TALAT Lecture 3402

Forging Process

17 pages, 20 figures

Basic Level

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Objectives:

- to understand the basic principles of die forging and the characteristic features of special aluminium die forging processes
- to learn about the basic design of dies in order to obtain optimum part qualities and tool life

Prerequisites:

- general understanding of metallurgy and deformation processes

Date of Issue: 1994

3402 Forging Process

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3402.01 Principles of the Forging Process

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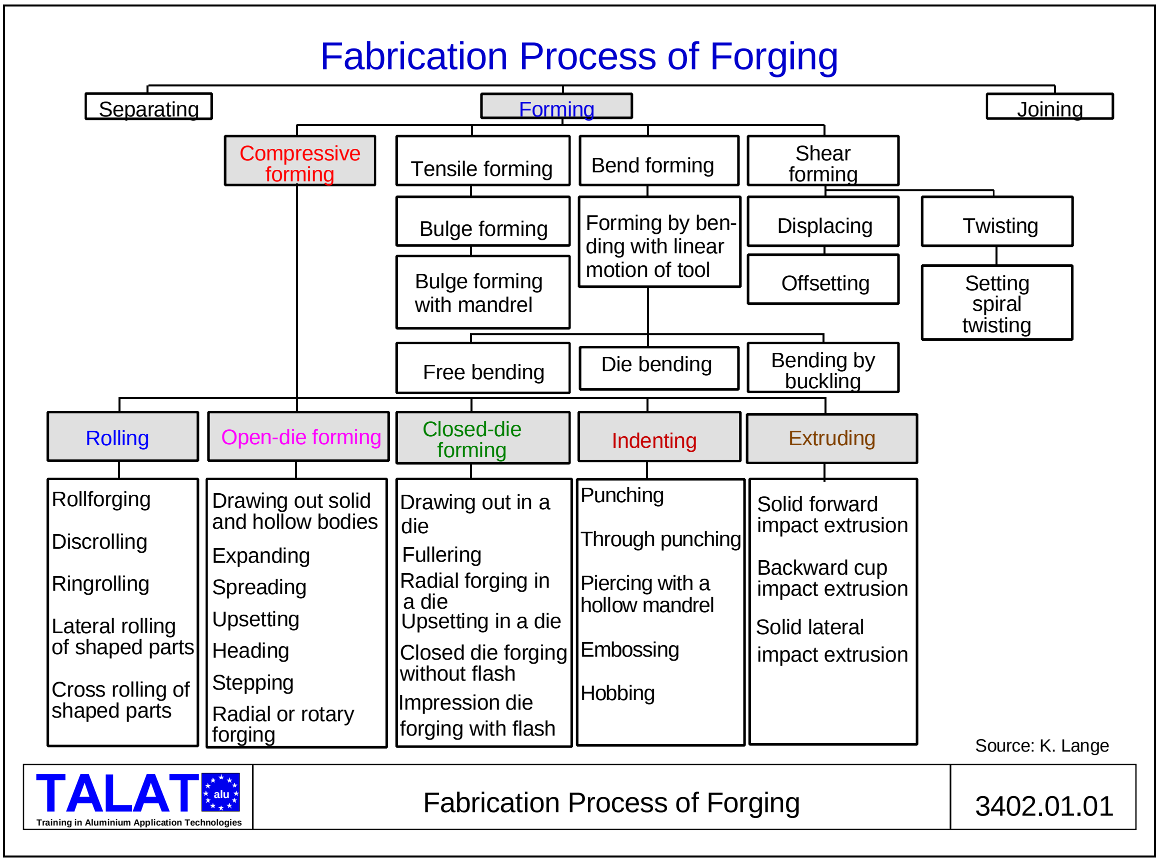
- Die forging processes

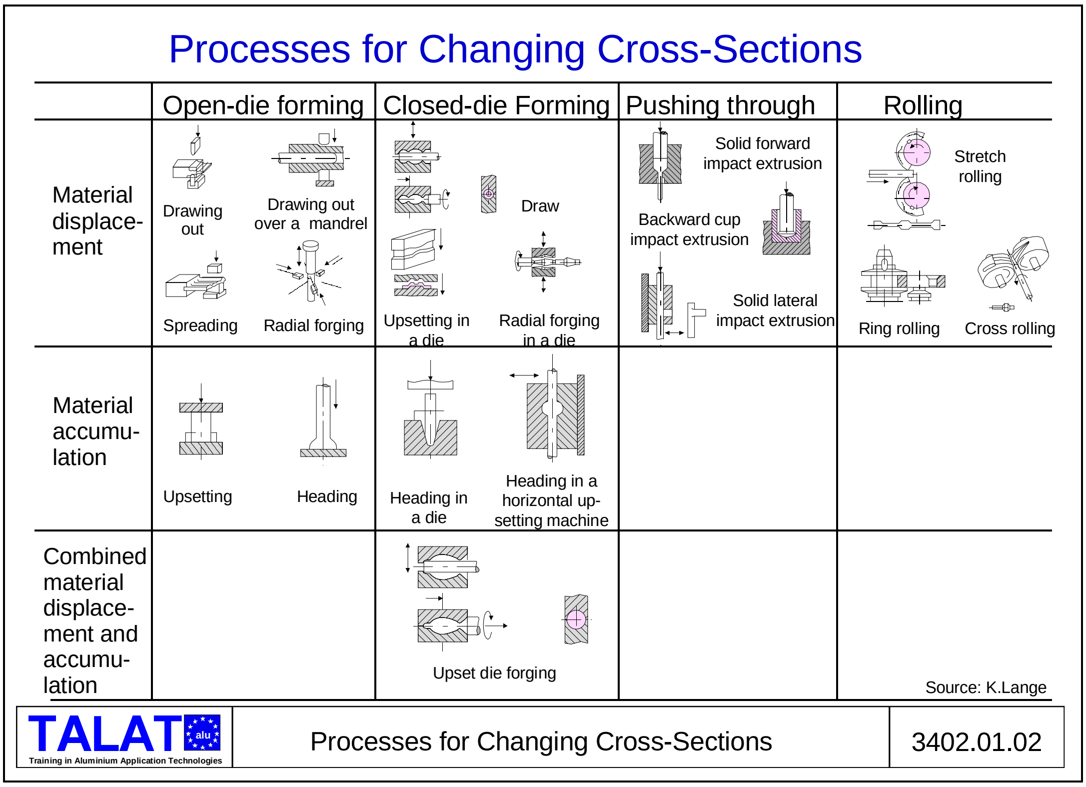
Fabricating Processes of Forging

The term forging is used to define a group of processes which are mainly forming processes (see **Figure 3402.01.01).** Additionally included are processes of separating (splitting) and joining, if large or complicated workpieces are built up out of individual parts. The exact processes of separating and joining are not listed here in detail. According to the characteristic differences in free forming (or unrestricted forming) and die forming (restricted forming), forging can be divided into open-die forging and die forging.



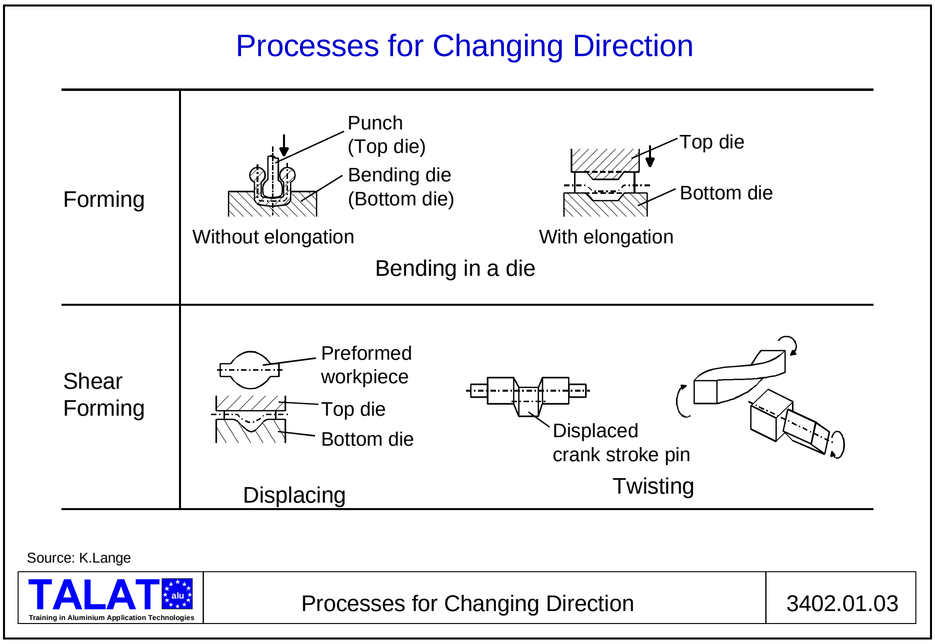
Processes for Changing Cross-Sections

The processes for changing cross-sections build-up the fundamentals of forging, see **Figure 3402.01.02**. According to the law of constant volumes, changes in cross-section lead to corresponding changes in length. The cross-section can be changed by material displacement and material accumulation, whereby the processes of material displacement dominate.



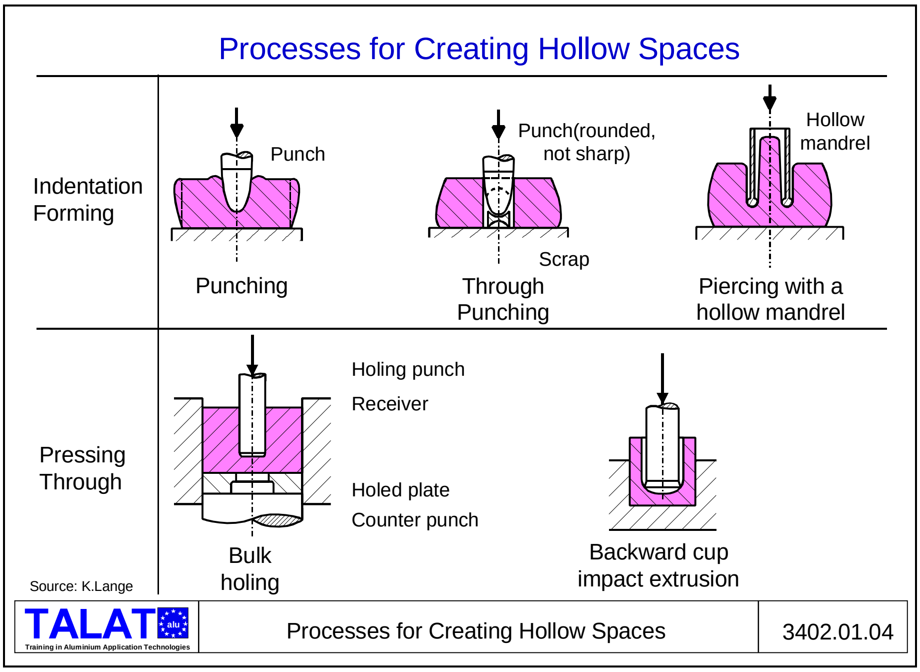
Processes for changing direction

These processes include bending processes (free bending, die bending) and shear forming processes (**Figure 3402.01.03**).



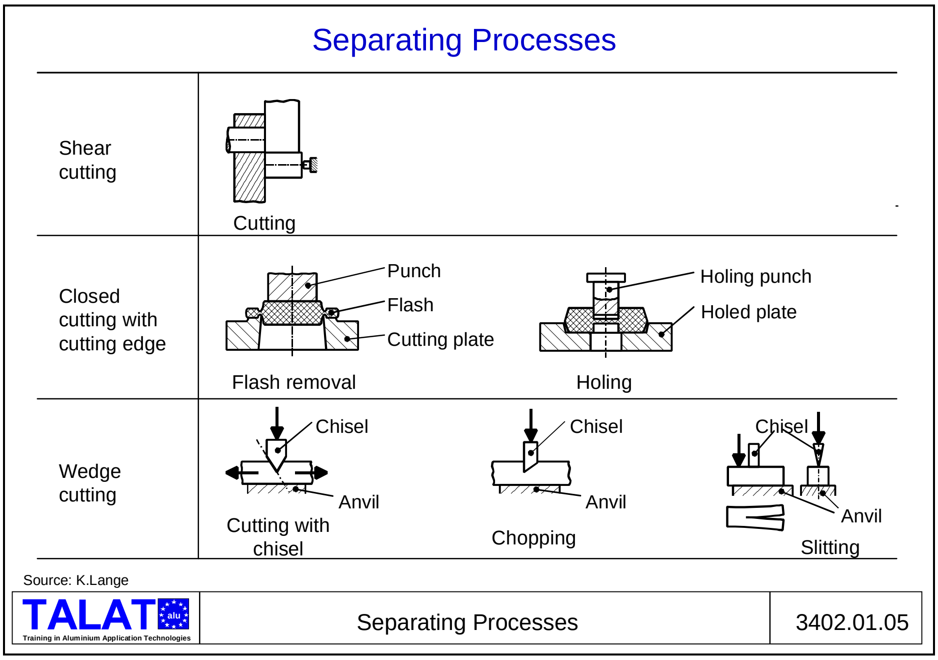
Processes for Creating Hollow spaces

Hollow spaces (cavities) are produced by the methods of indentation forming and extrusion forming (**Figure 3402.01.04**).



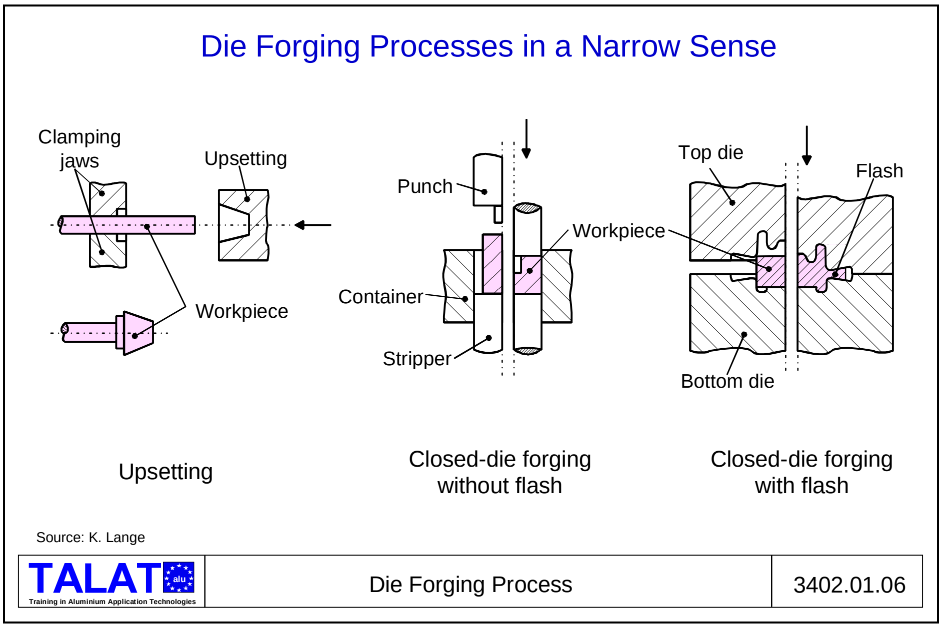
Separating Processes

Separating processes used for forging are mostly cutting processes (**Figure 3402.01.05**). Shear cutting processes are used for the loss-free cutting of raw parts with a given cross-section (extruded sections) and defined lengths or volumes.



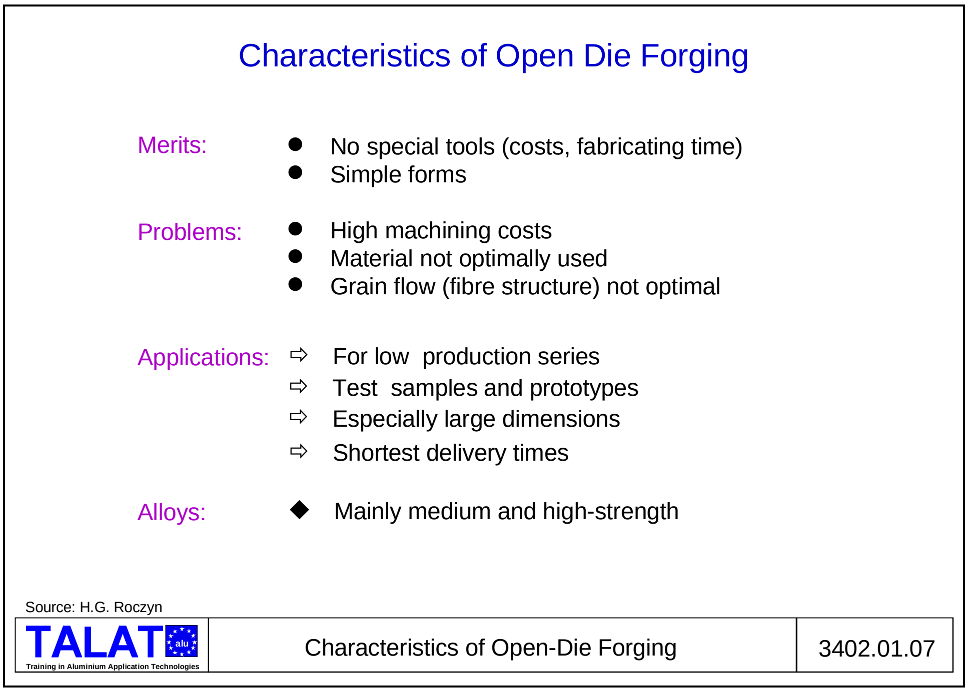
Die Forging Processes

These are processes which are used to produce a defined workpiece geometry having good dimension and volume accuracy. Such processes are: form pressing with flash, form pressing without flash and compressing in a die, see **Figure 3402.01.06**.



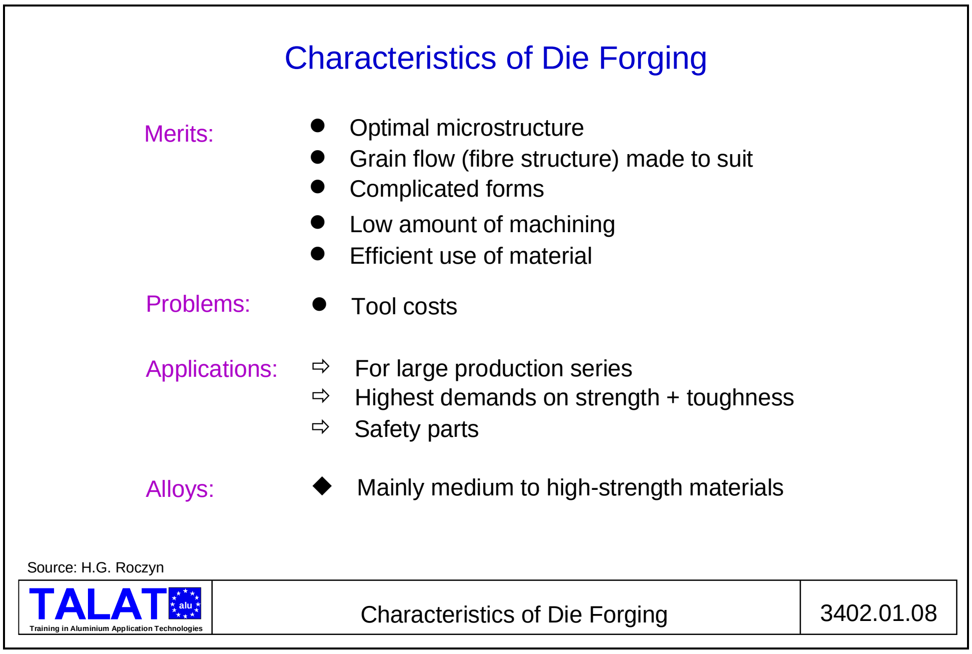
Open-Die Forging

The chacteristics of open-die forging are listed in **Figure 3402.01.07**.



Die Forging

The characteristics of die forging are listed in **Figure 3402.01.08**.



3402.02 Special Forging Processes for Aluminium

- List of characteristic features of precision forging
- List of characteristic features of high precision forging
- Characteristic features of closed die forging without flash
- Characteristic features of isothermal forging

List of the aims of various special die forging processes (Figure 3402.02.01)

Special Forging Processes and their Aims

Process	Characteristics	Advantages
1. Precision forging	better forging quality	narrower tolerances, better replication of final form
2. High precision forging	best forging quality	narrower tolerances, better replication of final form, better surfaces
3. Closed die forging without flash	forging in closed dies	material savings
4. Powder forging (mostly combined with 3.)	sintered raw parts	material savings, fewer forming process steps, narrower tolerances
5. Isothermal forging	tool temperature ~ work temperature	better replication of final form
6. Superplastic forging (mostly combined with 3)	as in 5. ; very low forming speeds	material savings, fewer forming process steps, better replication of final form
7.Squeeze casting	pressing in pasty state	fewer forming process steps, better replication of final form
8. Partial forging	stepwise fabrication	better replication of final form
9.Thermomechanical working	combined forging and structure change	better mechanical properties

Soerce: K. Lange, H. Meyer-Nolkemper

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List of characteristic features of precision forging
(**Figure 3402.02.02**)

Characteristics of Precision Forging

Precision Forging is a die forging process which saves at least one finishing or supplementary operation compared to conventional die forging.

Its merits are:

- 0° - 1° side tapers (draft)
- Thinner work-piece sections
- Narrower tolerances
- Smaller radii

⇨ High quality surface finish
⇨ Shorter production times for finished product

Problem: Higher tooling costs

Source: K. Lange, H. Meyer-Nolkemper

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List of characteristic features of high precision forging
(**Figure3402.02.03**)

Characteristics of High Precision Forging

- Special case of precision forging
- Production of "ready-to-use" parts

- 0° - 1° side tapers
- Thin work-piece regions
- Narrow tolerances
- Small radii

⇨ High quality surface finish
⇨ Shorter production times for finished product
⇨ Little or no machining required
⇨ Weight savings
⇨ Good reproducibility

Source: K. Lange, H. Meyer-Nolkemper

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Characteristic features of closed die forging without flash
(Figure 3402.02.04)

Closed Die Forging without Flash

Characteristics:

= Die forms in closed tools from which no material is lost

- Constant volume of hot starting, intermediate and final form
- Exact mass distribution
- Exact positioning
- No flash

⇨ Weight savings
⇨ No flash
⇨ Shorter production times for finished part

Source: K. Lange, H. Meyer-Nolkemper

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Characteristic features of isothermal forging
(Figure 3402.02.05)

Isothermal Forging

- Form pressing with die temperatures almost equal to the work temperature

- Melted pockets due to local overheating caused by too high forming rates
- Low temperature gradient tool / work piece
- No flashed removal

⇨ High quality parts in almost "ready-to-use" shape
⇨ Shorter production times for finished part

Source: K. Lange, H. Meyer-Nolkemper

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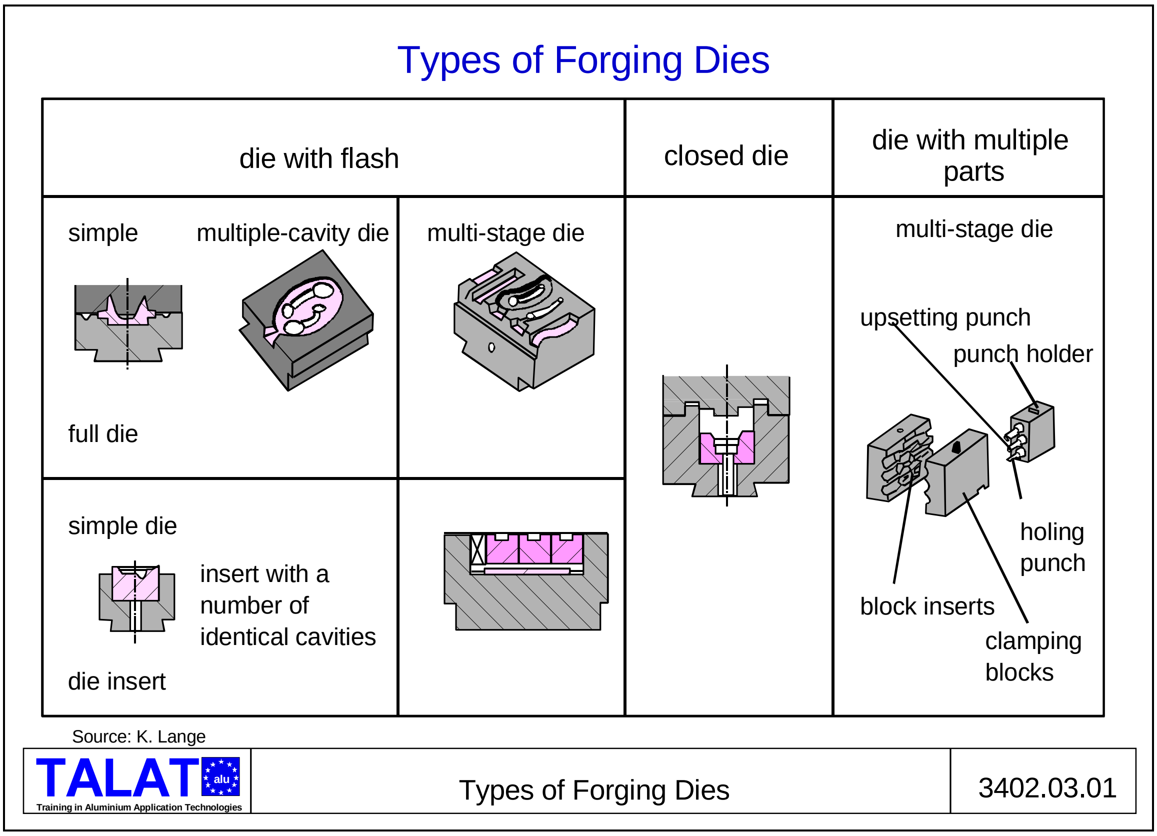
3402.03 Forging Dies

- Types of forging dies
- Parting of forging dies
- Rules for design of partings of forging dies
- Die inserts
- Fabricating forging dies
- Failure and damaging of forging dies

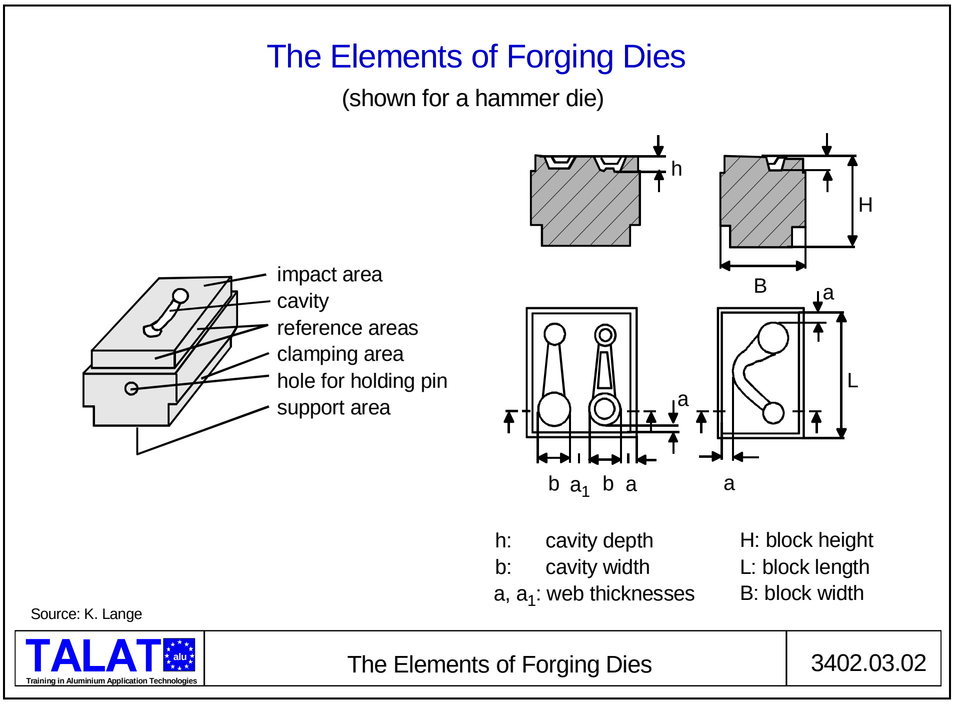
Types of Forging Dies

The following types of forging dies are encountered in die forging: **Figure 3402.03.01**:

- Single-cavity die
- Multiple-cavity die: a number of identical cavities in one die
- Multiple-stage die: more than one forming step for the workpiece in a die



The elements of forging dies are shown in **Figure 3402.03.02** for a hammer die.



While designing forging dies, the following aspects must be taken into consideration:

- Design to meet the stresses
  Forging dies are mostly subjected to repeated stress.
  The fatigue strength depends on the surface, cracks, residual stress and top-layer hardness.
- Design for dimensions
  Shrinkage of the formed part is taken into account.
  Particular attention must be given to the fact that both die (steel) and workpiece (aluminium) have different coefficients of thermal expansion and that the die geometry has various sources of errors.
- Design for machining
- Machining tolerances are to be considered.
- Design for optimal material flow

The tool stress can be reduced by avoiding sharp edges, abrupt transitions, long narrow fins (ribs) etc. (see also TALAT Lecture 3403).

Parting of Forging Dies

Dividing the cavity between top and bottom die (parting line of a forging) is of particular importance. The position of the parting line influences the tolerance of the forging and several other properties of the forging as well as die wear (see **Figure 3402.03.03**).

Partings of Forging Dies

The parting plane of dies determines the proportion of volume of the forging in the upper and lower die.

The parting has an influence on further values and properties:

- geometry of the forging
- fibre structure
- strength properties
- mass of material
- forging process (force required, form filling)
- further working
- wear of dies

Source: H.G. Roczyn

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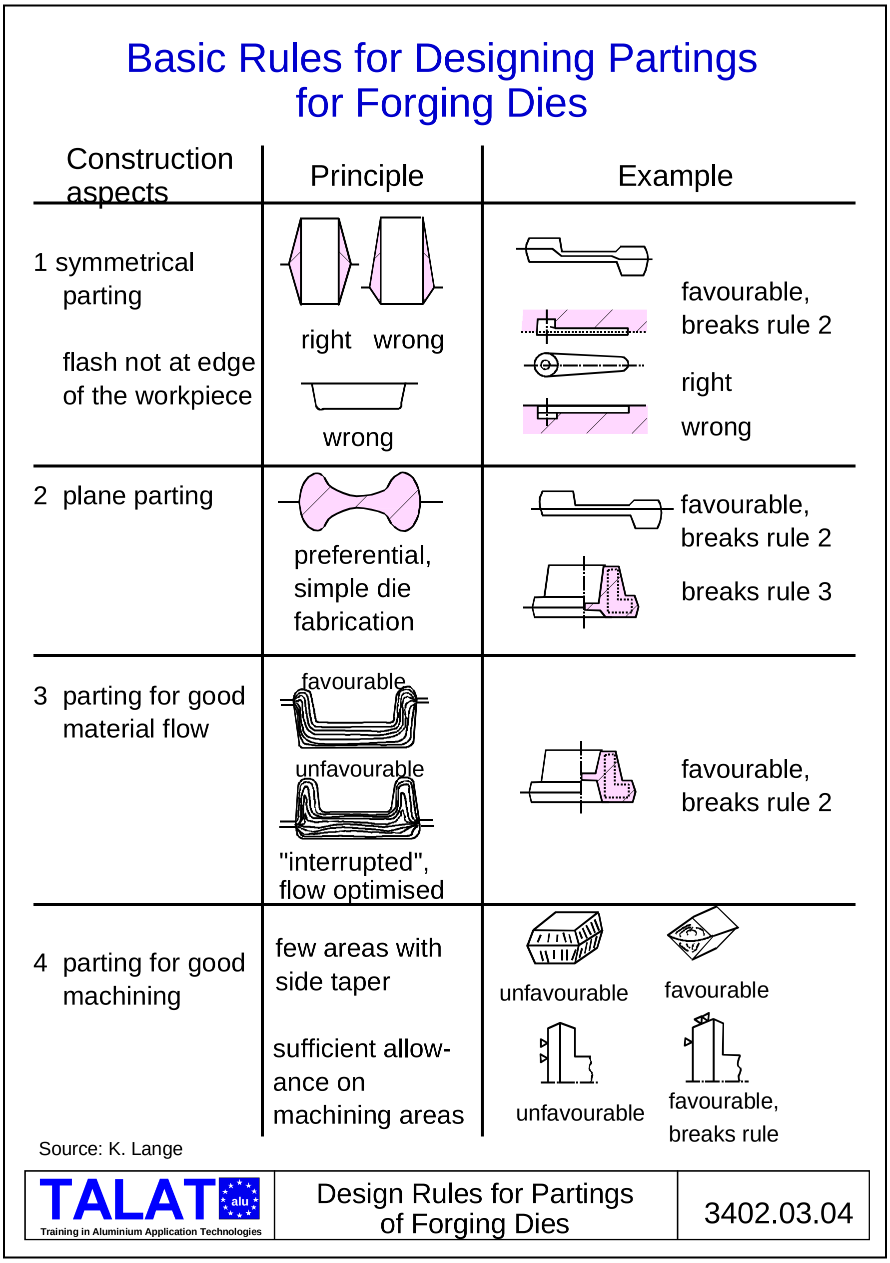
Rules for design of partings of forging dies

Rules for design of partings of forging dies:

1. Symmetrical parting:
   The effort for making the tool with a given wall taper is lowest.
2. Plane parting:
   The die block height is the lowest; the mechanical working is simplified.
3. Parting for good material flow:
   This makes the material flow easy.
4. Parting for good machining:
   This makes it easy to machine or to remove flash.

Basic rules for the positioning of the parting of forging dies are collected in **Figure 3402.03.04**.



Die Inserts

Die inserts are blocks which can accommodate the complete die cavity (see **Figure 3402.03.05**). One can save expensive die steel for the die holder if die inserts are used.

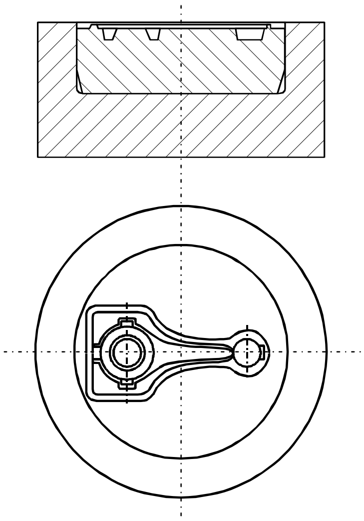
Die inserts are made of tempered alloy steel. due to the lowered stress acting on the die holders, these can be made of low alloy steel or tempered steel (e.g. steel 1.2713), thereby saving costs. The die insert is fastened to the die holder in a force or form locked type of joint.

Die Inserts

Merits of die inserts

- Easy handling due to reduced weight
- Insert can be constructed with high-strength materials
- Die holder can be made of unalloyed or low alloyed material
- Cost savings with replacements

Die insert in a die holder



Source: Thyssen

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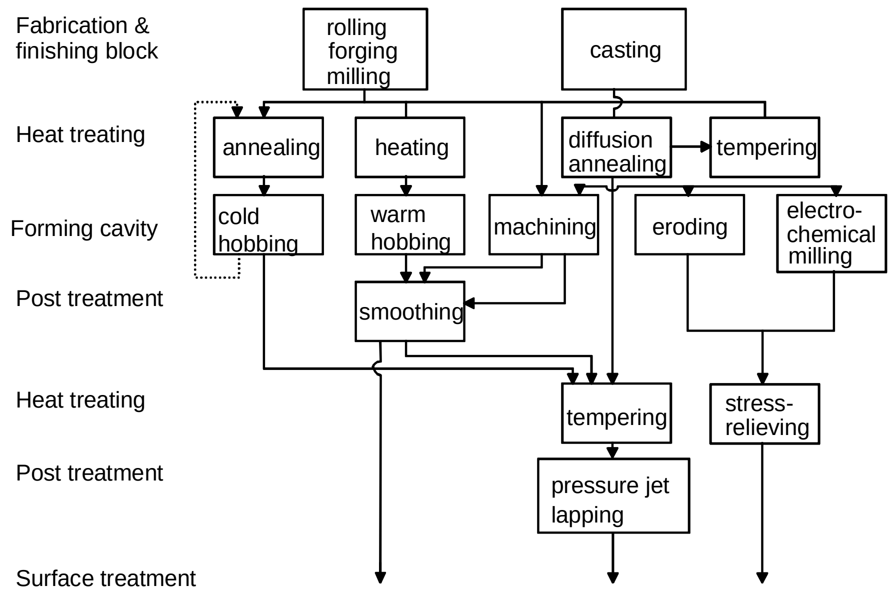
Fabricating Forging Dies

Fabricating forging dies



Source: K.Lange / H. Meyer-Nolkemper

TALAT Training in Aluminium Application Technologies	Fabricating Forging Dies	3402.03.06

The steps of fabrication of forging dies are described in **Figure 3402.03.06.**

- The die block is produced by casting or rolling/forging and finally mechanically working.
- The cavity is fabricated by machining, cold hobbing, eroding, electrochemical milling, etc..
- The die inserts (and die holder) are heat-treated to improve strength.
- After polishing, the cavity has a surface roughness of 3 µm.

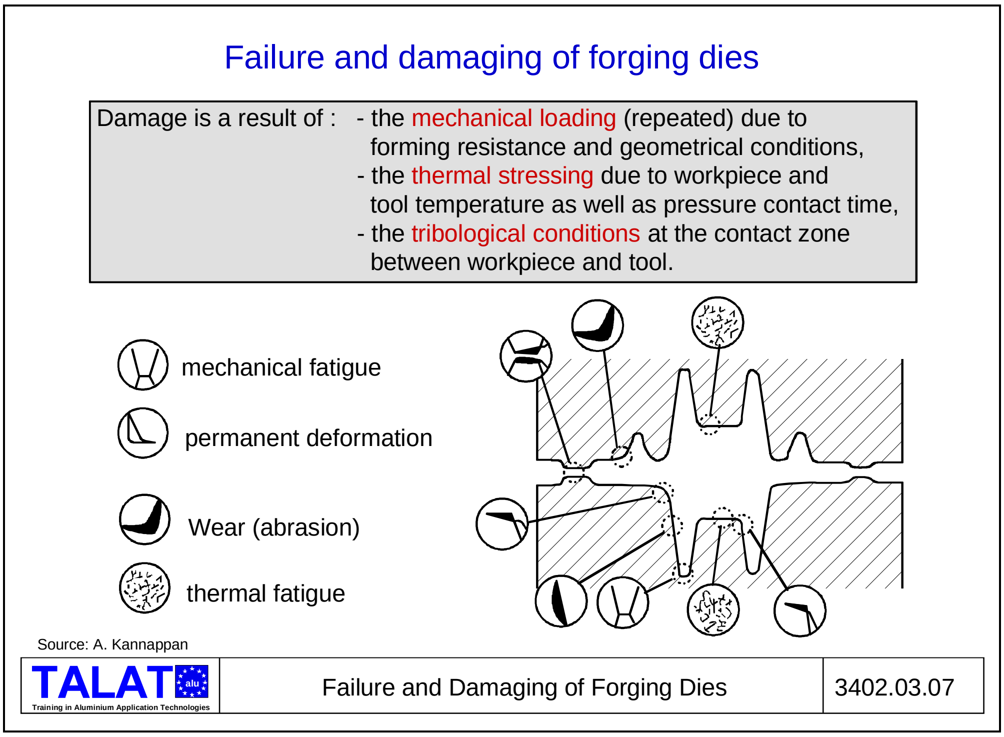
Since aluminium has a lower flow stress than steel, the contours of the die cavity are reproduced more exactly on aluminium forgings.

Failure and Damaging of Forging Dies

Damages occur on forging dies due to thermal and mechanical fatigue as well as due to wear and permanent deformation (see **Figure 3402.03.07).**

The individual effects occur in combinations of:

1. Warm fatigue cracks can occur due to thermal stresses in the tool. The temperature gradients depend on the geometry and forming conditions.
2. Plastic deformation occurs as a result of local stresses exceeding the yield strength, as may be the case in protruding form elements.
3. Fatigue cracks are initiated due to repeated die stresses occurring over the forming operation cycle. Thus, notches and abrupt transitions in the die should be avoided as far as possible.
4. Wear occurs due to small particles which detach from the surface. The degree of wear depends on the tribological system between tool and workpiece.



3402.04 Literature:

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3402.05 List of Figures