Projection Welding of Fasteners to Hot-Stamped Boron Steel

Manufacturing issues encountered during this process are reviewed along with the impact of using contact resistance

BY ALLEN M. AGIN AND BOB KOLLINS

Projection welding of fasteners is widely used in automotive component assembly. Hot-stamped boron steel is becoming more prevalent in the attempt to create lighter weight components with increased tensile strength, which helps manufacturers meet regulatory requirements while maintaining 5-Star Safety Ratings.

Over the last eight years, there have been many studies and articles written on the subject of spot welding boron aluminum silicon (AlSi) coated and uncoated hot-stamped material, but few have addressed projection welding of fasteners to these materials (Refs. 1–4).

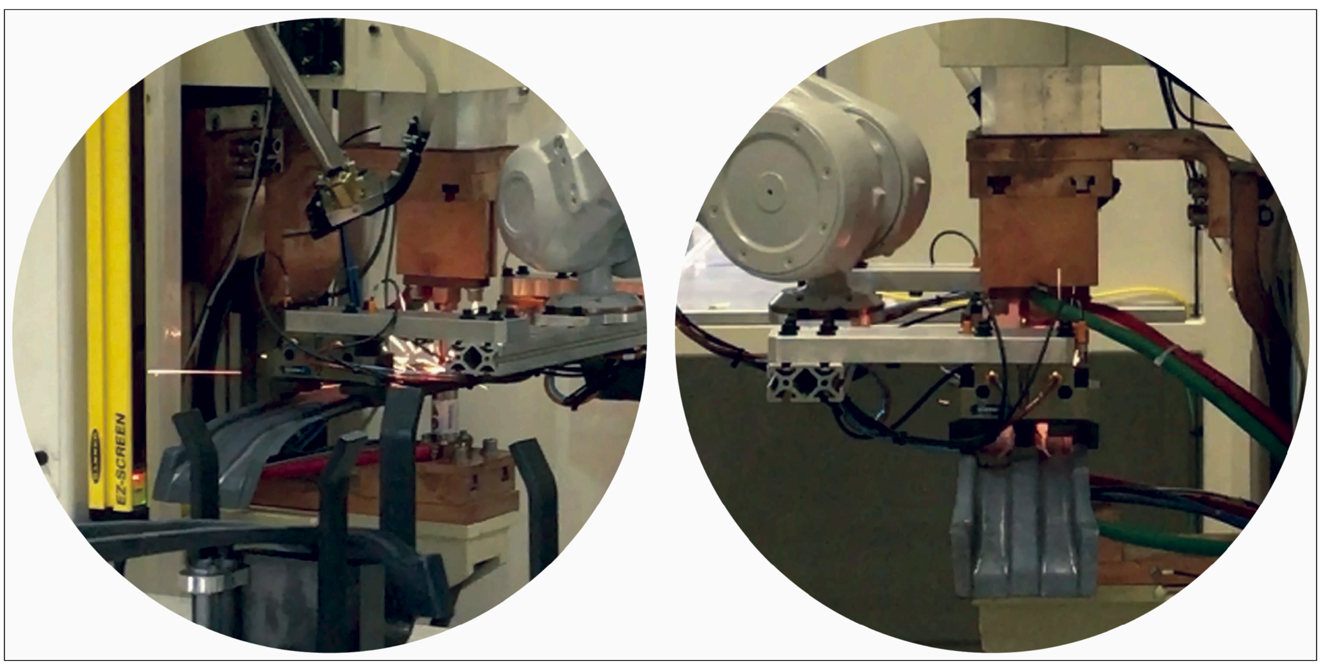
The in-house processes used to transform the boron steels for hot stamping can create obstacles for the welding of fasteners. The extreme change in hardness after the quenching process can harden base material by as much as 250%. In addition, an AlSi coating is tough to break through with traditional methods (Refs. 5–7).

The projection welding of fasteners to the coated AlSi or uncoated hot-stamped, high boron steels with consistent results will be addressed here.

Manufacturing Issues Identified

Several factors can lead to poor welds, increased welding costs, an "in process" manual inspection at the weld source, or 100% nondestructive evaluation (NDE) at the end user site. These include:

1. In-house processing of boron steel, causing drastic resistance changes at material interface;
2. Inconsistent torque and push-out test results;
3. Decreased electrode life;



Two different views of automated hot-stamped boron steel CD welding. (Photo courtesy of Weld Systems Integrators Inc.)

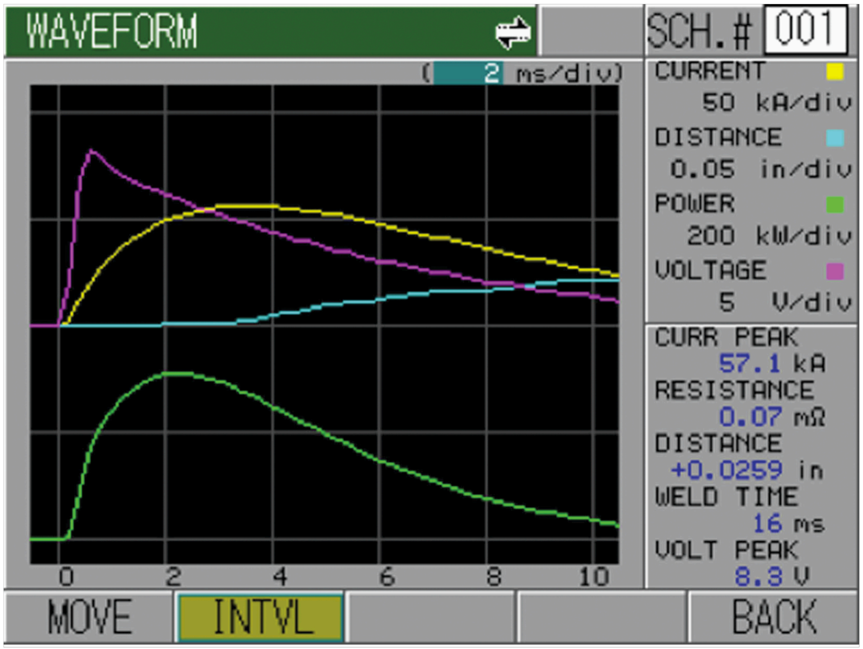


Fig. 1 — This graph shows a CD fast rise to current 57 kA in 3 ms.

4. Ineffective process feedback using constant current feedback;
5. AlSi coating.

Hardened Material

The addition of hot-stamped materials has two advantages: to create lighter weight components, and to achieve tensile strengths of 1500 mega pascals (MPa).

In most cases, the weld nuts and studs being used are considerably softer than the 1500 MPa stamping. Due to the large change in hardness, the projections in the fastener will collapse prior to a good weld being made. The end result is usually vaporized projections and extended weld times in an effort to forge the materials. When this type of weld process is incorporated, the end result is weak, inconsistent torque and push-out values.

Another concern is the consistency of the base material because the added strength is accomplished on-site. The influences observed were oven temperatures, heat cycle times, water flow rates, water temperatures, and quench times.

Impact of Weld Time on Process Response

Typical weld times with alternating current (AC) or mid-frequency direct current (MFDC) processes are in the range of 6–10 cycles (100 to 160 ms). These longer weld times make it almost impossible to utilize the high contact resistance present in the hot-stamped boron steels. Without being able to capture the heat on the rising edge of the current profile, the weld becomes more of a forging process than a projection welding process. Such extended weld times are known to result in delocalized deformation of the projection (refer to the *ASM Handbook*, Volume 6A), decreasing effective surface strains, and reducing joint performance. Longer weld times are also known to result in deformation of the nut and damage to any included threads.

Capacitor discharge (CD) weld controls can deliver a high peak current in 3 ms and total pulse widths on the order of 10 ms — Fig. 1. These shorter weld times allow concentrated heating at the projection tip with subsequent increases in local deformation.

This enhanced localized deformation is known to increase both performance and reliability of the resultant welds — Figs. 2, 3, and Table 1. This process can produce higher than normal push-out and torque values at a level consistent with automotive requirements. An added benefit is extended electrode life.

Fig. 2 — A M8 nut welded to 2-mm boron.

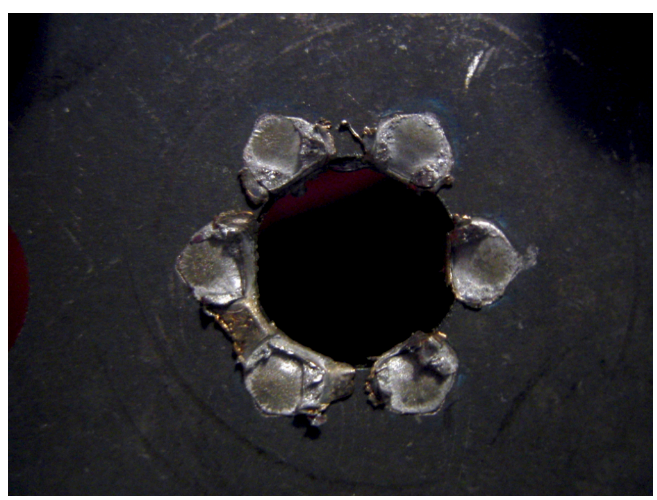


Fig. 3 — A M6 nut welded to 2-mm boron.

Table 1 — Push-Out Data for Figs. 2 and 3

M8 Nut 3.5 KJ	M8 Nut 3.8 KJ	M8 Nut 4.0 KJ	M6 Nut 4.0 KJ	M6 Nut 4.5 KJ	M6 Nut 5.0 KJ
3900 lb	5100 lb	5100 lb, 5100 lb	1550 lb, 1600 lb	1675 lb, 1775 lb, 1850 lb	1950 lb, 2025 lb, 2115 lb, 2250 lb

Machine Rigidity and Fast Follow-Up

The suggested shorter cycle times associated with CD welding must be supported with appropriate mechanical systems (refer once more to the *ASM Handbook*, Volume 6A). Rapid rise and short cycle times inevitably lead to rapid projection collapse. If the welding system cannot maintain force through projection collapse, expulsion is the unavoidable result.

Appropriate mechanical response is accomplished by sizing the weld cylinders, weld ram (this mechanism rides upon linear rails with little to no friction, allowing the welding electrode to maintain contact with collapsing parts during the transition period) and fast follow-up mechanism for each application. It is important to perform a lab study on the welding parameters using hot-stamped parts to size the fast follow-up system to meet the welding application. It is always best to use processed parts and not coupons when evaluating system mechanical response for this part of the process. When a welding machine manufacturer takes this important step, it can design a machine with a correctly configured fast follow-up package that will meet the application needs — Figs. 4 and 5.

In addition, a very rapid energy pulse requires that the welding machine's mechanical performance far exceed that of a conventional projection welding machine. The frame must be able to accommodate the added stresses caused by higher forces and increased rates of acceleration with little to no deflection — Fig. 6.

Alternative Technologies

The MFDC weld controls have been examined and tested with results not as favorable as the CD process. For example, Fig. 7 shows an Amada Miyachi 4000-A MFDC weld control reaching 83 kA in 6 ms. This is an extremely fast rise to current for a MFDC welding machine, but the cost of the equipment and additional cost of facilities (800-A, 3-phase primary feed) can add up quickly. Another issue associated with this technology is the closed-loop feedback. Normally, a constant current closed-loop process is preferred, but these systems work best when the weldment resistance is consistent. Hot-stamped boron steels with either an AlSi coating or an uncoated shot peened surface have a hard time presenting a consistent surface resistance, with the end result being inconsistent heat generation.

The CD weld process, while being open loop, produces a rapid pulse of current that creates instantaneous heating at the weld interface. This would be similar to a constant voltage feedback, where small changes in current based upon resistance changes while maintaining appropriate heat generation. The cost of the equipment is less than the larger MFDC power supplies, with the added additional

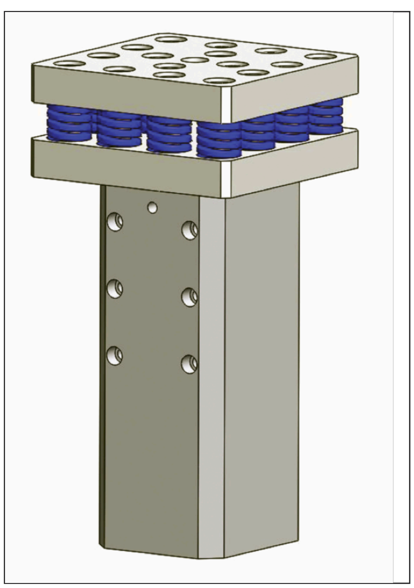


Fig. 4 — Die spring fast follow-up pack.

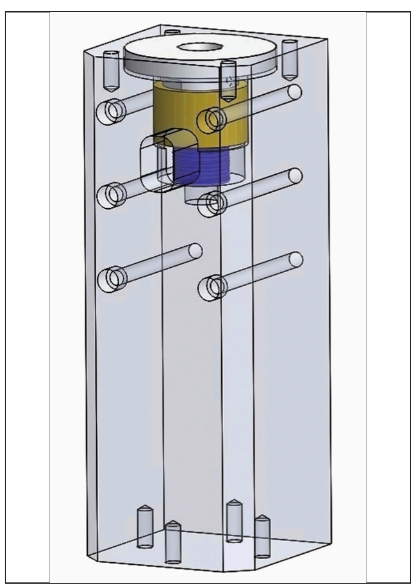


Fig. 5 — Belleville washer (also known as a coned-disc spring) fast follow-up.

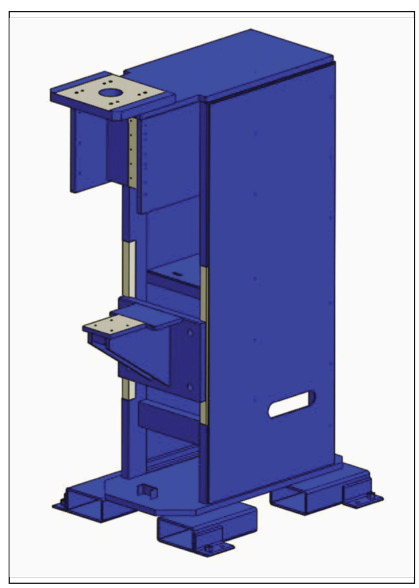


Fig. 6 — Expanded size, two extra rigid frame.

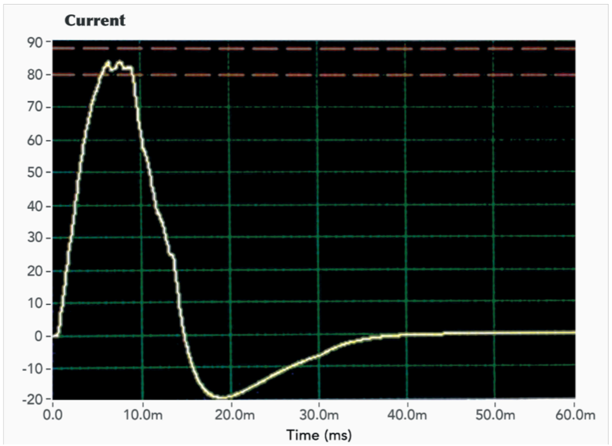


Fig. 7 — This graph displays the MFDC fast rise to current 83 kA, 6 ms.

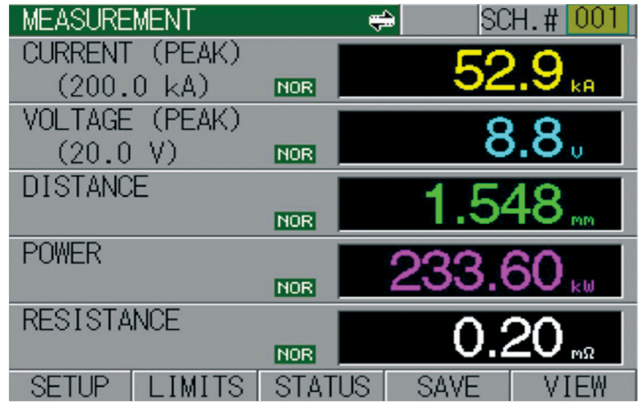


Fig. 8 — A MM-370B process monitor data.

benefit of lower facilities cost (60 A single phase).

Process Monitoring

A comprehensive weld monitor is necessary when using a CD welding process. Once baseline process parameters have been established, high and low windows should be set to ensure the process stays within the limits. Figure 8 shows the most common parameters used in CD welding. This enables measurement of the weld's electrical characteristics, as well as the projections amount of mechanical movement (distance).

Conclusion

Capacitor discharge welding is not a new technology; applying it to projection welding of fasteners to hot boron stamped components on a large scale has been used by many integrators over the past decade. It is a consistent, proven process chosen by many Tier 1 and 2 suppliers.

The CD power supply is only the beginning of the process. The complete answer requires high current, high weld force, short weld times, fast follow-up mechanisms, and ridged frame welding machines. Also, CD systems often use higher forces (compared to AC or MFDC variants) to ensure follow-up.

Customer installations and laboratory testing have shown CD welding to produce superior results. The test results show applications exceed manufacturers required push-out and torque requirements with no damage to the fasteners threads. The consistent results have virtually eliminated postweld inspections at the stamping and assembly plant.

Hot-stamped boron steel is here to stay. The best way to prepare for the influx of new applications is to start in the weld lab. Overall, capacitor discharge welding is a proven process with a record for quality and consistency. WJ

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This paper was presented at the AWS Detroit Section's Sheet Metal Welding Conference XVII held October 19 and 20, 2016, Livonia, Mich.