THE INFLUENCE OF THE DISK MANUFACTURING PROCESS ON THE FATIGUE LIFE OF COMMERCIAL VEHICLE WHEELS MANUFACTURED BY S355JR STEEL

Nicholas Spagnol
IOCHPE MAXION S/A – Maxion Wheels
Overview

• Commercial Vehicle Wheels
• Spinning Process for Steel Wheels
• Product Approval / Test Machines
• A Definition of S355JR – Low Carbon Steel
• Goals
• Test Methods
• Results
• Conclusion / Next Step
Commercial Vehicle Wheels

- **Wheel Components**

  ![Diagram of rim, disk, and wheel components](image)

- **Spinning Process for Steel Wheels**

  ![Diagram of spinning process](image)

Wheel Dimensions (inch)
17.5 x 6.0 up to 24.5 x 8.25
Product approval

- Rolling and Cornering Test in accordance with EUWA 3.11 and/or SAE J267

### Rolling

<table>
<thead>
<tr>
<th>Material</th>
<th>Vertical Force</th>
<th>Test Factor</th>
<th>Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous</td>
<td>100%</td>
<td>2.2</td>
<td>500.000</td>
</tr>
</tbody>
</table>

### Cornering

<table>
<thead>
<tr>
<th>Material</th>
<th>Bending Moment</th>
<th>Test Factor</th>
<th>Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous</td>
<td>75%</td>
<td>2.2</td>
<td>250.000</td>
</tr>
<tr>
<td>Ferrous</td>
<td>50%</td>
<td>2.2</td>
<td>2,000,000</td>
</tr>
</tbody>
</table>

Disc Wheels

Disc Wheels - Drop centre rims
Product approval

- Fraunhofer Biaxial Test Machine in accordance with EUWA 3.23
  - The most robust wheel test
    - $F_v_{\text{max}} = 250\text{kN}$
    - $F_h_{\text{max}} = 90\text{kN}$
S355JR – Low Carbon Steel

- Low Carbon Steel – DIN EN 10025-2
- Good Conformability
- Good Weldability
- Mechanical Properties / Chemical composition

<table>
<thead>
<tr>
<th>Standard / grade</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
<th>Al</th>
<th>Alloying element</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN10025 / S355JR</td>
<td>0.24max</td>
<td>1.6max</td>
<td>0.55max</td>
<td>0.035max</td>
<td>0.035max</td>
<td>0.020 / 0.080</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard / grade</th>
<th>Yield strength (MPa)</th>
<th>Tensile strength (MPa)</th>
<th>Elongation (%)</th>
<th>Bending (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN10025 / S355JR</td>
<td>355min</td>
<td>470/630</td>
<td>20 min</td>
<td>Zero</td>
</tr>
</tbody>
</table>

- A common steel

S355JR
Goals

• What is the aim of this study?
• “One way to reduce fuel consumption and CO\textsubscript{2} emission is by reducing the vehicle’s weight”.
Test Methods

• Tensile test
• 12 tests – 3 tests per sample condition
• 4 sample conditions – Raw material / 41%, 52% and 64% thickness reduction

Disk

Tensile samples

Tensile specimen
Test Methods

- Fatigue test
- 12 tests – 3 tests per sample condition
- 4 sample conditions - Raw material / 41%, 52% and 64% thickness reduction
- Load control / R = -1
- Run out – $2 \times 10^6$ cycles

Disk

Fatigue samples

Fatigue specimen
Results

- Surface Optical Microscopy
- Aspect ratio

<table>
<thead>
<tr>
<th>Raw material</th>
<th>41% thickness reduction</th>
<th>52% thickness reduction</th>
<th>64% thickness reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>RM - 1.8</td>
<td>41% - 3.8</td>
<td>52% - 7.1</td>
<td>64% - 10.0</td>
</tr>
</tbody>
</table>

Images showing surface optical microscopy at different thickness reductions.
Results

- Scanning Electron Microscopy
- Fracture Surface of Tensile test samples

✓ Raw material and 41% of Thickness Reduction - Ductile fracture behavior

✓ 52% and 64% of Thickness Reduction - Brittle fracture behavior appears
Results

• Stress v Strain Curves

Stress v Strain Curve - Raw Material

Stress v Strain Curve
41% Thickness Reduction

Stress v Strain Curve
52% Thickness Reduction

Stress v Strain Curve
64% Thickness Reduction
Results

• Fatigue Curves

SN Curve - Raw Material

SN Curve - 41% Thickness Reduction (#8mm)

SN Curve - 52% Thickness Reduction (#6.5mm)

SN Curve - 64% Thickness Reduction (#5mm)
Results

- Fatigue test – Median curve
- Fatigue test – R95C90 curve
- Yield strength – **had increased 37%**
- Tensile strength – **had increased 32%**
- Fatigue life – **had increased 14%**

<table>
<thead>
<tr>
<th>Mechanical Properties</th>
<th>Yield Strength (MPa) / [ksi]</th>
<th>Tensile Strength (MPa) / [ksi]</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Material</td>
<td>389.6 [56.51]</td>
<td>486.4 [70.49]</td>
<td>32.8</td>
</tr>
<tr>
<td>41% Thickness Reduction</td>
<td>665.6 [96.45]</td>
<td>694.2 [100.66]</td>
<td>16.7</td>
</tr>
<tr>
<td>52% Thickness Reduction</td>
<td>666.1 [96.60]</td>
<td>709.7 [102.83]</td>
<td>14.1</td>
</tr>
<tr>
<td>64% Thickness Reduction</td>
<td>618.1 [89.63]</td>
<td>721.0 [104.57]</td>
<td>14.5</td>
</tr>
</tbody>
</table>
✅ Yield strength and tensile strength increased
✅ Wheel weight reduction – up to 2Kg (5%)
✅ Low cost material

Material behavior

22.5 x 8.25 inch Wheel
Benchmarking - 38kg
Load Capacity – 3550Kg
- Weight Reduction ~5%
Next steps

- Discovering the S355JR limit of thickness reduction
- Spinning 70% of thickness reduction (#4.0mm)
- Spinning 78% of thickness reduction (#3.0mm)
- Wheel rolling and cornering test
- Biaxial test – the most robust wheel test
Thank you

Questions
PRESENTATIONS WILL BE AVAILABLE MAY 16

Use your web-enabled device to download the presentations from today’s event

Great Designs in Steel is Sponsored by: