Three generations of advanced high-strength steels for automotive applications, Part III

The third generation

BY EREN BILLUR AND TAYLAN ALTAN

Editor's Note: This article is Part III of a three-part series summarizing the three generations of advanced high-strength steels (AHSS) used in automotive applications. Part I, which appeared in the November/December 2013 issue, discussed first-generation AHSS. Part II, which appeared in the January/February 2014 issue, discussed second-generation AHSS.

First-generation AHSS have very limited formability; second-generation AHSS have high strength and are more formable, but they are relatively expensive because of their high-cost alloying elements. As a result, demand has grown for a new generation of steel that has high formability and high strength, but is available at a reasonable cost.

Several third-generation AHSS have been developed in the last few years, but only two classes currently are in production: quenching and partitioning (Q&P) steels and transformation-induced plasticity (TRIP)-aided bainitic ferrite (TBF) steels (see Figure 1).

Q&P Steels

The Q&P steel grade comprises carbon, manganese, silicon, nickel, and molybdenum alloying elements. Depending on the strength level, alloying elements can be as high as 4 percent, which is much lower than that of second-generation AHSS. During heat treating of Q&P steel, quenching is interrupted, and the steel is reheated for partitioning. This creates 5 to 12 percent stable retained austenite, 20 to 40 percent ferrite, and 50 to 80 percent martensite.

Baosteel was the first company to commercialize Q&P steels, initially with 980 MPa (140 KSI) and later 1,180 MPa (175 KSI). The firm has demonstrated that a B-pillar reinforcement can be cold-formed using Q&P 1180. Auto/Steel Partnership (A/SP) also has tested Q&P 980 using GM's B-pillar die, proving that the steel is more formable and less prone to edge cracking than DP 980. Several automakers in China have adopted Q&P steels in A- and B-pillar reinforcements.

Researchers have developed steels up to 2,100-MPa (305-KSI) tensile strength with 9 percent uni-

Figure 1

This "banana curve" compares the three generations of AHSS.

Figure 2

Several third-generation AHSS are compared here with first-generation AHSS at 980-MPa (140-KSI) and 1,180-MPa (175-KSI) strength levels.
form elongation and about 13 percent total elongation. The elongation level of this steel is comparable to DP 980, which is a cold-formable grade (see Figure 2).

TBF Steels
TBF, a low-alloy grade like Q&P, can be produced by existing heat-treatment facilities. Stable retained austenite is its key component.

Kobe Steel has developed TBF steels from 900 MPa (130 KSI) to 1,470 MPa (215 KSI). Nissan has developed cold-forming techniques to overcome springback and excessive necking, as well as spot welding techniques to help ensure the strength is not reduced around weld nuggets for TBF 1180 grade (175 KSI).

TBF 1180 has been used in A- and B-pillars and rocker reinforcements for the 2014 Nissan Infiniti® Q50 (see Figure 3). TBF currently is about 4 percent of the body-in-white. Nissan is planning to increase the use of cold-formed, ultrahigh-strength steels up to 25 percent by 2017.

NanoSteel
A third class of third-generation AHSS, NanoSteel®, is still under development and not yet commercially available. NanoSteel Co. was established in 2002 after six years of research at Idaho National Laboratory. In 2012 the company started production trials of this AHSS sheet, which has a nanocrystalline structure created by special chemistry and heat treatment. After casting, the steel is mainly austenitic with some borides. After heat treatment, austenite is refined to nanometer scale. During plastic deformation, stress-induced nanoscale phase formation increases strain hardening.

German company Engineering Design AG (EDAG) recently published a design study in which the steel used in a 2011 Honda Accord® was replaced with NanoSteel products. The results were compared to an earlier study funded by the National Highway Traffic Safety Administration (NHTSA) that used conventional AHSS. The results are summarized in Figure 4.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Mass</th>
<th>Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011 Honda Accord</td>
<td>328 kg (723 lbs.)</td>
<td>—</td>
</tr>
<tr>
<td>NHTSA LWV</td>
<td>255 kg (562 lbs.)</td>
<td>22</td>
</tr>
<tr>
<td>NanoSteel BIW</td>
<td>228 kg (503 lbs.)</td>
<td>30</td>
</tr>
</tbody>
</table>

EDAG compared a NanoSteel body-in-white with a Honda Accord benchmark and NHTSA’s Lightweight Vehicle, made of conventional AHSS.

Resources


