Advanced High-Strength Steels - A Collision Repair Perspective

The use of advanced high-strength steels (AHSS) is increasing in popularity for almost every vehicle maker. They are the result of a never-ending quest for a material that allows increased fuel efficiency while allowing for ease of manufacturability, performance, and styling. AHSS panels are thinner, lighter, and stronger than mild and many high-strength steel panels and accomplish the same desired effect for collision energy management. However, the addition of AHSS used in vehicle construction has raised some concerns about the identity and characteristics of these steels, where they are commonly located, and to what extent they can be repaired.

Tensile and Yield Strength

Throughout this article, and wherever steel strengths are defined or mentioned, yield strength and tensile strength are used as the common measurement. Tensile strength (or ultimate tensile strength) is defined as the measurement of the amount of force necessary to tear a piece of steel apart. Yield strength is the amount of stress a material can withstand without permanent deformation. Before the yield point, the steel will deform elastically and return to its original shape when the stress is removed. However, once the yield point is passed, the steel plastically deforms and the damage becomes permanent.

The amount of strength is typically measured in megapascals (MPa) or thousand pounds per square inch (ksi). A pascal is a unit of measurement equivalent to one Newton per square meter. A megapascal is one million pascals.

Boron-Alloyed Steel

Of all the advanced high-strength steels, Ultra-High-Strength Steel (UHSS) alloyed with boron is the material that has received much notoriety over the past several years. Vehicle makers, such as Volvo, have made this boron-alloyed material an integral part of their vehicle design. Volvo models such as the S40 and V50 have the inner bumper rails and door intrusion beams made from steel alloyed with boron and the XC90 uses the material for B-pillar inner reinforcements (see Figure 1), the centre roof bow, and inner rear body panels.

Since earlier articles on working with that steel, the steel and automotive industries have increased the use of a number of other AHSS steels, only a fraction of which have specific repair recommendations.

Dual-Phase (DP) Steel

Dual-phase(DP) steels are gaining in popularity with the vehicle makers. Characteristics of DP steels include a higher tensile strength than conventional steels of similar yield strength. DP steels also have a higher initial work-hardening rate, and lower yield strength/tensile strength than the similar strength High Strength Low Alloy (HSLA) steels.

One application example of DP steel is the 2006 Jeep Grand Cherokee and Commander. According to DaimlerChrysler service information, DP600 steel is used to increase crash performance (600 represents the approximate MPa of the steel). The yield strength of this material on the Jeep Grand Cherokee is 621–689 MPa (90–100 ksi). Examples of Jeep Grand Cherokee and Commander parts with this material type include the frame rails and A-pillars.

When working with DP steel, the repair issues may not be the same as when working on other types of AHSS. For example,

FIGURE 1

The inner B-pillar made from UHSS alloyed with boron is being cut with a cutoff wheel

FIGURE 2

The Land Rover Range Rover Sport has specific recommendations for working on dual-phase steel

Land Rover's recommendation for replacing UHSS parts requires removing spot welds on the part that is adjacent to the UHSS part, which is typically high-strength or DP (see Figure 2). This is because, according to Land Rover, DP and normal high-strength steel pose no great issues.

GM recommends to avoid heating any part made from DP steel, as the strength was substantially degraded by heating to 650°C (1,200°F).

Other Types of AHSS

The best method to determine a steel type on a vehicle is to look at the vehicle-specific body repair information. When doing so, be prepared to encounter a variety of acronyms that test the limit of the alphabet. DP, IF, TRIP, MART, CS, DDS, HSLA, BOR – each of these represents a different type of steel with varying strengths. What's important to note is that when identifying different types of AHSS, not all have the exact same strength and characteristics for the designation listed. For example, the characteristics of DP steel may vary since DP steel can have a tensile strength between 450 and 1000 MPa (65 and 145 ksi). The strength chosen for a specific part will vary from vehicle maker to vehicle maker or vehicle to vehicle.

Each grade of steel is chosen by the vehicle maker based on specific characteristics, such as formability and strength. Below is a list of common steel types. Notice that some of the steels overlap in strength.

Standard Steels

Commercial steel (CS)
Drawing steel (DS)
Deep drawing steel (DDS)
Interstitial-free (IF)
Mild

High-Strength Steels

Bake hardenable (BH)
Isotropic (IS)
Carbon-Manganese (CMn)
High-strength low alloy (HSLA)
Dual Phase (DP) - Complex phase (CP)
Transformation induced plasticity (TRIP)
Martensitic (MART)

Ultra High-Strength Steels

Dual Phase (DP) - Complex phase (CP)
Transformation induced plasticity (TRIP)
Martensitic (MART)
UHSS alloyed with boron (BOR)

Because of the wide range of strength for one particular type of steel, such as HSLA, which can range from 300–700 MPa (44–102 ksi), the steel strength cannot be determined by name alone. This is important to keep in mind when making a determination about repair. If a part is listed as being made from TRIP steel, don't assume that it is a high-strength steel. Each steel type has a range of strength and many steel types overlap with regards to hardness. For example, TRIP, DP, and HSLA could all have the same tensile strength depending on how they were manufactured.

High-strength steels are generally defined as having tensile strengths between 270–700 MPa (39–102 ksi). Ultra-high-strength steels (UHSS) are defined as steels with tensile strengths greater than 700 MPa (102 ksi). Advanced high-strength steels may start at 400 MPa (58 ksi).

Steel Strength Formation and Comparison

Steel hardness is dependent on the alloying elements used during the manufacturing process. Carbon is the primary hardening element in steels, and is used in varying percentages depending on the desired strength. However, many AHSS steels derive their strength from a combination of ferrite (more commonly known as iron), bainite, martensite, and retained austenite. Bainite, martensite, and austenite are metallic materials that exist in steel after it has been heated to a specific point. The percentage of these left in steel is determined by the rate of cooling and determines the steel strength.

The chart in Figure 3 on the next page graphs strengths of different steels (tensile strength) to ease of being formed (malleability or elongation). It can be seen that lower-strength steels are much more malleable than martensitic steels. Note that the steel alloyed with boron is in the far right section of the blue martensitic category.

The chart also shows that some steel types overlap, depending on added properties. For example, some AHSS, such as some TRIP and DP steels, are stronger and less malleable than some martensitic steels.

Identifying AHSS Locations

Currently, no field tests exist to determine the composition of a piece of steel. The only way to determine the strength of steel is to review the vehicle service information. However, even this information may be difficult to find depending on how in-depth the service information is.

Steel Grade	Yield Strength	Ultimate Tensile Strength
BH 180/300	180 MPa (26 ksi)	300 MPa (44 ksi)
HSLA 350/450	350 MPa (51 ksi)	450 MPa (65 ksi)
DP 300/500	300 MPa (44 ksi)	500 MPa (73 ksi)
TRIP 350/600	350 MPa (51 ksi)	600 MPa (87 ksi)
CP	700 MPa (102 ksi)	800 MPa (116 ksi)
MART	1250 MPa (181 ksi)	1700 MPa (247 ksi)
BOR	1350 MPa (196 ksi)	

Common areas where AHSS may exist include rocker panels, B-pillars, A-pillars, and roof rails. Most of this is used to increase the level of side-impact protection. Increasing the strength on the side stiffens the vehicle structure and reduces intrusion into the passenger compartment.

Repairability

With all these new steels, questions are constantly being brought up regarding how it can be repaired (straightened, heated, welded). According to the International Iron and Steel Institute (IISI), test results indicate that GMA (MIG) welding is acceptable as a repair method for AHSS such as DP, MART, and TRIP. Mechanical properties are within the expected range for each material in close proximity to the repair weld. Of course, any recommendations from the vehicle maker that are contrary to this recommendation should be followed.

Recommendations for heating AHSS are very specific. According to the IISI and the vehicle makers, heating should not be used to straighten AHSS. The temperature required to straighten damaged steel causes degradation to the mechanical properties of the work-hardened part.

Also, because the metals are thinner, they are more prone to fatigue and transfer more stress. The thin metal makes the shape of a weld a critical factor and any weld defects may result in increased fatigue and decreased strength when compared to HSS or mild steel. Welding could be an area where the industry will see possible differences in vehicle maker recommendations.

One vehicle maker recommends welding on AHSS such as UHSS alloyed with boron using squeeze-type resistance spot welds and GMA (MIG) welds. Another vehicle maker is considering using MIG brazing and adhesives to join parts made from UHSS alloyed with boron. Until a uniform procedure is developed, it is critical to follow each vehicle maker's recommendation when working on AHSS.

Conclusion

What is important to note is that when working on late model vehicles, the old rules may no longer apply. A part such as a front rail may be made from several different types of steel, attached together by a variety of joining methods.

The collision industry is currently in the infancy stage when it comes to repairing advanced high-strength steels. There is still a large amount of research that needs to be conducted to determine the limits of repairability. The steel and vehicle makers are working diligently to determine proper repair techniques such as welding, drilling, and cutting. Currently, the only universal recommendation for repairing AHSS is that heating for straightening purposes is not recommended due to the adverse affect on the strength of the steel.

I-CAR

These articles first appeared in the I-CAR Advantage Online, which is published and distributed free of charge. I-CAR, the Inter-Industry Conference on Auto Collision Repair, is a not-for-profit international training organization that researches and develops quality technical education programs related to automotive repair. To learn more about I-CAR, and to subscribe to the free publication, visit http://www.i-car.com

For information on I-CAR training courses conducted throughout New Zealand, contact I-CAR NEW ZEALAND Phone 07 847 02168

FIGURE 3