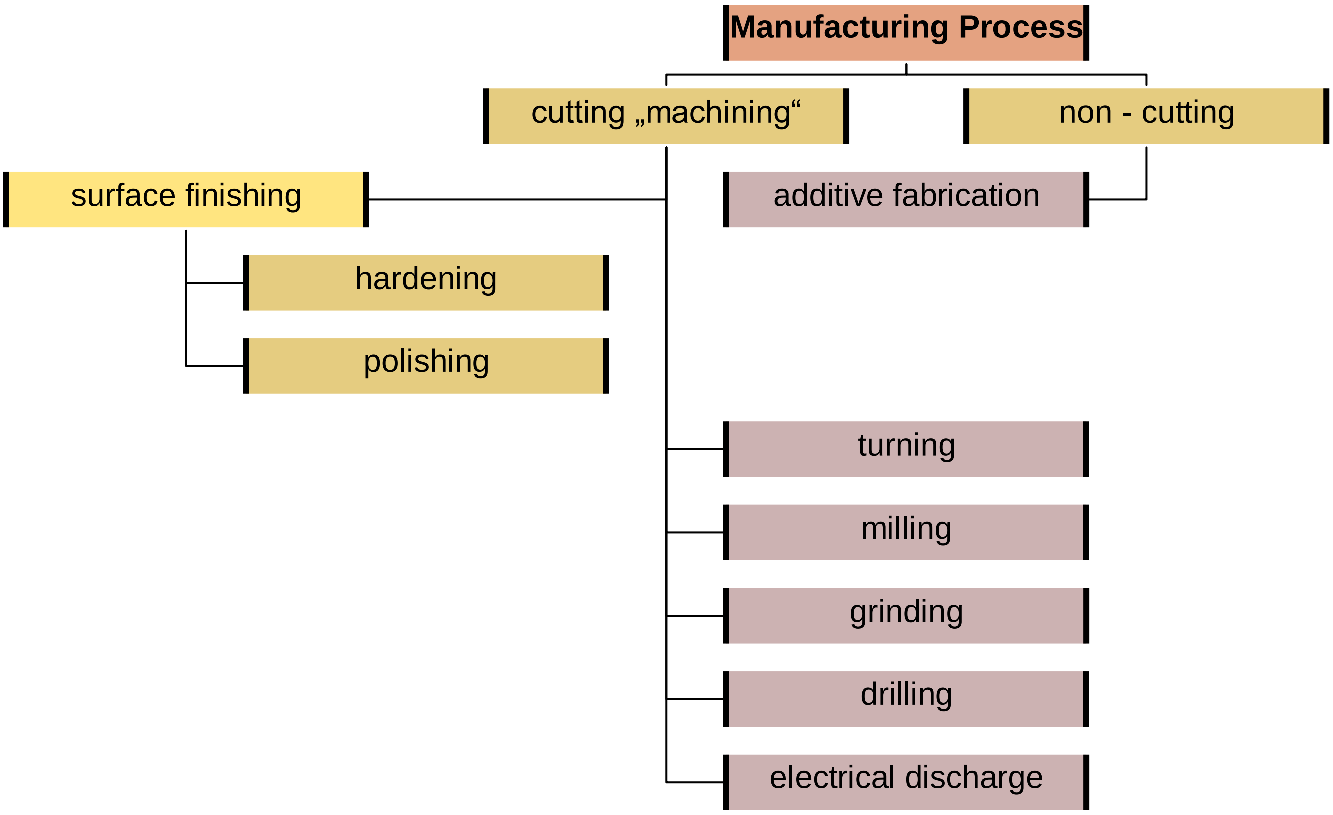
Cold work steel:

Is used if a core with a high toughness is desired, but also a high aggregate strength is needed.

It is a shock resisting steel exhibiting excellent toughness and wears resistance.

2.3.9 Manufacturing Process of Mould Making

The Manufacturing process can be subdivided into cutting, also called machining, and non-cutting processes.



Machining is a term used to describe a variety of material removal processes in which a cutting tool removes unwanted material from a work piece to produce the desired shape. The work piece is typically cut from a larger piece of stock,

which is available in a variety of standard shapes, such as flat sheets, solid bars, hollow tubes, and shaped beams. Machining can also be performed on an existing part, such as a casting or forging.

The decision which manufacturing process will be used dependents from factors like:

- time
- costs (tools, human resources)
- available machines

2.3.9.1 Electrical Discharge Machining (EDM)

After the hardening of inserts they get machined again. To make the cavity there will be used electrical discharge machining, also called EDM. There are many types of EDM. For the Leonardo Click – Cube we apply “Ram EDM”.

Operating mode of Ram EDM:

Ram EDM uses spark erosion to remove metal. Its power supply generates electrical impulses between the work piece and the electrode. A small gap between the electrode and the work piece allows a flow of dielectric fluid. When sufficient voltage is applied, the dielectric fluid ionizes and controlls sparks melting and vaporize the work piece.

The pressurized dielectric fluid cools the vaporized metal and removes the eroded material from the gap. A filter system cleans the suspended particles from the dielectric fluid. The fluid goes through a chiller to remove the generated heat from the spark erosion process. This chiller keeps the oil at a constant temperature, which aids in machining accuracy.

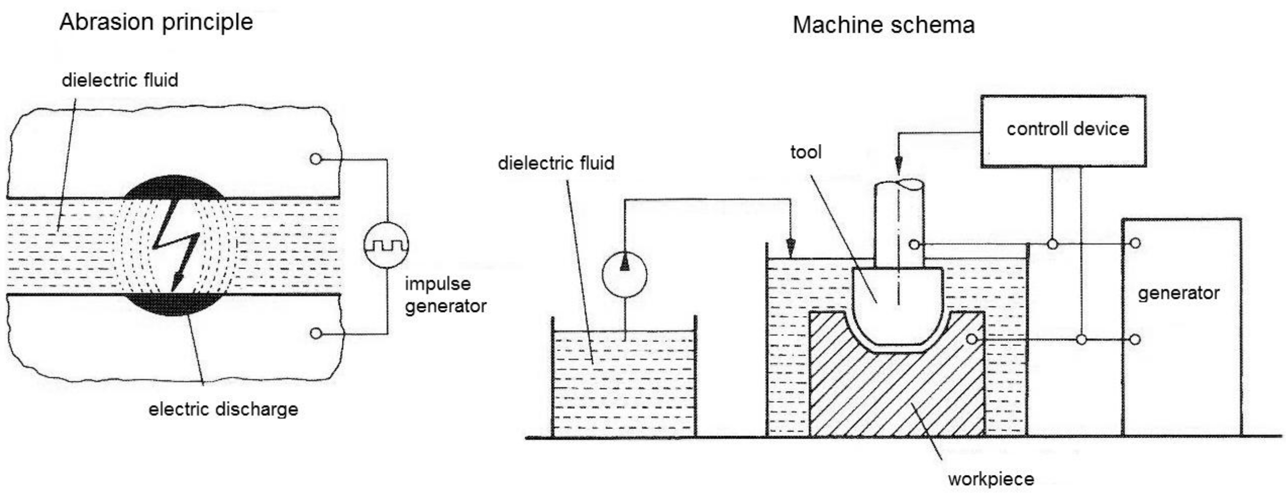


Figure 64: Ram EDM

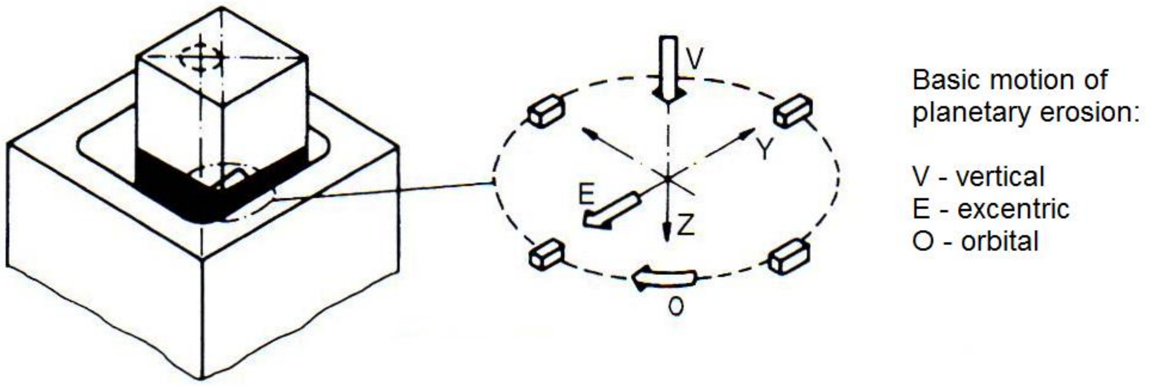


Figure 65: Planetary erosion [34]

2.3.9.2 Turning

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The work piece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds.

The cutter is typically a single-point cutting tool that is also secured in the machine, although some operations make use of multi-point tools. The cutting tool feeds into the rotating work piece and cuts away material in the form of small chips to create the desired shape.

Turning is used to produce rotational, typically axis-symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces [35]

2.3.9.3 Milling

Milling is the most common form of machining, a material removal process, which can create a variety of features on a part by cutting away the unwanted material. The work piece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to a platform inside the milling machine.

The cutter is a cutting tool with sharp teeth that is also secured in the milling machine and rotates at high speeds. By feeding the work piece into the rotating cutter, material is cut away from this work piece in the form of small chips to create the desired shape. [36]

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[34] Menges / Michaeli / Mohren, Spritzgießwerkzeuge, Verlag Hanser, pp 847-848
[35] http://www.custompartnet.com Stand: 12.03.2010
[36] http://www.custompartnet.com Stand: 12.03.2010

2.3.9.4 Drilling

Hole-making is a class of machining operations that are specifically used to cut a hole into a work piece.

Hole-making can be performed on a variety of machines, including general machining equipment such as CNC milling machines or CNC turning machines. Specialized equipment also exists for hole-making, such as drill presses or tapping machines. The work piece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to a platform inside the machine. The cutting tool is a cylindrical tool with sharp teeth that is secured inside a piece called a collet, which is then attached to the spindle, which rotates the tool at high speeds. [37]

2.3.9.5 Grinding

Grinding is a finishing process used to improve surface finish, abrade hard materials, and tighten the tolerance on flat and cylindrical surfaces by removing a small amount of material. Information in this section is organized according to the subcategory links in the menu bar to the left.

In grinding, an abrasive material rubs against the metal part and removes tiny pieces of material. The abrasive material is typically on the surface of a wheel or belt and abrades material in a way similar to sanding. On a microscopic scale, the chip formation in grinding is the same as that found in other machining processes. The abrasive action of grinding generates excessive heat so that flooding of the cutting area with fluid is necessary.

Reasons for grinding are:

- The material is too hard to be machined economically. (The material may have been hardened in order to produce a low-wear finish, such as that in a bearing raceway.)

- Tolerances required preclude machining. Grinding can produce flatness tolerances of less than ±0.0025 mm (±0.0001 in) on a 127 x 127 mm (5 x 5 in) steel surface if the surface is adequately supported.

- Machining removes excessive material. [38]

[37] http://www.custompartnet.com Stand 12.03.2010

[38] http://www.efunda.com/processes/machining/grind_flat_surface.cfm Stand: 16.03.2010

2.3.9.6 Surface Finishing

The target of surface finishing is to increase properties like:

- Surface quality
- Abrasion resistance
- Corrosion resistance
- Sliding properties

The figure below shows the six main groups of the surface finishing process.

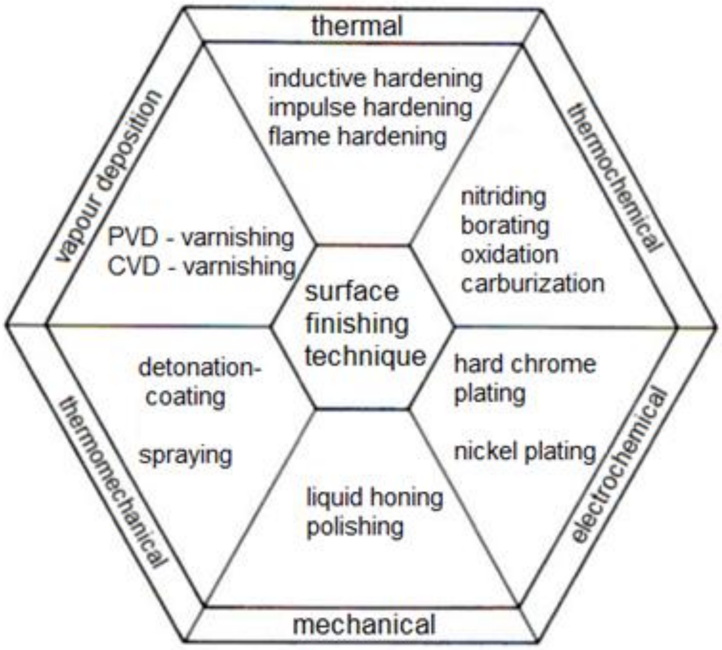

Figure 66: Surface finishing technique

2.3.9.7 Hardening

Inert gas hardening:

The inert gas atmosphere consists in principle of a neutral gas and an active gas. Neutral gas has the purpose to displace disadvantageous elements in the furnace atmosphere. The active gas has the function to retain the reductive conditions and to provide a certain carbon activity of the material to avoid un-wanted carburization and decarburization during the heat treatment process. [39]

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[39] http://www.feliksmetal.hr/download/literature2.pdf Stand 18.4.2010

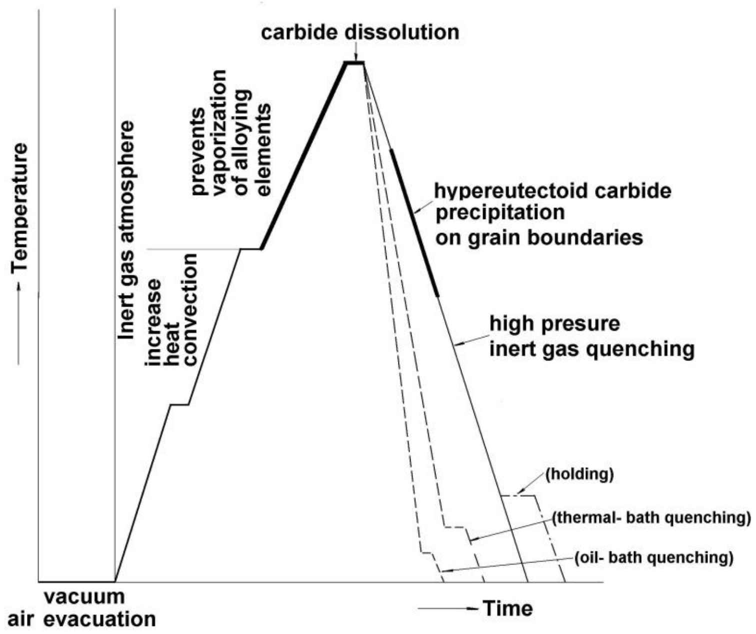


Figure 67: Hardening sequence in vacuum furnace

After the hardening of the material the hardness has to be defined. There are some processes for defining the hardness. As example the hardness test according to Vickers, the hardness test according to Brinell and the hardness test according to Rockwell.

In the tool manufacturing the hardness is often defined according to Rockwell with the degree of hardness HRC.

Here you can see the classification of HRC hardness:

50 HR C W

- W — Designation from the indenter material (globe) S = steel W = hard metal
- C — Designation of the hardness scale
- HR — Abbreviation for Rockwell hardness
- 50 — Rockwell hardness degree

For tool manufacturing the general HRC hardness degree after the hardening of the material is between 50 and 62 HRC.

2.4 Plastics Technology

2.4.1 Commercial Relevance

The injection moulding technology covers not only the injection moulding machine and the injection mould or tool. It has got a big surrounding field, for example the material stocking and –preparation, the injection tool preparation and –maintenance of the machines and manufacturing technique. It covers also the automation, electronic- and computer technology and of course the recycling and environment protection.

Injection moulding is the most important manufacturing process to produce plastic parts. The range of compact dimensions is between mg and 150 kg and the cyclic time is between 1 sec. and 15 min.

After the production the moulded parts are ready for application and true to size contrary to other manufacturing processes. And so the manufacturing process is very economic and the plastics competitiveness increase.[40]

The history of plastics is nearly 500 years old. Bartholomäus Schobinger (1500 – 1585) invented the first plastic material in 1530. Over the following centuries plastics were developed and improved. In the years between 1930 and 1950, technical plastics became more and more important.

The chart below shows the increasing demand for plastics from 1950 to 2005. A reason of the enormous jump at the beginning of the 90's was the rapid economic growth in Asia.

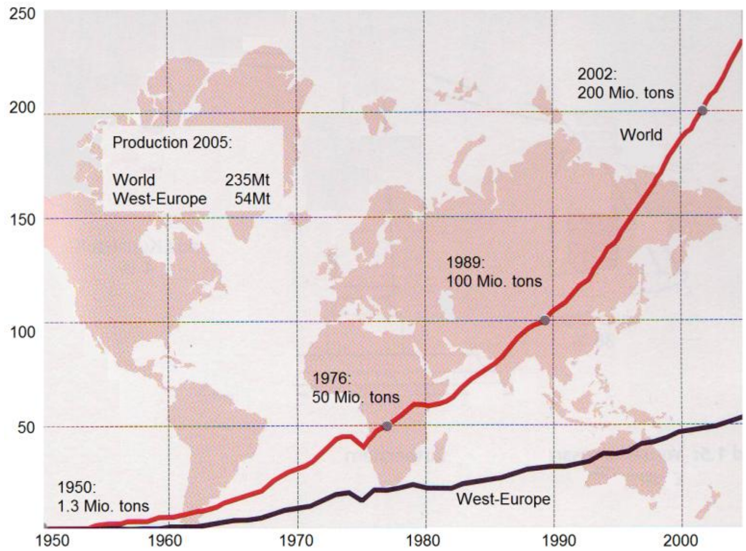


Figure 68: Demand of plastics

[40] Johannaber / Michaeli, Handbuch Spritzgießen, Verlag Hanser, pp 1-6

This chart shows the expected requirements of plastics in the future. The increase will hold on and at the beginning of the 22nd century the demand won't increase and stay nearly constant.

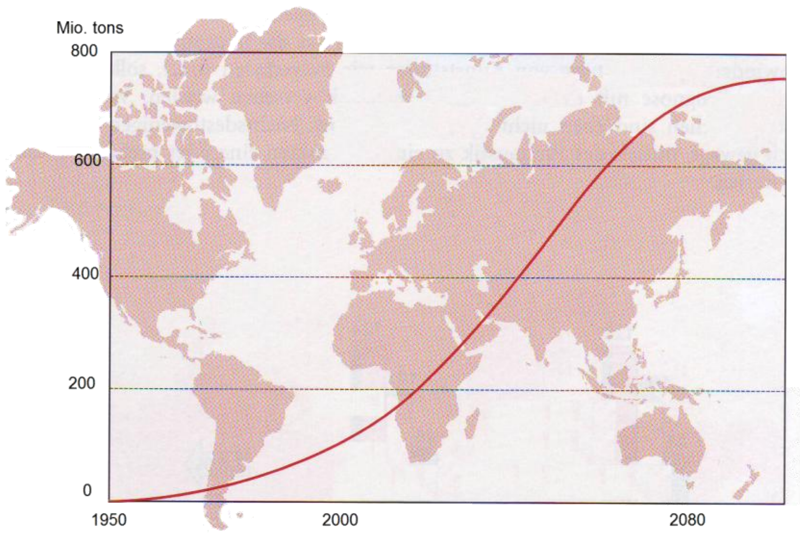


Figure 69: Requirements of plastics in the future [41]

Application Range:

The applications for plastics are essentially limitless. Plastics are found almost everywhere. The chart below shows the distribution of plastics in its main areas of application.

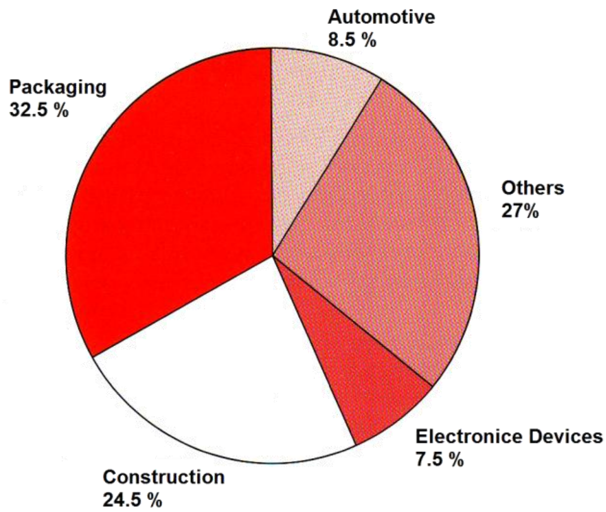


Figure 70: Application range

Packaging:

The packaging industry is primarily responsible for the use of plastics. Clear low-density polyethylene plastic wrap coverings account for most of the plastic

[41] Kaiser, Kunststofftechnik für Ingenieure, Verlag Hanser, pp 3-24

packaging materials, followed closely by high-density polyethylene plastic films used in trash bags and containers.

Construction:

The building industry is the second largest consumer of plastic products. In addition to using many of the packaging materials listed above, construction also requires high-density polyethylenes and polyvinyl chlorides for pipes and siding sheets.

Automotive:

A variety of plastics are used in the manufacture of automobiles, trucks, and airplanes, fuel lines, brake linings, windshield, wipers, tires and many more. Even the outer bodies of some cars are made of fibreglass-reinforced plastic.

Electronic Devices:

The wires of most electronic devices are encased in some type of plastic. As well, plastics are used in the outer casings of telephones, lighting fixtures, electric mixer housings, fans, radio cabinets, coffee makers, computers, and clocks.

2.4.2 Basics of Plastics

Plastics belong to the category of organic/synthetic materials. They are produced by chemically modifying natural substances or are synthesized from inorganic and organic raw materials. On the basis of their physical characteristics, plastics are usually divided into thermosets, elastomers and thermoplastics. These groups differ primarily with regard to molecular structure, which is what determines their differing thermal behaviour. [42]

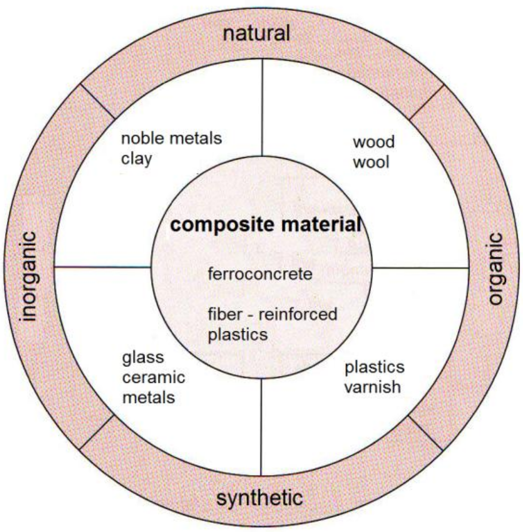


Figure 71: Class of materials (schematic)

[42] Kaiser, Kunststofftechnik für Ingenieure, Verlag Hanser, p 120

Fabrication:

Plastics are made up of polymers. Polymeric materials are characterized by long chains of repeated molecule units. These long chains intertwine to form the bulk of the plastic. The ways in which the chains intertwine determine the plastic's macroscopic properties.

The production of plastics can be roughly divided into four categories:

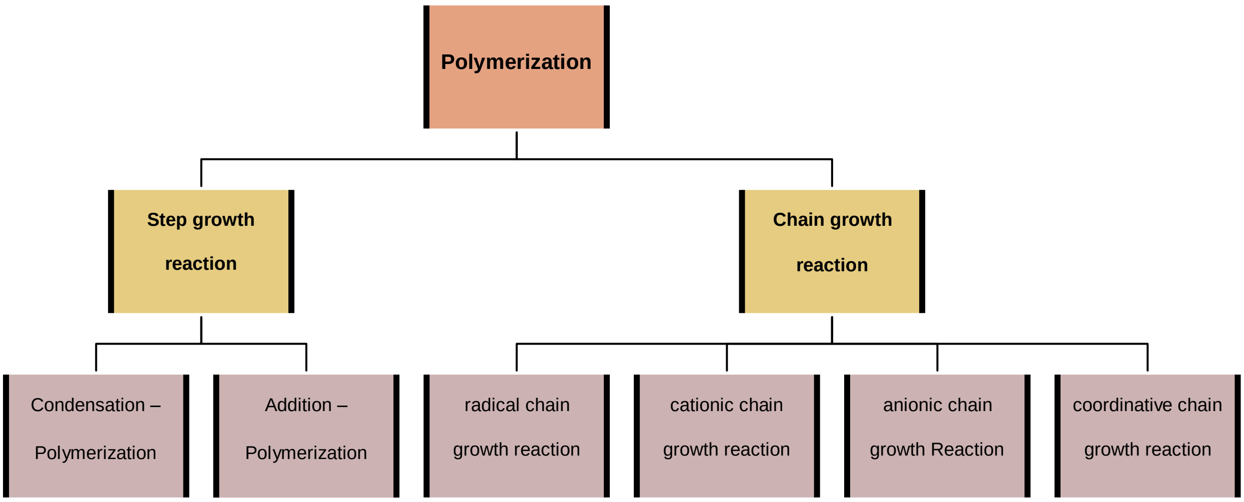
- Acquiring the raw material or monomer
- Synthesizing the basic polymer
- Compounding the polymer into a material that can be used for fabrication
- Moulding or shaping the plastic into its final form

Raw Materials:

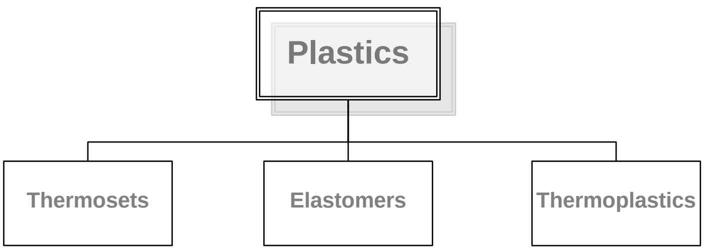
Most plastics are produced from petrochemicals which are widely available and tend to be cheaper than other raw materials. However, the global supply of oil is exhaustible, so researchers are investigating other sources of raw materials.

Synthesis of the Polymer:

The first step in plastic manufacturing is polymerization. The two basic methods by which polymerization can occur are addition and condensation reactions.



The plastics are subdivided into three different groups:



2.4.3 Thermosets

Characteristics and Application:
Thermosets are hard and have a very tight-meshed, branched molecular structure. Curing proceeds during shaping, after which it is no longer possible to shape the material by heating. Further shaping may then only be performed by machining. Thermosets are used, for example, to make light switches.

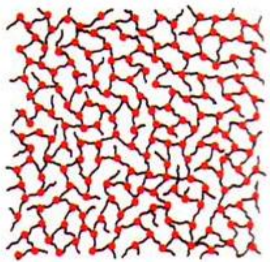


Figure 72: Thermosets molecular structure [43]

2.4.4 Elastomers

Characteristic and Application:
While elastomers also have a cross - linked structure, they have a looser mesh than thermosets, giving rise to a degree of elasticity. Once shaped, elastomers also cannot be reshaped by heating. Elastomers are used, for example, to produce automobile tires.

physical cross - linked chemical cross - linked

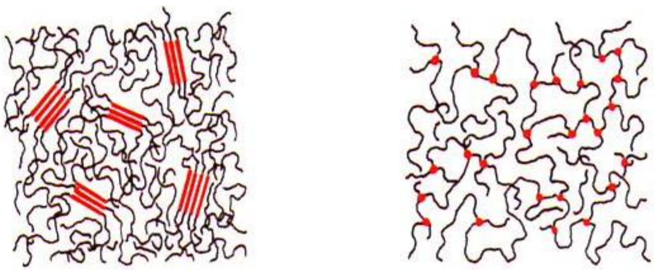


Figure 73: Elastomers molecular structure

2.4.5 Thermoplastics

Characteristic and Application:
Thermoplastics have a linear or branched molecular structure which determines their strength and thermal behaviour; they are flexible at ordinary temperatures. At approx. 120 - 180°C, thermoplastics become a pasty/liquid mass. The service temperature range for thermoplastics is considerably lower than that for

[43] Kaiser, Kunststofftechnik für Ingenieure, Verlag Hanser, p 1

thermosets. The thermoplastics polyethylene (PE), polyvinyl chloride (PVC) and polystyrene (PS) are used, for example, in packaging applications.

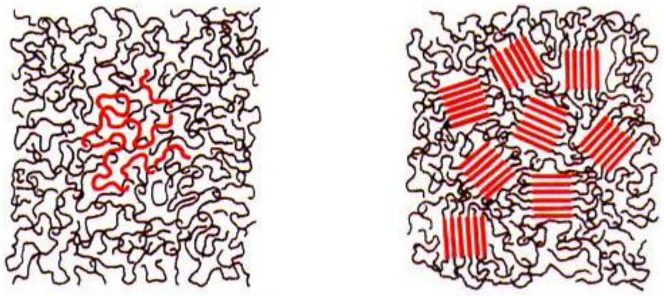


Figure 74: Thermoplastics molecular structure [44]

This chart shows the classification of thermoplastics after aspects like price, performance and production capacity.

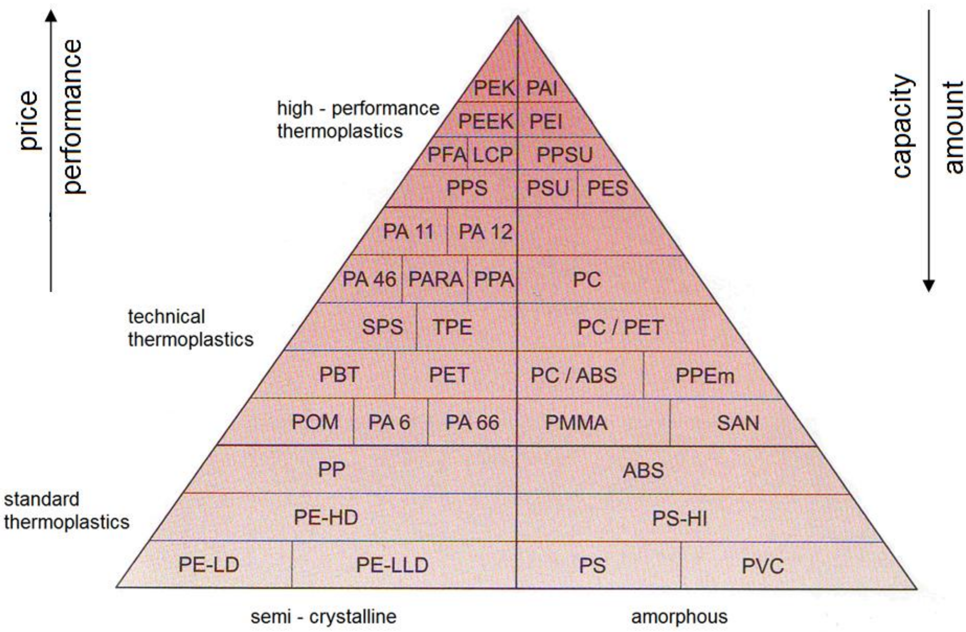


Figure 75: Classification of thermoplastics after aspects

Standard thermoplastics:

This type will be produced and manufactured in very high amounts. So they got the name standard plastics or “bulk plastics”. Concerning to its low price and useful properties they are widely-spread.

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[44] Kaiser, Kunststofftechnik für Ingenieure, Verlag Hanser, p 36

Technical thermoplastics:

They are often used for resilient parts which have to be very strong.

The engineering demands and special requirements:

- low deformation
- low shrinkage
- slight thermal expansion
- temperature resistant
- high impact strength

High – performance thermoplastics:

The market share of these new plastics is smaller than 1%. The special feature of this material is its high temperature resistance of over 150 °C and extremely high tightness.

High – performance thermoplastics are very expensive. One kilogram of non-manufactured pellets can cost more than 20 €. If the machine cannot handle the material because of the high processing temperature it will be necessary to mount special equipment.

To improve the technical and thermal features there are often used additives like fibreglass. [45]

Characteristics of Thermoplastics:

Thermoplastics can be subdivided in amorphous and semi – crystalline thermo-plastics.

The charts below show the dependency between the temperature and the shear modulus.

Amorphous Thermoplastics:

In cooled condition the molecules are fixed, hard and rough. After crossing the temperature "T_g" the molecular structure becomes softer and the shear modulus rapidly decreases.

With increasing temperature the material becomes softer and softer. This leads to the possibility to use more manufacturing methods like injection moulding.

[45] Kaiser, Kunststofftechnik für Ingenieure, Verlag Hanser, pp 119-121

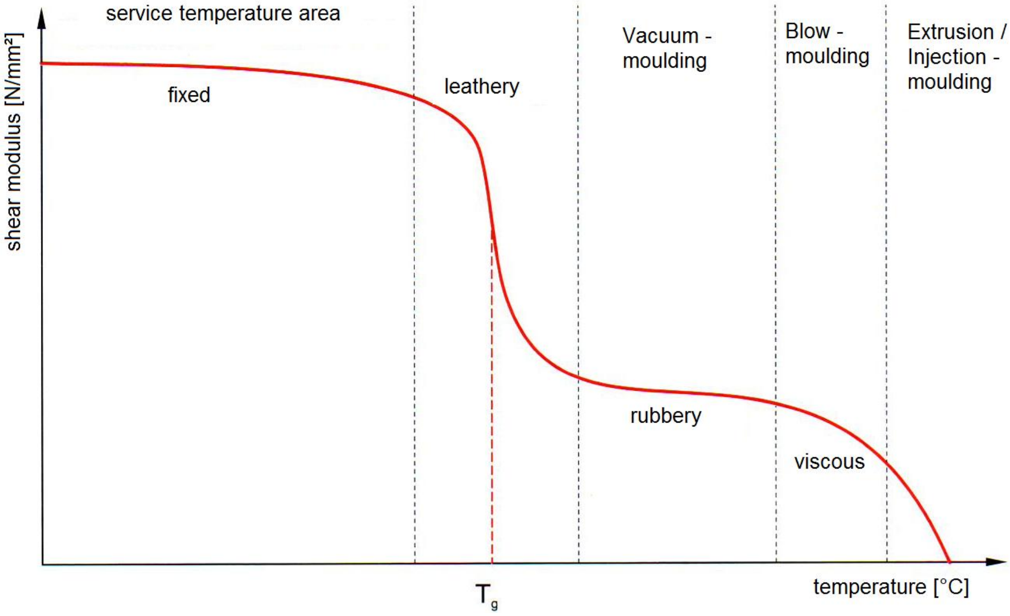


Figure 76: Shear modulus of amorphous thermoplastics

Semi - crystalline Thermoplastics:

This type shows a similar behaviour like amorphous thermoplastics. In addition to the change – over point "T_g" they have got a second temperature point "T_m". This point describes the melting temperature. PP, PE and other important plastics belongs to the category of semi – crystalline thermoplastics.

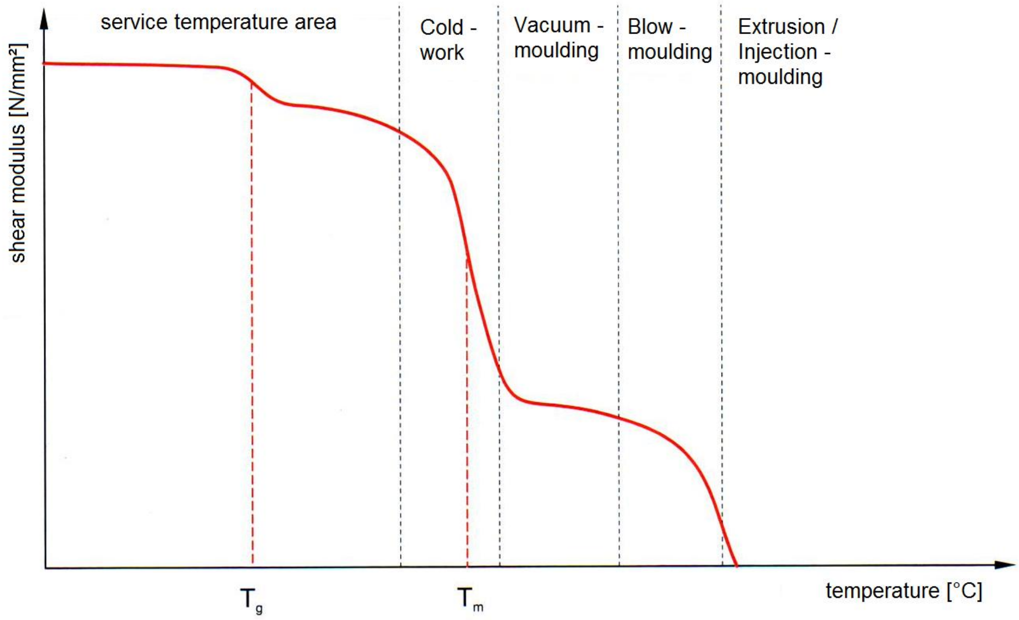


Figure 77: Shear modulus of semi-crystalline thermoplastics [46]

[46] Kaiser, Kunststofftechnik für Ingenieure, Verlag Hanser, pp 107-108

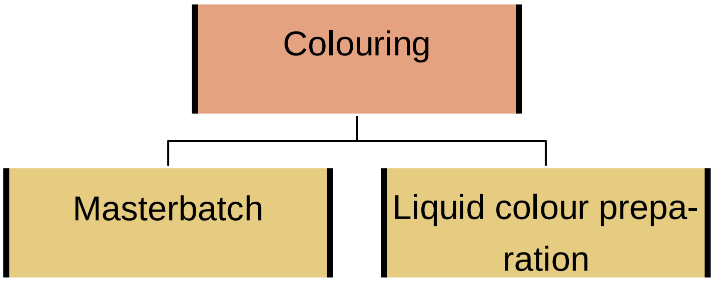
2.4.6 Additives

Chemical additives can be used in the production of plastics to achieve certain characteristics. These additives include:

- antioxidants to protect the polymer from degradation by ozone or oxygen
- ultraviolet stabilizers to protect against weathering
- plasticizers to increase the polymer's flexibility
- lubricants to reduce friction problems
- pigments to give the plastic colour
- flame retardants
- antistatics

Colouring:

Many thermoplastics are able to colorize. There are different methods to do this.



Masterbatch:

Today this is the most preferred type of preparation, well documented by the large volume of sales.

A masterbatch consists of:

- Polymer as carrier
- Colourants
- Dispersing agent
- If necessary, additives such as stabilizers, nucleating agents, antistatic agents, lubricants, and so forth

The concentration of the components varies corresponding to the desired intensity of colour and/or hiding power. Very intensive colours with a good hiding power require a high concentration, which very often lies in the range of 50% colorant, 40–45% polymer, and 5–10% dispersing agent. When the presence of

an additive is required in a colour preparation, there is no other way than to reduce the concentration of the colorants.

For pastel shades and/or transparent colours a few percent of colorant in the preparation are enough, especially when a colorant with a high tinting strength can be used to match the desired colour. The result is a much diluted masterbatch.

Advantages:

- smallest expenditure of work when changing colours during production
- no problems when high amounts have to be used for colouring
- very good metering

Disadvantages:

- not universally applicable with all polymers
- most expensive type of colour preparation

Liquid Colour Preparation:

The composition of a liquid colour preparation is quite similar to that of a masterbatch.

The main difference is that instead of a polymer a liquid binder is used as carrier. A liquid preparation may contain additives.[47]

[47] http://www.plasticscolor.com Stand: 18.04.2010

2.5 Development of an Injection Moulded Product

2.5.1 Product Development Process

In the praxis there are often complex and technical problems which have to work out in a structured course, this is also called product development process.

That means there are some steps which have to be done, before the product can be produced. This course of action is important to reach defined objectives in a high quality and with an economic solution.

Here you can see a standard product development process with the reference to the Leonardo project:

I. **Preparation of the requirement specification**

This specification includes the detailed description of the efforts which are necessary to reach the objectives. The efforts include not only technical terms and conditions also organisational and business-management parts are in the requirement specification.

The reference content for the requirement specification of the Leonardo project you can see under point *(1 Situation).*

II. **Feasibility study**

This means that every idea, design or construction, which is the basis for the production have to be analysed with reference to technology and economical aspects.

In our case the analysis for the injection moulded part, the EU-Click Cube, was the rapid prototyping operation *(2.5.3 Rapid Prototyping)*. It was necessary to check the click system and the assembly of the cube. Further considerations under this point were the selection of the material and the costs calculation.

III. **Preparation of a project schedule**

In the project schedule the course of the realisation will be planned. It starts with the design, engineering and goes on with the moulding construction, material selection and ends after the manufacturing of the mould with the last point the production and testing of the part.

We have planned our diploma thesis with Windows Microsoft Project and you can see the project schedule under point *(3.5 Project Schedule).*

IV. Product design

This point includes the engineering:

It starts with the design, construction, dimensioning (mechanical and rheological) of the part and the mould, selection of material and ends with the testing of the part.

The product design of the EU-Click Cube you can see in point (*3 Technical Part).*

V. Calculation

This is the last and a very important point of the product development process, because the best idea and construction isn't successful, if the costs will be too high and nobody will buy the products.

The manufacturer will calculate the costs for the development and production of the product and he has to check the economical situation and the earning in the future.

The calculation for the EU- Click cube you will see in point *(3.6 Calculation).*

This is a product development process which is reasonable for complex projects and will help to reach defined objectives.

2.5.2 Design Rules for Injection Moulded Parts

In terms of injection moulding designs, many experts have given their opinions as to what designs should be followed. However, the rules for designing injection mouldings can be summed up in just five guidelines.

Maximum wall thickness:

Decrease the maximum wall thickness of a part to shorten the cycle time (injection time and cooling time specifically) and reduce the part volume. This also can minimize the sinking, residual stress and warping.

Figure 78: Wall thickness

Uniform wall thickness:

This will ensure uniform cooling and reduce defects.

Figure 79: Design rules - uniform wall thickness

Corners:

- Round corners to reduce stress concentrations and fracture
- Inner radius should be at least the thickness of the walls

Figure 80: Design rules - corners

Draft:

The parts should be designed so that it can be ejected from your tools with a reduced cycle time and without damages to your product. Since plastic shrinks when it cools down, ejecting it without draft can make the plastic prone to stress. Drafting before production can prevent product defects and other issues

before your part designs are completed. This can ultimately save time and costs.

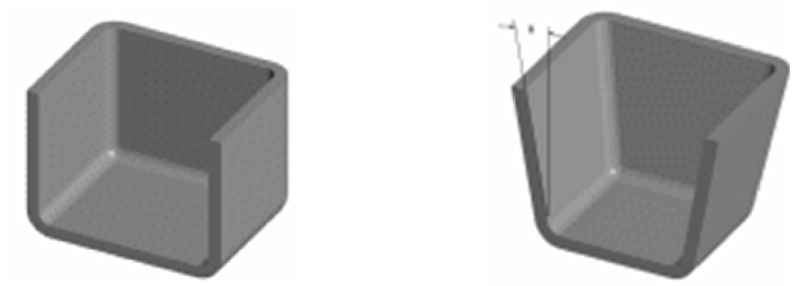
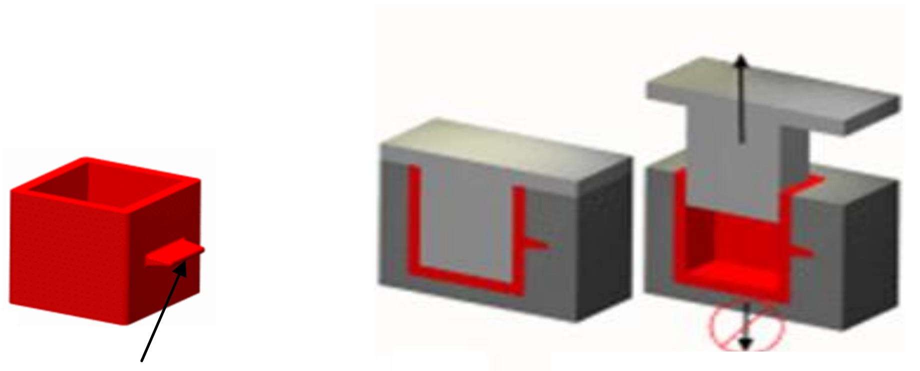


Figure 81: Design rules - draft

Undercuts:

- Minimize the number of external undercuts
- External undercuts require side-cores which add to the tooling cost
- Some simple external undercuts can be cast by relocating the parting line

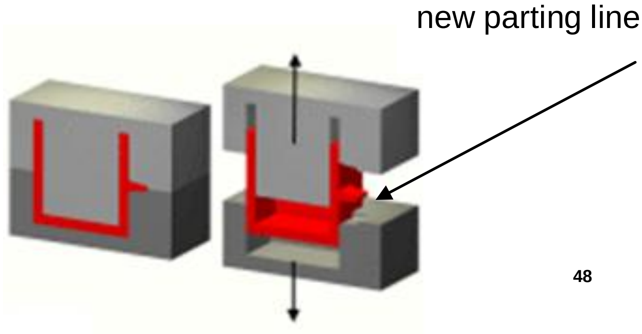


external undercut

seperation impossible

Figure 82: Design rules - undercuts

new parting line allows undercut



[48]

Figure 83: Design rules – parting line

[48] http://www.custompartnet.com/wu/die-casting Stand 29.01.2010

Shrinkage:

All plastics have more or less pronounced shrinkage behaviour.

This means that the moulded thermoplastic part has smaller dimensions than the mould in which it is produced. The total shrinkage of a moulding is the moulding shrinkage added to the after-shrinkage.

As it cools, the part begins to shrink in the injection mould. This process also continues after demoulding. The dimensional changes until thermodynamic equilibrium is reached after 16 to 24h at 23 º C ambient temperatures are referred to as moulding shrinkage.

To produce the mould and also the electrodes, which are used for the manufacturing with the exact measurements is important to take account of the shrinkage. Another important point is the different shrinkage characteristic for each material.

For calculation there is a formula which should be used in the mould construction process.

$$\mathbf{L_1 = (L * 100\%) / (100\% - S)}$$

L_1 … length of the cavity

L … length of the work piece

S … shrinkage of the material

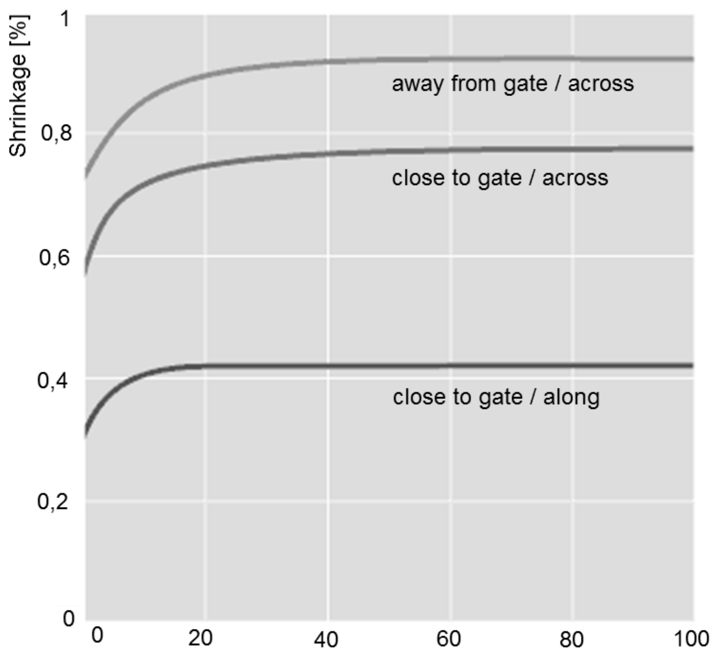


Figure 84: Shrinkage after demoulding [49]

[49] http://www.plasticsportal.net/wa/plastics~de_DE/portal Stand 20.02.2010

2.5.3 Rapid Prototyping

Rapid prototyping is subordinate additive fabrication and refers to a class of manufacturing processes, in which a part is built by adding layers of material upon one another.

Additive processes, do not require custom tooling or planned tool movements. Instead, the part is constructed directly from a digital 3-D model created through computer aided design (CAD) software. The 3-D CAD model is converted into many thin layers and the manufacturing equipment uses this geometric data to build each layer sequentially until the part is completed. Due to this approach, additive fabrication is often referred to as layered manufacturing, direct digital manufacturing, or solid freeform fabrication.

Rapid prototyping is a fast process to make a model from a design or construction based on a construction drawing. Often in the product development phase in the plastics technology it is used for visualization, form/fit testing, and functional testing or to check the feasibility.[50]

In the Leonardo project we used the rapid prototyping to analyse the functions of the click cube. We print the cube with the dimensions of the first construction drawing. With this model we were sure that it is possible to click the 6 pieces of the cube together and use it as a key fob.

In the figure below you can see the EU- click cube as rapid prototyping 3- D model.

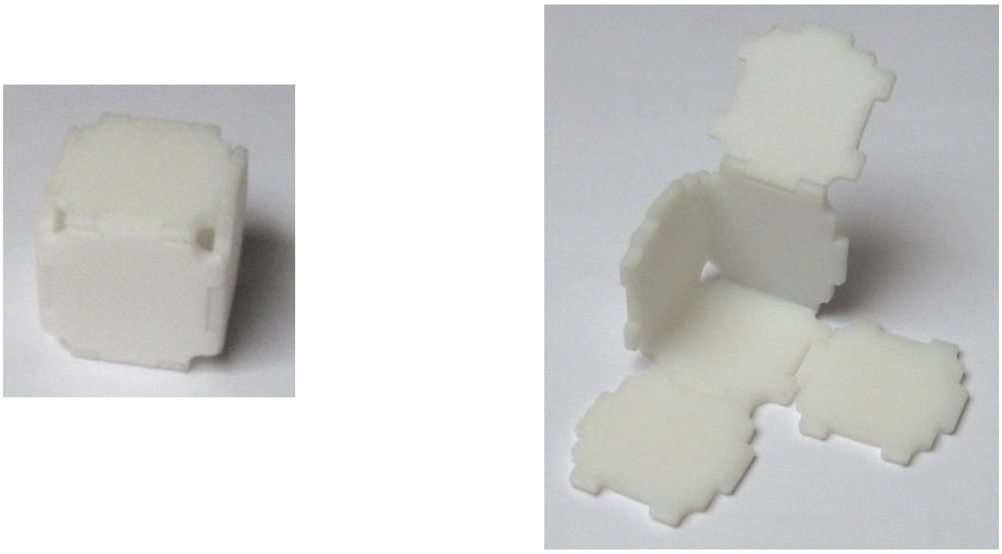


Figure 85: Rapid prototyping 3- D model

[50] Menges / Michaeli / Mohren, Spritzgießwerkzeuge, Verlag Hanser, p 817

3 Technical Part

In this chapter you will see the product development process in the Leonardo project from the idea up to the ready part.

The idea was to produce a key fob out of plastic with injection moulding technology. The next step was the design of the key fob with the result of an EU-Click Cube.

The next question after the design was the material selection. There were three kinds of thermoplastics ABS, POM and PP.

After the design and the material selection the injection mould engineering, dimensioning and construction were to do. Combined with the injection mould is the injection moulding machine, which is placed in our participating school HTL Fulpmes.

At last an economic calculation of the production was done by us.

Here you can see the course of the technical part of our diploma.

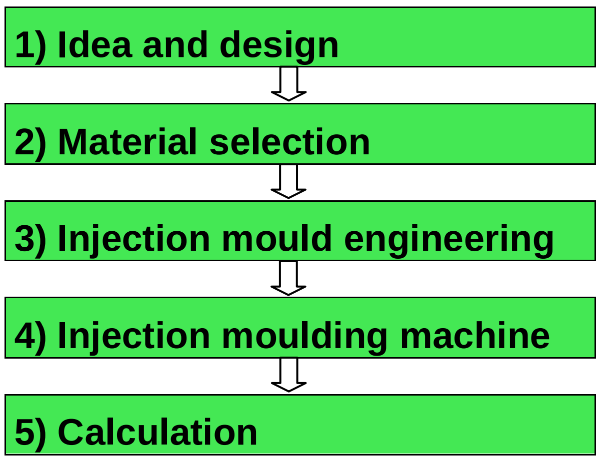


Figure 86: Course of the technical part

3.1 Design of the Injection Moulding Part

At the first meeting of the Leonardo project in Barcelona the participating schools decided that the project work should be about a key fob out of plastic and will be produced with injection moulding technology.

At the next two meetings in Gaziantep and St. Pölten the project work was to design and construct a key fob. It was a decision-making process between the participating schools.

3.1.1 Designs for the Meeting in Gaziantep

EU- Letter:

front side back side A for Austria

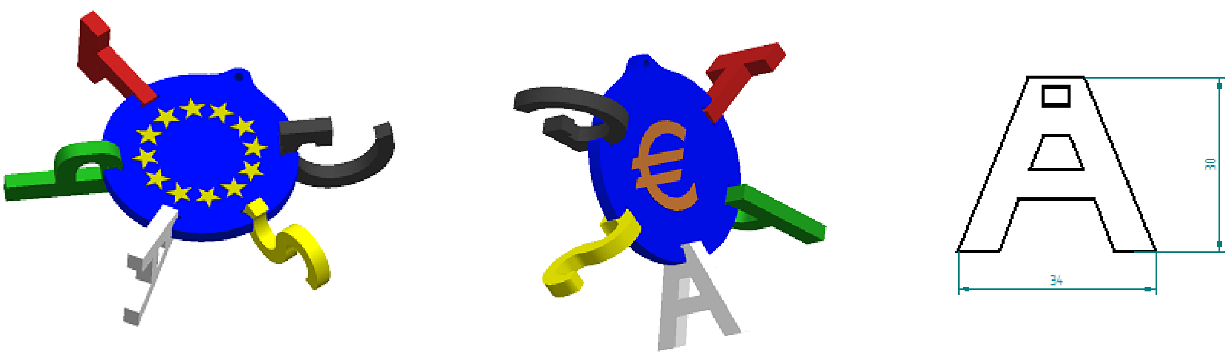


Figure 87: EU- Letter

There is one base body with the EU-stars and on the other side the EURO-emblem.

Every country could design its own letter, so there are 5 letters with stick system to put in and out.

The dimension of the complete key fob is about 100 mm. The dimension for the letter is about 35mm x 30 mm.

EU- KEY:

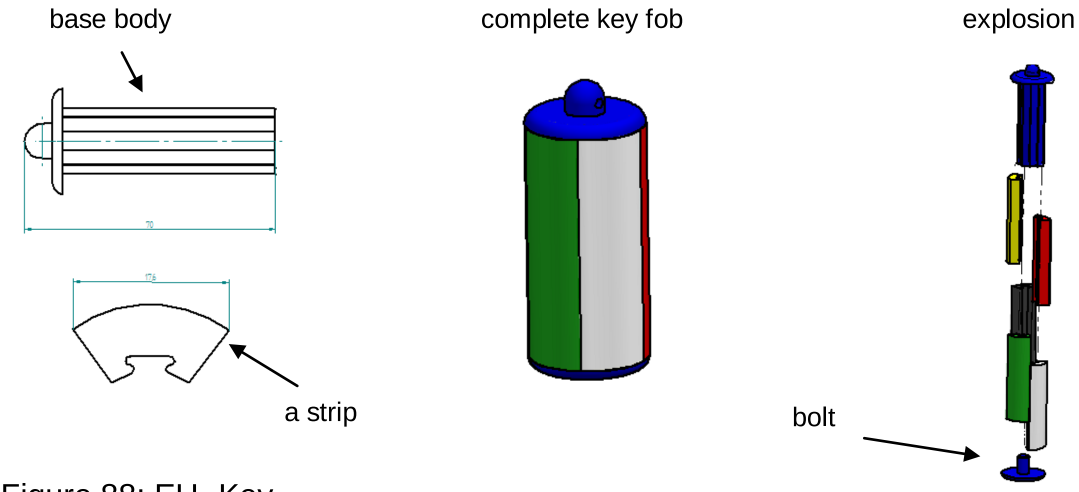


Figure 88: EU- Key

The parts are on a base body, like strips and they fixes with a bolt in the ground. We think 5 strips are reasonable, so there is one part for every attending country.

The dimension is about 70 mm in lenght, but it could be variable. It’s a question of the production machine.

Also the design of the strips are variable, so every state could design a own strip

EU– DISC:

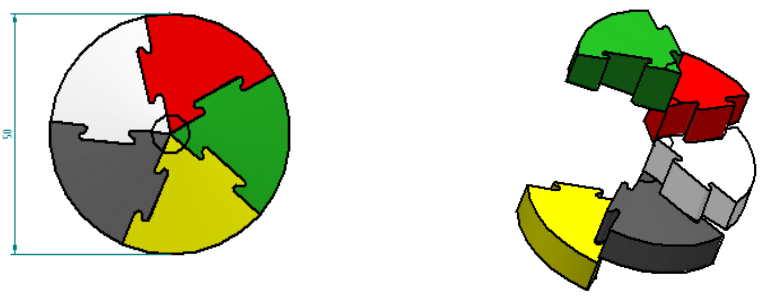


Figure 89: EU- Spiral

This is a disk out of 5 puzzle parts, so there is one part for every attending country. The diameter of the disc is about 50 mm.

3.1.2 Designs for the Meeting in St. Pölten

In this meeting was discussed about the idea of a cube, which is used as key fob. There were some ideas and designs of the cube and the ready EU- Click Cube were found after some designs steps.

Cube with brackets and boards:

- 2 brackets
- 6 boards

So there are only two different parts.

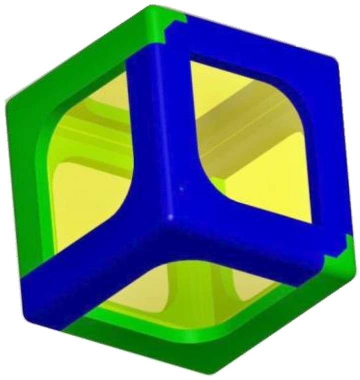


Figure 90: Cube with brackets and boards

Cube with lateral faces:

- 2 covers of slide valve
- 4 lateral faces
- so there are two different parts

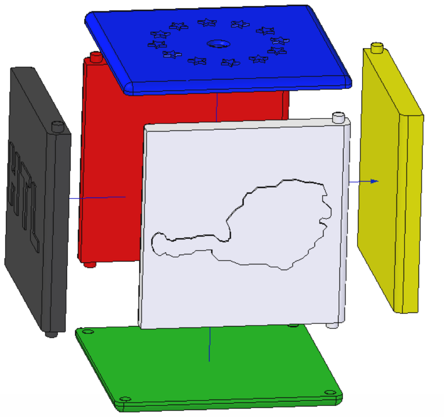


Figure 91: Cube with lateral faces

Click Cube:

The characteristic of this idea is the easy click system, which connects the parts and allows you to assemble the cube in your own way.

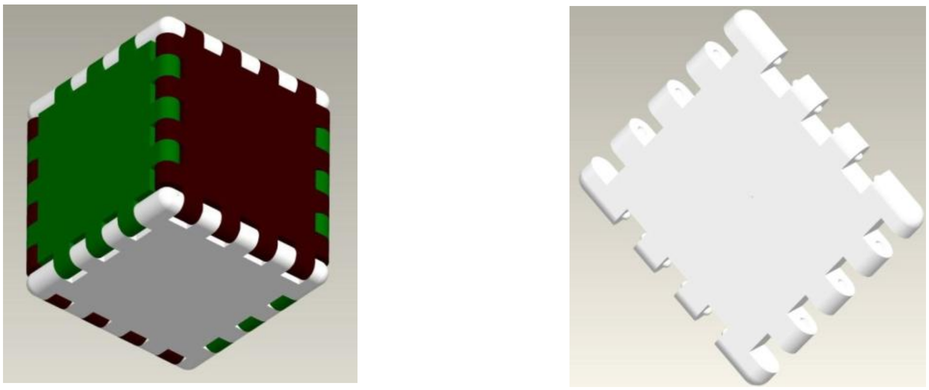


Figure 92: Click Cube

For this Click- Cube 3 different parts are necessary and so we made some changes and this is now the EU-Click Cube for the Leonardo Project.

3.1.3 EU- Click Cube

This was the final idea and so the base for the material selection and Injection mould engineering were found.

Appendix, reference drawing number: EU-01-03-10

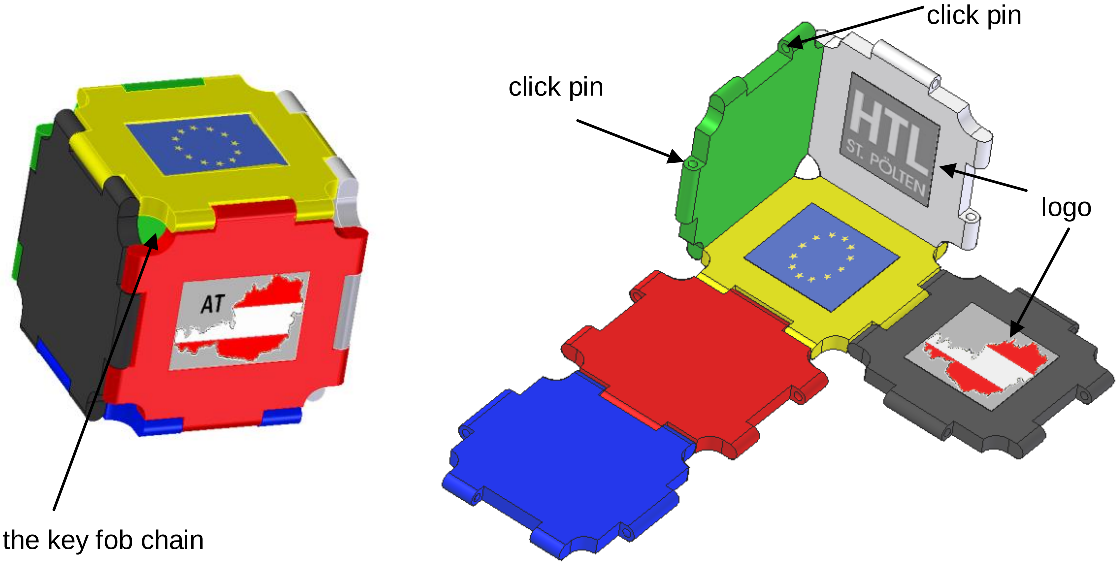


Figure 93: EU- Click Cube

The characteristic of the EU- Click Cube is the easy click system, which connect the parts and allows assembling the cube in your own way. With this design it is possible that every part has an in- and outside. So the school logo and the country map could be placed on one lateral surface. It is also possible to have only one part 6 times. That is important for the assembly in your own way. The cube consists of 6 lateral surfaces, one for each school and one for Europe. The key fob chain could be placed in the corners.

In the figure above you can see the idea with the logos. This is only a suggestion of HTL- St. Pölten. The other schools could design their own part with the logos on it.

Pros for this idea:

- 6 same parts
- easy click system
- in- and outside
- billions of possibilities to assemble different cubes
- easy to injection mould

Functionality:

The system, which makes the cube work, is made of click pins and the negative indentations to these pins. The negative is in the part and the pin is outside. So they can fit together.

It was important to choose the right material because the click system needs a slippery and strong thermoplastic. The decision was to take PP, which will provide the expected requirements, but this will be worked out in point *(3.2 Selection of the Injection Moulding Material)*

Another necessary point regards the tolerances of the measurements between the pins and the negative. The pins on the outside have to be a little bit smaller than the inside negative.

Regards to the click system:

This construction drawing with tolerances is the basis for the mould construction and the application of the injection moulding technology. *Appendix, reference drawing number: EU-01-03-10*

Important points are the Detail A and Detail B for the design of the injection mould, because these are the pins and the holes for the click system.

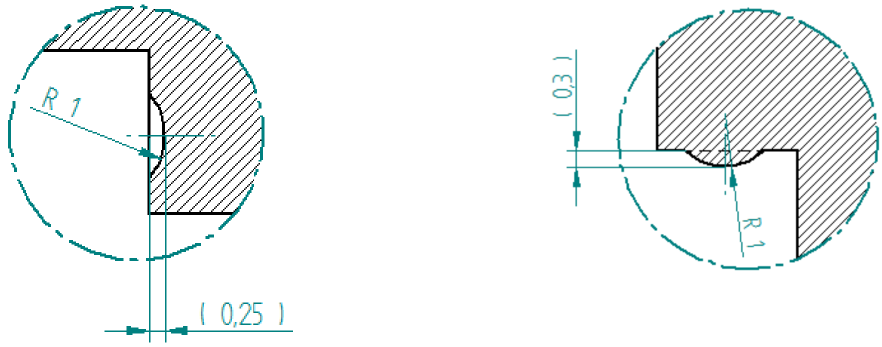


Figure 94: Undercuts of the Click-Cube

The problem was to construct these details for a forced demoulding. This means we have got undercuts in the mould, because there are holes or pins at all four sides of the part and we didn't want to construct a slider mould. The cause of this is the parting line.

The tolerances were the next point. The problem is the cavity production, because 6 different schools have to make cavity inserts for both form platens. So there are some different productions and so there could be some measurements out of tolerance limit and then we won't be able to assemble the parts to a cube.

This was the reason for the tolerances, which can be seen in the *Appendix, reference drawing number: EU-01-03-11*

Shrinkage:

All plastics have more or less pronounced shrinkage behaviour.

This means that the moulded thermoplastic part has to be smaller dimensions than the mould in which it is produced. The total shrinkage of a moulding is the moulding shrinkage added to the after-shrinkage.

PP has shrinkage (=S) of nearly 2%, so we had to calculate the new measures (=L_1) for the work piece (L= original length).

For calculation we used this formula:

$L_1 = (L * 100\%) / (100\% - S)$

and we took the *Appendix, reference drawing number: EU-01-03-11* as base.

In the table below, you can see the new calculated measures in relation to the old.

Shrinkage for PP = 2,00%

L	L1	
30	30,612	[mm]
27,5	28,061	[mm]
24,8	25,306	[mm]
10,55	10,765	[mm]
10,45	10,663	[mm]
10,05	10,255	[mm]
9,85	10,051	[mm]
2,5	2,551	[mm]
1	1,020	[mm]

$$L_1 = (L * 100\%) / (100\% - S)$$

The new calculated measures will be used as basis for the form insert. In the drawing *Appendix, reference drawing number: EU-01-01-07* you can see the negative form of the work piece plus two percent shrinkage. After the moulding process and cooling, the ejected part will have the required dimensions. This ensures the functionality of the cube.

Regards to the logos:

The finished cube should represent the schools and the European spirit. Therefore, we decided to place logos on the surface. On the outside of the cube the outline of the country with the common initials (in the mould at the nozzle side) is placed, inside the logo of the school (in the mould at the ejector side) is placed. This means that there are 6 cavities in one form plate. So the idea with two logos on every part is ideal.

The figure below shows the outline of Austria, which is the logo for the cube’s outside. The borders were milled on a CNC – machine.

After the moulding process the outline is 0,3 – 0,5 mm embossed.

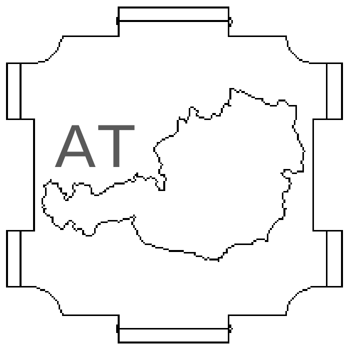


Figure 95: Logo outside

In the injection moulding technology the nozzle side is the side with the better surface, because there are no ejector marks. They are placed outside the logo. Every cavity insert will have 4 ejectors with a diameter of 4 mm and they will be placed around the logo in a distance of 18mm x 18mm.

This is the figure of the inside surface and shows which school is part of this project and made this part.

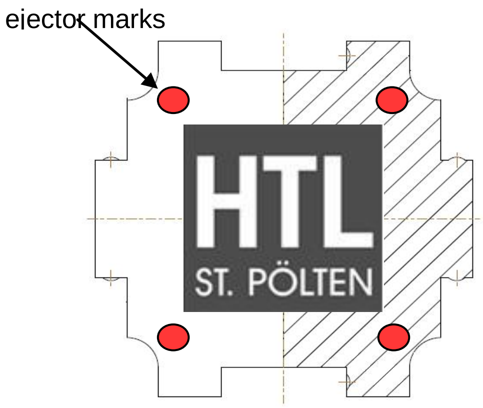


Figure 96: Logo inside - location with ejector marks

The designs for the logos are in the hands of each school. Austria has two participating schools. So HTL St. Pölten made the Austria- part, while HTL Fulpmes made the EU- part.

3.2 Selection of the Injection Moulding Material

There are many types of materials that may be used in the injection moulding process. Most polymers may be used, including all thermoplastics, some thermosets and some elastomers.

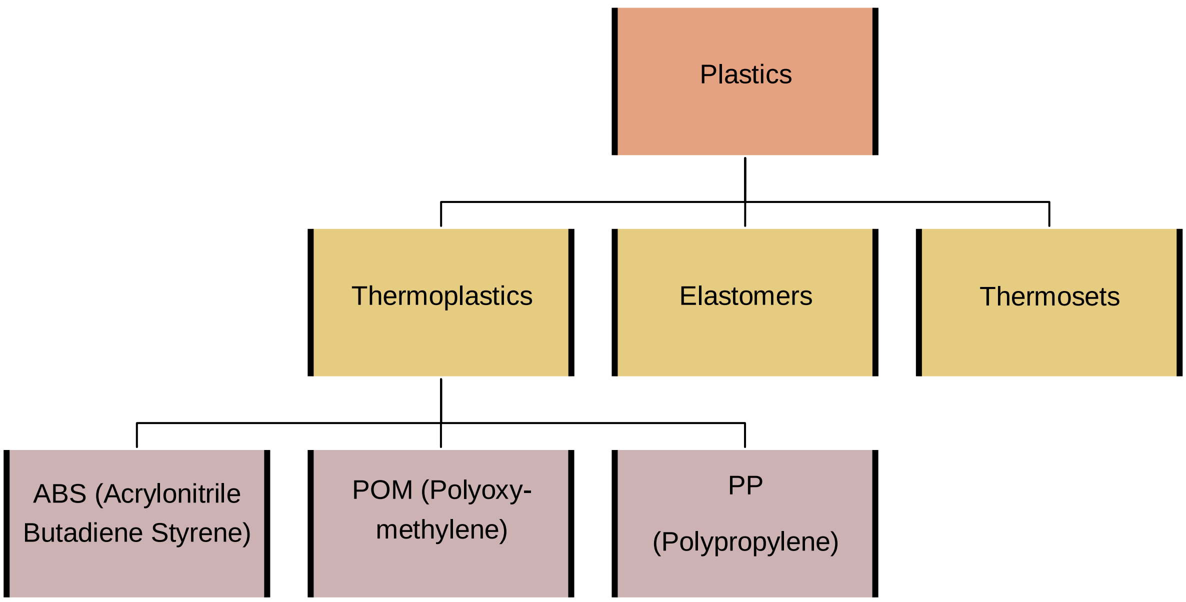
When these materials are used in the injection moulding process, their raw form is usually small pellets or a fine powder. Also, colorants may be added in the process to control the color of the final part.

The selection of a material for creating injection moulded parts is not solely based upon the desired characteristics of the final part. While each material has different properties that will affect the strength and function of the final part, these properties also dictate the parameters used in processing these materials.

Each material requires a different set of processing parameters in the injection moulding process, including the injection temperature, injection pressure, mould temperature, ejection temperature, and cycle time.

For the Leonardo Click Cube we need a strong, rigid material with low shrinkage.

The decision tree shows the way how we decided which material should be used for the cube.



3.2.1 Overview about Thermoplastics

Material name	Abbr.	Trade names	Description	Applications
Polyoxymethylen	**POM**	Celcon, Lucel, Delrin, Hostaform	strong, rigid, excellent fatigue resistance, excellent creep resistance, chemical resistance, moisture resistance, naturally opaque white, low/medium cost	bearings, cams, gears, handles, plumbing components, rollers, rotors, slide guides, valves
Polymethylmethacrylat	PMMA	Diakon, Oroglas, Lucite, Plexiglas	rigid, brittle, scratch resistant, transparent, optical clarity, low/medium cost	diakon, oroglas, lucite, plexiglas display stands, knobs, lenses, light housings, panels, reflectors, signs, shelves, trays
Acrylonitrile Butadiene Styrene	**ABS**	Cycolac, Magnum, Novodur, Terluran	strong, flexible, low mould shrinkage (tight tolerances), chemical resistance, electroplating capability, naturally opaque, low/medium cost	automotive (consoles, panels, trim, vents), boxes, gauges, housings, inhalors, toys
Polyvinyl Chloride	PVC	Welvic, Varlan	tough, flexible, flame resistance, transparent or opaque, low cost	electrical insulation, housewares, medical tubing, shoe soles, toys
Polypropylene	**PP**	Novolen, Appryl, Escorene	lightweight, heat resistance, high chemical resistance, scratch resistance, tough and stiff, low cost.	automotive (bumpers, covers, trim), bottles, caps, crates, handles, housings

[51]

[51] http://www.custompartnet.com/wu/InjectionMolding#materials Stand: 25.11.2009

For the EU – Click Cube there were 3 materials under consideration, ABS, POM and PP.

ABS is easier for the injection but not as slippery as it POM is and PP is easy to process and has got good characteristics for forced remoulding. All three thermoplastics are able to be colourized and possible to use with as click system and so it fits well together.

3.2.2 Plastic Types ABS, POM and PP

ABS (Acrylonitrile Butadiene Styrene) is an amorphous thermoplastic blend.

It consists of:

- 15-35% Acrylonitrile
- 5-30% Butadiene
- 40-60% Styrene.

Depending on the blend different properties can be achieved.

Acrylonitrile contributes with thermal and chemical resistence, and the rubber-like butadiene gives ductility and impact strength. Styrene gives the glossy surface and makes the material easily machinable and less expensive.

Characteristics of ABS:

- good impact strength also at low temperatures
- satisfactory stiffness
- dimensional stability
- glossy surface
- easy to machine

If UV-stabilizators are added, ABS is suitable for outdoor applications.

POM (Polyoxymethylene) is an engineering thermoplastic used in precision parts.

POM provides:

- high stiffness
- low friction
- excellent dimensional stability
- low costs

This material has got a wide application area. Bearings, cams, gears, handles, plumbing components, rollers, rotors, slide guides and much more components are made of POM.

Behaviour of POM:

The main advantages of POM are:

- strong
- rigid
- excellent fatigue resistance
- chemical resistance
- low/medium cost
- able to be colourized

PP (Polypropylene) is a semi-crystalline thermoplastic and is used for some technical applications, as example in the automobile industry or chemical industry.

PP provides:

- stiffness and strength
- good forced remoulding properties
- good colorization
- low costs
- low density

Behaviour of PP:

At the meeting in Germany we decided the tolerances about the Leonardo Click – Cube. This is very important because there could be problems by assembly.

Especially the tolerances between the radiuses have to be very fine, if this is not the case they won't click-in together.

The main advantages of PP are the good release properties, which provide the function of the click- system. The second advantage is the high quality of the surface and so the logos are good visible.[52]

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[52] http://www.designinsite.dk/htmsider/m0007.htm Stand: 04.02.2010

Important information:

PP is odourless and provides skin kindness.

Shrinkage:

PP shows shrinkage of about 2%, so all the measures have to be 2% bigger.

Calculation of shrinkage - example:

$L = 24.8$ mm; $S = 2$ % (PP)

$L_1 = ?$

$L_1 = (L * 100\%) / (100\% - S\ \%)$

$L_1 = (24{,}8 * 100\%) / (100\% - 2\%)$

$\underline{L_1 = 25{,}306 \text{ mm} \sim 25{,}31 \text{mm}}$

Another development of the Cube are the radiuses, they are small enough, that there is no problem for ejection.

Because of these 1 mm radiuses the parts can be ejected by forced remoulding.

This type of ejection is used for parts with undercuts. The Click-Cube has got undercuts by the negative to the click pins.

Colouring:

The Leonardo Click – Cube will be produced in six different colours (green, blue, red, yellow, white and black). For this purpose we will use masterbatches in these different colours.

3.3 Design of the Injection Mould

The injection mould for the EU- Click Cube is a quick-change mould system and has been especially developed for economic production of samples, prototypes and small series.

This quick-change system is a 2-way tool and has got a fixed and a moveable form plate. This mould will be used for moulded parts, which are easy to eject with ejector pins.

The quick-change system consists of:

- **Mould changing unit:**
  Bolster plate – Ejector- and Nozzle side, spacers: bought-in parts
- **Matching mould inserts:**
  2 form plates with cavity inserts:
- **Cavity inserts:**
  12 cavity inserts:
- **Ejector system**
  Ejector holding plate:
  Ejector head plate:
  Ejector pins: bought-in parts

Here you can see the list of drawings of the injection mould, which are in the appendix.

Drawing name	Drawing Nr.
Assembly drawing	EU-01-01
Form plate - Ejector side	EU-01-01-01
Form plate - Nozzle side	EU-01-02-02
Bolster plate - Ejector side	EU-01-01-03
Bolster plate - Nozzle side	EU-01-02-04
Ejector system - Holding plate	EU-01-01-05
Ejector system - Head plate	EU-01-01-06
Form insert - Ejector side	EU-01-01-07
Platen - Ejector side	EU-01-01-08
Platen - Nozzle side	EU-01-02-09
Leonardo - Click cube	EU-01-03-10
Leonardo - Click cube - mid. Tol.	EU-01-03-11
Ejector side - Assembly	EU-01-01-12
Nozzle side - Assembly	EU-01-02-13

Table 10: List of drawings

In the figure below you can see the injection mould, which is used to produce the EU- Click Cube in Fulpmes. The details of this injection mould you can see on the next pages and the appropriate workshop drawing. *Appendix, reference drawing number: EU-01-01*

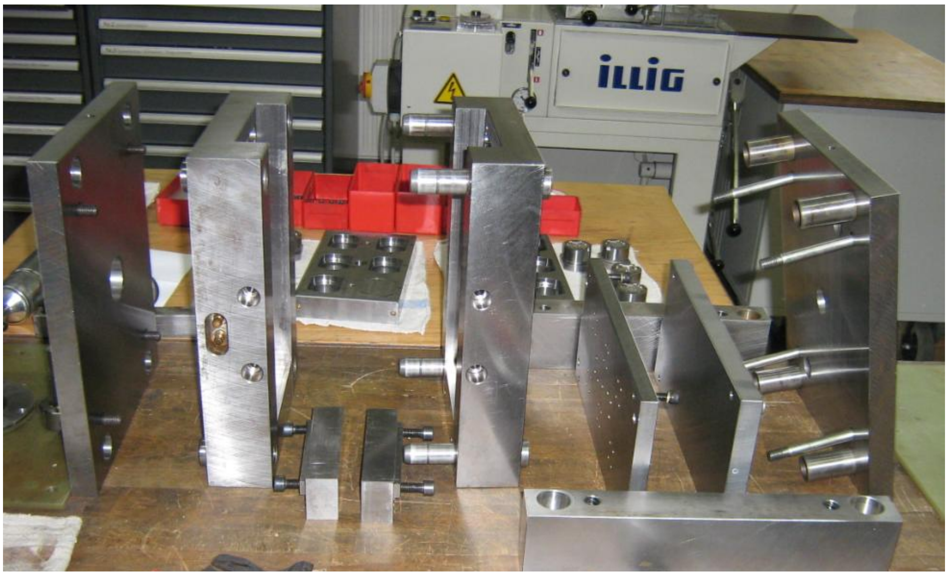


Figure 97: Injection Mould: Explosion

3.3.1 List of Items

Here you can see the list of items, which are necessary for the injection mould.

Pos.Nr.	Norm Nr.	Name	Material	Amount	Weight
1	BPM	Bolster Plate - Moveable	12.312	1	29,287 kg
2	DIN 16 716	Guide Bushing DIN 16 716	bought-in part	4	0,511 kg
3	EPES	End Piece - Ejector Side	12.312	2	3,371 kg
4	Z20_35 X 45	Centering Sleeve - Z20_35 X 45	bought-in part	4	0,745 kg
5	Z31_8 X40	Cylinder head bolt - Z31_8 X40	bought-in part	4	0,092 kg
6	Z942_8	Plug - Z942_8	20.401	20	0,059 kg
7	Z31_10 X 22	Cylinder head bolt - Z31_10 X 22	bought-in part	8	0,215 kg
8	ESHoP	Ejector System - Holding Plate	11.730	1	7,034 kg
9	SP	Spacer	12.312	2	10,328 kg
10	Z31_6 X 25	Cylinder head bolt - Z31_6 X 25	bought-in part	8	0,069 kg
11	FPES	Form Plate_Ejector Side	12.312	1	5,777 kg
12	MoP	Moveable Platen	12.312	1	38,420 kg
13	CIES	Cavity Insert - Ejector Side	12.767	6	2,571 kg
14	Z691_10 X 2,5	Lock edge washer - Z691_10 X 2,5	bought-in part	12	0,027 kg
15	Z 413 / 4 x 100	Ejector Pin - Z 413 / 4 x 100	14.125	24	0,222 kg
16	ESHeP	Ejector System - Head Plate	11.730	1	9,758 kg
17	Z31_10 X 90	Cylinder head bolt - Z31_10 X 90	bought-in part	4	0,274 kg
18	Z 413 / 6 x 100	Ejector Pin - Z 413 / 6 x 100	14.125	7	0,149 kg
19	Z 413 /10,5 x 250	Ejector Pin - Z 413 /10 x 250	14.125	4	0,247 kg
20	BPF	Bolster Plate - Fixed	12.312	1	29,473 kg

21	DIN 16 761	Guide pillar DIN 16 761	bought-in part	4	3,283 kg
22	FINS	Form Insert - Nozzle Side	12.767	6	2,614 kg
23	FPNS	Form Plate_Nozzle Side	12.312	1	5,781 kg
24	Z31_8 X 20	Cylinder head bolt - Z31_8 X 20	bought-in part	4	0,057 kg
25	FiP	Fixed Platen	12.312	1	38,543 kg
26	Z31_10 X 35	Cylinder head bolt - Z31_10 X 35	bought-in part	4	0,139 kg
27	DIN 16 752	Feed bush DIN 16 752	bought-in part	1	0,228 kg
28	EPNS	End Piece - Nozzle Side	12.312	2	3,459 kg
29	DIN 16 763	Centring flange DIN 16 763	bought-in part	1	0,476 kg

Table 11: List of items

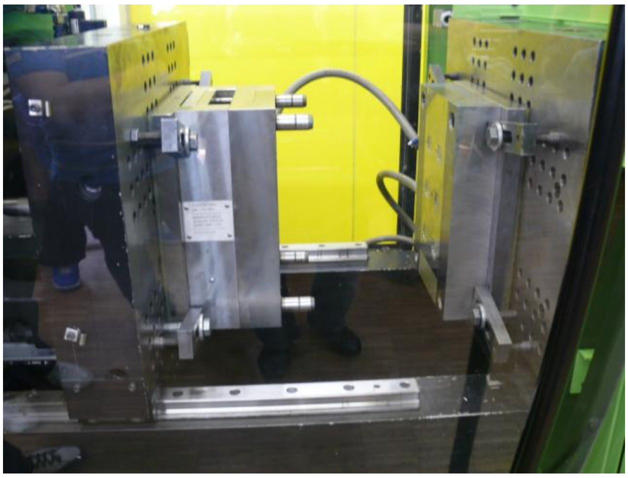


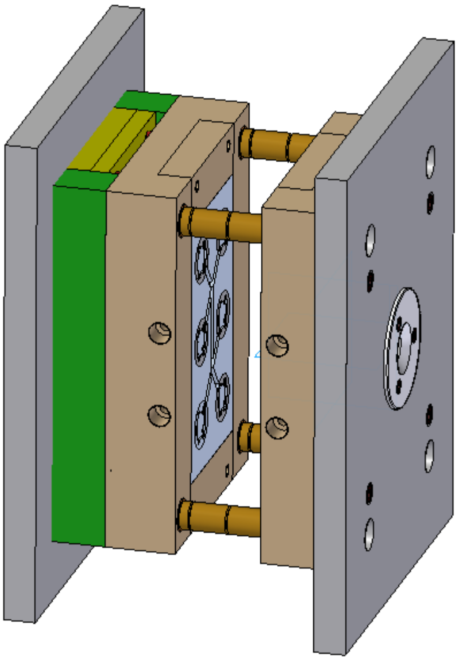
Figure 98: Injection Mould: Mounting

In the figure below you can see the assembly of the injection mould system.

Appendix, reference drawing number: EU-01-02-12

Appendix, reference drawing number: EU-01-01-13

Clamping side



Injection side

Figure 99: Injection Mould: Construction

3.3.2 Bolster Plate

Appendix, reference drawing number: EU-01-01-03

Appendix, reference drawing number: EU-01-02-04

For the injection mould two bolster plates are necessary:

- bolster plate at the nozzle side without ejector holes
- bolster plate at the clamping side with ejector holes for the ejector system

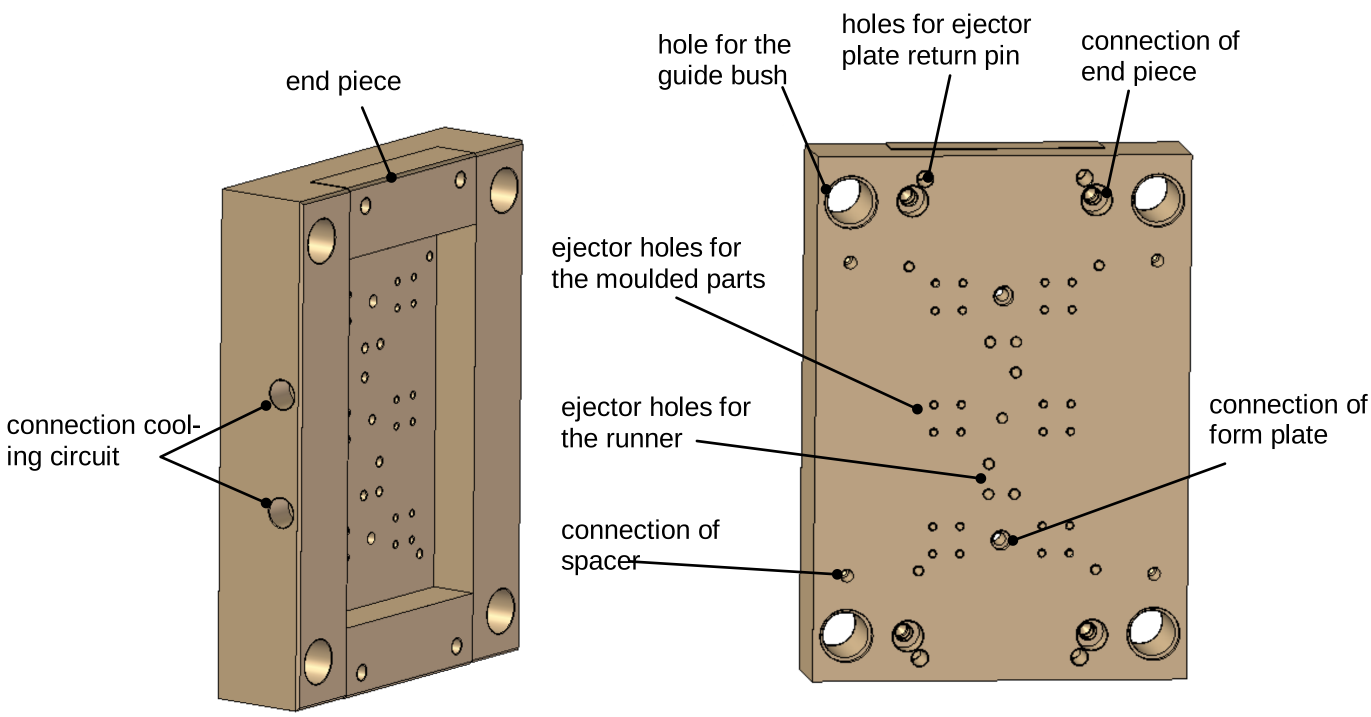


Figure 100: Bolster plate

The bolster plate of the nozzle side is equal, but without ejector holes.

The bolster plates have got pockets for the form plate. The size of the pockets is adapted to the form plates. The form plates are fixed with SHC screws in the bolster plate.

The bolster plate is a standard part and can be ordered at HASCO, for example. There are different sizes and tolerances. The bolster plate is available in the following steel grades: 1.1730, 1.2085 and 1.2312 [53]

In our project the bolster plates existed, because it is not necessary to change the bolster plate by producing new or other parts. The bolster plate is mounted

on the injection moulding machine. It is only necessary to manufacture new form plates, cavity inserts and the ejector system and then to adapt it for the existing bolster plates.

3.3.3 Form Plate

Appendix, reference drawing number: EU-01-01-01

Appendix, reference drawing number: EU-01-02-02

For the injection mould two form plates are necessary:

- form plate at the nozzle side with the injection point and cooling channels
- form plate at the ejector side with the gating system and the cooling channels

Construction:

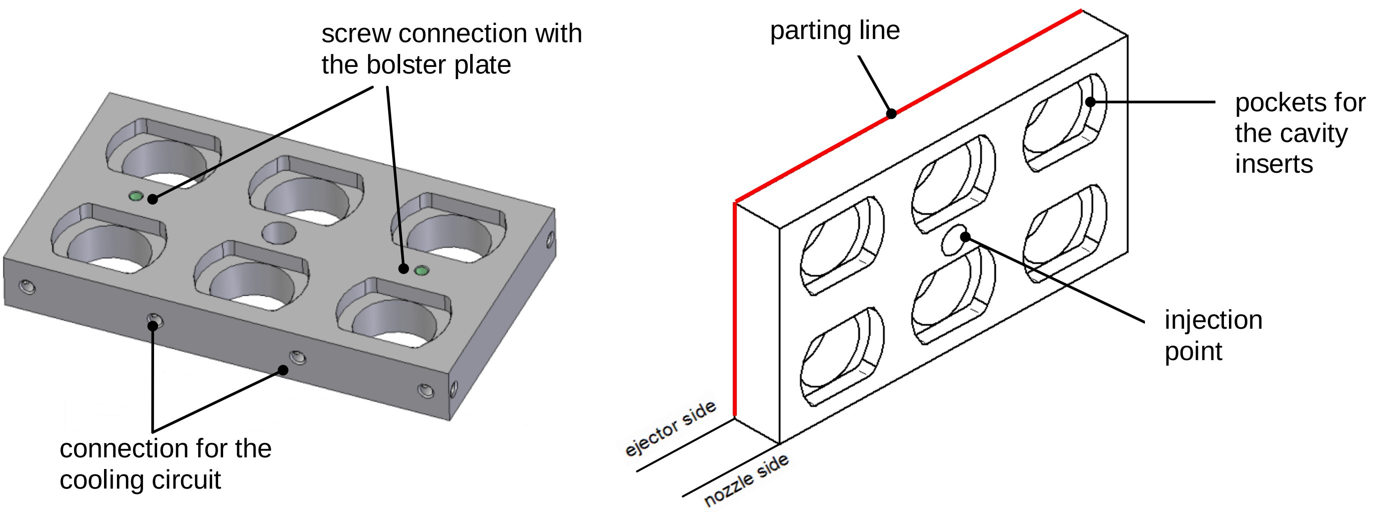


Figure 101: Form plate – nozzle side

In every form plate 6 cavity inserts are located. They are deployed and only served against twisting. The cavity inserts are described in point *(3.3.4 Cavity Insert)*

The external dimensions from the form plates are adapted to the bolster plates on the injection mould. The location of the pockets for the cavity inserts have to be in strict tolerances, because the parting line is between the form plates. That means the alignment of the pockets and also the gating system is important for

[53] http://www.hasco.com/de/content/view/full/18795 Stand: 04.04.2010

the injection moulding process. This means the quality of the moulded parts heavily dependent on the correct fitting of the form plates.

The form plate on the ejection side, the moveable mould half is mirror inverted located to the form plate at the nozzle side.

The pockets for the cavity inserts are symmetrically located and so a equal flow distance to every insert is possible.

Gating system:

Appendix, reference drawing number: EU-01-01-01

The cavity inserts of the injection side have a pin – point gate where the melting flows into the cavity and fills it. The position of the gate depends on the position of the cavity. Therefore, each school have a defined position on the form plate.

The gating system is on the moveable mould half, the ejector side and is designed for the right form filling. The injection happens with an open nozzle over a sprue gate, the runners and the ingates into the cavities.

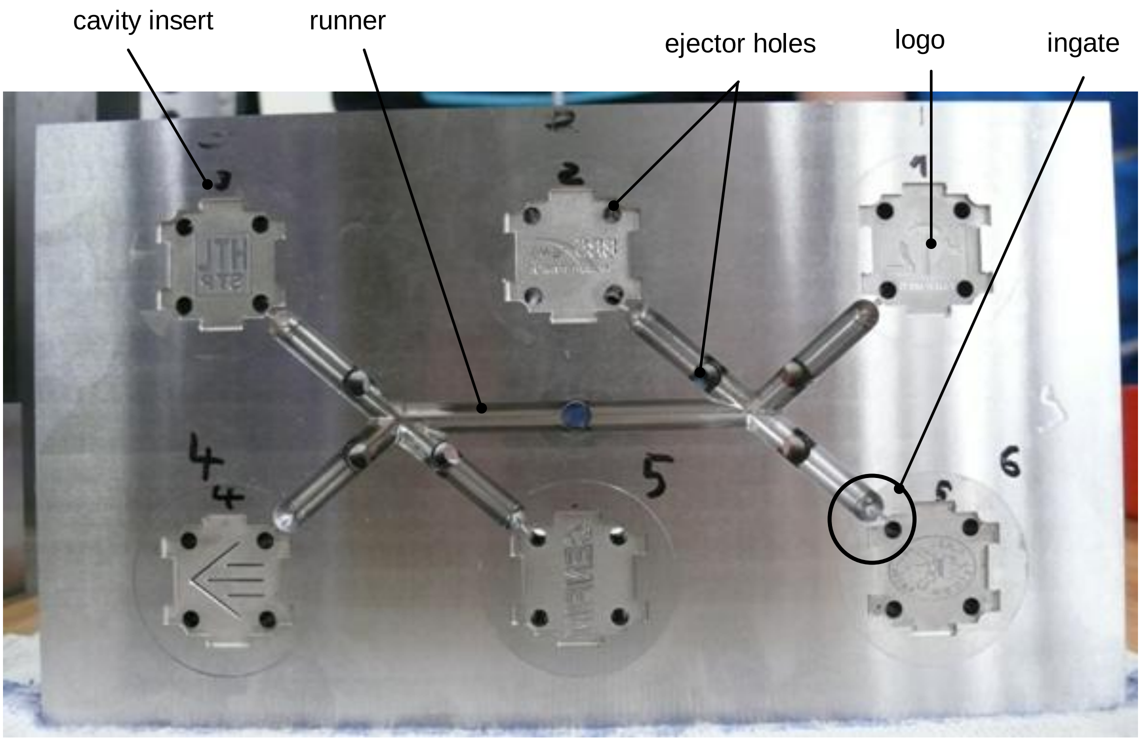
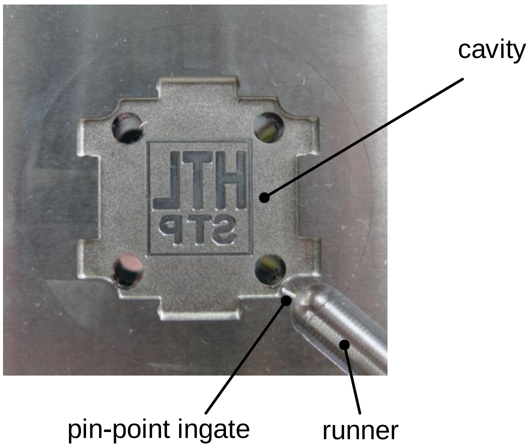


Figure 102: Form plate – ejector side with gating system



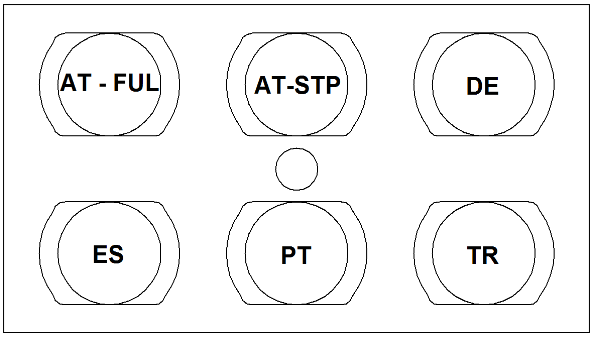


Figure 103: Location of the inserts

Figure 104: Runner, ingate and cavity insert

Runner profile:

The runner profile is a parabolic channel with a width of 6 mm and a half round profile at the ground with a Ø 6 mm. The breadth at the parting line is 7,15 mm. This channel profile is easy to produce, because it is only in one mould half

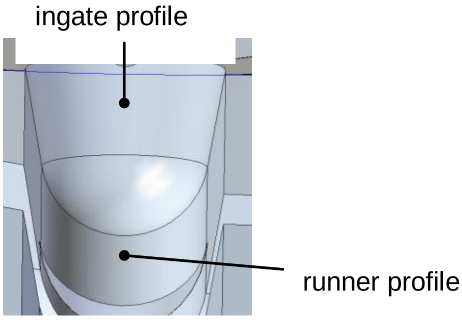


Figure 105: Runner profile

The dimensioning of the runner profile depends on expert knowledge and on empiric experience. Therefore the *(chart 1 – chart 3 in point 2.3.3 Gating System)* is helpful.

The plastic material of the click cube is PP.
The length of the gating system is 200 mm and the weight of the moulded part is 21,7 g at 0,9 kg/dm³ density. The weight is made up of the 6 cavity inserts and the gating system.
The coefficient of the gate length is 1,3 and the runner diameter is 4 mm for a section thickness of 2,5 mm of the click cube.

After this considerations we came to a runner diameter of 5,2 mm, but we choose a runner diameter of 6 mm.

Ingate profile:

The ingate profile is eccentric and so easy to produce, easier to eject and to disconnect. Another pro of this profile is that there is no free jet development. The pro of this ingate profile is the angle of flaring and so the compound will be sheared and heated.

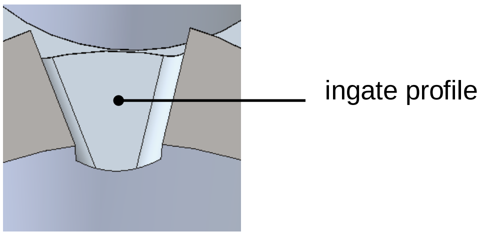


Figure 106: Ingate profile

Cooling channels:

Appendix, reference drawing number: EU-01-01-01

The cooling channels are located in both form plates of the injection mould. There are two connections for the cooling unit and the other cooling holes at the border of the form plates will be closed with close stoppers.

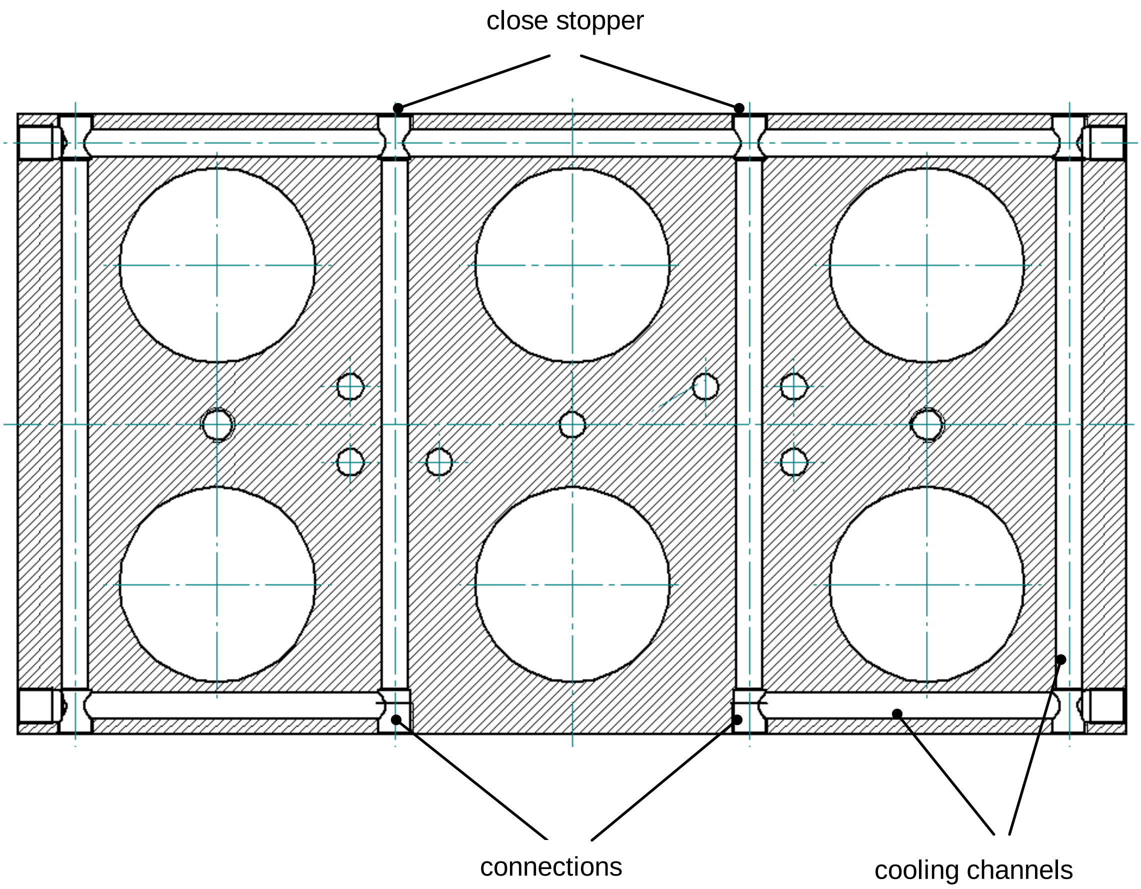


Figure 107: Form plate - cooling channels

The profile of the cooling channel is circular, because it is easy to produce and to seal. Another consideration was to make a balanced cooling with an equal distance of the cooling channels to the cavity inserts.

In point *(2.3.5 Mould Temperature Control)* you can see a suggestion of the cooling channels diameter, but we choose a smaller diameter than in the records, because we have got a parallel cooling circuit with a higher flow capacity than a serial cooling circuit. The diameter of the channel is 6 mm for a section thickness of 2,5 mm of the moulded part.

Manufacturing:

The form plates were ordered form the company HASCO, but only with the external dimensions of 250x140x32,2 mm [54]. The other elements were manufactured inside the EU-Project of the participating schools.

Manufacturing process:

It is important that the height of the form plate and the height of the cavity inserts are the same, because they should be planar. In cause of this it is necessary to let an oversize in height and to mill the form plate with the inserts together. After this manufacturing process the gating system is milled with the same clamping (cavity inserts and form plate together).

Nr.	**work step**	**manufacturing process**
1	injection point (not at ejector side)	drilling, galling
2	pockets for the cavity inserts	milling
3	adaption of the mounted cavity inserts (flush surface)	milling
4	gating system (runners, ingates), when the cavity inserts are mounted	milling
5	cooling channels	drilling

Table 12: Manufacturing process – Form plates

[54] http://www.hasco.com/de/content/view/full/18728 Stand: 29.03.2010

3.3.4 Cavity Insert

Appendix, reference drawing number: EU-01-01-07

The cavity insert contains the shape of the part and is mounted in the form plates. Six these inserts are fixed in the form plate of the nozzle side. These inserts are filled in the injection process with a pin-point gate and runners, which are milled in the form plate.

The other six inserts are mounted in the form plate of the ejector side. For the task of ejection, the cavity inserts have got four holes for the ejection pins. The inserts of the ejection side do not have a pin-point gate. The mould is filled on the nozzle side.

Figure 108: Cavity insert – Nozzle side

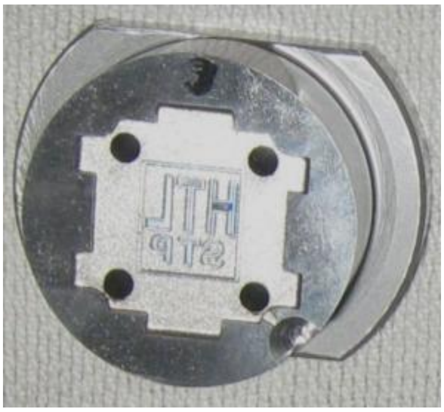


Figure 109: Cavity insert – Ejector side

Cavity

The cavity of the insert is made by electrical discharge machining (EDM). For this working step three electrodes are necessary. A more detailed information of the EDM – process is described in point *(3.3.5 Electrodes).*The depth of the cavity is 1,25 mm. This is half the thickness of the moulded part.

Logos

As explained in point *(3.1.3 EU- Click Cube)* the cube has two logos, one in- and one outside. The logos were milled with a CNC – machine after the finished EDM – process. The contours were transferred with a CAD- CAM- system.

The logos are milled into the material with a depth of 0,3 – 0,5 mm. After the moulding, the logos are embossed.

Important was, that the logo and the writing were manufactured mirror – inverted.

Material:

At the meeting in Germany we decided for material 2767 or 2343, but finally we took another material, because the properties are almost the same and it was easier to supply and easier to find a company to harden the inserts. We chose the material with the standard 2550 or EN / DIN 1.2550 with the configuration 60WCrV7.

This is a cold work steel. We order the material at Böhler by standard K455.

Qualitative comparison of the major steel properties

EN / DIN	Böhler standard	wear resistance abrasiv	wear resistance adhesive	toughness	machinability	Dimensional stability in heat
2550	**K455**					
2767	**K600**					
2343	**K353**					

Data about the K455 / DIN 2550

Properties:

Shock resisting steel exhibiting excellent toughness and wear resistance.

Application:

Cutting tools (dies and punches) for the processing of plate;
cold punches and shear blades;
woodworking, coining and pneumatic tools.
Hot work tools for use at moderate heat

Chemical composition:

C	Si	Mn	Cr	V	W
0,63	0,60	0,30	1,10	0,18	2,00

Heat treatment – Hardening:

870 to 900°C / Oil
Holding time after temperature equalization: 15 to 30 minutes.
Obtainable hardness: 58 - 62 HRC

Hardening of the inserts:

Modern vacuum furnaces for hardening of tools and dies are designed in the way that the heating and quenching processes are carried out under inert gas atmosphere, the latter by high pressure.

These vacuum furnaces thus operate in the vacuum condition only at the beginning of the hardening cycle, i.e. at the stage of air evacuation, which actually classifies them as inert gas furnaces.

Heating is carried out in inert gas in order to improve the heat transfer by convection, as the heat transfer by radiation is very slow at low temperatures in the vacuum and different in the charge.

Inert gas has an important function in tool steel hardening as it prevents the selective vaporization of alloying elements from the steel surface at temperatures exceeding 1000°C.

After the hardening, the inserts have a hardness of 54– 56 HRC Rockwell.

Manufacturing:

<table>
<tr><th colspan="4">Process sheet - Cavity Insert</th><th>Drawing Nr:
EU-01-01-07</th></tr>
<tr><td colspan="3">Applied quantity:
2 pcs.</td><td>Gross weight:
0,78 kg
Material designation:
K455 / DIN 2550 conf.: 60WCrV7</td><td>Rough size :
60 x 35 mm</td></tr>
<tr><td>Machine</td><td>Cost centre</td><td>Nr.</td><td>Working cycle</td><td>Tool</td></tr>
<tr><td>CNC - lathe</td><td>CNC - turning</td><td>1</td><td>Fix the blank and face the front side</td><td>HM - cutting chisel</td></tr>
<tr><td>CNC - lathe</td><td>CNC - turning</td><td>2</td><td>Turn the blank on Ø 58 $^{+0,1}$</td><td>HM - cutting chisel</td></tr>
<tr><td>CNC - lathe</td><td>CNC - turning</td><td>3</td><td>Turn the step Ø 44 $^{+0,1}$ x 22,2</td><td>HM - cutting chisel</td></tr>
<tr><td>CNC - lathe</td><td>CNC - turning</td><td>4</td><td>Turn the relief groove DIN 509 E0.3x25</td><td>HSS - recessing tool</td></tr>
<tr><td>CNC - miller</td><td>CNC - milling</td><td>5</td><td>Fix the the workpiece in the milling machine</td><td>bench vise</td></tr>
<tr><td>CNC - miller</td><td>CNC - milling</td><td>6</td><td>Mill the top of the Ø 58 to Ø 44</td><td>HM - chamfer Ø 30</td></tr>
<tr><td>CNC - miller</td><td>CNC - milling</td><td>7</td><td>Unclamp the workpiece and fix it inverted</td><td>bench vise</td></tr>
<tr><td>CNC - miller</td><td>CNC - milling</td><td>8</td><td>Mill the second top to Ø 44</td><td>HM - chamfer Ø 30</td></tr>
<tr><td>CNC - miller</td><td>CNC - milling</td><td>9</td><td>Unclamp the workpiece and fix in ot he flat surfaces</td><td>bench vise</td></tr>
<tr><td>CNC - miller</td><td>CNC - milling</td><td>10</td><td>** Drill the 4 holes with Ø 4</td><td>HSS - drill Ø 4</td></tr>
<tr><td>CNC - miller</td><td>CNC - milling</td><td>11</td><td>** ream the holes; fit Ø 4 H7</td><td>Reamer Ø 4 H7</td></tr>
<tr><td>CNC - miller</td><td>CNC - milling</td><td>12</td><td>** Unclamp the insert, turn it about 180° and fix it again</td><td>bench vise</td></tr>
<tr><td>CNC - miller</td><td>CNC - milling</td><td>13</td><td>** Drill the 4 holes with Ø 5 x 18</td><td>HSS - drill Ø 5</td></tr>
<tr><td>Curing oven</td><td>(FIRMA - GUT)</td><td>14</td><td>Hardening of the insert with "inert gas hardening" HRC 54-56</td><td>WELSER Profile AG</td></tr>
<tr><td>radial grinding machine</td><td>Toolroom</td><td>15</td><td>Fix the hardend insert in the turning grinding machine</td><td>jaw chuck</td></tr>
<tr><td>radial grinding machine</td><td>Toolroom</td><td>16</td><td>Grind the Ø 58 $^{+0 / -0,01}$; Ra 0.8</td><td>grinding disc</td></tr>
</table>

radial grinding machine	Toolroom	17	Grind the Ø 44 $^{+0 / -0,01}$; Ra 0.8	grinding disc
planar grindin machine	Toolroom	18	Unclamp the insert and fix it on the planar grinding machine	magnetig clamping chuck
planar grindin machine	Toolroom	19	Grind the flat tops to the meassure 44 $^{+0 / -0,01}$; Ra 0.8	grinding disc
EDM - machi-ne	Mangel GesmbH	20	Fix the grinded insert in the eroding machine and adjust it	clamping device
EDM - machi-ne	Mangel GesmbH	21	Erode the shape of the cavity in the middle of the diameter Ø 44, with a depth of 1,25 mm	Main electrode
EDM - machi-ne	Mangel GesmbH	22	Erode the undercuts	Dome electrode
CNC - miller	CNC - milling	23	Fix the the workpiece (Injection side) in the milling machine	bench vise
CNC - miller	CNC - milling	24	Mill the outline contour of Austria with a depth of 0,3 mm in the cavity	HSS - chamfer Ø 1,5
CNC - miller	CNC - milling	25	Unclamp the insert of the injection side	bench vise
CNC - miller	CNC - milling	26	Fix the the workpiece (Ejector side) in the milling machine	bench vise
CNC - miller	CNC - milling	27	Mill the writing of the "HTL St.Pölten" with a depth of 0,3 mm in the cavity	HSS - chamfer Ø 3
CNC - miller	CNC - milling	28	Unclamp the insert of the ejection side	bench vise

3.3.5 Electrodes

The electrodes were needed for the cavity in the insert. Three electrodes are necessary to erode the cavity:

- main electrode
- deflect electrode
- dome electrode

It is important to secure that the EDM machine provides planetary deflection, because then it is possible to machine the click pin geometries with this deflecting electrode.

The next important point is the gap of the different electrodes. Normally the differentiation is between two electrodes:

- rough machining electrode, for the prefabrication
- finish machining electrode, for a good surface

And so every electrode has got a different gap. The normal evaluation of the electrodes measurements is to look at the workshop drawing of the work piece and then to subtract the gap from the work piece measurement.

$$\mathbf{L_{electrode} = L_{work\ piece} - gap}$$

Attention has been paid to symmetrical elements, because then you have to attend the gap two times. An example is a cylinder.

Constructions of the cavity insert:

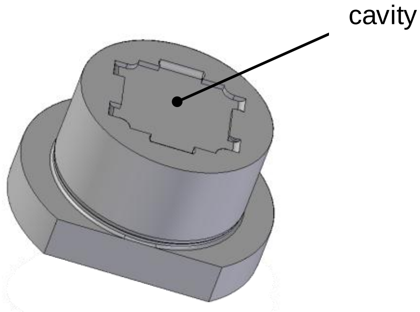


Figure 110: Cavity insert

Main electrode:

This electrode is necessary to erode the profile of the Click- Cube face.

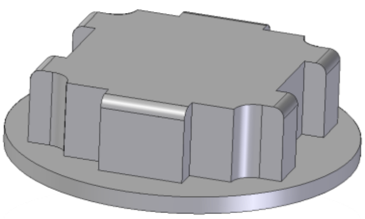


Figure 111: Main electrode

Deflecting electrode:

This electrode is necessary to erode the click pins of the click- system.

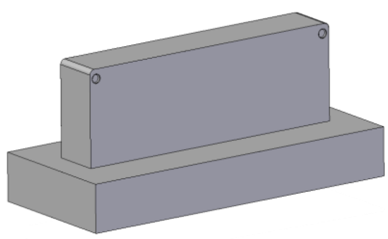


Figure 112: Deflecting electrode

Dome electrode:

This electrode is necessary to erode the negative of the click pins.

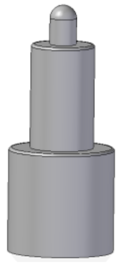


Figure 113: Dome electrode

Manufacturing:

The electrodes for the cavity inserts were made by each partner school or partners of these schools, because every school had to produce one cavity insert.

In our case the work of eroding the cavity inserts was done at the partner company Mangel Formenbau GesmbH. The reason for this outsourcing was the problem of the clamping device at the EDM machines in the HTL St. Pölten.

Manufacturing process:

Nr.	work step	manufacturing process
1	main electrode *2 times	milling, erode (EDM)
2	deflect electrode *2 times	milling, erode (EDM)
3	dome electrode *2 times	turning

Table 13: Manufacturing process – Electrodes

*2 times: one rough machining electrode and one finish machining electrode

3.3.6 Ejector Package

The Ejector package of the quick-change mould is placed on the moveable side of the injection mould.

The ejector package consists of the:

- Ejector head plate:
  Appendix, reference drawing number: EU-01-01-06
- Ejector holding plate:
  Appendix, reference drawing number: EU-01-01-05
- 24 Ejector pins Ø 4: bought-in part
- 7 Ejector pins Ø 6: bought-in part
- 4 Ejector pins Ø 10,5: bought-in part

In the figure below you can see the moveable side of the injection mould, before the injection of the compound. In this moment the ejector plates in the back range at the moving platen and the ejector pins ends with the surface.

Ejector pins Ø 4:

This ejector pin is for the ejection of the moulded parts and is inside the cavity inserts. It has to end with the surface of the moulded part and this is the cause, that the ejector pins are placed outside the logo in the cavity insert. Every cavity insert will have 4 ejectors with a diameter of 4 mm and they will be placed in the corners around the logo in a distance of 18mm x 18mm.

Ejector pins Ø 6:

This ejector pin is for the ejection of the runners. There are 6 ejector pins from this kind. It has to end with the runner surface and so the ending is matched with the half round runner profile in the ground.

Ejector pins Ø 10,5:

This ejector pin is for the assurance of the other ejector pins, he is also called the ejector plate return pin. This 4 ejector pins are longer as the other ones, they ends with the parting line. If the ejector system (hydraulic or with springs) didn't return before closing of the mould, the ejector plate return pins push the ejector plate back, because they against the fixed mould half at the closing of the mould.

The ejector pins are only guided in the bore hole of the cavity inserts.

Spacer:

The spacers are the distance piece for the ejector plates. This means the stroke of the ejector plates and so the ejector pins are limited by the spacers. The length of the spacer minus the thickness of the ejector plates gives the ejection stroke.

Every spacer is centered with 2 centering sleeves and mounted with 2 SHC screws.

In the figure below you can see the moveable mould half at the ejection.

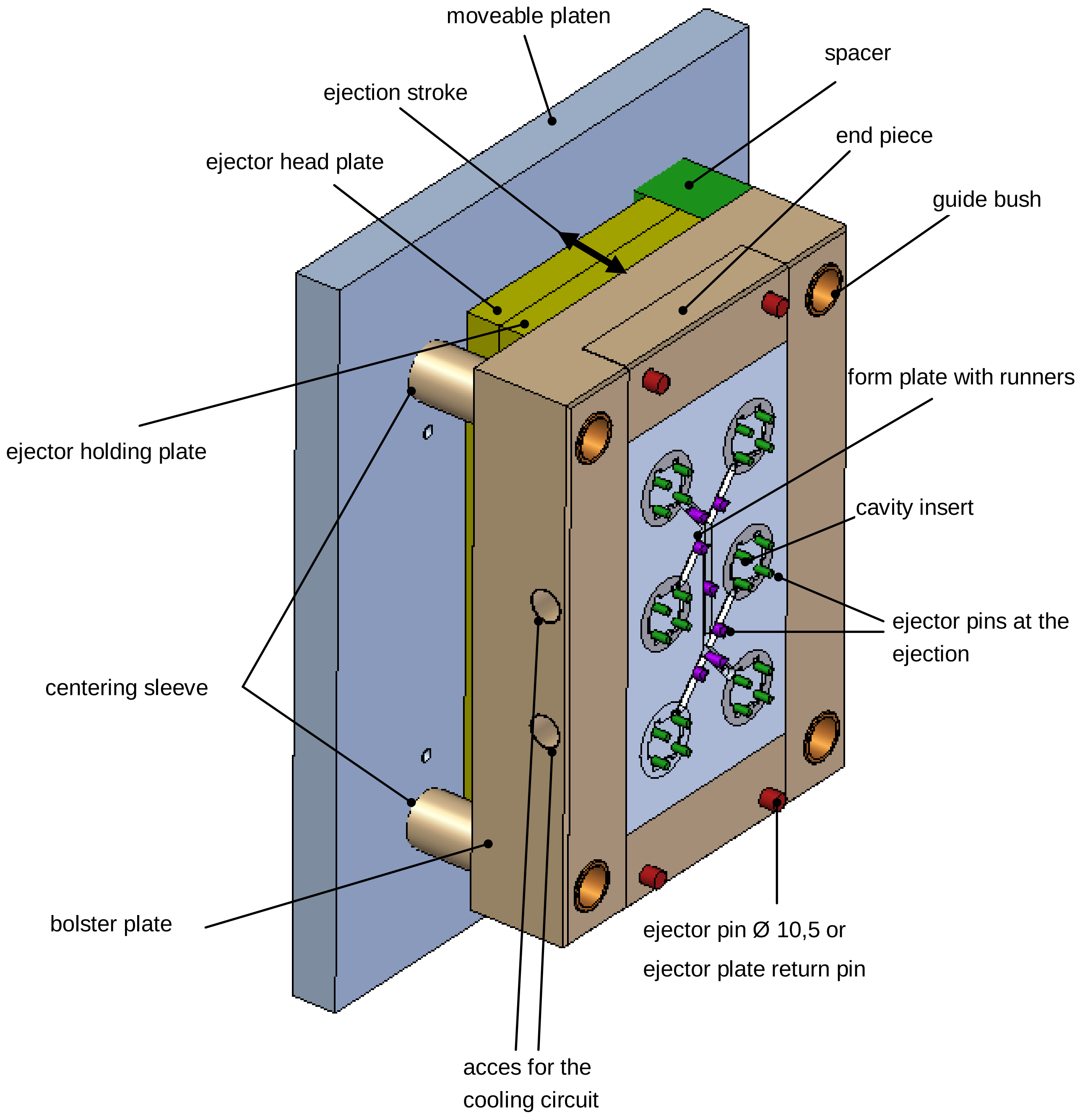


Figure 114: Moveable mould half at the ejection

The ejector head plate is pressed against the bolster plate and the ejector pins eject the moulded parts and the runner. In this mould the ejection stroke is only ten millimeters, because this is enough for parts with a section thickness of 2.5 mm. the ejector head plate is hydraulically acted with a pusher from the injection moulding machine. The head plate is bolted to the ejector holding plate.

Ejector head plate –holding plate:

In the figure below you can see the bolted ejector plates on the left side and the ejector holding plate with the inserted ejector pins.

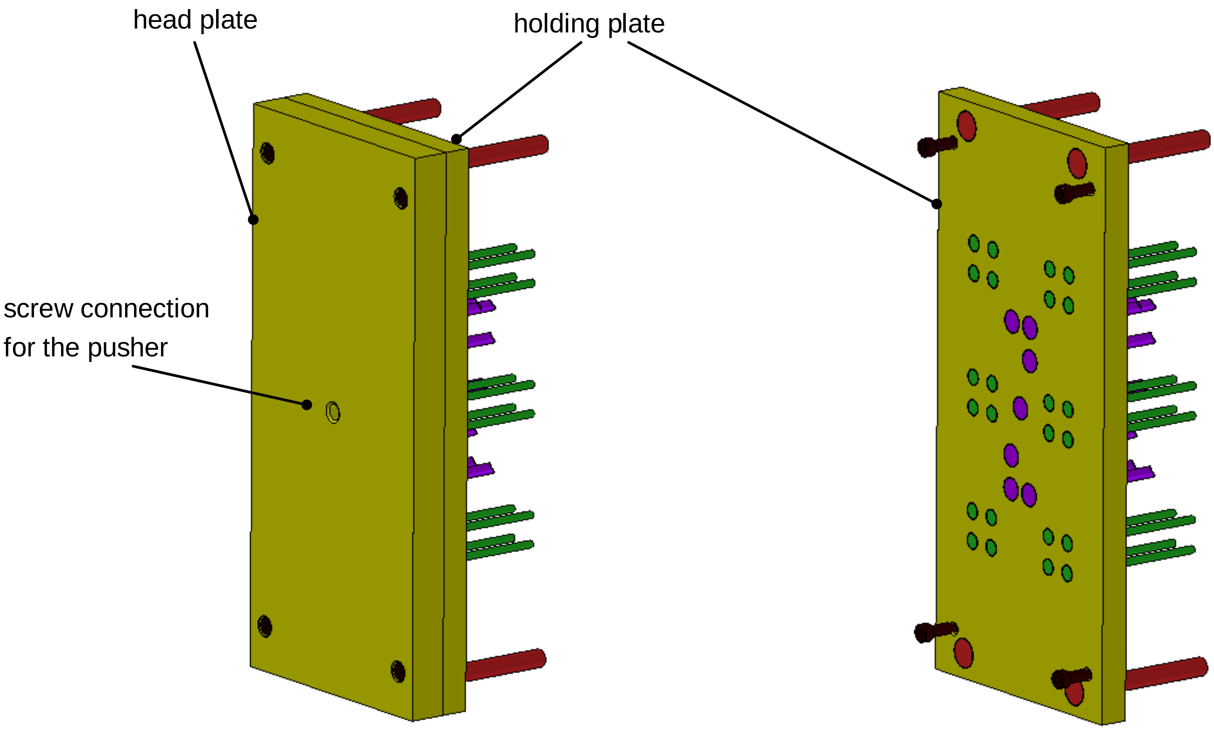


Figure 115: Ejector head plate – holding plate

The task of the head plate is to fix and press against the ejector pins and to transmit the ejection pressure from the pusher.

Manufacturing:

The ejector pins were ordered from company HASCO and had to be cut to length for the injection mould of the project. The ejector head and holding plate were also ordered as standard part with the basic measurements, but the ejector holes and screw connections were manufactured from the participating schools.

Electrodes for the cavity inserts were made by each partner school or partners of these schools, because every school had to produce its own cavity insert.

Manufacturing process:

Nr.	work step	manufacturing process
1	ejector head plate	drilling, milling, threading
2	ejector holding plate	drilling, milling, threading
3	ejector pins	erode (EDM)

Table 14: Manufacturing process – Ejector plates

3.3.7 Platen – Ejector Side, Platen – Nozzle Side

Appendix, reference drawing number: EU-01-01-08

Appendix, reference drawing number: EU-01-02-09

The task of the platens is to fix the injection mould on the platens of the injection moulding machine. The fixing is often done with clamping shoes or directly bolted down.

3.4 Design of the Injection Moulding Machine

Here you can see the injection moulding machine, where the EU- Click Cube is produced. This injection moulding machine is placed in the workshop of our partner school HTL Fulpmes and is a tie-bar less injection moulding machine.

Figure 116: Injection Moulding Machine ES 330/75 HL-V

It is an ENGEL injection moulding machine with this specifications:

Machine Marking: **ES 330/75 HL-V**

It exists a designation of injection moulding machines, EUROMAP 1, this is a standard description of the European Committee of Machinery Manufactures and is described in point *(2.1 Injection Moulding Machine).*

The designation for injection moulding machines from every manufacturer can differ.

In our case the designation differs from EUROMAP 1. The injection moulding machine manufacturer ENGEL interchanges the clamping force and the injection volume [cm³] at 1000 [bar] injection pressure in the designation of the data sheet.

EUROMAP 1 designation	**ENGEL designation**
75/330	ES 330/75 HL-V

This type designation means:

ES… manufacturer designation, ENGEL Schwertberg

330… 330 cm³ injection volume at 1000 [bar] injection pressure.

75… 75 [kN] clamping force

H… horizontal clamping unit

L… injection into the separating plate with horizontal clamping and injection unit

V… the design with vertical injection or clamping unit exists also

Calculation of the injection moulding machine classification:

Here you can see the important parameters from the data sheet.

Appendix, reference: Data sheet Injection Moulding Machine

- clamping force 750 kN
- metering stroke 160 mm
- injection pressure 1600 respectively 2180 bar
- screw diameter 35 mm

It is important to know that ENGEL calculates the injection pressure of the injection moulding machine with the raised value. The raised value is achieved when the oil from the hydraulic actuator of the injection unit is directly conducted back to the hydraulic oil tank.

Here you can see the calculation of the injection volume at 1000 bar.

$$V_d = (D_s)^2 \cdot \frac{\pi}{4} \cdot ms$$

$$V_d = 3.5^2 \cdot \frac{\pi}{4} \cdot 16$$

$$V_d = 154\mathrm{cm}^3$$

$$\frac{V_I}{1000\mathrm{bar}} = \frac{V_d \cdot I_p}{1000}$$

$$\frac{V_I}{1000\mathrm{bar}} = \frac{154 \cdot 2180}{1000}$$

$$\frac{V_I}{1000\mathrm{bar}} = 336\,\frac{\mathrm{cm}^3}{1000}$$

V_d... displacement volume

D_s... screw diameter

ms... metering stroke

V_I... injection volume

I_p... injection pressure

The clamping force [750 kN] and the injection volume at 1000 bar injection pressure [330 cm³/1000 bar] is relevant for the selection of the injection moulding machine, which is used for the injection moulding process to produce the moulded parts.

Setting parameter for the production:

ES 330/75 HL-V - setting parameters		
Metering stroke	31 mm	
Injection pressure	70 bar	limitation at 1600 bar
Holding pressure	max. 65 bar	
Back pressure	max. 5,1 bar	
Cooling time	13 sec.	during the holding pressure time the cooling is also existing
Holding pressure time	8 sec.	
Nozzle temperature	230 °C	
Mould die temperature	35 °C	
Mould release temperature	60 °C	
Resulting data		
Cycle time	29,5 sec.	
weight of the part	21,7 g	weight of the whole injection material

Table 15: Setting parameters

Calculation of setting parameters:

Before the first injection the producer have to make a rough estimate or to calculate some setting parameters. As example the cooling time will be calculate with a formula of the injection moulding machine manufacturer ENGEL.

$$t_c = \frac{s^2}{\pi^2 \cdot a_{eff}} \cdot \ln\left(\frac{4}{\pi} \cdot \frac{t_n - t_m}{t_r - t_m}\right)$$

$$t_c = \frac{2.5^2}{\pi^2 \cdot 0.067} \cdot \ln\left(\frac{4}{\pi} \cdot \frac{230 - 35}{65 - 35}\right)$$

$$t_c = 20\text{sec}$$

t_c... cooling time
s... section thickness
a_{eff}... coefficient of thermal conductivity
t_n... temperature of the injection nozzle
t_m... temperature of the injection mould
t_r... mould release temperature

After this calculation it is easier to find the right parameters. In the table above you can see that the cooling time in the injection moulding process only differs 1 second.

3.5 Project Schedule

On the following pages you can see the project schedule. At first the Leonardo project meetings are listed and then the diploma thesis course is listed in point 2. It is important to know that the Leonardo project started in October 2008 and ended in May 2010. This schedule was the guideline for our diploma thesis and made it possible to have the overview about important appointments, but we also had a detailed planning for every month of our operations.

The start and end of the work tasks with the associated working hours are obvious in the project schedule. You can also see the individuals from every work task.

The classification of the work time and the work steps of our diploma thesis are combined for every month under “work schedule Pfannhauser” and “work schedule Wieland”. But important meetings, conferences and production steps are also mentioned in the project schedule.

	PSP-Code	Work task	Start	End	[h]	Individuals
1	**1**	**EU- Project LEONARDO - "Moulding for Europe"**	**Mo 27.10.08**	**Do 20.05.10**	428	
2	**1.1**	**Projectmeetings**	**Mo 27.10.08**	**Mo 10.05.10**	**0**	
3	1.1.1	1. Meeting Spain: Barcelona	Mo 27.10.08	Di 28.10.08	0	Dipl. Päd. Amstätter, Dipl. Ing. Wiedlack
4	1.1.2	2. Meeting Turkey: Gaziantep	Fr 27.02.09	Di 03.03.09	20	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
5	1.1.3	3. Meeting Austria: St.Pölten	Fr 05.06.09	Di 09.06.09	20	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
6	1.1.4	4. Meeting Germany: Bad Kreuznach	Fr 06.11.09	Mo 09.11.09	18	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
7	1.1.5	5. Meeting Portugal: Porto	Do 21.01.10	Mo 25.01.10	18	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
8	1.1.6	6. Meeting Austria: Fulpmes	Mi 05.05.10	Mo 10.05.10	16	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Dipl. Ing. Dr. Zveglic, Pfannhauser, Wieland
9	1.2	MS	Do 20.05.10	Do 20.05.10	0	
10	**2**	**Diploma thesis: EU- Project**	**Mo 07.09.09**	**Do 17.06.10**	**388**	**hours of work in total (Pfannhauser, Wieland)**
11	**2.1**	**DA: September**	**Mo 07.09.09**	**Mi 30.09.09**	**20**	
12	2.1.1	Work schedule Pfannhauser	Mo 07.09.09	Mi 30.09.09	10	Pfannhauser
13	2.1.2	Work schedule Wieland	Mo 07.09.09	Mi 30.09.09	10	Wieland
14	2.2	MS	Mi 30.09.09	Mi 30.09.09	0	
15	**2.3**	**DA: October**	**Do 01.10.09**	**Sa 31.10.09**	**32**	
16	2.3.1	Work schedule Pfannhauser	Do 01.10.09	Sa 31.10.09	18	Pfannhauser
17	2.3.2	Work schedule Wieland	Do 01.10.09	Sa 31.10.09	14	Wieland
18	2.3.3	Conference: Meeting Bad Kreuznach - Construction	Do 08.10.09	Do 08.10.09	2	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
19	2.3.4	Moulding Dictionary: Description Injection Moulding	Mo 12.10.09	Mo 19.10.09	5	Pfannhauser, Wieland
20	2.3.5	Conference: Meeting Bad Kreuznach - Design	Do 29.10.09	Do 29.10.09	2	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
21	2.4	MS	Sa 31.10.09	Sa 31.10.09	0	
22	**2.5**	**DA: November**	**So 01.11.09**	**Mo 30.11.09**	**25**	
23	2.5.1	Work schedule Pfannhauser	So 01.11.09	Mo 30.11.09	15	Pfannhauser
24	2.5.2	Work schedule Wieland	So 01.11.09	Mo 30.11.09	10	Wieland
25	2.5.3	4. Meeting Germany: Bad Kreuznach	Fr 06.11.09	Mo 09.11.09	18	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
26	2.5.4	Conference: Meeting Bad Kreuznach - Cavity Inserts	Di 17.11.09	Di 17.11.09	2	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
27	2.5.5	Production: Cavity Inserts	Do 19.11.09	Do 26.11.09	8	Walzer, Winkler
28	2.5.6	Conference: Diploma	Do 26.11.09	Do 26.11.09	2	Dipl. Päd. Gutmann, Pfannhauser, Wieland
29	2.6	MS	Mo 30.11.09	Mo 30.11.09	0	

30	**2.7**	⊟ **DA: December**	**Di 01.12.09**	**Do 31.12.09**	**37**	
31	2.7.1	Work schedule Pfannhauser	Di 01.12.09	Do 31.12.09	21	Pfannhauser
32	2.7.2	Work schedule Wieland	Di 01.12.09	Do 31.12.09	16	Wieland
33	2.7.3	Production: Cavity Insert	Di 01.12.09	Mo 21.12.09	0	Welser Profile AG
34	**2.7.4**	**DA: Correction - Advisers**	**Mi 23.12.09**	**Mi 23.12.09**	0	**Dipl. Päd. Gutmann, Dipl. Ing. Wiedlack, Dipl. Ing. Dr. Zveglic**
35	2.8	MS	Do 31.12.09	Do 31.12.09	0	
36	**2.9**	⊟ **DA: January**	**Fr 01.01.10**	**So 31.01.10**	**54**	----
37	2.9.1	Work schedule Pfannhauser	Fr 01.01.10	So 31.01.10	29	Pfannhauser
38	2.9.2	Work schedule Wieland	Fr 01.01.10	So 31.01.10	25	Wieland
39	2.9.3	Conference: Meeting Portugal - Cavity Inserts	Do 07.01.10	Do 07.01.10	2	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
40	2.9.4	Production: Cavity Inserts	Do 14.01.10	Do 14.01.10	6	Pfannhauser, Wieland
41	2.9.5	Leonardo Moodle-platform: Description posting	Fr 15.01.10	Fr 15.01.10	1	Pfannhauser, Wieland
42	2.9.6	5. Meeting Portugal: Porto	Do 21.01.10	Mo 25.01.10	18	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
43	2.9.7	Conference: Diploma Thesis	Di 26.01.10	Di 26.01.10	3	Dipl. Päd. Gutmann, Pfannhauser, Wieland
44	2.9.8	Conference: Diploma Thesis - structure	Do 28.01.10	Do 28.01.10	4	Pfannhauser, Wieland, Dipl. Ing. Dr. Zveglic
45	**2.9.9**	**DA: Correction - Advisers**	**Do 28.01.10**	**Do 28.01.10**	0	**Dipl. Päd. Gutmann, Dipl. Ing. Wiedlack, Dipl. Ing. Dr. Zveglic**
46	2.10	MS	So 31.01.10	So 31.01.10	0	
47	**2.11**	⊟ **DA: February**	**Mo 01.02.10**	**So 28.02.10**	**48**	----
48	2.11.1	Work schedule Pfannhauser	Mo 01.02.10	So 28.02.10	26	Pfannhauser
49	2.11.2	Work schedule Wieland	Mo 01.02.10	So 28.02.10	22	Wieland
50	2.11.3	Conference: Diploma Thesis- Workshop drawings	Do 25.02.10	Do 25.02.10	2	Dipl. Päd. Gutmann, Pfannhauser, Wieland
51	2.12	MS	So 28.02.10	So 28.02.10	0	
52	**2.13**	⊟ **DA: March**	**Mo 01.03.10**	**Mi 31.03.10**	**55**	----
53	2.13.1	Work schedule Pfannhauser	Mo 01.03.10	Mi 31.03.10	30	Pfannhauser
54	2.13.2	Work schedule Wieland	Mo 01.03.10	Mi 31.03.10	25	Wieland
55	2.13.3	Conference: Diploma Thesis - Theoretical Part	Do 04.03.10	Do 04.03.10	4	Pfannhauser, Wieland, Dipl. Ing. Dr. Zveglic
56	2.13.4	Conference: Electrodes	Do 04.03.10	Do 04.03.10	1	Dipl. Päd. Amstätter, Pfannhauser, Wieland
57	2.13.5	Production: Electrodes	Mo 08.03.10	Fr 19.03.10	0	Mangel Formenbau GesmbH
58	2.13.6	Conference: Diploma Thesis	Do 18.03.10	Do 18.03.10	3	Pfannhauser, Wieland, Dipl. Ing. Wiedlack, Dipl. Ing. Dr. Zveglic
59	2.13.7	Production: Cavity Inserts - Logos	Mo 22.03.10	Mo 22.03.10	3	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
60	2.13.8	Consignment of the cavity inserts to fulpmes	Fr 26.03.10	Fr 26.03.10	0	
61	2.14	MS	Mi 31.03.10	Mi 31.03.10	0	

62	**2.15**	**⊟ DA: April**	**Do 01.04.10**	**Fr 30.04.10**	**62**	----
63	2.15.1	Work schedule Pfannhauser	Do 01.04.10	Fr 30.04.10	34	Pfannhauser
64	2.15.2	Work schedule Wieland	Do 01.04.10	Fr 30.04.10	28	Wieland
65	2.15.3	Conference: Moodle Forum	Do 15.04.10	Do 15.04.10	1	Dipl. Päd. Amstätter, Pfannhauser, Wieland, Dipl. Ing. Dr. Egon Zveglic
66	2.15.4	Leonardo Moodle-platform: Test posting	Mo 19.04.10	Mo 19.04.10	2	Wieland
67	2.15.5	Visiting of partner company Mangel Formenbau	Di 20.04.10	Di 20.04.10	3	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
68	2.15.6	Conference: Diploma Thesis	Do 22.04.10	Do 22.04.10	3	Pfannhauser, Wieland, Dipl. Ing. Dr. Zveglic
69	2.15.7	Conference: Meeting Fulpmes	Do 29.04.10	Do 29.04.10	1	Dipl. Päd. Amstätter, Pfannhauser, Wieland
70	2.16	MS	Fr 30.04.10	Fr 30.04.10	0	
71	**2.17**	**⊟ DA: May**	**Fr 30.04.10**	**Do 17.06.10**	**55**	----
72	2.17.1	Work schedule Pfannhauser	Sa 01.05.10	Do 20.05.10	30	Pfannhauser
73	2.17.2	Work schedule Wieland	Sa 01.05.10	Do 20.05.10	25	Wieland
74	**2.17.3**	**DA: Correction - Advisers**	**Mo 03.05.10**	**Mo 03.05.10**	0	**Dipl. Päd. Gutmann, Dipl. Ing. Wiedlack**
75	2.17.4	6. Meeting Austria: Fulpmes	Fr 30.04.10	Do 17.06.10	16	Dipl. Päd. Amstätter, Dipl. Päd. Gutmann, Pfannhauser, Wieland
76	**2.17.5**	**DA: Correction - Advisers**	**Mi 05.05.10**	**Mi 05.05.10**	0	**Dipl. Ing. Dr. Egon Zveglic**
77	2.17.6	Conference: Diploma Thesis	Fr 07.05.10	Fr 07.05.10	3	Pfannhauser, Wieland, Dipl. Ing. Dr. Zveglic
78	2.17.7	Conference: Diploma Thesis	Di 11.05.10	Di 11.05.10	1	Pfannhauser, Wieland, Dipl. Ing. Wiedlack, Dipl. Ing. Dr. Zveglic
79	2.17.8	Conference: Diploma Thesis	Di 18.05.10	Di 18.05.10	2	Pfannhauser, Wieland, Dipl. Ing. Wiedlack, Dipl. Ing. Dr. Zveglic
80	2.17.9	Diploma Thesis: Hard copy	Mi 19.05.10	Mi 19.05.10	2	Pfannhauser, Wieland
81	**2.18**	**DA: Deadline**	**Do 20.05.10**	**Do 20.05.10**	0	
82	2.19	MS	Do 20.05.10	Do 20.05.10	0	

3.6 Calculation

The following calculation compares two different machines with two different moulds (one with 6 cavities and one with 3 cavities). The target is to calculate the price for one cube and find the Break – Even Point. This calculation is important for the decision which machine will be used for the production.

Machine data:	IMM 330/75 [1]	IMM 200/45 [1]	Machine hour rate	per hour	
Costs of purchase [2]	€70.000,00	€55.000,00	Cost-accounting depreciation	5,30	5,73
Service life (years)	6	6			
Efficiency p.a. (hours)	2.200	1.600			
Interest rate p.a.	5%	5%	Imputed interest	0,80	0,86
Floor space required (m^2)	16	8			
Lease p.a. (m^2)	40	50	Maintainance costs	0,29	0,25
Power consumption (kW) [3]	12	6			
Electricity tariff (kWh)	0,20	0,20	Energy costs	2,40	1,20
Repair (per year)	€3.500,00	€2.700,00	Repair costs	1,59	1,69
			Sum of costs / hour	€ 10,38	€ 9,73
			costs/cycle per pc	0,0144	0,0216
Applied quantity (1000 cubes 6 plates each)	6000	6000			
Cyclus time [h]	0,0014	0,0022			
Cyclus time [sec.]	5	8			
Tool data:					
Costs (special direct costs of production) [4]	€2.500,00	€1.000,00			
Quantity of cavitys [4]	6	3			
Workpiece data:					
Cycle time (min.)	0,5	0,4			
Weight (gram) [5]	10	10			
Material costs (kg) [6]	€ 1,20	€ 1,20	Material costs	€ 72,00	€ 72,00
			Material costs/ piece	€ 0,0120	€ 0,0120
General data for the calculation					
variable overhead rate [7]	25%	35%			
fixed costs overhead [7]	50%	50%			
Manufacturing costs / order	€ 614,79	€ 605,60			
Break EVEN	**6.744**	**pieces**	**1124 cubes**		
Costs / order	€ 922,19	€ 908,40			
Costs for 1 injection moulded part	€ 0,15	€ 0,15			
Costs for 1 cube	€ 0,92	€ 0,91			

Table 16: Calculation

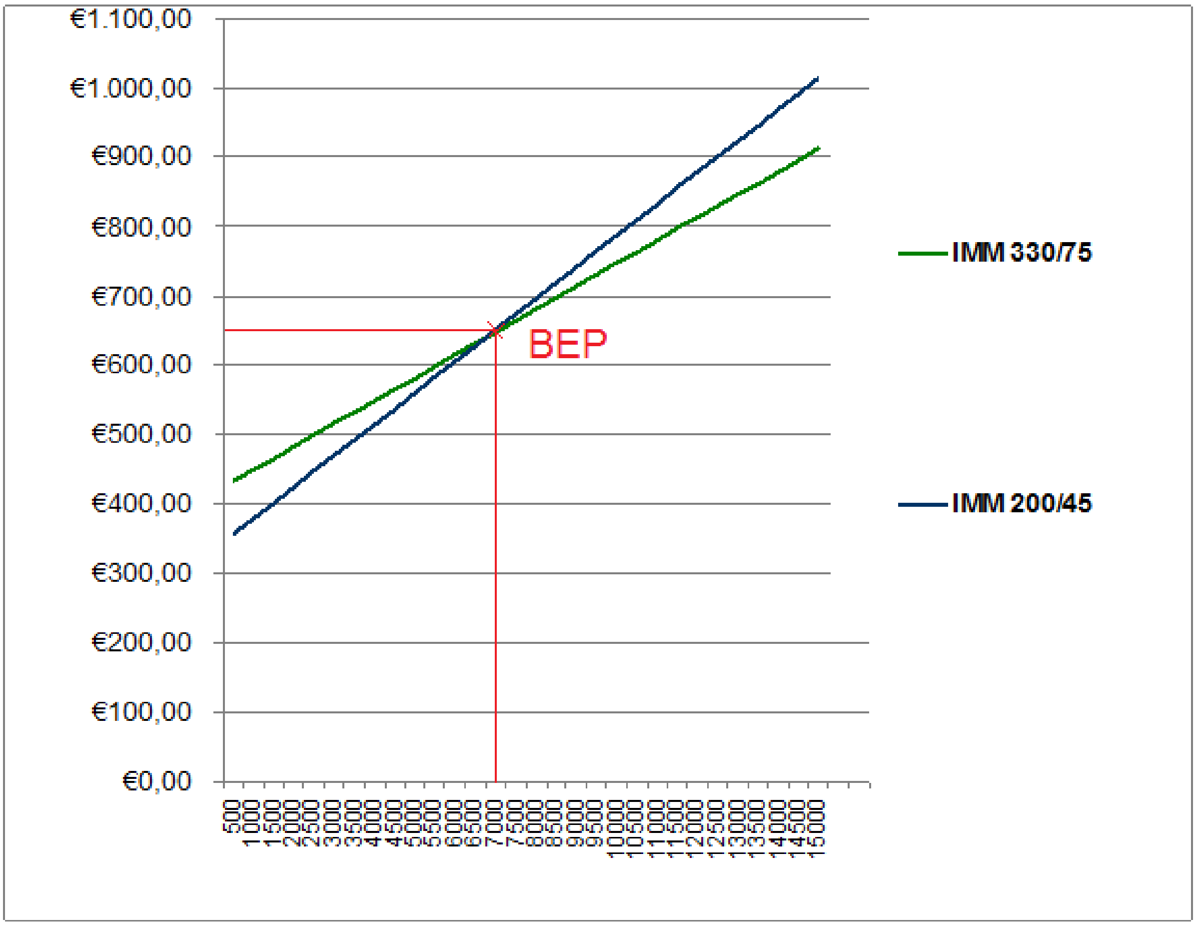


Figure 117: Calculation - break even point

Description of the Calclulation:

[1]… We compared two injection moulding machines. It is a comparison between a machine, which can produce with an injection mould with 6 cavity inserts and a machine, which can produce with 3 cavity inserts. Due to the different machines, there are different technical data and costs. We wanted to find out which machine is better for our production. It means for the production of 1000 EU-Click cubes.

[2]…The costs of purchase are roughly calculated, but this purchase costs are comparable with the costs of purchase from the injection moulding machine of the HTL Fulpmes where we produced the EU- Click cube. The costs of purchase for the second machine were calculated in cause of the smaller size.

[3]… The power consumption is calculated from the connected load of the machines. We got the data for the connected load from the data sheet of the injec-

tion moulding machine from the HTL Fulpmes and decided that the real power consumption is only 50 % of the connected load. The power consumption of the second injection moulding machine is roughly calculated.

4… We got an offer from HASCO for the ejection system, form plate and the inserts. These parts costed about € 1.500,-. We guessed that the costs of working time, supplies, energy and other tools were about € 1.000,-. So we got an amount of € 2.500,-.

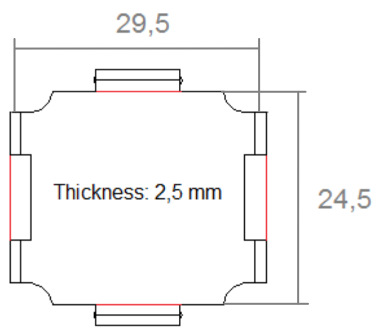
5…The costs of the mould for the second injection-moulding machine are lower because it is a smaller machine and the tool can only have 3 cavity inserts. The bigger machine can have 6 cavity inserts.

6… We calculated the weight with a rough calculation. For this calculation, we needed density of PP, which is 0,905 kg/dm³.

Volume = 24,5 * 29,5 * 2,5 = 1807 mm³ = 1,807cm³

Weight = 1,807 cm³ * 0,905 g/cm³ = 1,64 g

One part of the cube weights 1,64 g, the whole cube consists of 6 parts.
The weight of a cube is 1,64g * 6 = 9,84 g



We took a weight of 10 gram for our calculation because of the loss of material for gates, which are not recyclable.

7… The material PP for injection moulding costs 1.200 €/t. We got this price from an online price overview. [55]

8… The variable overhead rate and the fixed costs overhead are roughly calculated. The production in schools cannot be compared with the data in companies and so we took a fictitious data. Normally this data will be finding in the operational accounting sheet of the cost accounting department.

[55] http://plasticker.de/preise/marktbericht2.php?j=10&mt=3&quelle=bvse Stand: 18.5.2010

Review of the result:

The result of the calculation is that the cost price is smaller at the machine with 3 cavities than by producing with the bigger machine. But in the calculation sheet you can see that the bigger machine is to prefer when the applied quantity is higher than 6.744 pieces, which means at 1124 cubes. This point is called, break even point.

The price of one cube is about € 0.91,- by producing with the smaller injection moulding machine and an applied quantity of 1000 cubes.

The price of one cube is about € 0.92,- by producing with the bigger injection moulding machine and an applied quantity of 1000 cubes.

The causes for the break even point at 1124 cubes are the lower variable costs of the production and the shorter cycle time.

4 Communication in the Project

4.1 Leonardo - Forum

The communication in the Leonardo project was almost completely done by internet. At the beginning of the project each participant handed out his/ her own e-mail address.

Further on, we got an online forum, which exists since the forerunner - project "Comenius". The forum is used for discussions, to provide drawings and to share schedules for the next meetings. You have to be a registered member to use the forum. Every member is able to post articles, upload data and comment other articles. The administration is done by the German partner school.

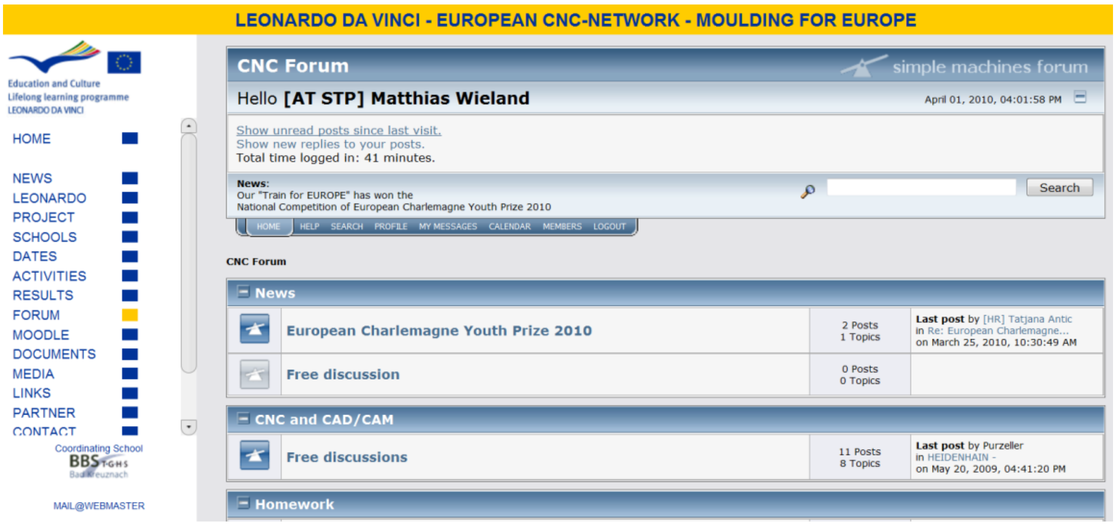


Figure 118: Leonardo da Vinci CNC- forum [56]

[56] http://mould.cnc-network.eu/; Stand: 15.4.2010

4.2 Moodle- Platform

Another chance to communicate is via the Moodle- platform. In the figure below you can see the welcome page of the Moodle- platform.

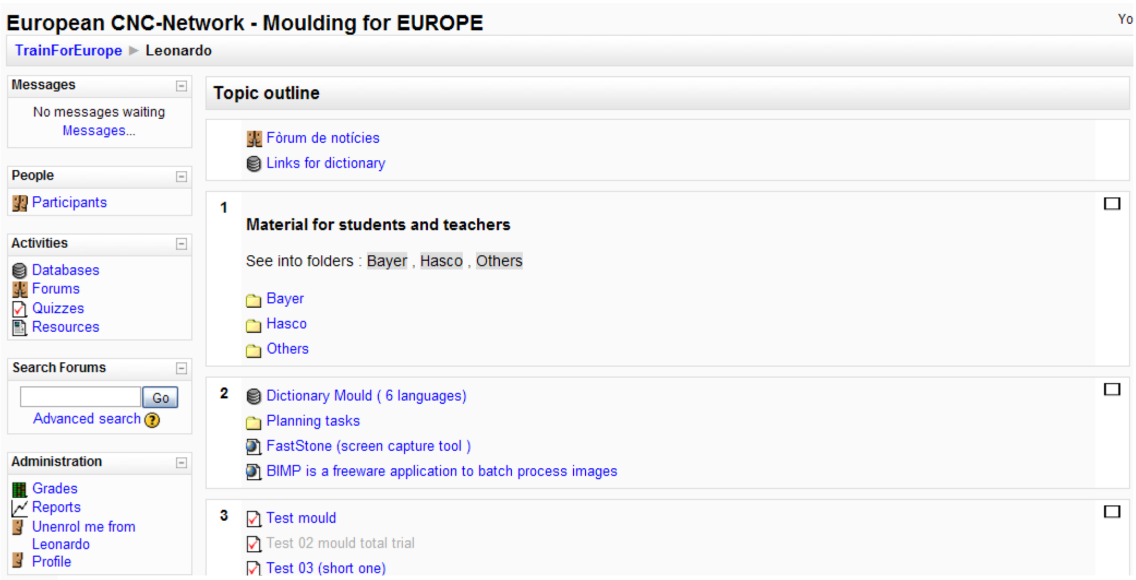


Figure 119: Moodle- platform

At first each school got a task, like injection “moulding machine” or “sprue, gates and runners”. Further on, we had to find twenty words with a convenient picture related to this task and to describe the words. These twenty words had to be in our own language and then translated into English. After the posting of every participating school the other members of the project have to translate the words into their own language.

So it was possible to make a dictionary and e- learning platform for every participating school.

English Name: Clamping

Description: The two halfes of the moulds must be closed securely by the clamping unit.

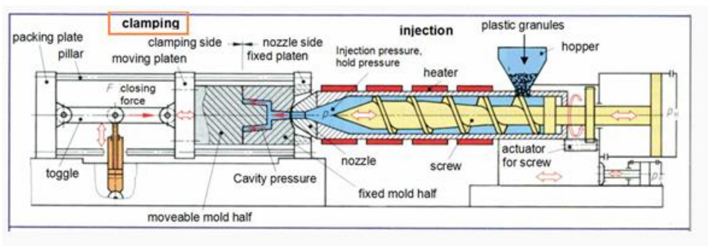
German Name: Schließeinheit

Portuguese Name: Fecho

Spanish Name: Cierre

Catalan Name: Tancament

Turkish Name: Germe



The second task we had to do was to write a final exam. Every school had to make questions with four possible answers. This will be put in a template on the Moodle- platform. On completion, every student has the chance to make this test.

In the figure below you can see two questions from the test and after the selection the correction “Correct or Incorrect”.

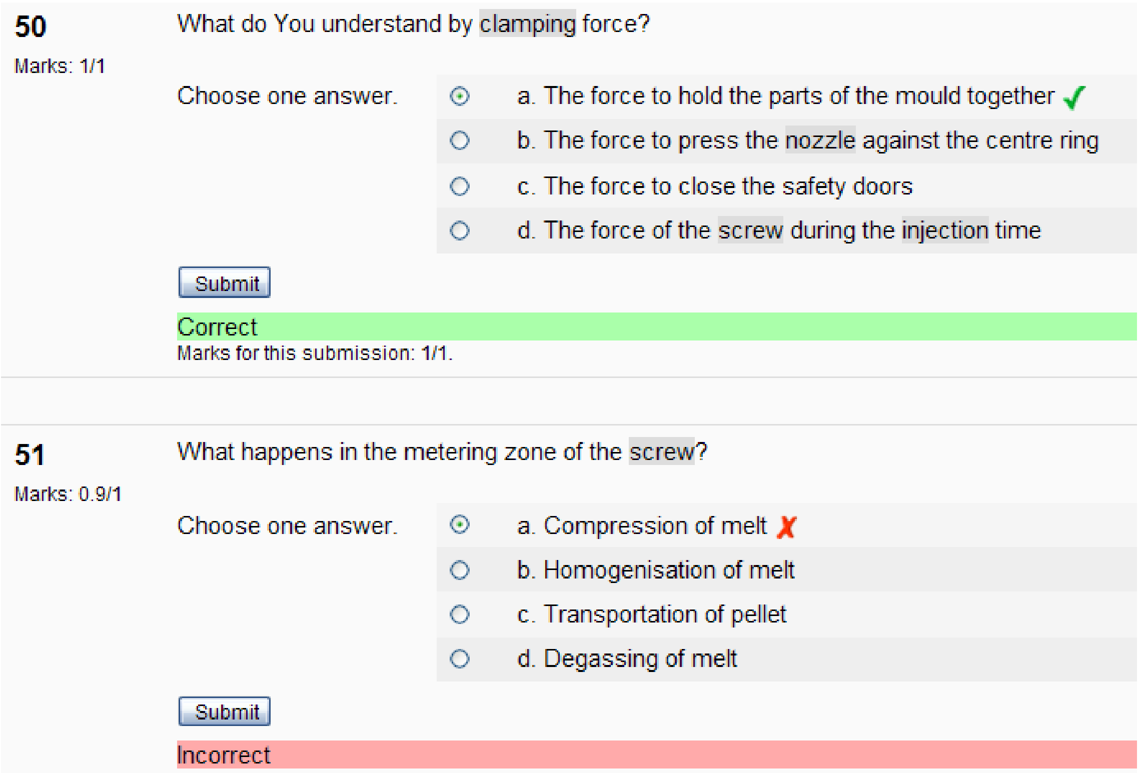


Figure 120: Moodle- Test: Injection moulding technology

Other contents of the Moodle- Platform were the reference to materials and documents of injection moulding technology manufacturers.

4.3 Meetings of the EU- Project

4.3.1 Meeting Barcelona, Spain

Agenda:

- Discussion what should be produced
- Discussion about the time tables of the meetings

Decision:

Discussion what should be produced

Therefore, within this LdV project, different ideas are introduced as follows:

Turkey: An "extendible" conical cup with six flexible sections (representing the six partners), used for travel and car.

Spain: A key fob with a logo on it, very easy to produce

Austria: A graduated compass/ruler for technical measuring

Portugal: A pencil/pen "container" in hexagonal form and flexible with six faces (representing the six partners) and with a puzzle on the six containers

Germany:

1. A puzzle in circular shape, may be useable as a mat to put hot pots on,
2. A model train like the one from Aarburg company, seen at Expoquimia fair in Barcelona or
3. A whistle similar to the aluminum model manufactured by the Heidenhain company.

Result of the discussion:

a key fob (Spain) and a puzzle (Germany) will be produced in a combinated unit and all partners have to be involved in the design, programming and production of the mould and the product itself.

<u>Decisions on the number of meetings and the schedule of the project are taken</u>

Not only the places, but also the times for the different meeting need to be discussed and fixed in order to offer planning reliability:

- **2nd meeting: between 10th and 20th January, 2009, Turkey:**

  Design and shape of the product - Homework: for all participants: Prepare a presentation of your ideas drawings or a prototype in aluminium may be shown.

- **3rd meeting: 26th to 30th October, 2009, Bad Kreuznach, Germany**

  Presentation of mould design and planning of production procedure;

- **4th meeting: between 10th and 20th January, 2010, Portugal:**

  Presentation of structure and electrodes, further planning

- **Final meeting: 3rd week of May, 2010, Austria:**

  Presentation of the injected final product, strategy of dissemination of the product will have to be defined.

Homework:

Homework was to make design suggestions of the part. These ideas should be presented during the following meeting in Turkey.

4.4 Meeting Gaziantep, Turkey

Agenda:

- Presentation of the ideas
- Making a decision which concept will be developed
- Decisions of time tables for the following meetings

Decision:

The project work began with the work presentation by each school. The ideas of a key fob were prepared at home by the participants and their advisors. So each school had got a suggestion for the key fob and all members discussed together about their function, design, pros, cons and their execution.

Turkey:	a puzzle
Spain:	a cube an atom model consisting of 6 spheres a locomotive
Austria – St. Pölten:	EU- letter: letters in a circle around the EU emblem EU- key EU- puzzle
Austria – Fulpmes:	puzzle with an EU star in the centre
Portugal:	several suggestions for a puzzle in a ground plate
Germany:	a snake out of cubes connected by rubber band a box with additional 3D puzzles is shown

After the presentations we began to discuss, which concept would be the best out of twelve. 3 voting's were necessary to find the right one.

The concept of the Spanish school persuades by its characteristics and so we will produce a cube.

Schedule for the next meetings:

05. June to 09. June 2009 in Austria/ St.Pölten

05. November to 09. November in Germany/ Bad Kreuznach

21. January to 25. January 2010 in Portugal/ Porto

05. May to 10. May 2010 in Austria/ Fulpmes - final meeting

Homework:

1. Every school should use their contacts to the HASCO Company to ask for support as effectively as possible.

2. Every school should produce a mould insert for the last meeting. Constructive suggestions should be directed to the school in Austria – Fulpmes until the 05. June 2009. Important are the principal form, which will be use for the production. Admissible file formats are *.PDF, *.DXF and *.IGES.

3. Suggestions and ideas for the logos on the 6 faces of the cube should be prepared.

The decision for the dimension of the cube as follows.

30 mm x 30 mm, 2 to a maximum of 2,5 mm in thickness.

The next guideline for our project was the decision for using the cube as a key fob with a chain.

Five countries are involved in the project. So each group had to design one face of the cube. The idea was to use the sixth face as the EU- face. Possibly with the 12 EU stars. The key fob chain could be attached in the circle centre. A different idea proposed to attach the chain in the cube's corner.

The outer surface of the cube parts should present the country code and the EU- symbol. The inner surface should feature the logo of each school. One of the Austrian schools will be responsible for the EU- part. The country codes should be up (max 0,3mm) and not sunk in.

Further tasks were assigned. The focus remained on moulding technology:

1. Internet platform for LEONARDO on www.cnc-network.eu

   The homepage will be coordinated by Heinz Wildgrube.

2. Technical Glossary

   Spain provides the environment. Jaume doesn’t need only terms but also pictures for each term and a corresponding explanation in English (max. 250 characters per term). The translations into the countries’ native languages will be handled by the respective schools. MOODLE will be used for communication, so each country has to announce a person responsible for the translation. Jaume is the administrator.

3. Comparing the educational training process

   Turkey will provide the environment.

4. Comparing the final exams

   Not every school has final exams featuring the topic of moulding.

   Tests about moulding technology should be collected also mechanical manufacturing. This task will be handled by Portugal.

4.5 Meeting St.Pölten, Austria

Agenda:

- Each school will show their own ideas of the Leonardo Click – Cube
- Discuss about the different concepts, show there pros and cons.
- Decide which idea is probably the best and would be produced.

Decision:

Friday 5th of June 2009

Day of arrival of all participants.

In the evening was the opening speech by Dipl. Ing. Johann Wiedlack, headmaster of the HTL St.Pölten. After the speech we had a dinner in the hotel "Hauser – Eck"

Saturday 6th of June

The meeting began at 9:00, after the greeting each school started with their presentations.

Austria – STP:

1. Concept

Consists of 3 different parts, works like a puzzle with logos and ensigns, which are variable. The assembly works with a click system with holes and burlings The first prototype was made by rapid prototyping.

2. Concept

Works with 2 racks and 6 equal boards. The boards are also variable for designing and turnable. The dimensions are about 32 x 32 x 32mm.

A short discussion about the concept comes to the conclusion that it is to complicated.

3. Concept

Consists of 2 top – plates and 4 wedge faces. It is variable to assembly and different logos are possible too. The dimensions of the top – plate are about 30 x 30 x 1.5 and the wedge faces 27 x 27 x 3.

Germany:

1. Concept

Works witch holes and burlings, nearly the same system like Austria's first one.

2. Concept

Dimensions 30 x 30 and not turnable.

3. Concept

Works also with pins and holes, but it is much to big, if the cube gets smaller the click system will be to small to produce and doesn't work.

Austria Fulpmes:

1. Concept

2 top parts and 4 side parts, made by the Fachschule.

2. Concept

Was made by the HTL, 6 same parts, works with holes and burlings too, but placed at the inside, so that is impossible to turn. On each corner is a hole, this is essential for assembly. This concept is without moving parts.

Turkey:

1. Concept

It works like a puzzle. Concept was known as a toy for children.

Spain:

1. Concept

3 different parts, 2 top and 4 side faces. A blot through the cube fixes the parts. There are just 2 possibilities of assembly.

2. Concept

Also 3 different kinds of parts, 2 parts of every system clicks in the hols with burlings. The problem is that 2 wedge faces are bigger than the other ones. It was nearly the same system like Austria's 3rd concept.

Portugal:

1. Concept

One cross in the middle which fixes the six parts, all of them are equal.

There is no chance to turn the plates. They made a mould and tried to produce it out of plastic. A short video presentation shows how the mould assemblies. The disadvantage is that the edges are sharp and the cube is instable.

After the presentations we began to discuss, which concept would be the best out of twelve. 3 voting's were necessary to find the right one.

The concept "**AT-STP 1**" can persuade with its characteristics and so we will take this click system.

Sunday 7th of June

Culture day at the famous world Heritage "Wachau"

- Travelling to Melk and visit the famous abbey
- Lunch in the city
- Trip with a Danube – boat to Dürnstein with a following dinner in an original restaurant, also called "Heuriger"

<u>Monday 8th of June</u>

At this das we visit a company and the HTL St. Pölten.

Travel to our partner company GEBERIT [57], to learn something about injection moulding and to watch the manufacturing process of plastic parts.

In the school we visited the CAD – rooms, classes and the workshop, includeing the injection moulding machine.

After this we did the work conclusion, homework and review of the meeting.

In the evening there was the farewell dinner in the hotel "Hauser Eck"

Homework:

Things to do for the next meeting in Germany:

1. Get member in the forum (http://mould.cnc-network.eu)

Username:

- national ID: [AT STP], [DE], [POR],…
- then first name and last name

2. Collect all pictures also from Gaziantep, but eliminate unusable pictures. Bring the pictures from Gaziantep to the next meeting in Germany or send them on DVD to Germany.

   Also collect the CAD documents (step, dxf, PDF files) on DVD.

3. Moulding Dictionary:
   - 20 words for every school in English and in an excel – file.
   - Define in a category (CAD, CNC, …)
   - 6 languages
   - Describe it with max. 25 words
   - Examples: injection machine, terminology,…

[57] www.geberit.com Stand: 12.12.2009

Homework for Portugal: Compare “final exams” to the meeting in Portugal in January 2010

4. Drawing of the plastic parts, which we have to produce:
   This is the task of AT – STP.

   What we need for the next meeting:

   - drawing of the plastic part
   - drawing of inserts, drawing of the electrodes for EDM and of the whole mould (form plate, cavity insert gating system, ejector package)

   Decision on the material:

   - ABS easier for injection
   - POM is slippery
   - PP better for the click system, because it did not affect the function of the click system
   - All three are possible to colourize

   Whole group chooses PP (Polypropylene). The drawings of the plastic parts should be finished before the holidays.

   Mould:

   - No. 237175 (Hasco Catalog)
   - 2 form – inserts (measurement 140 x 250 x 32)
   - The different blades will be bought (Cavity, Ejector, Bolster)

5. Ask HASCO – office in your country for discount. Order just after the meeting in Germany, we will look, which school gets the highest discount.

6. Suggestion for the logo:
   The logo will be discussed in Germany.

4.6 Meeting Bad Kreuznach, Germany

Agenda:

- Checking the cube and planning the mould (board plot, core and cavity insert)
- Discussion further activities (material, insert roughness, logo and ejectors)

Decision:

Saturday 7th of November

In the first workshop we discussed the cube and began to plan the mould.

The board plot:

The original draw can be found at the forum.

[AUT- STP] showed a click-cube prototype made with a rapid prototyping machine.

Some minor dimensional changes were made on the tolerances proposed by [AUT - FU]. The final drawing with the correct dimensions and tolerances will be done by [AUT- STP] and posted at the forum as soon as it will possible.

The core and cavity insert:

[AUT- FU] obtained a 50% discount in the price of HASCO components, during the other partners got between 25 and 30%, so it was agreed that [AUT - FU] will buy the components and then the rest of partners will pay their part by bank transfer (or other means).

It was agreed that every school will produce its own inserts. If one school has any problem with any specific job, they will look for help at other schools, using the forum as a communication tool. The position of the injection channels was defined and they will be done by [Aut- FU] when all the partners provide their complete inserts.

Things to discuss in a further session**:**

- Logo: size, depth
- Ejectors: dimension, position
- Gates
- Materials: inserts, polymer to inject
- Dates: dead line, schedule

<u>Monday 9th November 2009</u>

In the second part of our working session we discussed about:

The materials:
Polymer: PP (shrinkage: about 2%)

Steel: 1.2343, 1.2767 (to be hardened)

The insert roughness:
VDI 20 (see the Charmilles VDI 3400 table attached)

It was agreed that [AUT-STP] will provide a drawing with dimensions in the middle of the tolerances.

In order to check the fitting of the insert, every partner will bring it to Portugal (without cavity) where the channel and gates design will be discussed.

The logo:
The school logo must be on the ejection side with a depth between 0.3 and 0.5 mm.

The country logo and name will be done on the injection side. The total depth of the country shortcut and the silhouette goes from 0.3 to 0.5 mm.

Since there are two Austria schools, one of them will make an European logo instead of the country logo.

The ejectors:
4xØ4 next to the click points. (See the draw)

Homework:

1. Every school has to bring to Portugal the pictures they took in Germany.

2. Dictionary: every school should post the terms on the moodle platform using the username and password that Jaume [ESP] has provided for them. Deadline: Christmas 2009. Be careful with the pictures copyrights!

3. Each school has to draw the electrodes, being aware of the shrinkage.

4. Each school has to send to the Portuguese team one complete final exam concerning moulding (10 questions, multiple choices). Deadline: Christmas 2009.

5. Each school should check a budget for the chain and the key ring (1000 units).

The inserts (without cavity) must be produced and hardened (HRC 54-56) and brought to Portugal. The complete inserts, with cavities but no gates, should be done and sent to [AUT-FU] before the end of April 2010.

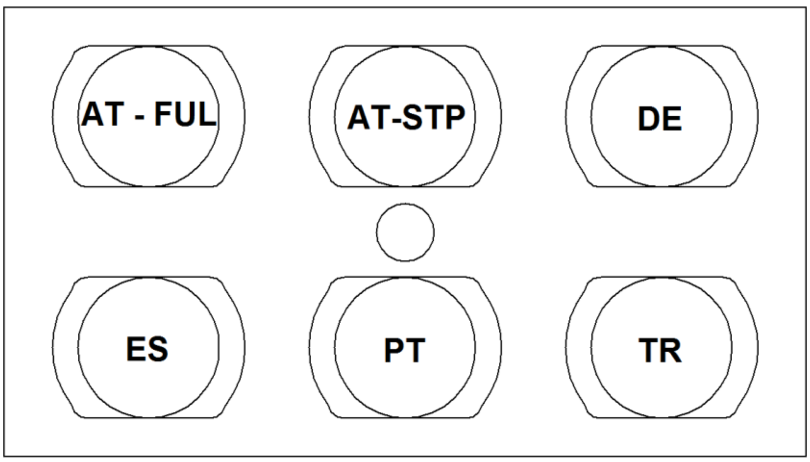
4.7 Meeting Porto, Portugal

Agenda:

- Position of the inserts
- Testing the inserts
- Continuing work on the dictionary
- Comparison of final exams
- Design technology for logos
- Cooling system
- Grinding the inserts
- Eroding the cavities
- How to produce the electrode
- Venting of cavities
- Production of runners
- Chain for the key
- Discuss about the following steps of work

Decision:

Position of the inserts:



Testing the inserts:

Austria – STP:

- measurement of 44 +0/-0,01
- the height also has to be ground to the right measurement
- the radius of the relief groove have to be removed, because the radius don't let fit the insert

Meeting in Fulpmes:

- 5th May 2010 will be the meeting in Fulpmes, Austria.
- Last day in March (31st) the finished inserts have to be in Fulpmes, so that they can fit and adjust the inserts and to make the whole running system.

Ejection System:

The decision was that Portugal will produce the ejection system.

They get the drawing of the exact position of the ejectors from Fulpmes.

Key – Fob Chain:

Fulpmes found a chain, which costs 0,15 € / Piece.

Each school will buy 200 pieces, which makes an amount of 30€.

Design of Logos:

- School letters will be on the ejector side
- Landscape is on the nozzle-side (injection side)
- The National ID and the landscape is on the same side.

Venting system:

If there are burning marks there has to be a venting system.

The cooling system will be positioned on the ejector side.

Electrodes:

They must be bigger, because of the shrinkage of the PP – material.

The gap of deflection has to be drown off from the measures.

Electrode measure = part measure + 2% shrinkage of PP – GAP of deflection.

Drawings:

The drawing to the insert with cavity plus shrinkage is already in the forum.

Homework for all teachers and students is to read the drawing of the cavity + shrinkage and correct it if needed.

Material:

The Cube will have 6 different colours (green, red, blue, yellow, white and orange).

Homework:

Collect pictures:

15th of February is deadline to put the pictures on the internet platform

Evaluation sheet:

Every teacher and student has to fill in the form to give a response of efficiency of work in the project.

4.8 Meeting Fulpmes, Austria

Agenda:

- Tool assembly
- Mounting the tool in the injection machine
- Testing
- Production of the cubes
- Finish the dictionary
- Do the final exam

Decision:

On the first day we assembled the whole mould and mounted it in the injection machine and connected the circuit points of the cooling system.

After these steps we adjusted the machine and setted parameters. Then we filled the hopper with POM – resin and collored the resin with a blue masterbatch. Then the injection process started and the first pieces were produced. At the beginning the cavities were not completely filled; these parts were unusable. To solve this problem the metering stroke has been raised. The next problem were the matt surfaces of the cube, the damaging of the click system and the troubles at the ejection process. The decision was to take another material as POM. We took Polypropylene (PP) which leads to a shiny surface, a lower damaging of the click system and en easier ejection.

On the next day the production of cubes began. We decided that each school gets 200 cubes in six different colours. So we produced 1000 cubes in red, blue, green, white, black and yellow. The gates were cutted off and the single pieces where sorted and packaged.

Another point was de completion of the dictionary. There were some equal words which have to be deleted and some words were not translated in all six languages. After the correction the dictionary was finished. The next step was to do the final exam in moodle.

Summary (English)

The diploma thesis “Product development, implementation and production of a plastic injection moulded part in liaison with European schools” describes our task to produce a plastic cube by means of injection moulding. Our part was to write the documentation of the project, to make constructions of the inje ction mould, and to make calculations.

We subdivided our diploma thesis into four main parts: the beginning, theoretical part, technical part and communicative part.

In the first chapter we described the initial situation of our thesis, what it is about, and introduced the schools taking part in this project.

The theoretical part deals with the whole injection moulding technology. This includes the injection process, mould making, plastics and economical importance.

The theoretical part is also important for non-involved people to get a quick overview about injection moulding and to understand the following steps in the next part.

The technical part especially describes the mould making, selection of plastics and the constructions of the individual parts of the mould. Finally, we made an assembly of all the single parts to show the whole mould. Afterwards we did some calculations and compared two different machines to find out which one would be cheaper for production. Due to this calculation we could calculate the price of one cube.

Below you can see a preview of the finished cube we produce. The cube consists of six equal parts and each school made one of them.

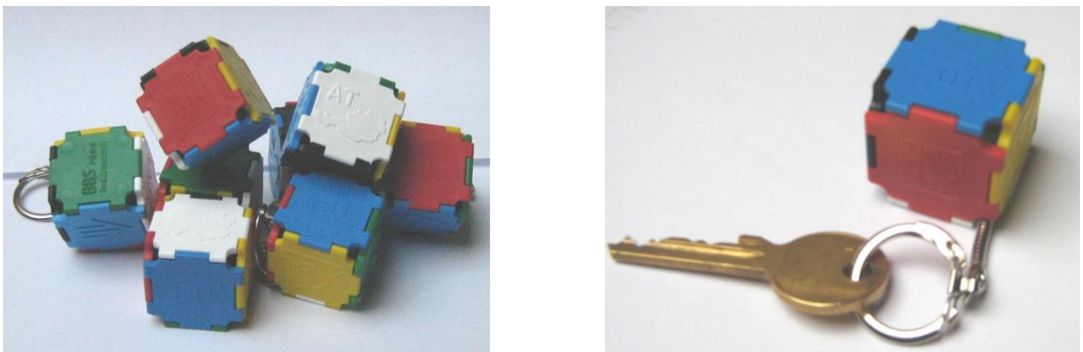


Figure 121: EU- Click cube

According to this decision we had to produce the inserts for our part. This six different insert pairs are mounted in the mould. We used a special steel for our insert, called K455 from Böhler. For the use in an injection mould the inserts have to be hardened. The inserts were hardened by the company "Welser Profile AG" because we do not have the possibility to do this special work step. The company "Mangel Formenbau GesmbH" helped with eroding of the cavity.
In the picture below you can see the insert of our workpiece.
The cube should represent the European spirit and the schools which took part.
Therefore we decided to put logos on the surfaces. For example, the part of the College of Engineering, Arts and Crafts St.Pölten has two logos. Outside you find the outline of Austria and inside there is the logo of our school.

Figure 122: Cavity insert with moulded part

The communicative part shows how we communicated in this European project. First of all, our common language was English. We had to write minutes about every single meeting. The minutes contain all the decision taking processes, for example what material should be taken, and they also describe the work progress in the project step for step. We were offered an international forum and a moodle platform where we could post drawings or discuss further activities.

Zusammenfassung (Deutsch)

Unsere Diplomarbeit war mit dem europäische Projekt “European CNC-Network-Moulding for Europe” einem sogenannten “LEONARDO DA VINCI, Education and Culture Lifelong Learning Programme” verbunden. Ziel dieses Projekts war es einen Plastikwürfel mittels Spritzgusstechnik herzustellen.

Unsere Aufgabe war es nun dieses Projekt zu dokumentieren, Konstruktionen der Spritzgussform zu erstellen und die Fertigung der erforderlichen Teile anzustellen, sowie bei der Produktion der EU- Klickwürfel mitzuwirken.

Die Diplomarbeit ist in vier Hauptbereiche gegliedert: Ausgangssituation, theoretischer, technischer und kommunikativer Teil.

Im Kapitel „Ausgangssituation“ wird die Entstehung der Diplomarbeit erläutert und wie wir zu diesem Projekt kamen, welche Schulen teilnahmen und was das Projektziel war.

Der theoretische Teil handelt von der gesamten Spritzgusstechnik. Hier werden die Grundlagen der Spritzgusstechnik wie Spritzgussprozess, Spritzgussmaschine und Spritzgusswerkzeug, aber auch Kunststoffe und ihre wirtschaftliche Bedeutung beschrieben. Dieses Kapitel ermöglicht außenstehenden Personen einen kurzen Einblick in die Spritzgusstechnik um den nachfolgenden technischen Teil zu verstehen.

Im technischen Teil unserer Diplomarbeit ist der gesamte Produktentwicklungsprozess dokumentiert. Dieser beginnt mit dem Entwurf und Design des Spritzgussteils, der Auswahl des Materials und den Überlegungen bezüglich der Konstruktion und Auslegung der Spritzgussform. Weiters betrachten wir in diesem Teil die Spritzgussmaschine auf welcher der EU- Click Cube schlussendlich gefertig wurde. Anschließend führten wir eine Kalkulation durch um den Preis des fertigen Würfels zu ermitteln. Weiters wurde eine Wirtschaftlichkeitsrechnung bezüglich verschiedener Maschinen und Werkzeuge durchgeführt.

Der Würfel soll den europäischen Gedanken und die Schulen die an diesem Projekt beteiligt waren repräsentieren. Für diesen Zweck entschied man sich auf den Grundflächen Logos zu platzieren.

Der Teil der HTL – St.Pölten hat auf der Außenfläche die Grenzen von Österreich mit der Länderbezeichnung AT und an der innen liegenden Fläche das Logo der Schule. Das Klick- System ermöglicht das Öffnen und Schließen, sowie die unterschiedlichsten Zusammenbaumöglichkeiten des Würfels.

Der kommunikative Teil zeigt wie im Projekt kommuniziert wurde und die Zusammenarbeit erfolgte. Weiters enthält er die Protokolle der einzelnen Meetings, in denen der Projektablauf festgehalten ist.

Zur Kommunikation standen uns zwei Möglichkeiten zur Verfügung.

Das erste war ein internationales Forum wo man Dateien an andere weiterleiten und darüber diskutieren konnte. Die zweite Möglichkeit Informationen und Wissen an Teilnehmer des Projekts weiter zu geben ist eine Moodle – Plattform die es uns ermöglichte ein mehrsprachiges Wörterbuch über die Spritzgusstechnik, sowie einen Multiple- Joice Test über dieses Thema zu erstellen.

List of Literature

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3) Menges / Michaeli / Mohren, Spritzgießwerkzeuge (Auslegung, Bau, Anwendung), Verlag Hanser München, 6. Auflage, Jahr 2007

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List of Figures

List of Tables

List of Charts

Glossary (German – English)

A

Abfall – cull

Abreiß- Punktanguss - seperation pin-point gate

Abschraubwerkzeug - twist off mould

Abschreckmedium - quenching medium

Abstandhalter – spacer

Abstreifer – deflector

Abstreiferwerkzeug – deflector mould

aktive Entlüftung – active bleeding

aktiver Hydraulikantrieb – hydraulic active actuator

Anguss – gate

Angussbuchse – feed bush

Angussbuchsenkanal – bushing gate

Angusskegel - sprue

Angussloses Anspritzen - non gate injection

Angussplatte – gate plate

Angusssystem – gating system

Anschnitt – ingate

Antrieb Einspritzzylinder – injection drive

Antrieb für Schnecke – actuator for screw

Antriebseinheit - drive unit

aufschrumpfen - shrink fitting

Ausschraubwerkzeug – screw mould

Auswerfer – ejector pin

Auswerferhalteplatte – ejector holding plate

Auswerferkopfplatte – ejector head plate

Auswerferplatte – ejector plate

Auswerferseite - ejector side

Auswerferstange - ejector rod

Auswerferweg - ejection stroke

B

Backenfutter - jaw chuck

Backenwerkzeug - split mould

Backenwerkzeug – split mould

Band – oder Filmanguss - film gate

Beanspruchung – wear

bewegliche Formhälfte – moveable mould half

bewegliche Werkzeugaufspannplatte - moving platen

Biegesteifheit – rigidity

Biegewechselfestigkeit - bending fatigue strength

Bindenaht - joint line

Brandschutzmittel - lame retardants

D

Dehnung - elongation

Dichtheit – leak tightness / tightness

Dimensionsbeständigkeit - dimensional

Drehmeißel - cutting chisel

Druckbedarf - pressure demand

Druckgefälle - drop of pressure

Druckstempel – plunger

Druckverlauf – march of pressure

Düse – nozzle

Düsenheizung – nozzle heater

Düsenseite – nozzle side

Durchbiegung – deflection

Durchbiegungsbereich - deflection area

durchhärtende Stähle - full-hardening steels

stability

E

Einfachwerkzeug - single impression mould

Einfülltrichter – hopper

Einsatzstahl - case-hardening steels

Einspritzdruck, Nachdruck – injection pres

Einspritzstrom - injection flow rate

Einzugszone – feed section

Endschalter - position switch

Endstück – end piece

Energieverbrauch - power consumption

Entformbarkeit - release properties

Entformbarkeit - release properties

entformen – demoulded, remoulded

Entformungstemperatur - mould release

erhöhter Ausschuss - high rejections

erodieren - electrical discharge machining

Etagenwerkzeug – level-tool

exzentrischer Anschnitt - eccentric ingate

F

Fadenziehen – stringing

Festigkeitsminderung - stability lowering

feststehende Werkzeugaufspannplatte - fixed platen

feststehende Formhälfte – fixed mould half

Führungsbuchse - guide bushing

Führungssäule – guide pillar

Filmanguss – flash gate

Fixkostenzuschlagssatz - fixed costs overhead

Fließverhalten – flowability

Fließwiderstand - flow resistance

Füllstoffe – fillars

Formbelag - film at the mould

Formeinsatz – cavity insert

Formfüllung – form filling

Formhöhlung – mould cavity

Forminnendruck - cavity pressure

Formmasse – compound

Formplatte – form plate / pattern plate

Fräser – chamfer

Freistrahlbildung – free jet development / jetting

G

Gewindespindel - work gear spindle

Gleitmittel – lubricants

H

Halteplatte - packing plate

Heißkanal – hot runner

Heißkanalverteiler - hot runner distributor

Heizband – heater

Heizpatrone - heating cartridge

Herstellkosten - manufacturing costs

Hinterschnitt – undercut

holmlos - tie bar-less

Hubvoulmen - stroke volume / metering stroke / displacement volume

I

Instandhaltungskosten – maintainance costs

K

kalkulatorische Abschreibung - cost-accounting depreciation

Kaltarbeitsstahl - cold work steel

Kalte Außenhaut – cold bodyshell

Kaltkanal - cold runner

Kerbschlagzähigkeit - impact strength

Kerbwirkung - notch effect

Kühlgerät - temper device

Kühlmittel – coolant

Kühlzeit – cooling time

Kniehebel – toggle

Kniehebelsystem – toggle system

Kolbenstange - plunger

korrosionsbeständige Stähle - corrosion-resistant steels

Kraftübertragung - load transmission

Kratzfestigkeit - scratch resistance

Kugelführung - ball track

Kunststoffgranulat - plastic granules

Kunststoffindustrie - Plastics and Rubber Industries

L

laminare Strömung - laminary stream

Lufteinschluss – blowhole / blowhole

Leitfähigkeit - conductivity

M

Machbarkeitsstudie - feasibility study

Magnetspannfutter – magnetic clamping chuck

martensitisch aushärtende Stähle - martensite hardening steels

Maschinenkennlinie – machine characteristic

Masseanhäufung - material accumulations

Materialmenge - compound bulk

Mehrfachpunktanguss - multiple pin-point gate

Mehrfachwerkzeuge - multi cavity mould

Meteringzone – metering zone

Molekülorientierung - molecular orientation

N

Nachdruck – holding pressure

Nitrierstahl - nitride steels

Nutzungsdauer - service life

O

Oberflächenbearbeitung - surface finishing

Öffnungshub - opening stroke

Ölsäule - oil column

P

2-Platten-Werkzeug - 2-way tool

3-Platten-Werkzeug – 3-way tool

parabelförmiger Kanal - parabolic arc channel

parallele Anordnung - parallel adjustment

passive Entlüftung - passive bleeding

Pflichtenheft - requirement specification

Plastifizierstrom - plasticising flow rate

plastische Seele - ductile bore

PMMA - polymethyl methacrylate

Punktanguss - pin-point gate

PVC - polyvinyl chloride

Q

Quernadel - transverse needle

R

Rahmenformplatte – bolster plate

Randschichtenthärtung - edge-zone softening

Rauigkeit - roughness

Rückdruckstift – ejector plate return pin

Rückholfeder - recuperating spring

Rückholfeder - recuperating spring

Rückstromsperre - non-return valve

Regranulat - re-granulate

Reibahle – reamer

Reibungsverlust – friction loss

Reibungswärme - frictional heat

Reihenverteilung - bank allocation

Restkraft – remaining force

Restspannung - residual stresses

Ringanguss - ring gate

Ringschraube - ring bolt

Rissempfindlichkeit - crack sensitivity

Rohrheizkörper - tubular heating element

Rohrleitungskomponenten - plumbing components

S

Säule – pillar

Scheibenauswerfer - disk ejector

Schieberverschlussdüse - slide closure nozzle

Schieberwerkzeug - slide mould

Schirmanguss - fan gate

Schließeinheit – clamping unit

Schließkraft- clamping force

Schließseite – clamping side

Schmelzbereich – melting range

Schmelzviskosität - melting viscosity

Schnecke – screw

Schneckenantrieb - screw drive

Schneckenhub - screw stroke

Schneckenvorraum - space in front of the screw

Schneckenvorraum – space in front of the screw

Schraubstock – bench vise

Schrumpfverhalten - shrinkage behaviour

Schubmodul – shear modulus

Schwachstelle - weak spot

Schwimmhautbildung – flash

serielle Anordnung - serialise adjustment

Sichtfläche - visible surfaces

Spannpratze – clamping shoe

Spannungsrissempfindlilchkeit – stress crack sensitivity

spezifischer Energieverbrauch - specific energy consumption

Spritzeinheit – injection unit

Stabilisatoren – stabilizers

Stangenanguss - sprue gate

Stauchung – buckling

Stauchung der Form - buckling of the mould

Staudruck – back pressure

Sternverteiler - stars allocation

Steuerungseinheit – control unit

Stützplatte - backing plate

Stützrollen - support roller

Stützsäule - column support

Symmetrieverteilung - symmetry allocation

T

Temperaturbehandlung - heat treatment

thermische Leitfähigkeit - thermal conductivity

trapezförmiger Kanal - trapezoidal channel

Trennebene - parting line

Tunnelanguss - tunnel gate

U

Überspritzung – overmoulding

Umlaufgeschwindigkeit - circumferential speed

V

variabler Gemeinkostenzuschlagssatz - variable overhead rate

Verformung – deformation

Vergütungsstähle - tempered steels

Verschlussdüse - shut-off nozzle

Verschlussstopfen – close stopper

Verteilerkanäle – runners

Verteilerkanalrand - runner barrier

Verzug – distortion

voreilender Strang - leading leg

Vorkammer- Punktanguss - antechamber pin-point gate

W

Wanddicke - section thickness

Wärmeabfuhr - heat dissipation

Wärmebehandlung - heat treating

Wärmeleitfähigkeit - heat conductance

Werkzeugaufspannplatte – pattern plate, platen

Werkzeugbelastung - mould strain

Werkzeuginnendruck – cavity pressure

Werkzeugkennlinie - mould charactetristic

Werkzeugplatte – pattern plate

Z

zähelastisch – viscoplastic

Zähigkeit – toughness

Zentralrechner - host system

Zentrierflansch - centring flange

Zentrierhülse - centre sleeve

Zentrierring – centre ring

zentrischer Anschnitt - centric ingate

Zinssatz - interest rate

Zugbeanspruchung - tensile load

Zuhaltekraft - locking pressure

Zwangsentformung – forced remoulding

Zwischenplatte - sandwich plate

Zylinderkopfschraube - cylinder head screw