Application of high strength steel in design and processing utilisation for construction machines and agricultural machines

V. Braun, S. Vanrostenberghe, J. De Moor

Werkstoff-Forum Hannover Messe 2013
Contents

• Lightweight design
• Design recommendations
• Steel grades
• Examples
  – Concept study tipper
  – Drawbar
  – Transverse stiffener
• Summary
Lightweight design

- Conventional vehicle: high mass, low payload
- Lightweight vehicle: reduced mass, increased payload
Lightweight design

• Goals
  – Increase of maximum payload
  – Increase of amount of transported goods
  – Reduction of loading cycles
  – Reduction of costs for unloaded vehicle
  – Reduction of fuel consumption
  – Reduction of CO₂ emissions

• Shape lightweight design
• Sandwich lightweight design
• Conceptional lightweight design
• Modular lightweight design
• Material lightweight design
• …
Lightweight design

- Material lightweight design: exchange of (specific heavier) material with (lighter) high-strength materials
- Reduction of wall thickness of constructions by utilisation of materials with higher strength
- Reduction of weight of construction
- Modification of construction to lighter materials
Design recommendations tension/compression

\[ t_{\text{new}} = t_{\text{old}} \times \frac{YS_{\text{old}}}{YS_{\text{new}}} \]

**Calculation**

<table>
<thead>
<tr>
<th></th>
<th>old</th>
<th>new</th>
</tr>
</thead>
<tbody>
<tr>
<td>yield strength (MPa)</td>
<td>355</td>
<td>700</td>
</tr>
<tr>
<td>thickness (mm)</td>
<td>4</td>
<td>2,02</td>
</tr>
</tbody>
</table>
Design recommendations tension/compression

\[ t_{\text{new}} = t_{\text{old}} \times \frac{Y_{S,\text{old}}}{Y_{S,\text{new}}} \]

S235JR → S600MC
61% weight reduction

S235JR → S355JR
34% weight reduction
## Design recommendations bending

The equation for calculating the new thickness based on the old thickness and yield strength is given by:

\[
t_{\text{new}} = t_{\text{old}} \sqrt{\frac{\text{YS}_{\text{old}}}{\text{YS}_{\text{new}}}}
\]

### Table: Yield Strength and Weight Reduction

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Old Yield Strength (MPa)</th>
<th>Old Thickness (mm)</th>
<th>New Thickness (mm)</th>
<th>Weight Reduction in %</th>
<th>Increase in Yield Strength in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>yield strength (MPa)</td>
<td>350</td>
<td>(w)</td>
<td>4</td>
<td>3,19</td>
<td>2</td>
</tr>
<tr>
<td>thickness (mm)</td>
<td>old</td>
<td>550</td>
<td>new</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Diagram

The graph shows the relationship between weight reduction in % and increase in yield strength in %. The points marked 1 and 2 indicate specific data points for comparison.
Steel grades

- Drawing grades
- Gas tanks grades
- Grades for pressure vessels
- HSLA (High Strength Low Alloy)
- Structural grades
- High carbon grades
- Formable structural grades
- Grades for laser cutting
- Grades for pressure vessels after quenching
- Boron steel grades

Strength in MPa vs. elongation in %

- 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
- 0 5 10 15 20 25 30 35 40 45 50

9. April 2013 Werkstoff-Forum Hannover Messe 2013
Steel grades

- Structural steel grades according DIN EN 10025
- Carbon-manganese-steel
- Ferritic-pearlitic structure
- Alloying with manganese, silicon, molybdenum, carbon
- Guaranteed minimum strength levels (yield strength, tensile strength)
- Weldable with all conventional welding processes
- Examples: S235, S275, S355, S450
  - Nomination according to as-delivered condition, for example S355J2
Steel grades

- Micro-alloyed grades according to DIN EN 10149
  - Fine-grained structural steel based on precipitation hardening
  - Alloying elements: titanium, niobium, vanadium
  - Guaranteed strength levels (yield strength, tensile strength)
  - Weldable with all conventional welding processes
  - Low carbon content
  - Examples: S355, S420, S500, S550, S600, S700
    - nomination according to as-delivered condition, for example S700MC
Steel grades

- Amstrong® HSS and UHSS
  - Thermomechanically hot rolled, cold formable grades
  - High yield strength and tensile strength, combined with excellent formability
  - Toughness at low temperatures
  - Fatigue resistance
  - Low carbon equivalent value easy to weld, no preheating

Trailer part out of Amstrong® 700MC 12 mm, laser cut and bent
**Abrasion resistant steel**

- **Amstrong®Wear400**
  - High hardness (HBW 360-420)
  - Resistant to dents and impact damage (YS: 1000 MPa, TS: 1250 MPa, elongation: 8%)
  - Significantly longer service life compared to HSLA grades
  - Good bendability and weldability
  - Guarantees on hardness and specific chemistry
Concept study tipper

- Existing concept:
  - 92% S235JR 4 mm – 12 mm
  - 8% S355JR 4 mm – 12 mm

- Weight tipper 3000 kg
- 23.2 t payload
Concept study tipper

- Application of high strength steel
- Existing or improved functionality
- Lightweight design
  - 20% weight reduction
  - 5% cost reduction
- Number of members
- Joining operations
- Applied materials
- Compatibility to existing products
Concept study tipper

- co-operation with ISD
  (*International School of Design, Valenciennes, France*)

<table>
<thead>
<tr>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Concept 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Concept 1" /></td>
<td><img src="image2.png" alt="Concept 2" /></td>
<td><img src="image3.png" alt="Concept 3" /></td>
</tr>
</tbody>
</table>
Concept study tipper

- Simulation of critical operations (unloading)
**Concept study tipper**

**existing concept**

- Steel grades:
  - S235 (92%)
  - S355 (8%)
- Thickness: 4 mm – 12 mm
- Weight of skip: 3000 kg

**lightweight concept**

- Steel grades:
  - S235 (3%)
  - S355 (4%)
  - Amstrong® S420MC (72%)
  - Amstrong® S500MC (7%)
  - Amstrong® S700MC (14%)
- Thickness: 4 mm – 12 mm
- Weight of skip: 2400 kg
Concept study tipper

- 22% less weight for skip
- 8% less costs due to improved material utilisation
- Additional costs advantages due to modified processing
  - For example 80 m less welds
  - Less bending or cutting operations
Drawbar

- Existing concept: S235 (6 mm and 15 mm thickness)
- Lightweight concept:
  - Amstrong® 500MC (5 mm and 10 mm thickness)
  - Amstrong® 700MC (4 mm and 9 mm thickness)
- 30% weight reduction with Amstrong® 500MC
- 45% weight reduction with Amstrong® 700MC
Transverse stiffener

- Lightweight concept:
  - Amstrong® 700MC (material input: 12 mm x 2000 mm)
  - 39% weight reduction with Amstrong® 700MC, laser cutting and bending operations

weight 70kg

27cm

85cm

22cm
Summary

• High strength steel offers high potential for weight reduction for construction machines and agricultural machines
  – Increase of maximum payloads
  – Reduction of operating costs
• Additional cost savings with modified processing
• Abrasion resistant steel are available
• Steel grades could be processed and welded with conventional processes
• Steel grades are available in numerous dimensions and thickness
Thank you for your attention!