Forming - Bulk Forming

Manufacturing Technology II
Lecture 4

Laboratory for Machine Tools and Production Engineering
Chair of Manufacturing Technologies

Prof. Dr.-Ing. Dr.-Ing. E. h. F. Klocke

Outline

- Introduction
- Cold forming
- Warm forming
- Forging
Methods of Forming – Classification DIN 8580 ff

Introduction

Methods of Forming – Classification DIN 8580 ff

Manufacturing Processes

- Casting
- Forming
- Cutting
- Joining
- Coating
- Changing of Material properties

Compressive Forming:
- Open die forging
- Closed die forging
- Cold extrusion
- Rod extrusion
- Rolling
- Upsetting
- Hubbing
- Thread rolling

Tension Compressive Forming:
- Deep drawing
- Ironing
- Spinning
- Hydroforming
- Wire drawing
- Pipe drawing
- Collar forming

Tensile Forming:
- Stretch forming
- Extending
- Expanding
- Embossing

Bending:
- With linear tool movement
- With rotational tool movement

Shear Forming:
- Translate
- Twist
- Intersperse

Severing:
- Shearing
- Fine Blanking
- Cutting with a single blade
- Cutting with two approaching blades
- Splitting
- Tearing

Introduction

Process of Forming Technology: Bulk Forming – Sheet Metal Forming

Bulk forming:
- large changing of cross section and dimension
- large form modification
- large material strain hardening
- high forces
- high tool stresses

Sheet metal forming:
- no or low unwanted changing of the original wall thickness
- smaller deformations
- smaller material strain hardening
- lower forces
- than by bulk forming procedures
Introduction

What is Bulk Forming?

Bulk forming

massive semi-finished material

component

Introduction

Advantages of Bulk Forming

<table>
<thead>
<tr>
<th>Cutting</th>
<th>Forming</th>
</tr>
</thead>
<tbody>
<tr>
<td>semi-finished part</td>
<td>basic workpiece</td>
</tr>
<tr>
<td>1.3 kg</td>
<td>0.4 kg</td>
</tr>
<tr>
<td>component</td>
<td>component</td>
</tr>
</tbody>
</table>
Introduction

Advantages of Bulk Forming

<table>
<thead>
<tr>
<th>Joining of singel-piece</th>
<th>Function integration by bulk forming</th>
</tr>
</thead>
<tbody>
<tr>
<td>flange</td>
<td>e.g. stability and leak tightness</td>
</tr>
<tr>
<td>can</td>
<td></td>
</tr>
<tr>
<td>fitting</td>
<td></td>
</tr>
<tr>
<td>joined by welding</td>
<td>formed by extrusion</td>
</tr>
</tbody>
</table>

- bulk forming allows function integration

Outline

- Introduction
  - Cold forming
    - Introduction
    - Upsetting
    - Extrusion
  - Warm forming
  - Forging
Cold forming
Iron-Carbon Diagramm

- fcc
- bcc

Recrystallizing

Cold forming
Material Properties

- high flow stresses and low achievable strain by classic steel materials
Cold forming

Advantages and Disadvantages of Cold Forming

Cold Forming

Advantages:
- low tool material costs
- low influence of forming velocity
- no energy costs for heating
- no dimension faults caused by dwindling
- high surface quality
- increasing strength of the component

Disadvantages:
- high forces
- limited plastic strain

Cold forming

Efficiency

<table>
<thead>
<tr>
<th>forming</th>
<th>cold</th>
</tr>
</thead>
<tbody>
<tr>
<td>workpiece weight</td>
<td>0.001 – 30 kg</td>
</tr>
<tr>
<td>plasticity</td>
<td>$\varphi &lt; 1.6$</td>
</tr>
<tr>
<td>finishing effort</td>
<td>less</td>
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</table>

with cold forming processes a good workpiece quality can be reached by low strain
Cold forming

Efficiency

<table>
<thead>
<tr>
<th>Forming process</th>
<th>IT-statement like DIN ISO quality</th>
<th>Centerline average Ra / µm</th>
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<tbody>
<tr>
<td></td>
<td>5 6 7 8 9 10 11 12 13 14 15 16</td>
<td>0.5 1 2 3 4 6 8 10 12 15 20 25 30</td>
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<td>Cold extrusion</td>
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<tr>
<td>Hot extrusion</td>
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</table>

- achievable with special proceedings
- achievable without special proceedings

- small shape, dimension and position tolerances as well as
  good surface qualities are possible

Cold forming

Forming Processes

extrusion | full extrusion | hollow extrusion | cup extrusion
---|---------------|------------------|------------------
forward extrusion | before | after |     |
backward extrusion |     |     |     |
radial extrusion |     |     |     |

a: punch, b: die, c: workpiece, d: ejector, e: counter punch, f: spike
Cold forming

**Full Forward Extrusion**

- workpiece insertion
- compression
- extrusion
- ejection

1. punch
2. workpiece
3. cavity
4. ejector
5. die

Production of a pin

---

Cold forming

**Cup Backward Extrusion**

- workpiece insertion
- compression
- extrusion
- ejection

1. punch
2. workpiece
3. die
4. ejector

Production of a cup
Cold forming

Radial Extrusion of a Cardan Joint

- Workpiece insertion
- Closing of the die
- Extrusion
- Ejection

Production of a cardan joint

Cold forming

Typical Cold Formed Components

- Gear shafts
- Tubes
- Denticulations
- Screws

Hirschvogel
Fuchshofer
Schraubenwerk
almost all screw geometries are produced by extrusion processes.

the production of components is usually characterized by a combination of different extrusion processes.
Cold forming

**Film: Cold Extrusion of a Gear Shaft**

During upsetting or radial extrusion processes, surface cracks can appear on the collar surface.
Cold forming

Crack Reduction by Superposition of Compressive Stresses

- tearing could effectively be shifted to higher strains by superposition of compressive stresses

Crack Prevention by Superposition of Compressive Stresses

- superposition of compressive stresses can be realized by modifying the tool concept
Cold forming
Chevron Cracks by Full Forward Extrusion

- an unfavourable dispersion of the interior material generates cracks

FEM-Simulation
3. forming step
real workpiece

Chevrons
### Phases of Production of a Bevel Gear

<table>
<thead>
<tr>
<th>bucking</th>
<th>upsetting</th>
<th>indirect cup extrusion</th>
<th>cutting</th>
<th>radial extrusion</th>
<th>burr cutting</th>
<th>calibration</th>
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- recrystallization
- recrystallization
- recrystallization

Achievable deformation can be increased by recrystallization.

### Outline

- Introduction
- Cold forming
  - Warm forming
  - Forging
Warm forming
Iron-Carbon Diagram

fcc

bcc

recrystallization

Carbon content in weight percent

Cementite content in weight percent

Warm forming
Material properties

Layer of scale / µm

Flow stress \( k \) / MPa

workpiece temperature / °C

- reduction of flow stress and increase of the achievable strain
**Advantages and Disadvantages of Warm Forming**

**Warm forming**

- **Advantages:**
  - strengthening of the workpiece
  - small range of tolerance caused by dwindling
  - good surface quality

- **Disadvantages:**
  - energy input for heating
  - high flow stresses

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**Warm forming Efficiency**

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<td>finishing effort</td>
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- **semi-finished part**
  - cold forming
  - warm forming
Warm forming

**Efficiency**

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- mean shape, dimension and position tolerances as well as mean surface quality are possible

Warm forming

**Typical Warm Formed Components**

- Hinge
- Flange cylinder injector
Outline

- Introduction
- Cold forming
- Warm forming
  - Forging
    - Introduction
    - Open die forging
    - Closed die forging
    - Ring rolling

Forging
Iron-Carbon Diagram

 FCC

BCC

Recrystallization

Carbon content in weight percent
Cementite content in weight percent
Forging

Material Properties

- low flow stress and high achievable strain

Advantages and Disadvantages of Forging

**Advantages:**
- less effort
- high plasticity

**Disadvantages:**
- high energy input for heating
- high material costs for tools
- dimension faults by shrinkage
- material loss and finishing caused by tinder
Forging Efficiency

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Initial state

- cold forming
- warm forming
- forging

Forming process IT-statement like DIN ISO quality

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- low shape, dimension and position tolerances as well as low surface quality possible
Forging

Heating Methods

- Heating in furnaces:
  - furnaces are heated by gas, oil or electricity
  - heat transmission to the workpiece by radiation and convection

- Heating by induction:
  - heat in the workpiece rim is generated by electromagnetic induction by eddy current formation

- Conductive heating:
  - heating by high-frequency current with direct workpiece contact

Inductive and conductive heating reduces the production of primary tinder as a result of the heating rate

Forging

Tinder

- if iron materials are heated above 600°C under the influence of oxygen, iron oxid will be generated on the surface, which is called tinder
- tinder peels away of the workpiece during the forming process
- the results are loss of material, surface marking and tool wear
Forging

**Generation of Tinder During Forging Operations**

Streching and upsetting are the main processes of open die forging.

- Streching
- Rotary swaging
- Latidudinal forming
- Upsetting
- Driving
- Free curving by streching
- Thinning
- Smoothing
- Bulging
- Corrective streching
- Forging a step by streching
- Surfacing
- Upending

- streching and upsetting are the main processes of open die forging
Forging

Processes – Open Die Forging

- upsetting
- streching

- simple tool geometries are used for open die forging processes

Forging

Process cycle

- blank
- round forging
- upsetting
- streching
- forging and shearing
- forging a step
- forging

- simple tool geometries can produce complex workpiece geometries
Forging

Open Die Forging

Material Properties Override

a: tensile strength
b: strain at fracture Z
c: ductile yield A
d: yield strength R_p
e: notch impact strength a_k

- parallel vertical direction of deformation
- across the direction of deformation
- transition direction across along
- decrease by material impurity

by increasing the stretching degree the material properties can be improved
Forging

Film: Open Die Forging

Forging without burr:
- low forming forces
- complete material utilization
- max. permitted volume fluctuation 0.5%
- exact workpiece positioning required

Forging with burr:
- less standards on workpiece volume fluctuation
- no exact workpiece positioning required
- the removal of the burr needs an extra process step
Forging

Stages of Closed Die forging

- crankshaft
- connection rod
- hinge bearing

An effective preform production is the key for short production chains.

Closed Die Forging
1 - wear / abrasion
2 - thermal fatigue / crack formation
3 - mechanical fatigue / crack formation
4 - plastic deformation

The main reason for tool change is the abrasion on edges and cracks in cavitations.

Forging
Die Wear

Wear in the Burr Channel Area

Massive burr formation as reason for abrasion in the burr channel area.
Forging
Wear in the Burr Channel Area

Massive flash formation as reason for abrasion in the burr channel area

Massive flash formation as reason for abrasion in the burr channel area
Forging
Film: Closed Die Forging with Forging Hammer

Forging
Film: Closed Die Forging of a Crankshaft
Forging

Process principle: Radial Axial Rolling Mill

- by ring rolling small output rings can be formed to big, thin-walled, and profiled rings

Forging

Ring Rolling
Forging

Possible Ring Geometries

Possible profiles

- by profiling the pin- and/or main roll many different ring geometries can be produced

Forging

Dimensions

big and small rings can be produced by ring rolling
Forging

Typical Components

Film: Axial Radial Ring Rolling