Electromagnetic embossing and forming of optical microstructures

I2FG
workshop on impulse metalworking
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Motivation

diamond tool
convex base geometry
toolpath
workpiece
cf. [Schö - LFM]

IDEA

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Diamond micro chiseling (DMC)

process kinematics

- Toolpath: [X Y Z]
- Workpiece: [-X Y -Z]
- Diamond tool

- 0°
- 120°
- 240°
- 3-sided cavity

SEM 50 μm
SEM 60 μm
SEM 500 μm

→ conventional process

reference: Schönemann - LFM
Technology

1\textsuperscript{st} step tool

2\textsuperscript{nd} step tool

coil

sheet

magnetic field

tool

1\textsuperscript{st} step

2\textsuperscript{nd} step
Experimental set up

- Inductor
- Sheet (Al99.5)
- Clearance tool

Energy $E_c$ 1.8 kJ
Current $I_{max}$ 70 kA
Frequency $f_0$ 22 kHz
Workpiece velocity 200 m/s
Impact pressure 500 MPa
Structural deformation behavior

![Graph showing the structural deformation behavior with two profiles: one for \( s_0 = 50 \mu m \) and another for \( s_0 = 300 \mu m \). The profiles are compared with the corresponding images showing the deformation at 100 \( \mu m \).]
Quality of embossed structure

![Profile graph](image)

- **Height $h$**
- **Profile $x$**

- **Tool**

- **Sheet ($s_0 = 300 \, \mu m$)**
Embossing efficiency

![Graph showing embossing efficiency vs. profile width. The graph highlights the forming width \( d_{w50} \) and the width of the inductor. There is an image of a micrograph showing a 300 µm scale.]
Lateral deformation behavior

\[
\begin{align*}
    s_0 &= 50 \mu m + \text{driver} \\
    s_0 &= 300 \mu m
\end{align*}
\]

kinetic energy e.g. air cushions and rebounding
Quality of embossed surface

probe initial surface
\( S_a = 1000 \text{ nm} \)

tool surface
\( S_a = 20 \text{ nm} \)

probe embossed surface
\( S_a = 44 \text{ nm} \)

\( s_0 = 0.3 \text{ mm} \)
\( d = 0.9 \text{ mm} \)
\( E_C = 1.8 \text{ kJ} \)
Sequenced forming

1st step
embossing
d = 0.9 mm; \( E_C = 1.8 \text{ kJ} \)

2nd step
free forming
d = 0 mm; \( E_C = 0.6 \text{ J} \)

microstructure can be inside or outside of the freeformed macrogeometry due to the application of the formed part
Cross structure – 1st step

\[ s_0 = 0.05 \text{ mm } + \text{ driver} \]
\[ d = 0.9 \text{ mm} \]
\[ E_C = 1.8 \text{ kJ} \]
Cross structure – 2nd step

microstructure deformation:
with 20 % strain in the makro geometry no influence on width

1st step probe

1st step

2nd step

Profile x

Height h
Conclusion

• replication of microstructures
• replication of surface quality with near optical finish
• embossing thin micro metal sheets
• free forming of structured sheets
• complex optical geometries realizable
• shorter manufacturing times
• lower invest (tools)
Future work

- embossing of more complex micro structures
- embossing of optical diffractive structures
- controlling macro geometry and shape by adapted micro structures
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