Fatigue Behavior of Advanced High Strength Steels for Automotive Applications

Benda Yan
Ispat Inland Inc.
February 19, 2003
Purpose of the Work

- Generate fatigue data for new advanced high strength steels
- Study the effect of notch on fatigue strength
Steel Grades Tested

- 440W - GA - 1.40mm
- BH300 - GI - 1.43mm
- HSLA350 - GI - 1.60mm
- HSS590 - CR, bare - 1.40mm
- DP600 - GI - 1.25mm
- DP600 - HR - 2.62mm
- DP800 - GA - 1.19mm
Steel Grades Tested

- TRIP590 - EG - 1.45mm
- TRIP600 - CR, bare - 1.56mm
- TRIP780 - CR, bare - 1.56mm
- TRIP980 - CR, bare - 1.47mm
Table 1 Tensile Properties (As received, ASTM E8, "L" direction)

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th></th>
<th>Group 2</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BH300 GI</td>
<td>440W GA</td>
<td>HSLA350 GI</td>
<td>HSS590 CR</td>
<td>DP600 GI</td>
<td>DP600 HR</td>
<td>TRIP590 EG</td>
</tr>
<tr>
<td>YS (Mpa)</td>
<td>309</td>
<td>326</td>
<td>356</td>
<td>431</td>
<td>412</td>
<td>437</td>
<td>428</td>
</tr>
<tr>
<td>UTS (Mpa)</td>
<td>412</td>
<td>462</td>
<td>441</td>
<td>608</td>
<td>666</td>
<td>616</td>
<td>605</td>
</tr>
<tr>
<td>TE (%)</td>
<td>35.8</td>
<td>29.0</td>
<td>28.1</td>
<td>24.5</td>
<td>23.2</td>
<td>28.9</td>
<td>32.0</td>
</tr>
<tr>
<td>UE (%)</td>
<td>20.4</td>
<td>16.3</td>
<td>15.8</td>
<td>15.1</td>
<td>15.3</td>
<td>19.6</td>
<td>22.6</td>
</tr>
<tr>
<td>n (6-12)</td>
<td>0.19</td>
<td>0.18</td>
<td>0.13</td>
<td>0.17</td>
<td>0.16</td>
<td>0.22</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Steels and Tensile Properties
Table 1 Tensile Properties (As received, ASTM E8, "L" direction)

<table>
<thead>
<tr>
<th></th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DP800 GA</td>
<td>TRIP780 CR</td>
</tr>
<tr>
<td>YS (Mpa)</td>
<td>462</td>
<td>505</td>
</tr>
<tr>
<td>UTS (Mpa)</td>
<td>839</td>
<td>793</td>
</tr>
<tr>
<td>TE (%)</td>
<td>17.9</td>
<td>29.4</td>
</tr>
<tr>
<td>UE (%)</td>
<td>12.3</td>
<td>23.9</td>
</tr>
<tr>
<td>n (6-12)</td>
<td>0.13</td>
<td>0.26</td>
</tr>
</tbody>
</table>
Testing Methods

Strain Controlled Fatigue

Notched Fatigue

ASTM E606
Tension-Compression

ASTM E466
Tension-Compression

$K_t = 2.5$
Strain Controlled Fatigue Results

Number of Reversals to Failure, 2Nf vs. Neuber Stress, MPa

- BH300-GI
- 440W-GA
- HSLA350-GI
- HSS590-CR
- DP600-GI
- DP800-GA
- DP600-HR
Strain Controlled Fatigue Results

Steels in Group 2

Number of Reversals to Failure, 2Nf

Neuber Stress, Mpa

HSS590-CR
DP600-GI
DP600-HR
TRIP590-EG
TRIP600-CR

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 100000 1000000 10000000

0 100 200 300 400 500 600 700 800 900

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

www.autosteel.org
Strain Controlled Fatigue Results

Steels in Group 3

![Graph showing Strain Controlled Fatigue Results for DP800-GA and TRIP780-CR steels. The graph plots Neuber Stress (Mpa) against Number of Reversals to Failure, 2Nf. DP800-GA is represented by a solid line, while TRIP780-CR is represented by a dashed line.](www.autosteel.org)
Strain Controlled Fatigue Results

TRIP Steels

Number of Reversals to Failure, $2N_f$

Neuber Stress, Mpa

TRIP590-CR
TRIP600-CR
TRIP780-CR
TRIP980-CR
TRIP590-EG

www.autosteel.org
Strain Controlled Fatigue Results

HSLA350 vs. AHSS

Number of Reversals to Failure, 2Nf

Neuber Stress, Mpa

HSLA350-GI

TRIP590-EG

TRIP600-CR

HSS590-CR

DP600-GI

DP600-HR

HSLA350-GI
Notched Fatigue Results

Nominal Stress Amplitude, MPa

Number of Reversals to Failure

BH300-GI
440W-GA
HSLA350-GI
HSS590-CR
DP600-GI
DP800-GA
DP600-HR
Notched Fatigue Results

Steels in Group 2

Number of Reversals to Failure

Nominal Stress Amplitude, MPa

HSS590
DP600
DP600-HR
TRIP590
TRIP600

www.autosteel.org
Strain Controlled Fatigue Results

Steels in Group 3

Graph showing the relationship between nominal stress amplitude (MPa) and number of reversals to failure for TRIP780-CR and DP800-GA steels.
Notched Fatigue Results

AHSS vs. HSLA350

Graph showing the relationship between the number of reversals to failure and the nominal stress amplitude for various steels, including HSLA350, HSS600, DP600, and TRIP600, both in calculated (cal) and experimental (exp) results.
## Fatigue Properties in Summary

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>UTS (MPa)</th>
<th>Endurance Limit (MPa)</th>
<th>Notch Endur. Limit (MPa)</th>
<th>$K_f = \frac{EL}{NNL}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH300 GI</td>
<td>412</td>
<td>193</td>
<td>120</td>
<td>1.61</td>
</tr>
<tr>
<td>440W GA</td>
<td>462</td>
<td>209</td>
<td>130</td>
<td>1.61</td>
</tr>
<tr>
<td>HSLA350 GI</td>
<td>441</td>
<td>203</td>
<td>125</td>
<td>1.62</td>
</tr>
<tr>
<td>HSS590 CR</td>
<td>608</td>
<td>230</td>
<td>144</td>
<td>1.60</td>
</tr>
<tr>
<td>DP600 GI</td>
<td>666</td>
<td>228</td>
<td>142</td>
<td>1.61</td>
</tr>
<tr>
<td>DP600 HR</td>
<td>616</td>
<td>296</td>
<td>154</td>
<td>1.92</td>
</tr>
<tr>
<td>TRIP590 EG</td>
<td>605</td>
<td>336</td>
<td>178</td>
<td>1.89</td>
</tr>
<tr>
<td>TRIP600 CR</td>
<td>679</td>
<td>365</td>
<td>173</td>
<td>2.11</td>
</tr>
</tbody>
</table>
## Fatigue Properties in Summary

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>UTS (MPa)</th>
<th>Endurance Limit (MPa)</th>
<th>Notch Endur. Limit (MPa)</th>
<th>Kf = EL/NEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 DP800 GA</td>
<td>839</td>
<td>307</td>
<td>147</td>
<td>2.09</td>
</tr>
<tr>
<td>10 TRIP780 CR</td>
<td>793</td>
<td>400</td>
<td>189</td>
<td>2.11</td>
</tr>
<tr>
<td>11 TRIP980 CR</td>
<td>984</td>
<td>427</td>
<td>190</td>
<td>2.25</td>
</tr>
</tbody>
</table>
AHSS exhibited much higher fatigue strength over conventional HSS.
TRIP steel exhibited exceptionally good fatigue strength than steels of similar UTS but different microstructure.
Comparing with HSLA350, DP600 exhibits 30% higher and TRIP600 70% higher endurance limit.
With the presence of notches, AHSS still show higher notch endurance limit than HSLA350.
• The project was funded and completed under the AISI/DOE Technical Road Map Program #0038
• Work was performed and results were analyzed by Ispat Inland Research Laboratories
• Support from AISI AAC member companies is greatly appreciated.