Casting Technique

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Objective

This chapter shall provide the course participant with an overview about the die casting technology. It will concentrate on the principal aspects of gating systems, die filling, die venting, injection pressure and solidification.

Lesson contents

- Die filling process and cavity
- Flow technology
- Method for the design of gating systems
- Venting and overflows
- Vacuum
- Casting calculation

Lesson aims (the participant can / knows)

- Describe the important aspects of the flow in the die casting process.
- The design of a proper runner.
- Explain the function of venting and overflows.
- Describe the effect of vacuum.
- Independently calculate castings.
Melting and solidification

These two physical processes are very important for the casting process.

Melting

The change of the state of matter from solid to fluid and vice-versa, because of their alloying components in most alloys, does not take place suddenly but within a stretch of the melting process.

The "casting temperature" which is required for processing lies above the melting range, while this difference between casting temperature and melting range is indicated as overheating. This difference can sometimes be 100° C or more.

Solidification

Structure and thus the quality of the casting is decisively influenced by the nature and speed of solidification. The speed of solidification, as related to the different casting methods, varies widely.

<table>
<thead>
<tr>
<th>Casing procedure</th>
<th>Solidification velocity</th>
<th>Solidification times</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand casting</td>
<td>slow</td>
<td>sec. - min.</td>
<td></td>
</tr>
<tr>
<td>Gravity die casting</td>
<td>fast</td>
<td>sec. - min.</td>
<td></td>
</tr>
<tr>
<td>Pressure die casting</td>
<td>extremly fast</td>
<td>millisec. - sec.</td>
<td></td>
</tr>
</tbody>
</table>

The very fast solidification in die casting is due to the fact that the metal is injected into a die at high speed, while the temperature of the die lies about 300° below the solidification point.
How much energy is required to melt 1 kg AL 226 (melting temperature 720°C)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Melting Temperature</th>
<th>Solidification Temperature</th>
<th>ADC Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>AlSi9Cu3</td>
<td>226</td>
<td>380</td>
<td>ADC 12</td>
</tr>
<tr>
<td>AlSi12</td>
<td>230</td>
<td>413</td>
<td>ADC 1</td>
</tr>
<tr>
<td>AlSi12(Cu)</td>
<td>231</td>
<td>B413.1</td>
<td></td>
</tr>
</tbody>
</table>
The four basic principles of diecasting

Cavity filling

The die casting technology, especially the die filling technology, is based to a great extent on hydraulics.

Die temperature curve

Liquid alloy is injected into a die, which is at a temperature of about 300° below the alloy melting point, i.e. the solidification process starts as soon as the alloy touches the cavity surface of the die.
**Evacuation of gases**

The alloy is not injected into an empty cavity but into a die still full of air and residues of die lubricant. The metal is atomized at the gate and injected into the die cavity. Air and metal which is dirty and too cold are extracted via the overflows.

**Solidification / Intensification**

During the changes from liquid - solid (solidus-liquidus point) the metal shrinks about 4 - 7 %, depending on the alloy. With the application of a high final pressure, about 400 - 1'000 bar, this loss in volume is compensated by feeding additional metal through the runner, or with an external squeeze pin.
Solidification shrinkage
Solidification shrinkage, appearing mainly with sand and gravity casting, is caused by the loss in volume and the shrinkage of the metal during the solidification.

With the die casting process this problem is eliminated to a great extent, because the pressure on the metal allows enough material to be fed for a sufficient die filling.

Solidification shrinkage can be recognized by the irregular shape

Mark, where do you expect the solidification shrinkage!
By which measures the solidification shrinkage can be reduced?
Gas precipitation
Aluminium alloys normally have a higher hydrogen content than pure aluminium. This is mainly shown by the formation of porosity during the solidification. With the die casting process, however, the solidification speed as a rule is quick enough to prevent the precipitation of even high hydrogen contents. With the die casting process the gas content therefore is less critical than with the slower solidification processes of sand and gravity casting. Important, however, is the solidification interval in order to avoid the formation of gas porosity and shrinkage cavities. Even with a low hydrogen content die castings, especially the thick-walled sections, will have a porous structure at a solidification speed of less than 1 °C/s.

Gas porosity can be recognized by the round smooth shape

Mark, where do you expect the gas porosity!
By which measures the gas porosity can be reduced?
Die filling and intensification in three phases

1st phase
the metal is brought slowly to the gate area, during approx. 1-3 s, depending on volume and process.

2nd phase
the metal is injected at a high velocity into the die and fills up the whole cavity, during approx. 0.01-0.3 s, depending on volume and process.

3rd phase
intensification of the liquid metal in the die with a high pressure of approx. 400bar-1000bar, during approx. 0.01-0.3 s, depending on gate and process.
1st phase (prefilling)

With a smooth initial movement and constant acceleration (Parashot) of the plunger a turbulence-free filling of the shot sleeve can be achieved.

Parashot

Conventional
Influence of the filling rate on the casting process

**high filling rate**
%F 50-70%

Name the advantages of a **high filling rate**.

Name the disadvantages of a **high filling rate**.

**low filling rate**
%F 20-30%

Name the disadvantages of a **low filling rate**.

Name the disadvantages of a **low filling rate**.
Casting technique

What has to be done with a **high filling rate**?

1. ..........................................................................................
2. ..........................................................................................
3. ..........................................................................................

What has to be done with a **low filling rate**?

1. ..........................................................................................
2. ..........................................................................................
3. ..........................................................................................
Conditions of plunger clearance

The plunger clearance which is mainly influenced by the temperatures of shot sleeve and plunger, is very important for a troublefree casting operation.

This diagram shows that the clearance changes under the influence of the temperature. If the clearance is bigger than 0.12 mm the metal tends to shoot back past the plunger, which in the long run can lead to damage of the plunger and shot sleeve.

Idling clearance for 60mm / 0.05mm  80mm / 0.06mm  100-140 / 0.08mm

At which shot sleeve temperature is the metal shooting past the 80mm plunger if the plunger has reached 60°C at the end of the filling phase?
What happens if the cooling of the plunger is not able to eliminate the heat?

The diagram shows the clearance conditions when shot sleeve and plunger are at the same temperature.

What can be the cause if the plunger jams despite a proper cooling circuit?
2nd phase (cavity filling)

In the die filling phase the metal is injected into the die cavity.

To achieve a proper and at the same time gentle die filling, some parameters and their limits have to be considered.

- **Gate velocity standard**
  - vMA 20-60 m/s
  - Most dies: vMA 40-60 m/s
  - SC technology: vMA 20-120 m/s

- **Die filling time standard**
  - tF 0.01s - 0.3s
  - Most dies: tF 0.03s - 0.1s

- **Wall thickness** *
  - 1.5 mm: tF 0.01s - 0.03s
  - 2.0 mm: tF 0.02s - 0.06s
  - 3.0 mm: tF 0.05s - 0.1 s
  - 6.4 mm: tF 0.08s - 0.3 s

*Thinnest, ultimately filled die section
Gate velocity vMA

The maximum permissible gate velocity vMA is determined by various factors,

1. Angle of impact
2. Metal temperature
3. Alloy
4. Metal quantity
5. Surface
6. Die temperature

Maximum permissible gate velocity vMA 20m/s - 30m/s

Which problems will occur with this contour, if the velocity is too high?

Maximum permissible gate velocity vMA 30m/s - 45m/s

Which problems will occur with this contour, if the velocity is too high?

Maximum permissible gate velocity vMA 40m/s - 60m/s or higher

Which problems will occur with this contour, if the gate velocity is too high?

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What has to be specially considered with this shape?

What has to be considered with a high filling rate with regard to gate velocity?

What has to be considered with a low filling rate with regard to gate velocity?

What are the advantages of a high gate velocity?

What are the disadvantages of a high gate velocity?
Filling time \( t_F \)

The heat loss during the die filling is established with the calculation of the filling time. The alloy still has to be liquid at the end of the die filling process.

Which influence has a short cavity filling time \( t_F \) on the part quality?

Which influence has a cold insert on the die filling time \( t_F \)

Which influence have directional changes of the materialflow on the die filling time \( t_F \)

Which influence has the die filling rate \( %F \) on the die filling time \( t_F \)
Flow technology

The flow technology has to be considered to achieve an ideal and at the same time gentle die filling. The flow in the die is influenced by following parameters:

1) Location of the gate
2) Gate velocity $v_{MA}$
3) Location of the switch-over point $s_{1eff}$
4) Metal velocity at entering the die
5) Metal temperature
6) Alloy (viscosity)
7) Die temperature (solidification during the die filling)
8) Spray film (die surface)

The die filling is ideal if it is possible to completely fill die cavity with metal which is still liquid and to expel the air through the overflows, or to exhaust it through the vacuum channel.

Additionally the die should not be damaged with erosion, cavitation, corrosion or soldering.
Basic principles of flow technology

We distinguish between two types of flow:

**Laminar flow**
- The flow in the runner is laminar.

**Turbulent flow**
- The flow at the gate and in the die area is turbulent.

What are the advantages of the laminar flow in the runner?
- ...
- ...
- ...

What are the disadvantages of the laminar flow in the runner?
- ...
- ...
- ...

How can the laminar flow in the runner be disturbed?
- ...
- ...
- ...

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Flow examples
Flowing around an obstruction

Draw in the flow lines, where can cavitation be expected? where can erosion be expected?

Draw in the flow lines, where can cavitation be expected? where can erosion be expected?

Draw in the flow lines, where can cavitation be expected? where can erosion be expected?

Draw in the flow lines, where can cavitation be expected? where can erosion be expected? what happens at the flow obstruction?

Draw in the flow lines, where can cavitation be expected? where can erosion be expected? what happens at the flow obstruction?
**Casting technique**

**Casting process**

Flow examples

What is happening here during the prefilling phase?

Draw in the flow lines?

How is the flow through the gate?

What are the hazards of this gating system?

What is happening here during the prefilling phase?

Are all cavities filled simultaneously?

What are the hazards of this gating system?

How can they be eliminated?

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Flow examples

What is happening at the end of the die filling?

Mark the flow lines.

Where do the overflows have to be placed?

What is happening at the end of the die filling?

Mark the flow lines.

Where do the overflows have to be placed?
**Exemples**

Describe the flow behaviour?

- 
- 
- 
- 
- 
- 
- 
- 

Mark the flow lines.

Where is the die filled last?

- 
- 
- 
- 
- 
- 
- 

Where do the overflows have to be placed?

- 
- 
- 
- 
-
Draw in the flow lines!

What difference is made by the centrifugal force?

Where is the die filled last?

Where do the overflows have to be placed?
Tangential runner system

With the tangential runner the **flowing-in angle** is determined by the **vector** of the **velocity in the runner** and the **gate velocity**.

Draw in the angle of flow in the left die half?

The air is whirléd into the shock absorber and provides a dampening cushion. The shock absorber has the task of cushioning the pressure peak at the end of the runner fill, thereby preventing an uncontrolled prefilling of the alloy.
How is this plate-shaped cavity filled?
Please draw in the flow lines.

What would change if the cavity would be prefilled?

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Tangential runner systems

How is this plate-shaped cavity filled?

Please draw in the flow lines.

Where should the venting be located?
Standard gating system

How is this bucket-shaped cavity filled?

Please draw in the flow lines.

Where should the venting be located?

Which filling technique is applied with such dies?
Die venting

Die venting is very important. The venting in many dies is designed too small which leads to quality problems. Approximately 80-90% of the porosity are caused by entrapped air, or by residual greases or residual sprayagents. There are two types of venting, standard venting (overflows) and forced venting (vacuum).

Standard venting (overflows)

The maximum air velocity in the venting channel is 333m/s (velocity of sound). Higher velocities cannot be reached due to the shock wave (supersonic boom) at the end of the sealing section of the venting channel.

<table>
<thead>
<tr>
<th>Overflow</th>
<th>Sealing lip</th>
<th>Venting channel Sealing section</th>
<th>Venting channel Die holding block</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0,5mm</td>
<td>0,3-0,5mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0,1-0,12 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>min 25 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5-10 mm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Sealing lip</th>
<th>Sealing section TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AlSi9Cu3</td>
<td>0.5 mm</td>
<td>0.12 mm</td>
</tr>
<tr>
<td>AlSi12 (Cu)</td>
<td>0.3 mm</td>
<td>0.10 mm</td>
</tr>
</tbody>
</table>

What are the functions of:

Overflow

Sealing lip

Venting channel sealing section

Venting channel die holding block

If the area of the venting is not big enough, the air in the die cavity will be compressed and dispersed in the atomized alloy.
Example for the calculation of the venting area.

\[ SE = \frac{v_{MA} \cdot SA}{v_{SE}} = \frac{45 \text{ m/s} \cdot 180 \text{ mm}^2}{300 \text{ m/s}} = 27 \text{ mm}^2 \]

\[ BE_{tot} = \frac{SE}{TE} = \frac{27 \text{ mm}^2}{0.12 \text{ mm}} = 225 \text{ mm} \]

\[ BE = \frac{BE_{tot}}{n} = \frac{225 \text{ mm}}{5} = 45 \text{ mm} \]

The air resistance in the die holding block has to be kept as low as possible. Especially with steps in the parting line it has to be made certain that the venting area remains constant during the changes in direction.

What has to be specially observed when operating the die?

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Blisters
Blisters are due to gas porosity close to the casting surface, causing them to burst open during the opening of the die. With the increased pressure in the die the air gas mixture is absorbed into the atomized alloy. The oxygen contained in the gas combines with the alloy to Al2 O3 (aluminium oxide), the remaining gas appears in the shape of micro porosity. Conglomerates of gas result in visible porosity and with larger porosity directly under the surface blisters are formed.

Why do blisters appear with a hot die?

What has to be done when blisters appear?
Die venting

Available  SA 150mm²  vMA 55m/s

Required?
1) How large is the venting area?
2) Where should the venting be located?
Die venting and vacuum

In the previous chapter we have learned, that the die venting is very important and that the **forced venting (vacuum)** has big advantages for many applications. To get a good structure, maximum evacuation of air gas mixture from the die cavity is necessary.

Various vacuum systems are available for that purpose, we basically differentiate between two types.

**A**
Vacuum systems which shut off the evacuation opening with a metal stream

**Advantages**
The die cavity can be evacuated till the end of the die filling.

**Disadvantages**
The vacuum valve has to be handled with care

**B**
Vacuum systems which shut off the evacuation opening dependent on stroke or time

**Advantages**
Normally without material in the valve, always the same shot volume.

**Disadvantages**
No evacuation during the die filling phase, because the valve has to be closed before the die filling phase.

The Optivac from Fondarex has been successful among the self-closing systems.

Many custom-built designs are available for stroke or time dependent systems.
For the successful application of the vacuum system it is very important to know the progress of the flow in the die in order to establish the end point(s) of the die filling. The vacuum channel has to be placed at this point. Additional channels can be placed at critical die sections.

When operating dies with slides it is important to make certain that no die spray residue is sucked into the die cavity. In this case it has to be ensured that the die is not evacuated too early and too deeply.

Fondarex Optivac have four valve sizes

<table>
<thead>
<tr>
<th>Valve type</th>
<th>Flow volume</th>
<th>Vacuum channel area</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINI</td>
<td>1,8l/s</td>
<td>min. 30mm²</td>
</tr>
<tr>
<td>MEDIA</td>
<td>3,3l/s</td>
<td>min. 60mm²</td>
</tr>
<tr>
<td>MAXI</td>
<td>6,7l/s</td>
<td>min. 90mm²</td>
</tr>
<tr>
<td>MACRO</td>
<td>9,7l/s</td>
<td>min. 120mm²</td>
</tr>
</tbody>
</table>

Minimum gate thickness 1mm

Exercise

Available

<table>
<thead>
<tr>
<th>Shot weight</th>
<th>Filling rate</th>
<th>Time 1st phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>ml 2450g</td>
<td>%F 45%</td>
<td>tI1eff 0,75s</td>
</tr>
<tr>
<td>Weight from gate mA 1270g</td>
<td>vMA 50m/s</td>
<td>tF 0,06s</td>
</tr>
</tbody>
</table>

Required
1. Please draw in the vacuum channel.
2. Which valve do you recommend?

The specialists of FONDAREX are at your disposal for detailed information.
The p/Q-diagramm

Objectives
Displaying the machine line.
Displaying the die line.
Displaying the process security.

Features
Displaying the operation point. The value pair \((\text{pM}, \text{QM})\) can be called up with the key sequence \(<\text{Measuring}> <\text{p/Q}>\).

Lesson contents p/Q diagram
Elements and structure of the p/Q diagram.
Link from the Processtrol to the p/Q diagram.
Process changes in the p/Q diagram.
Difference between a controlled and a closed-loop controlled process.

Lesson aims p/Q diagram
Explain the elements and structure of the p/Q diagram.
Explain the link from the Processtrol to the p/Q diagram.
Display the process changes in the p/Q diagram.
Explain the difference between controlled and closed-loop controlled with the help of the p/Q diagram.
The p/Q diagram

The p/Q diagram is a graph used to display the hydraulic capacity of the shot end during the dynamic die filling phase. Displayed is the metal volume flow \( Q_M \) in \([\text{m}^3/\text{s}]\) (abscissa) in relation to the metal pressure \( p_M \) in \([\text{bar}]\) (ordinate). Generally valid is, the relation \( p_M \) is proportional to \( Q_M^2 \). By selecting a suitable display scale the die and machine lines can be displayed as straight lines.

For every shot the Processtrol calculates the value pair \( p/Q \). This is used to calculate the casting capacity \( P \) in [%] in comparison to a maximum possible casting capacity.

Figure 1: Processtrol and p/Q diagram of the B machines.

Figure 2: Processtrol and p/Q diagram of the SC machine.
Why would we have to refer to the p/Q² diagram and not simply p/Q diagram?

Elements of the p/Q diagram

The p/Q diagram is distinguished by three main elements, namely:
- The die line which is a measure of the gate resistance, the viscosity of the metal and the metal velocity.
- The machine line which is a measure of the hydraulic capacity of the shotend.
- The operation point indicates the current state of operation.

The value pair pM/QM can be taken from the corresponding Processtrol page.

Figure 3: Principle of the p/Q diagram.

Die and machine line

Exercise:
Draw in the die lines for 2 dies. Your test series resulted in following values:

<table>
<thead>
<tr>
<th></th>
<th>SA1</th>
<th></th>
<th>SA2</th>
</tr>
</thead>
<tbody>
<tr>
<td>pM [bar]</td>
<td>QM [dM³/s]</td>
<td>pM [bar]</td>
<td>QM [dM³/s]</td>
</tr>
<tr>
<td>27</td>
<td>8.0</td>
<td>50</td>
<td>7.0</td>
</tr>
<tr>
<td>50</td>
<td>10.5</td>
<td>75</td>
<td>8.2</td>
</tr>
<tr>
<td>77</td>
<td>13.0</td>
<td>112</td>
<td>10.0</td>
</tr>
</tbody>
</table>

And now also add the machine line. The maximum pressure pM is 175 [bar] and the maximum possible metal volume flow QM is 17 [dM³/s].
Exercise:
Given are the machine line and one die line. Draw in one die line each for a larger and a smaller gate section.

Figure 5: Influence of gate enlargement.

Exercise:
Given are the machine line and one die line. Draw in the lines for a larger and a smaller plunger. Which lines are affected and why?

Figure 6: Influence of the plunger diameter.

Exercise:
Given are the machine line and one die line. Draw in the lines for a higher and lower nitrogen charge. Which lines are affected and why?

Figure 7: Influence of the nitrogen pressure.
Exercise

Given are the machine line and one die line. Draw in the lines for a lower velocity $v_C$. Which lines are affected and why? Where is your operation point and how would you define this point with the Processstrol?

Comment on your solutions.

Figure 8: Influence of the nominal value of velocity.

Difference between a controlled and closed-loop controlled process

We already have shown the behaviour of the die line with different gate sections. Let us assume the gate is getting smaller during the die filling process. In this situation the conventionally controlled B shot end and the closed-loop controlled SC shot are reacting entirely different.

It is immediately recognizable that the closed-loop controlled machine does not permit a reduction of the volume flow and with it of the velocity. The moment a larger resistance appears in the die (in our case created by a reduction of the gate section), it will lead to a control deviation which is instantly countered by a larger opening of the shot control valve.

With the controlled machine the enlarged resistance in the die leads to a reduced metal volume flow and to a drop in velocity.

Exercise:

Figure out together with the colleague next to you why, on the diagram on the left, the shifting “controlled” is not horizontal.

Figure 9: Difference controlled/closed-loop controlled.
Figure 10: Display of the machine lines for various plunger diameters.

Exercise:

Appendix 1 and 2 contain one value selection each and various shot curves.
Find the operation point for this shot from the available data and enter it into figure 10.
3rd Phase (Pressure intensification)

Aluminium loses about 4-7% on volume during the change from liquid to solid state (solidus-liquidus point). This loss in volume has to be replaced by feeding additional material at high pressure through the gate. After the die filling the gate is open for a short time only.

The pressure intensification phase starts at the end of die filling and ends with the last stroke impulse.

An important parameter is the pressure building up time \( t\Sigma \)

Metal pressure during the pressure intensification phase in bar

<table>
<thead>
<tr>
<th></th>
<th>Al + Mg alloys</th>
<th>Zn zinc alloys</th>
<th>Ms brass alloys</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard parts</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parts without mech.</td>
<td>up to 400 bar</td>
<td>100 - 200 bar</td>
<td>300 - 400 bar</td>
</tr>
<tr>
<td>requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Technical parts</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parts with mech.</td>
<td>400 - 600 bar</td>
<td>200 - 300 bar</td>
<td>400 - 500 bar</td>
</tr>
<tr>
<td>requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pressure-tight parts</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parts with increased</td>
<td>800 - 1000 bar</td>
<td>250 - 400 bar</td>
<td>800 - 1000 bar</td>
</tr>
<tr>
<td>requirements for</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pressure tightness</td>
<td></td>
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<tr>
<td><strong>Galvano casting</strong></td>
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<tr>
<td>Chrome parts</td>
<td>220 - 250 bar</td>
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[http://www.upmold.com](http://www.upmold.com)
Where is the final solidification?

What can be done to improve the feeding of the critical section?

Final pressure delay $t_{\text{Ret}}$

Final pressure delay is often applied to fully utilize the machine locking force.

Why is it possible to operate with a higher injection pressure?
What advantages does the final pressure delay have?

What disadvantages does the final pressure delay have?

**Secondary squeezing (squeeze pin)**

After the die filling the gate is open for a short time only. Thereafter the alloy can only be compressed with an external squeeze pin.

The maximum displacement volume of the squeeze pin should be at least 4% of the casting volume to be compressed.

**Ejector sleeve (wearing part)**

When designing the die easy replacement of the wearing parts has to be allowed for.

**Squeeze pin , Standard ejector pin (wearing parts)**

When designing the die easy replacement of the wearing parts has to be allowed for.

**Note!**

The diameter of the squeeze pin will increase due to heat expansion, therefore it must not be inserted for too long, otherwise it cannot be withdrawn anymore.
Casting technique  Casting process

**Drive cylinder 150 bar**
The die has to be designed in such a way that the hydraulic cylinder does not get too hot. Do not go higher than 60°C, if necessary cooling might be required.

**Squeeze pin**
Squeeze pin and drive cylinder have to be designed in such a way that a metal pressure of approx. 3000 bar can be reached. Ratio of surface areas approx. 1:20

The gate has to solidify before the start of the secondary squeezing.

To be able to sufficiently compress the material through the gate the biscuit thickness \(B\) has to be at least 20mm.

![Diagram](http://www.upmold.com)

- **Starting point for delay timer**
- **Final pressure delay**
- **The drop in cavity pressure indicates that the gate is solidified.**

**Delay according to wall thickness 2-10 s**

**Start of the secondary squeezing**

http://www.upmold.com
Dependence of Penetration delay and penetration depth

Determination of the starting time delay and penetration velocity.

Which advantages has the squeeze pin?

Which disadvantages has the squeeze pin?
Die opening force

The die opening force $FLI$ is calculated with the parameters projected area $AIM$ and metal pressure $pI3M$.

$$FLI = \frac{AIM \cdot pI3M}{100} = kN$$

Calculation of the die opening force with mechanical or hydraulic cores.

Hydraulically actuated cores are interlocked with an angle of $3-5^\circ$.

Mechanically actuated cores are interlocked with an angle of $18-25^\circ$.
Exemples: Die opening force

Calculation of the total projected area with various core interlocking angles.

Tangent values of 3° = 0.052  5° = 0.087  10° = 0.176  15° = 0.26  20° = 0.36  25° = 0.46

\[
FLI = \left[ \frac{AIM + (AIM_{\text{CORE}} \cdot \tan \alpha)}{100} \right] \cdot p_{\text{I3M}} = \text{kN}
\]

Available

Area A incl. runner 400cm²
Area B 200cm²
Area C 300cm²
Area D 200cm²
Interlocking angle 20°
I3M metal pressure 600 bar

Required Die opening force FLI

Available

Area A incl. runner 400cm²
Area B 200cm²
Area C 300cm²
Area D 200cm²
Interlocking angle 3°
I3M metal pressure 600 bar

Required Die opening force FLI
Die opening force

Calculation of the total projected area with various core interlocking angles.