

# Projection Welding of Fasteners to Hot Stamped Boron Steel

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## ABSTRACT

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. The paper reviews the manufacturing issues encountered while projection welding fasteners onto hot stamped boron, AISi coated components, and examines the impact of using contact resistance, short weld times and high weld force coupled with fast mechanical response. Mid-frequency direct current (MFDC) processes are compared with capacitor discharge (CD) weld controls. Overall, customer installations and laboratory testing have shown CD welding to produce superior results. Success depends not only upon the CD power supply, but must also requires use high current, high weld force, short weld times, fast follow-up mechanisms, and rigid frame welders.

## INTRODUCTION

There have been many studies and articles written on the subject of spot welding boron aluminum silicon (AISi) coated and uncoated hot stamped material. These articles have appeared over the last 8 years, but few have addressed projection welding of fasteners to these materials.<sup>[1, 2, 3, 4]</sup>

The in-house processes used to transform the boron steels for hot stamping can create many obstacles for the welding of fasteners. The extreme change in hardness after the quenching process can harden base material by as much as 250 percent. In addition, an AISi coating is tough to break through with traditional methods.<sup>[5, 6, 7]</sup>

This paper will address the projection welding of fasteners to the coated AISi or uncoated hot stamped high boron steels with consistent results.

## **MANUFACTURING ISSUES IDENTIFIED**

Several factors can lead to poor welds, increased welding costs, an “in process” manual inspection at the weld source, or the very costly 100 percent 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 pushout test results
3. Decreased electrode life
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 usually weak, inconsistent torque and push out values.

Another concern is the consistency of the base material since 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 milliseconds (ms)/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 de-localized deformation of the projection (Ref. ASM Handbook 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. (This is shown in **Figure 1**). These shorter weld times allow concentrated heating at the projection tip with subsequent increases in local deformation.

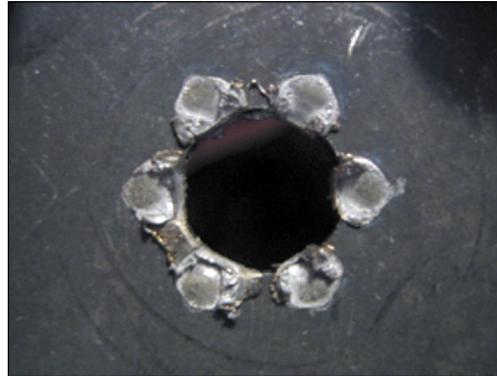


**Figure 1: CD fast rise to current 57 ka in 3 ms**

This enhanced localized deformation is known to increase both performance and reliability of the resultant welds (**Figure 2 and 3 and Table 1**). This process can produce higher than normal pushout and torque values at a level consistent with automotive requirements. An added benefit is extended electrode life.



**Figure 2: M8 Nut welded to 2 mm boron**



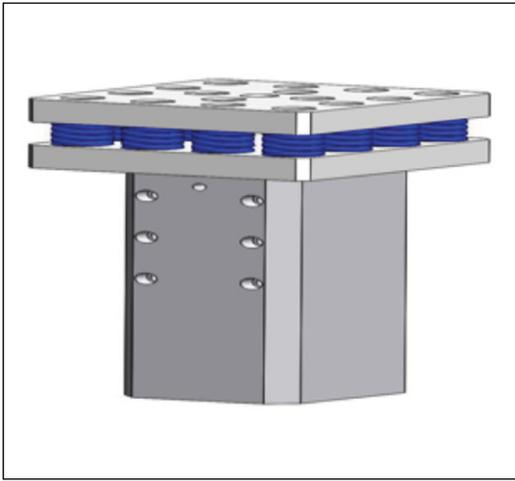
**Figure 3: M6 Nut welded to 2 mm boron**

M8 NUT 3.5KJ	M8 NUT 3.8KJ	M8 NUT 4.0KJ	M6 NUT 4.0KJ	M6 NUT 4.5KJ	M6 NUT 5.0KJ
3900 lbs	5100 lbs	5100 lbs 5100 lbs	1550 lbs 1600 lbs	1675 lbs 1775 lbs 1850 lbs	1950 lbs 2025 lbs 2115 lbs 2250 lbs

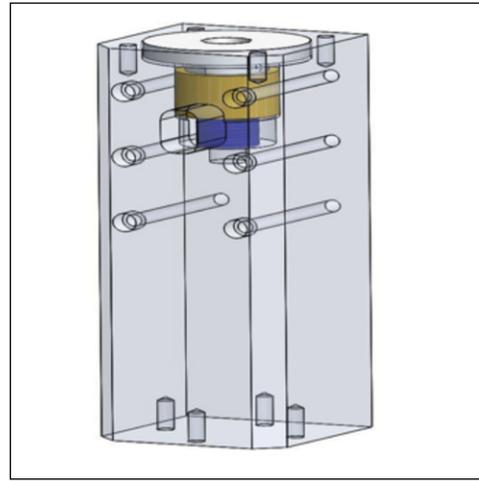
## MACHINE RIGIDITY AND FAST FOLLOW-UP

The suggested shorter cycle times associated with CD welding must be supported with appropriate mechanical systems (ref. ASM 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 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 welder manufacturer takes this important step, they can design a machine with a correctly configured fast follow-up package that will meet the application needs See **Figures 4 and 5**.

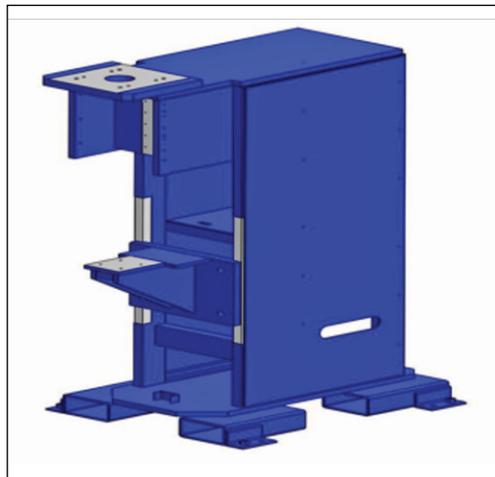


*Figure 4: Die spring fast follow-up pack*



*Figure 5: Belleville washers fast follow-up*

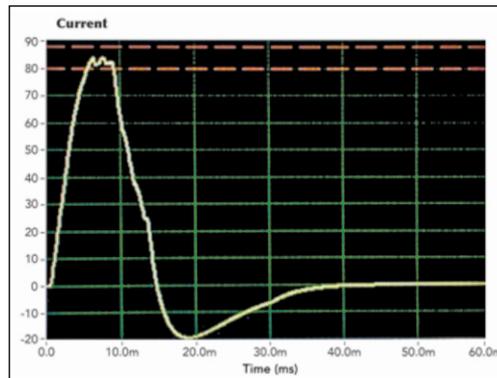
In addition, a very rapid energy pulse requires that the welder's mechanical performance far exceed that of a conventional projection welder. The frame must be able to accommodate the added stresses caused by higher forces and increased rates of acceleration with little or no deflection. See **Figure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



*Figure 6: Expanded size 2 extra rigid frame*

## ALTERNATIVE TECHNOLOGIES

MFDC weld controls have been examined and tested with results not as favorable as the CD process. For example, **Figure 7** shows an Amada Miyachi 4000 amp MFDC weld control reaching 83 kA in 6 ms. This is an extremely fast rise to current for a MFDC welder but the cost of the equipment and additional cost of facilities (800 amp 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 AISi coating or an uncoated shot peened surface have a hard time presenting a consistent surface resistance, so the end result is inconsistent heat generation.

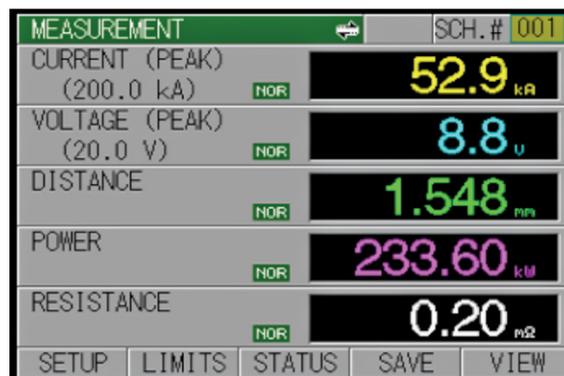


*Figure 7: MFDC fast rise to current 83 ka 6 ms*

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, 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 benefit of lower facilities cost (60 amp single phase).

### Process Monitoring

A comprehensive weld monitor is a must-have 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 projection's amount of mechanical movement (distance).



*Figure 8: MM-370B process monitor data*

## **CONCLUSION**

CD 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 Tier 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 welders. 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 costly post-weld inspections at the stamping and assembly plant.

Hot stamped boron steel is here to stay, as many suppliers are installing new lines every year. 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 an excellent record for quality and consistency.

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