Improved Lightweight Manufacturing Flexibility by Stamping of Selectively Laser Heat Treated Boron Steel Sheet

Nader Asnafi\textsuperscript{1}, Roger Andersson\textsuperscript{2}, Martin Persson\textsuperscript{3} and Magnus Liljengren\textsuperscript{4}

\textsuperscript{1} Vice President & CTEO, VA Automotive, & Professor of Mechanical Engineering, Örebro University, Sweden (nader.asnafi@oru.se, +46 70 311 00 74)
\textsuperscript{2} CEO, Duroc Special Steel & Senior Research Manager, Swerea MEFOS, Sweden
\textsuperscript{3} CEO, Duroc Laser Coating, Sweden
\textsuperscript{4} CEO, Industrial Dev. Centre in Olofström & Researcher, Swerea IVF, Sweden
Techtank is a technology cluster in southern Sweden which gathers advanced industrial and technology companies.

Techtank has its headquarters in Olofström/Blekinge and has a sales office in Coventry (UK).
TECHTANK AUTOMOTIVE - a Stamping Center of Excellence

A COMMON BASED SUPPLIER NETWORK WITHIN THE TECHTANK GROUP

- We design, manufacture and deliver automotive body and interior parts, tooling, assemblies and systems. We can offer R&D, Pre-series Production, Prototypes and Manufacturing.

- Each company has its own unique specialty, however, together we can offer a large number of possibilities depending on our customers’ needs. Our customer base is typically automotive premium brands with volumes ranging from low to medium.

- We are able to deliver a combination of solutions as well as single components depending on our customers’ needs.

- We use the latest manufacturing processes & technologies and assist our current customers in many ways with such services as advanced machining/manufacturing strategies and tool development.
TECHTANK AUTOMOTIVE
EXAMPLES OF CUSTOMERS

- Aston Martin
- Audi
- Scania
- IAC
- Jaguar
- Mercedes-Benz
- Lear Corporation
- BMW
- Volkswagen
- Volvo
- Eberspächer
- ABB
MORE INFORMATION

WWW.TECHTANK.SE

ANDERS BORGEHEJD
TECHTANK CLUSTER DEVELOPMENT MANAGER
ANDERS.BORGEHEJD@TECHTANK.SE
+46 (0)454572742
TECHTANK
C/O OLOFSTRÖMS NÄRINGSLIV AB INNOVATION PARK, VÄLLAREGATAN 30
293 38 OLOFSTRÖM
SWEDEN

PAUL SULLIVAN
DIRECTOR NEW BUSINESS
TECHTANK UK REPRESENTATIVE
PAUL.SULLIVAN@S2GLOBAL.COM
+44 (0) 7711102150
CHEYLESMORE HOUSE
5 QUINTON RD
CHEYLESMORE
COVENTRY
CV1 2WT
WEST MIDLANDS
UNITED KINGDOM
Improved Lightweight Manufacturing Flexibility by Stamping of Selectively Laser Heat Treated Boron Steel Sheet

Nader Asnafi¹, Roger Andersson², Martin Persson³ and Magnus Liljengren⁴

¹ Vice President & CTEO, VA Automotive, & Professor of Mechanical Engineering, Örebro University, Sweden (nader.asnafi@oru.se, +46 70 311 00 74)
² CEO, Duroc Special Steel & Senior Research Manager, Swerea MEFOS, Sweden
³ CEO, Duroc Laser Coating, Sweden
⁴ CEO, Industrial Dev. Centre in Olofström & Researcher, Swerea IVF, Sweden
Objectives and Goals

- Greater manufacturing flexibility
- No process-bound equipment
- Lower costs
- In-house production or easily/temporarily outsourced production
- Reduced lead time
- Greater weight reduction
**Background**

**Selective laser** or induction **heat treatment to locally**
- improve the blank formability and/or trimability AND/OR
- reinforce the component to accomplish the required component strength/behaviour.

The size, position and shape of this heat treatment grid is decided during the initial analysis of the required blank and component properties.

Heat temperature examples:
- **Carbon** & stainless **steel sheet**: 925-1250 °C
- Sheet Aluminium/Automotive (5000- & 6000-series): 200-400 °C
- Sheet Magnesium: 100-350 °C
- Sheet Titanium: 925 °C
Background

Pilot study

CO₂ Laser Heat Treatment/Hardening

Fiber Laser Heat Treatment/Hardening
## Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>C (%) min-max</th>
<th>Si (%) min-max</th>
<th>Mn (%) min-max</th>
<th>P (%) max</th>
<th>S (%) max</th>
<th>Cr (%) min-max</th>
<th>B (%) min-max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boloc 02</td>
<td>0.20-0.25</td>
<td>0.20-0.35</td>
<td>1.00-1.30</td>
<td>0.030</td>
<td>0.010</td>
<td>0.140-0.260</td>
<td>0.0015-0.0050</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness (mm)</th>
<th>$R_e$ (MPa)</th>
<th>$R_m$ (MPa)</th>
<th>$A_{80}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boloc 02</td>
<td>1.0</td>
<td>ca 340</td>
<td>ca 480</td>
<td>28</td>
</tr>
</tbody>
</table>
Experimental Procedure

Selected Test Component - Flexrail

Flexrail Blank Shape and Size

Rolling direction 500

Sheet material = Boloc02
Sheet thickness = 1 mm
Experimental Procedure
The Flexrail Stamping Tool/Die Set
Experimental Procedure

The Laser Pattern

Sheet material = Boloc 02
Blank size = 350 mm x 500 mm
Sheet thickness = 1 mm
Experimental Procedure

The Laser Pattern
# Experimental Procedure

## Four (4) Flexrail Production & Testing Routes

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GridBlank</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Laser speed = 500 mm/min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GridTube</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Laser speed = 1500 mm/min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RapidLaser</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Laser speed = 5000 mm/min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Experimental Procedure

Stamping Parameter Setting: GridBlank Route – “Tryout” Flexrails

- Grid Blank 2, BP = 100 bar
- Grid Blank 3, BP = 90 bar
- Grid Blank 6, BP = 90 bar, Trimmed Blank
- Grid Blank 9, BP = 90 bar, Trimmed Blank, 1 mm Shimming
Experimental Procedure

Four (4) Flexrail Production & Testing Routes

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference</strong></td>
<td></td>
<td></td>
<td>BP = 90 bar, Trimmed Blank, 1 mm Shimming</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><strong>GridBlank</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Laser speed = 500 mm/min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><strong>GridTube</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Laser speed = 1500 mm/min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><strong>RapidLaser</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Laser speed = 5000 mm/min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results and Discussion
Flexrail stamped according to the Reference track
Results and Discussion

1 mm thick Boloc02 Grid Blank Laser Treated Boron steel sheet
Results and Discussion

The Grid Blank Placed in the Stamping Tool Prior to Forming
Results and Discussion

Stamping of 1 mm thick Laser Treated Grid Blank Boloc02 @ room temperature
Results and Discussion

Flexrail stamped according to the Grid Blank track
Results and Discussion

Flexrail stamped according to the Grid Tube track
Results and Discussion
Laser Robot Path Generation
Based on the Scanned Shape of Grid Tube Flexrail
Results and Discussion

Laser Processing Parameters for the Grid Tube Track
(Determined experimentally)

Results of the test run 12
- Sheet material = Boloc02
- Sheet thickness = 1 mm
- Spot size and shape ≈ 5 mm
- Laser speed = 25 mm/s
- Laser effect = 32%
- Temperature = 1500-1530°C
- The sheet graphitized before laser processing
- No cooling used at any time (except still air)
- Measured case hardness ≈ 550 HV
Results and Discussion

Grid Pattern Application to the Flexrail following the Grid Tube Track
Results and Discussion

Flexrail Produced According to the Grid Tube Track
Results and Discussion

1 mm thick Boloc02 Rapid Laser Treated Boron steel sheet
(A strain measurement grid is also applied to the blank)
Results and Discussion

Flexrail Produced According to the Rapid Laser Track
# Experimental Procedure

## Four (4) Flexrail Production & Testing Routes

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
</tr>
<tr>
<td>GridBlank</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>BP = 90 bar, Trimmed Blank, 1 mm Shimming</td>
<td>[Diagram]</td>
<td>Yes</td>
<td>[Diagram]</td>
</tr>
<tr>
<td>GridTube</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td></td>
<td>[Diagram]</td>
<td>Yes</td>
<td>[Diagram]</td>
</tr>
<tr>
<td>RapidLaser</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td></td>
<td>[Diagram]</td>
<td>Yes</td>
<td>[Diagram]</td>
</tr>
</tbody>
</table>

- **Laser speed = 500 mm/min**
- **Laser speed = 1500 mm/min**
- **Laser speed = 5000 mm/min**
Results and Discussion
Forming/Stamping Punch Force

100% = 100 kN
Results and Discussion
Geometrical Shape / Springback
Results and Discussion
Geometrical Shape / Springback
Results and Discussion
Geometrical Shape / Springback
Results and Discussion
Geometrical Shape / Springback
Results and Discussion
Geometrical Shape / Springback
Results and Discussion

Geometrical Shape / Springback
Results and Discussion
Geometrical Shape / Springback

<table>
<thead>
<tr>
<th>Section</th>
<th>Ref</th>
<th>GridBlank</th>
<th>GridTube</th>
<th>RapidLaser</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-A</td>
<td>Reference</td>
<td>7.19</td>
<td>5.69</td>
<td>5.29</td>
</tr>
<tr>
<td></td>
<td>GridBlank</td>
<td>7.19</td>
<td>5.69</td>
<td>5.29</td>
</tr>
<tr>
<td></td>
<td>GridTube</td>
<td></td>
<td>5.29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RapidLaser</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-B</td>
<td>Reference</td>
<td>4.74</td>
<td>3.25</td>
<td>5.76</td>
</tr>
<tr>
<td></td>
<td>GridBlank</td>
<td></td>
<td>3.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GridTube</td>
<td></td>
<td></td>
<td>5.76</td>
</tr>
<tr>
<td></td>
<td>RapidLaser</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-C</td>
<td>Reference</td>
<td>9.18</td>
<td>5.42</td>
<td>10.81</td>
</tr>
<tr>
<td></td>
<td>GridBlank</td>
<td></td>
<td>5.42</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GridTube</td>
<td></td>
<td></td>
<td>10.81</td>
</tr>
<tr>
<td></td>
<td>RapidLaser</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results and Discussion

Flexrail Hardness (HV)

50 mm
Transverse
Longitudinal

40
Results and Discussion

Flexrail Hardness (HV)
Results and Discussion

Flexrail Hardness (HV)
Results and Discussion

Flexrail Hardness (HV)
Results and Discussion
Flexrail Hardness (HV)
Summary and Conclusions

• **It is possible to tailor boron steel sheet component properties by selective laser heat treatment.** This selected laser heat treatment can be conducted on the
  - blanks prior to stamping at ambient (room) temperature or
  - component after stamping at ambient (room) temperature.

• **The GridBlank production route**, in which 1 mm thick blanks of Boloc 02 was
  - selectively laser heat treated,
  - allowed to cool down (still air cooling),
  - transported to the stamping plant where it was stamped at ambient (room) temperature,
  
  yields the best component (flexrail) shape accuracy and the best hardness (700 HV) but required 41% higher maximum press force than the none laser heat treated Boloc 02.

• The selective laser heat treatment of the sheet material (the blank) before stamping yields **the most efficient and flexible route for large volume production**. The laser heat treatment can be conducted at the material supplier or at a supplier between the material supplier and the stamping plant or at the stamping plant. The existing press/stamping lines can be used as usual.

The investigation continues…
THANK YOU
FOR YOUR ATTENTION