Influences of different process parameters on the deformation of tubes and sheet metals using pneumo-mechanic and electrohydraulic forming

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Motivation – High speed forming

Save resources and environmental protection

- New materials: high strength steels, hybrid materials …
- Multifunctional parts
- Innovative and efficient processes like high speed forming
  - Prepare high speed forming processes for a wide field of industrial use
  - Analyse and control the process’ phenomena
  - Influence of different process parameters on the forming result
Content

• Electrohydraulic Forming
  – Influence of the load energy on the repeatability of the forming height and the pressure distribution on the blank
  – Influence of the working medium on the forming result

• Pneumo-mechanic Forming
  – Forming of tubes by pneumo-mechanic Forming compared to conventional forming processes
  – Influence of different process parameters on tube forming
Set-up for Electrohydraulic Forming

SSG 0620 (two capacitor banks):
- Max. Load energy: 6 kJ (3 kJ/capacitor); overload: 9 kJ
- Capacity: 30 µF (15 µF/capacitor)
- Max. Load voltage: 20 kV; overload: 25 kV
- Max. current: 160 kA (80 kA/bank)

1: Pulse power generator
2: HV-Cable
3: Table
4: Partition/ Fence
5: EHF-Tool
6: Protective case
7: Oscilloscope
8: Rogowski-coil
9: Vacuum pump
Overview on the process parameters used

- Reproducibility of the forming height
- Reproducibility of the discharge process
- Pressure distribution on the blank

Load energies
- 2 kJ…4 kJ

Electrodes
- Material: CuCrZr
- Geometry: plane

Wire
- Material: CrNi44 (Constantan)
- Thickness: 0.3 mm

Working medium
- Water
- Starch + Water
- Slime
- Ethylen glycol

Sheet metal
- Material: AA1050, 1.0338
- Thickness: 0.5 mm
Pressure distribution and reproducibility using water

Material: AA1050
Thickness: 0.5 mm
Load Energy: 1.5 kJ
Voltage: 14.14 kV
Working Media: water
Conductivity: 460 µS/cm

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Material: 1.0338
Thickness: 0.5 mm
Load Energy: 1.75 kJ
Voltage: 15.28 kV
Working Media: water
Conductivity: 460 µS/cm

Material: AA1050, 1.0338
Thickness: 0.5 mm
Load Energy: 1.75 kJ
Load Voltage: 15.28 kV
Working Media: water
Conductivity: 460 µS/cm

Each color represents a workpiece
Influence of load energy/voltage on the forming height

Material: AA1050
Thickness: 0.5 mm
Load Energy: 0.5 … 1.75 kJ
Working Media: water
Conductivity: 460 µS/cm

Material: 1.0338
Thickness: 0.5 mm
Load Energy: 1 kJ … 4 kJ
Working Media: water
Conductivity: 460 µS/cm
Working medium - Slime
Reproducibility and pressure distribution using Slime

Material: AA1050
Thickness: 0.5 mm
Load Energy: 2 kJ
Load Voltage: 16.33 kV
Working Media: Slime
Conductivity: 1820 µS/cm

Material: AA1050
Thickness: 0.5 mm
Load Energy: 4 kJ
Load Voltage: 16.33 kV
Working Media: Slime
Conductivity: 1820 µS/cm
Reproducibility and pressure distribution using Slime

Material: 1.0388
Thickness: 0.5 mm
Load Energy: 4 kJ
Load Voltage: 16.33 kV
Working Media: Slime
Conductivity: 1820 µS/cm
Working medium - Starch+Water
Starch+Water (non-Newtonian fluid)

Material: AA1050
Thickness: 0.5 mm
Load Energy: 2 kJ
Load Voltage: 16.33 kV
Working Media: Starch+water
Conductivity: 210 µS/cm

Material: 1.0388
Thickness: 0.5 mm
Load Energy: 4 kJ
Load Voltage: 16.33 kV
Working Media: Starch+water
Conductivity: 210 µS/cm
Material: AA1050
Thickness: 0.5 mm
Load Energy: 2 kJ
Load Voltage: 16.33 kV
Working Media: Ethylen glycol
Conductivity: 0 µS/cm

Material: 1.0338
Thickness: 0.5 mm
Load Energy: 4 kJ
Load Voltage: 16.33 kV
Working Media: Ethylen glycol
Conductivity: 0 µS/cm
Comparison of different working media

Material: AA1050
Thickness: 0.5 mm
Load Energy: 2 kJ
Load Voltage: 16.33 kV
Working Media: various

Conductivities:
- Water: 460 µS/cm
- Slime: 1820 µS/cm
- Starch+water: 210 µS/cm
- Ethylen glycol: 0 µS/cm

Material: 1.0338
Thickness: 0.5 mm
Load Energy: 4 kJ
Load Voltage: 16.33 kV
Working Media: various
Content

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Motivation and Aims

Investigation of important process parameters

- Pressure
- Pressure distribution
- Working media
- Kinetic energy

Aims

- Understanding of the process phenomena
- Efficient production of complex, multifunctional part geometries
- Preparation for the industrial use
Pneumomechanical setup

Parameter
- Accelerating distance
- Accelerating pressure
- Plunger mass
- Working media
- Filling level

Specification
- Overall height: 5.2 m
- Plunger diameter: 33 mm
- Plunger mass: 620 g
- Air pressure: 1.5 MPa
- Typical plunger speed: 0-135 m/s
- Typical kinetic energy: 5.6 kJ
Process characteristic

Process parameters

**Pressure**
- Ekin = 0,90 kJ
- Ekin = 0,36 kJ
- Ekin = 0,03 kJ

**Pressure distribution**
- Ekin = 2,5 kJ
- Ekin = 1,3 kJ
- Ekin = 0,7 kJ
- Ekin = 0,25 kJ

**Plungerspeed**
- Plungerspeed exp.
- Plungerspeed theo.
Influence of kinetic energy

- Energy levels: 0.7 kJ, 1.3 kJ, 2.1 kJ
- Materials: AA6060-T6
- Working media: water
- Accelerating height: 5.1 m
- Filling level: 160 ml

Non-deformed state: tube Ø 40 mm
Influence of working media consistence

material: AA6060-T6
kinetic energie $E_{\text{kin}}$: 1.3 kJ
working media: variates
accelerating height: 5.1 m
filling level: 160 ml

Non deformed state: tube Ø 40 mm

- Water
- 125/75
- 125/105

$E_{\text{kin}}$: 2.3 kJ
$R=10$ + 5 %
$R=8$

$y$ (mm)
$y$ (mm)
Influence of filling level

Non-deformed state: tube Ø 40 mm

- 100 ml
- 160 ml
- 220 ml

Filling levels:
- 220 ml
- 160 ml
- 100 ml
- 50 ml

Material: AA6060-T6
Kinetic energy $E_{\text{kin}}$: 1.8 kJ
Working media: water
Accelerating height: 5.1 m
Filling level: varies
Conclusion and Outlook

Electrohydraulical forming

- Load energy, Working medium, Kinetic energy as well as the chosen material has an major influence on the forming result

- The Reproducibility of the process is given, but the pressure distribution is not satisfactory

Pneumo-mechanic Forming

- The pressure effect can effectively increase by varying the working media density

- It could be shown that a minimum filling level is absolutely necessary for the homogeneous forming of tubular geometries

Outlook

- Investigation on process parameter

- Forming of semi finished parts

- Development of new setups
Thank you for your attention