Determining precision of a high performance transfer press in micro metal forming

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Why micro forming is interesting?

- **Remarkable accuracy**
  - Diameters down to 0.15 mm (OD)
  - With wall thicknesses as low as 0.013mm
  - With the length about 60 mm
  - Length-to-diameter ratios greater than 55:1 are attainable
  - Finished part tolerances are as low as ±0.003mm

- **Material saving**
  - Material loss is usually 0-3%, while in machining, chip or grinding loss can be as much as 70% or more.
Why in forming process transferring is important?

- High rate of production
  - Production speeds are 50-400 parts/minute, compared to 1-2 parts/minute in screw machining
  - Because of these super high production rates and material usage, cold formed part prices are often 40-60% of machined part prices
Process parameters

- Process Parameters influencing on Geometric and Surface accuracy
  - Line
    - Machine
      - Kinematics
      - Stiffness
      - Heating behaviour
      - Natural frequency
      - Guide precision
      - Off-center load
  - Billet
  - Process
  - Die
  - Human Elements
    - Automation
      - Weight control
      - Positioning accuracy
      - Transfer study
      - Press force control
      - Feed & Discharge
    - Temperature Control
Challenges

(High performance transfer press in micro cold forming)

- Precision
  - Diversification of components
  - Calculation of tolerances
  - Process safety

- Increased function density
  - Component integration (electric, magnetic, mechanic)

- Cost effectiveness
  - Process design
  - Quick start-up
  - Short cycle times
Conventional Transferring Tools

Tschätsch, H., 1977

NEDSCHROEF Machinery
Miniature parts typically require smaller, more precise equipment.

Courtesy of Deringer-Ney
Previous studies

Geiger et al. 2001

- Principle: A mechanical gripper with a vacuum microgripper
- Repeating accuracy: between 5 µm and 15 µm
- The transfer length is 25 mm
- Wire: Ø0.85 mm
- Speed: max. 260 strokes/min.

Wafios AG, 2007

- Principle: Horizontally mounted rotor with eight dies
- Wire: max. Ø1.4 - 2.6 mm
- Feed length: max. 12 mm
- Speed: max. 400 strokes/min.
Recent studies

Experimental study of a full forward extrusion process from metal strip [Merklein, et al., 2012]

Micro-scaled progressive forming of bulk micropart from sheet metals [Fu, et al., 2013]

Investigation on Flow Stress Level of Spherical Preforms Generated by Laser Melting [Heiko Brüning & Frank Vollertsen, 2013]
Experimental setup

Main servo motor
Die set with two guides
Upper tool
Punches
Manipulator
Lower tool
Handling servo motor
Feeder
x
y
## Dynamic parameters

<table>
<thead>
<tr>
<th></th>
<th>Servo motor (Press)</th>
<th>Servo motor (Transport device)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement (mm)</td>
<td>7.5</td>
<td>20</td>
</tr>
<tr>
<td>Half cycle time (ms)</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>Velocity (mm/s)</td>
<td>187.5</td>
<td>500</td>
</tr>
<tr>
<td>Acceleration (mm/s²)</td>
<td>9400</td>
<td>40000</td>
</tr>
<tr>
<td>Dwell time (ms)</td>
<td>0</td>
<td>120</td>
</tr>
<tr>
<td>Moving mass (kg)</td>
<td>App. 15</td>
<td>App. 0.3</td>
</tr>
</tbody>
</table>

![Graph showing motion parameters](image.png)
Error graph for single-axis error

Accuracy and repeatability according to ISO 230-2
Gripping unit

Curvature:

Distance 1=20mm
Distance 2=20mm

Station 1
Station 2
Station 3

Fingers
workpiece

Ø1.5mm
Ø2mm
Ø2.5mm
Ø3mm
Experimental setup
# Accuracy and grippers’ profile

<table>
<thead>
<tr>
<th>Max. deviation [µm]</th>
<th>Station 1(dir.)</th>
<th>Station 2(dir.)</th>
<th>Station 3(dir.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ø 3 mm</td>
<td>6(x)</td>
<td>8(y)</td>
<td>6(y)</td>
</tr>
<tr>
<td>Ø 2.5 mm</td>
<td>4(x)</td>
<td>6(x)</td>
<td>5(x)</td>
</tr>
<tr>
<td>Ø 2 mm</td>
<td>8(y)</td>
<td>8(x)</td>
<td>12(x)</td>
</tr>
<tr>
<td>Ø 1.5 mm</td>
<td>27(y)</td>
<td>38(x)</td>
<td>20(y)</td>
</tr>
</tbody>
</table>

![Graph showing max deviation vs workpiece diameter]
## Reproducibility

<table>
<thead>
<tr>
<th>Ø 2.5 mm</th>
<th>Distance 1</th>
<th>Distance 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean value</td>
<td>20.020 mm</td>
<td>19.985 mm</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.002 mm</td>
<td>0.002 mm</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>0.009 mm</td>
<td>0.009 mm</td>
</tr>
</tbody>
</table>
Two Dimensional Transfer Study

- Workpiece
- Upper tool
- Lower tool
- Gripper
- Ejector

1. Approach feed
2. Workpiece fed
3. Upper tool profile
4. Ejector
5. Manipulator’s displacement
Circuit Diagram
Setup of Cameras

Direction of transferring: Right to left
Processing sequence (Dimensions)

Billet

Forward Extrusion

Upsetting
Initial production
END

Questions ?