Forming AHSS—Several Heads are Better than One

Tool-and-die shops collaborate to help automotive OEMs and their suppliers form advanced high-strength steels.

by Jay Baron and Jody Shaw

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In the quest for safer and lighter cars, automotive and steel companies are rapidly introducing new advanced high-strength steels (AHSS) for body structures. AHSS alloys include high tensile strengths--500 MPa or greater--with good formability, and include grades like dual phase (DP), complex phase (CP), transformation-induced plasticity (TRIP) and some martensitic steels. The high strengths of these materials allow for mass-efficient designs for improved fuel economy, while simultaneously increasing crashworthiness. Unlike many competitive materials, AHSS can accomplish these objectives without increasing the overall cost to the manufacturer. Several full-vehicle concept designs and subsystem concept designs have demonstrated 25-percent mass savings over current conventional high-strength-steel designs while improving crash performance, without increasing cost. The advantages of these materials for meeting automotive manufacturers' goals are well recognized by the design community and, consequently, are being incorporated into nearly every new

vehicle design in increasing percentages and strength levels. Several vehicles on the road today contain significant amounts of AHSS. Examples include the Chevy Malibu, Jeep Grand Cherokee, Ford Five Hundred, Volkswagen Touareg, and Honda Ridgeline. Challenges in implementing these new materials come in forming and welding. As steel strength increases, formability and weldability generally decrease. To help manufacturers form and weld AHSS alloys, automotive manufacturers have been working through the Auto/Steel Partnership (A/SP, www.a-sp.org) to pursue a collective approach. The A/SP comprises DaimlerChrysler, Ford, General Motors and seven North American steel companies--AK Steel, Dofasco, Mittal Steel USA, Nucor, Severstal North America, Stelco and U.S. Steel. This partnership shares the common vision of improving the efficiency of the use of steel in producing automobiles.

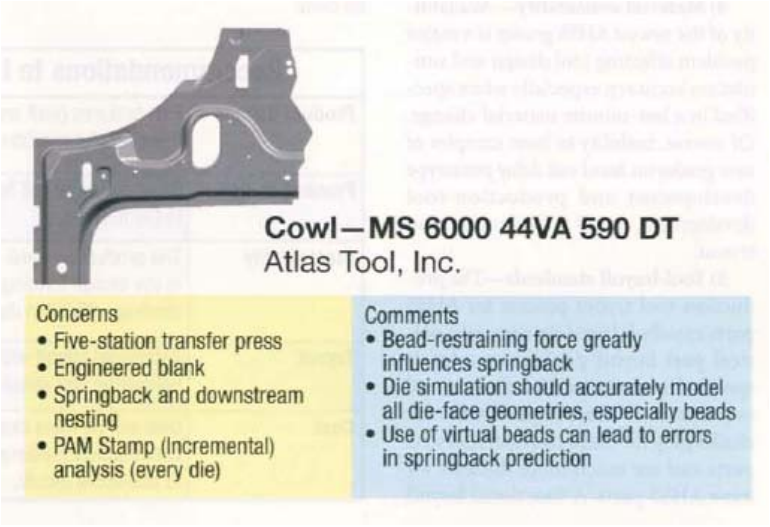
Coalition Tackles Major Production Challenges

The A/SP has identified three major AHSS stamping and forming challenges:

- Tool breakage resulting from the increased tonnage requirements to form parts from grades with double and triple the strength of that of conventional high-strength steels;
- Tool wear such that hardened inserts and shear edges can wear out during a single production run as a result of the AHSS material hardness nearly equaling the hardness of the die material itself; and
- Dimensional part-quality problems arising from increased springback associated with the higher strengths and the increased process sensitivity to material property variation at the higher strength levels.

Much steel-processing engineering knowledge and experience resides in the (traditionally) fiercely independent North American tooling industry. The automobile

and steel industries have traditionally relied on tool-and-die companies to address many of today's tooling challenges. This knowledge base has been extremely helpful to the A/SP in solving many AHSS stamping problems.



The Center for Automotive Research (CAR, www.cargroup.org) is a consulting partner with the A/SP that retains a close relationship with the tooling industry. The average tool shop has less than 25 employees, but has in-depth expertise in certain specialized forming technologies. Because of the industry's diversity of small yet highly competent engineering companies, CAR has assembled tooling coalitions to tackle common challenges, including AHSS. CAR has brought together tooling companies from the United Tooling Coalition (UTC) and the United States Tooling Coalition (USTC) to work with the A/SP on AHSS forming (www.toolingcoalition.com). The premise of the tooling coalition is the same as that of the Auto/Steel Partnership: Share knowledge on a pre-competitive basis. This enables all coalition participants to benefit from the work and expand the expertise of the group, much like what is done in large corporations.

Additional Challenges Identified

The coalition of tool shops has identified several additional challenges not initially raised by the automotive companies in dealing with AHSS. Among them:

- *The absence of detailed metallurgical steel data early in die development to support forming simulations, and ensuring the continuity of the same material throughout the development and tryout process.* This would help reduce errors in predicting springback and improve tool quality.

- *Numerous die re-cuts during tryout because of extensive springback not predicted by simulation.* Some tools must be re-cut more than 10 times, driving up tooling cost and deteriorating tool quality.
- *Dimensional tool-buyoff criteria are too difficult for AHSS.* The unattainable goal of 100-percent compliance to dimensional Cpk levels of 1.33 or higher often places every tool program into a crisis mode and can result in late delivery.

Based on historical experience in producing tools for AHSS, the coalition of North American tool shops identified five general recommendations to improve part and process design for AHSS stamped parts.

1. Springback Springback prediction and springback management of AHSS grades need improvement. Springback prediction refers to simulation software development and accurate material properties. Springback management relates to adjustments that can be made to part design and process design--without affecting part functionality--that help cope with springback.
2. Product design Certain product features, such as radii and part shape, affect springback, including curl and twist. Knowing these features and anticipating their impact beforehand can eliminate some springback problems.
3. Tool and die standards Special tool-and-die standards are appropriate for many AHSS grades. Unfortunately, conventional tool standards often find use today, but are not adapted to the higher tonnages and wear characteristics of AHSS alloys.
4. Material availability Availability of the newest AHSS grades is a major problem affecting tool design and simulation accuracy, especially when specified in a last-minute material change. Of course, inability to have samples of new grades on hand can delay prototype development and production-tool development, as well as final production tryout.
5. Tool-buyoff standards–The production-tool tryout process for AHSS parts usually is based on conventional-steel part-buyoff performance levels specified by numerous Cpk dimensional requirements. These

requirements are challenging for many conventional steel parts and are much more difficult for most AHSS parts. A functional buyoff process is needed. One recommended functional buyoff approach:

a. Rework the tool to achieve a high level of repeatability (minimize the variation from production of one part to the next);
b. Evaluate assembly of the part to see how mating parts fit. In many cases, since sheetmetal conforms to other parts (weaker parts will adjust to the stronger parts), not all parts require rework. Select the part/tool to adjust based on the assembly rather than independently evaluating Cpk.
c. Accept all parts in the assembly if the assembly is dimensionally acceptable, even when one of the detail parts in the assembly does not meet Cpk on its own.

These recommendations are summarized in the following table.

Product design	Part features (wall angle, radii, flange length, etc.) need careful consideration to help control springback.
Process design	Product design will have to allow forming to be completed in the first die.
Steel supply	The production-steel supplier should be selected early in the design forming-simulation stage so that accurate steel-specification data is available.
Tryout	Functional buyoff will be necessary rather than chasing unrealistic Cpk detail-part dimensional compliance.
Cost	Dies will be more expensive due to more demanding die construction, hardened inserts and longer tryout time due to additional re-cuts.

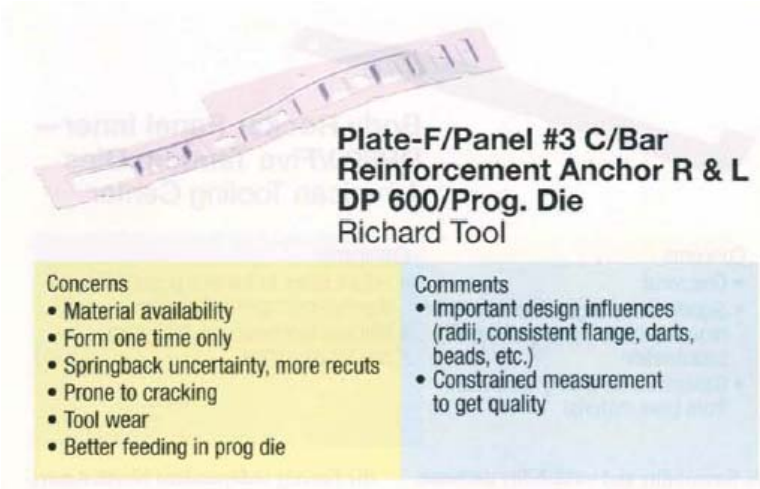
Four Case Studies

Four tool shops from the coalition provided detailed case studies to illustrate the problems encountered and solutions recommended: Atlas Tool, Inc., Roseville, MI; Richard Tool & Die Corp., New Hudson, MI; American Tooling Center, Inc., Grass Lake, MI; and Riviera Tool Co., Grand Rapids, MI. Each company took one case example (see boxes) and highlighted problems or concerns, and then commented on how to improve the design or process. These examples, with 590- or 600-MPa grades,

represent the lower strength levels of today's AHSS steel materials. Future applications will incorporate tensile strengths of 780, 980, 1180 MPa and greater.

With increasing production applications, the steel industry's experience will increase with these grades as they move from development and trial production to full-scale production. This will result in improved consistency of the materials delivered from the steel mills and will improve material availability needed for die development.

DP590 grades already are used in many automotive applications. The higher-strength AHSS will follow the same path. Product designers will become more capable of designing parts with geometrical attributes that address the formability and springback challenges through appropriate part radii, draw-wall angles, sidewall darts and beads. The early sourcing of steel for a specific application from the early stages of die development into final production is already a standard for OEM internally stamped parts. This practice will need to be extended to outsourced stampings, allowing die makers to develop dies around consistent material attributes. Through experience, diemakers will develop a greater understanding of the AHSS materials and the stamping practices that will accommodate these grades.



Stay Tuned

The combined efforts of coalitions such as AISI, A/SP, UTC and USTC are important to accelerating the pace of development of new steel grades and improving the competitiveness of the North American automotive industry. Just as the introduction of high-strength low-alloy steels resulted in early process difficulties that were soon overcome, so will the process issues of AHSS grades be handled through collaboration and experience. However, until then, the industry is raising the bar and forcing a more scientific discipline in the design, tryout and production of AHSS parts. Although the

challenges and risks in developing these tools are high due to the uncertainty in forming many of today's AHSS parts, domestic tool shops are as knowledgeable as any in the world and capable of helping the automotive and steel companies overcome them.

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