Hot Stamping Experience and Tech Tour

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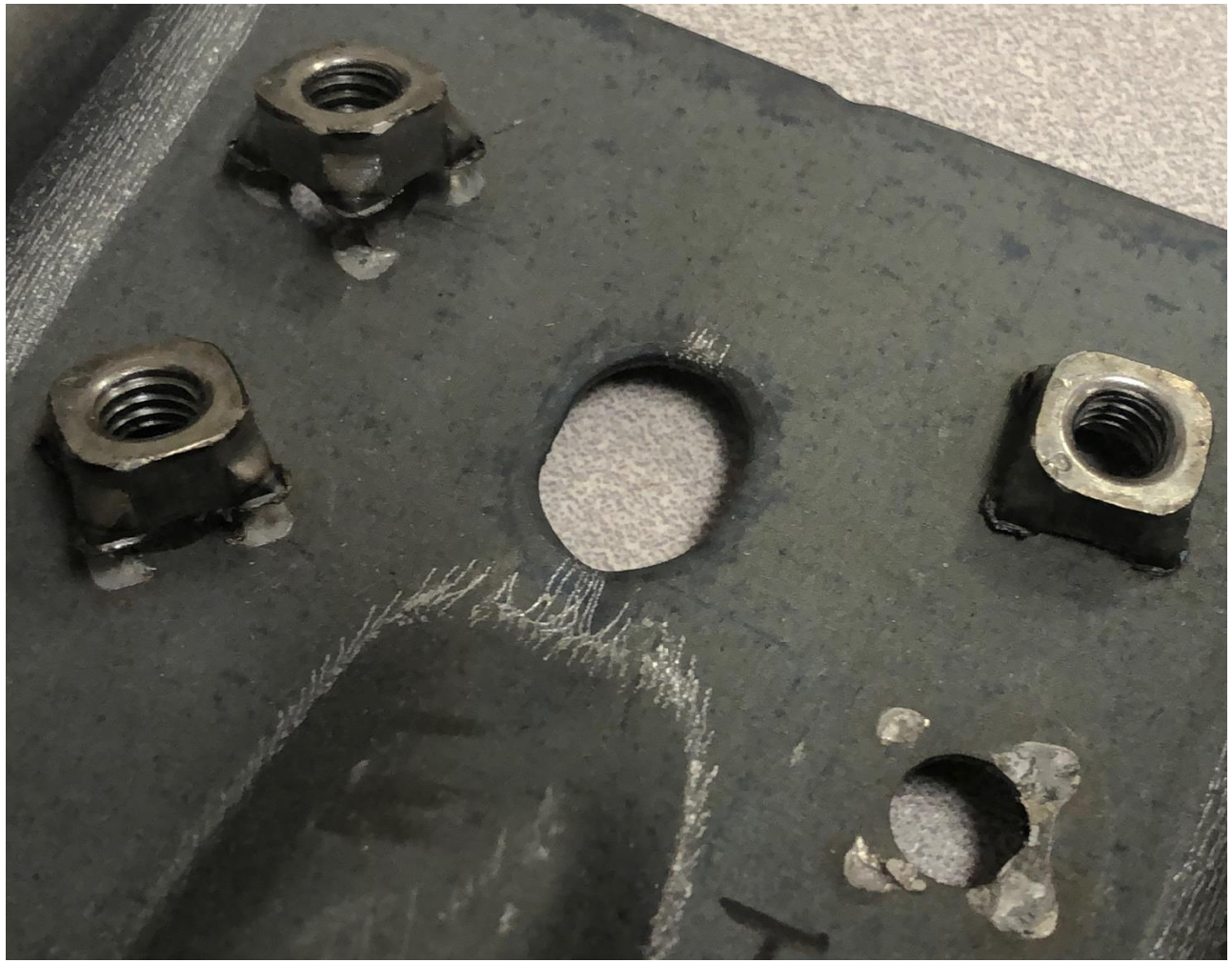
Why is it so difficult to weld Projection Welded Fasteners to HOT STAMPED STEELS?



What is HOT STAMPED STEEL?

What *is* HOT STAMPED STEEL?

- Process to transform boron sheets for hot stamping creates many obstacles:
  a) Extreme change in hardness after quenching process
     • Can strengthen base material by 250%
  b) An AlSi coating is tough to break trough
  c) If uncoated, heating typically causes oxidation (scaling) and surface decarburization
- Hot-stamped boron steels
  a) Lightweight
  b) Tensile strengths of 1,500 Mpa
- Problems with Projection Welding Fasteners to Hot-Stamped
  a) Weld nuts and studs – considerably softer
     • Causes fastener projections to collapse before a good weld can be made
       - Resulting in vaporized projections causing weak, inconsistent torque and pushout values

How *is* HOT STAMPED STEEL made?

- Steel blanks put into furnaces for heating to temperature above 1500*F
  - Makes the blanks malleable (soft)
- Blanks move into press capable of controlling stroke rate and dwell time for forming
- Followed immediately by in-die quenching for 3 to 10 seconds
  - Completes transformation to a full martensitic phase – creates the hardened material
- Process creates a surface oxide
  - Aluminum-silicon (Al Si)
  - Very resistive coating
  - Inconsistent thickness layer

Principal Challenges of RPW on Hot Stamped Steel

- **Hot Stamped Steels** – ***involves inhouse processing, which varies from manufacturer to manufacturer***
  - **Affecting material hardness variations**

- **Surface oxide coating** - ***variations exist across the industry and even across a part (in terms of contact resistance)***
  - **Specifically at interface where fastener projections attaches to the part**

- **Hard, less conductive aluminum-oxide coating thickness variations**
  - **A few micrometers variation can cause previously approved setup to fail destructive tests**
    - With no apparent visual difference in the parts

Challenges of RPW with Hot-Stamped Boron Steels

1. Variations in part flatness
2. Coating thickness
3. Projection height consistency

** Material requires respect for Projection Welding fundamentals*

- look at every aspect of process (FCTF)

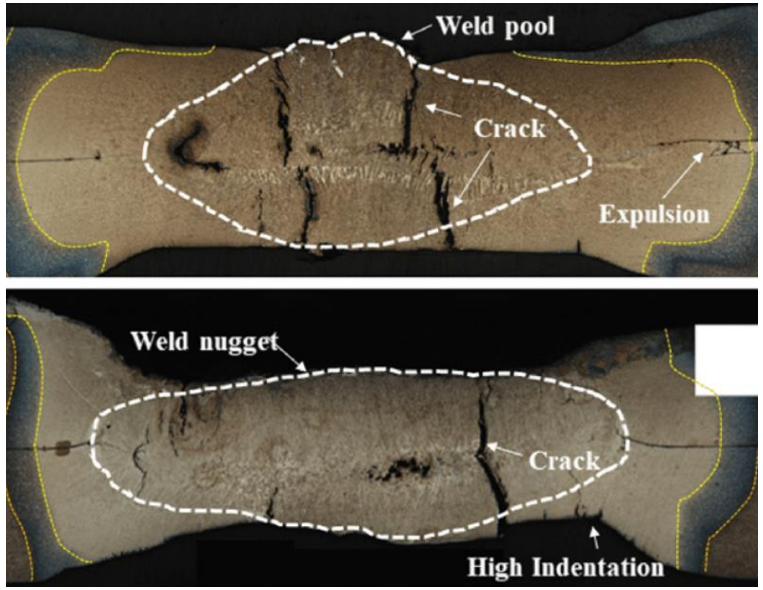
* Projections to UHSS & HSS using conventional RPW equipment

- *exhibits different behavior* compared to CRS
- *shift of Failure Mode*
  - from fracture in base metal to fracture in weld joint or fastener material
  - difficult to develop bond stronger than UHSS base material
  - *due to extraordinary strength of modern steels – not weld strength*

Principal Challenges of RPW on Hot Stamped Steel

1. Shift of Failure Mode
   - From fracture in the sheet base material to failure in the weld joint or fastener projection material
2. Difficult to develop a weld bond stronger than the Ultra-high Strength Steel
   - Weld (projection) frequently fractures
   - May not be an issue with the strength of the weld
3. If weld fails but the base material doesn't
   - Materials high strength or was cold weld?
   - Weakest link fails – *may be fastener material*
   - Pulled metal in destruct tests is no longer feasible for certain applications

Weld Failures! Was it base material strength or *cold weld*?



Interfacial Weld Failures

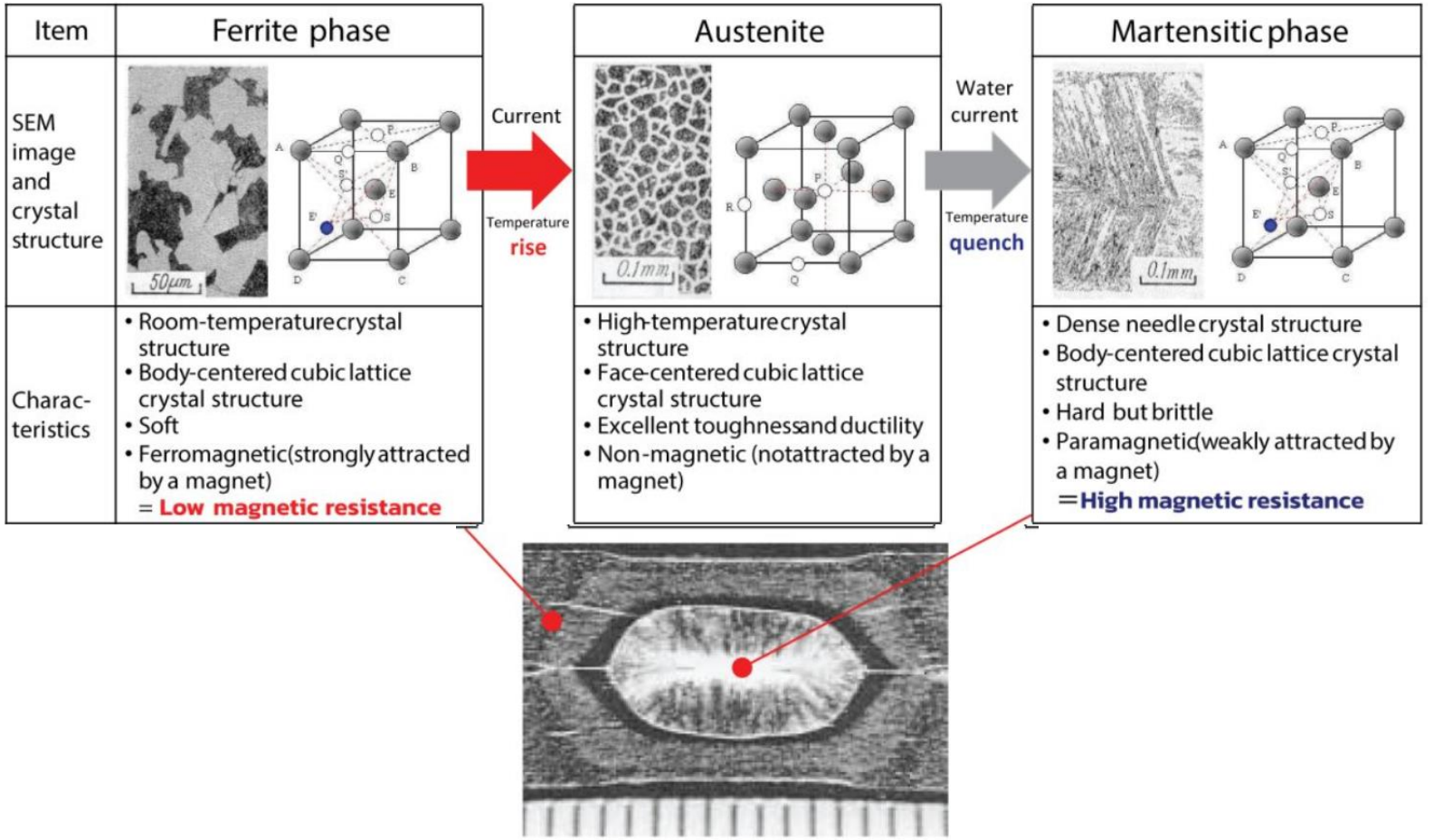
1. **Disadvantageous stress state of the weld**
   - **Small nugget diameters combined with thicker sections**
     - **Greater degree of ductile crack growth during peel testing**

2. **Presence of preferential crack paths within nugget**
   - **Porosity or solidification cracks – allow cracks to initiate at faying surface notch & propagate from porosity or crack to another, along faying surface line**

Weld Failures!

Interfacial Weld Failures

3. **Susceptible microstructure**
   - **hardened microstructure with large amount of martensite**
     - **could result in brittle**
       - ***cleavage fracture**



fracture of brittle particles that can propagate within adjacent ferrite, can cause rapid advancement of micro-crack, in which grains have failed by splitting along definite plane

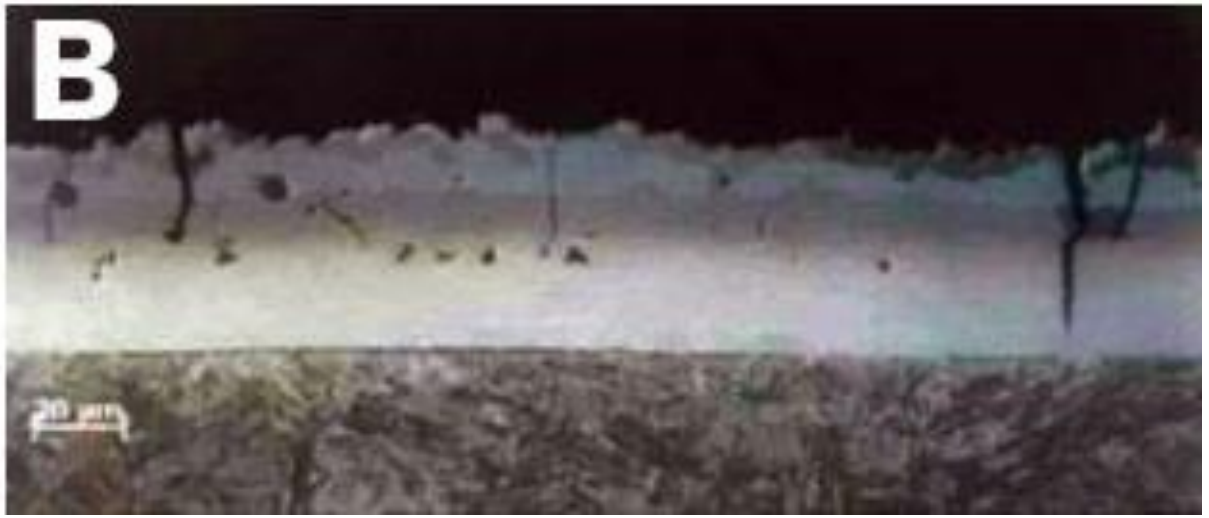
- resulting in a visual of bright, reflective facets (diamonds)

Weld Failures!

1. Obvious difference in surface color (AlSi coating)
   a) Caused by variability of in-plant processing
   b) By changes in the coating thickness due to deviations in line speed or in-die cooling

Weld Failures!

1. Obvious difference in surface color (AlSi coating)
    c) Changes in thickness coating changes the resistivity of the surface, which directly affects weld quality and repeatability



What can I do to get consistent weld results?

- When using in-plant processing, make sure no deviation from the recommended parameters of time, temperature, and die cooling for the stamping blanks
  - Even slight change in the process *WILL* create a problem due to the AlSi coating
- Success depends on several factors, including in-plant processing, thickness of material, AlSi coating, projection style, nut/stud size, and weld specifications

What is the best way to weld projection nuts to hot-stamped materials?

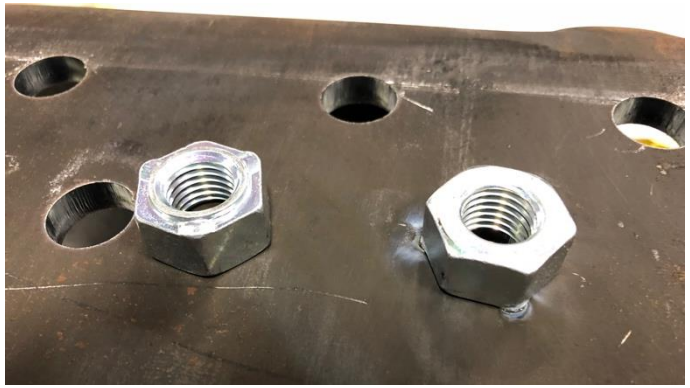
- Most common welding processes are capacitive discharge (CD) and medium-frequency direct current (MFDC)
- A combination of short weld times, high current, high weld force and fast follow up
  - Deliver the greatest consistency
- MFDC process- ideal for the right application, requires tight control of in-plant processing
- CD process - allows for variations due to in-plant processing in real-world conditions

Resistance Projection Welding Basics:

It's a Science! ***FORCE – CURRENT - TIME***

FOLLOW-UP - for Projection Welding

Do The Projections Have To Be Different?



Heat-affected zone (HAZ), why does this matter?

- HAZ is a very important, often the critical factor in all HSBS (Hot Stamped Boron Steel) welds
- Ideal resistance weld utilizes highest possible amount of heat for shortest possible amount of time
- Using a process that cannot deliver weld current in the shortest amount of time, can end up heating an area far outside the weld zone
- May cause change in hardness in base material, can lead to material failure in HAZ.

Metal formers typically overlook and fail to account for difference in hardness of HSBS and fastener itself

- According to data from fastener manufacturers:
  - Fastener tensile strength ranges from 400 to 450 Mpa
  - Stark contrast from the 1500-MPa tensile strength of formed HSBS
  - This means that traditional destructive testing can be difficult to gauge
  - Fasteners fail before base metal, which result in anomalies in final pushout-test data

Why MFDC Welding May Not Be Best Choice!

- Attribute to the inconsistency of the post-processed AlSi coating
- When weld current is held at a steady state and resistance rises above baseline, increased energy is created at fastener interface
- This results in excessive heating and reduced weld strength
- Same problem can occur inversely when resistance drops below baseline and results in an insufficient amount of heat generated at projection interface, causing weak weld

➢ Can happen during destructive testing of weldments where fastener and base material have significantly different tensile strengths

➢ MFDC performs well when welding HSBS material in normal flat-to-flat configuration, *MFDC is not recommended for projection welding to HSBS*, MFDC weld controls cannot overcome the challenges created by inconsistent AlSi-coating thickness

Alternatives to MFDC:

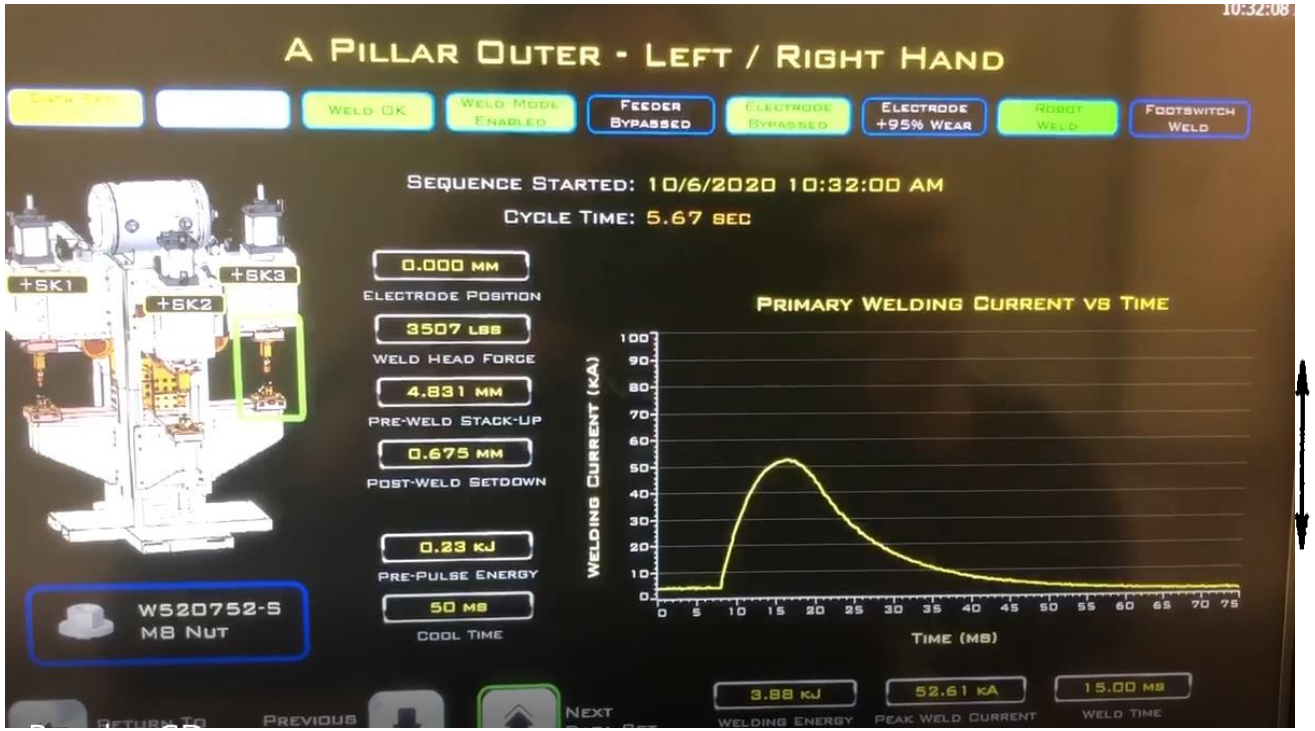
- Perform 100-percent inspection of each fastener and reweld any that fail
- Tack weld (using gas-metal-arc welding) each nut to act as a safety weld
- Use a capacitor-discharge (CD) fastener welding machine, which will overcome resistance inconsistencies and deliver repeatable process
- Use MFDC Fast Rise Transformer System

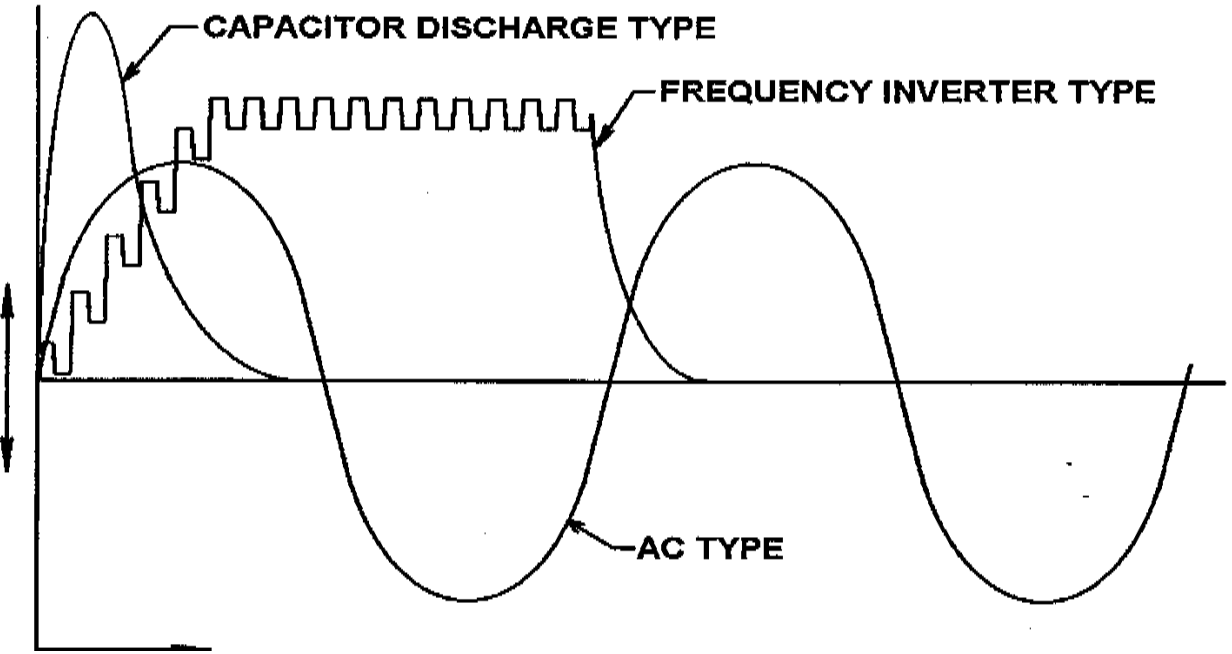
QUESTIONS ABOUT THE PROCESS

1. **If we weld projection fasteners now, what is going to be the difference welding projection welded fasteners to Hot Stamped Steels?**
2. **Is there an easy way to visually tell if I am welding Hot Stamped Steel?**
3. **Are the projections formed in the Hot Stamped Material or on the fasteners?**
4. **Can full-ring style projections be welded to Hot Stamped Steels?**
5. **Can I use Piloted-Nuts?**
6. **Do Powdered-Metal projection welded fasteners work on Hot Stamped Steels?**
7. **Can I use the same consumables (electrodes) as my other projection welding?**
8. **Does the oxide coating on Hot Stamped Steels react like galvanized coatings?**

LET'S DISCUSS THE PROCESS

9. **Between AC, MFDC and CD Resistance Welding Processes, which process works best for projection welded fasteners on Hot Stamped Steels?**





LET'S DISCUSS THE PROCESS

10. Why will the Capacitor Discharge Process provide the best weld?
11. Will any special training be needed for the operators using the CD process?
12. Is the CD welder larger than other resistance welders?
13. Will any special hook-ups be required for a CD welder in my plant?
14. Will the CD welder require a special start-up procedure?
15. What about the Safety with CD welders and with the CD process?

Harnessing and Controlling the CD Energy

- Welding-machine frame - must be rigid with little to no deflection (about 0.002-in. deflection at a weld force of 7500 lb.)
- Because average weld force for HSBS fastener weld is approximately 3000 lb.
  - Standard fastener-welding machines typically will not suffice.
- In addition, standard projection-welding machine has weld time of around 160 msec, enough time to maintain consistent force across weld interface
- However, a CD welder has weld time less than 10 msec and requires much greater force
- Heat generation in CD resistance weld directly relates to contact resistance and not bulk resistance
- Rate of acceleration of projection collapse is much greater than in a traditional weld
  - This requires appropriate mechanical response
  - Accomplished by properly sizing welding-machine cylinders, ram and the fast follow-up mechanism
- Old welding machine with die-cast ram, roller cams with grease fittings and coil springs for follow-up ***IS NOT*** an option for CD welding of Hot Stamped Boron Steel

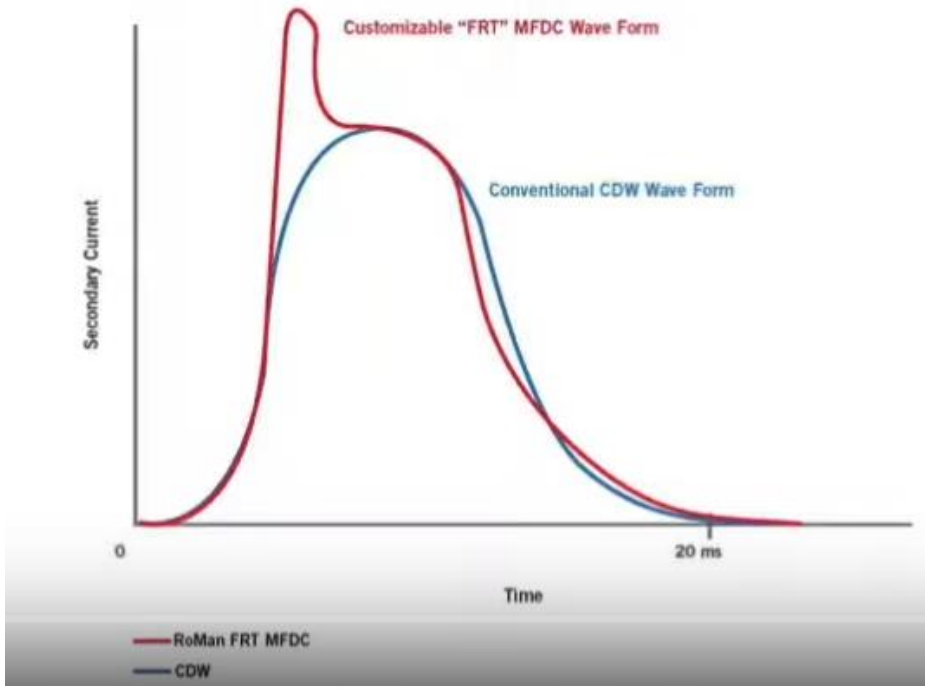
LET'S DISCUSS THE PROCESS

16. What maintenance should I expect using a CD welder doing these projection welds on Hot Stamped Steels?
17. Will my maintenance team and set-up personnel need specialized training on the Capacitor Discharge Welder and CD Welding Process?
18. Will the CD Welding Process ensure consistency for projection welded fasteners to Hot Stamped Steels?
19. What are some of the other variables that I need to be aware of with this process?
20. What about the other process, MFDC FAST-RISE TRANSFORMER SYSTEM?

IS THERE ANY OTHER PROCESS?

MFDC Fast Rise Transformer System

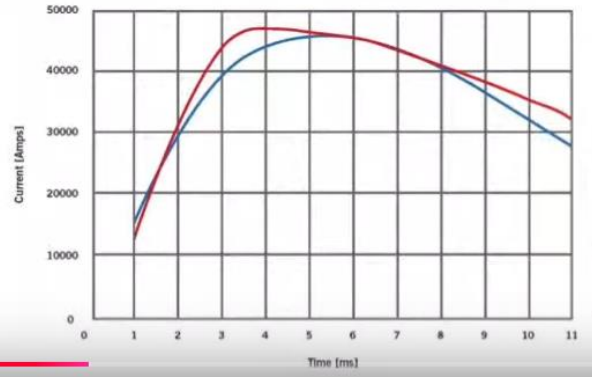
1. Customizable wave form developed through weld control
2. Easier removal of metal coating (breaks through coating), utilizing high initial peak current
3. Can use standard weld controls that are presently used on MFDC
4. Smaller transformers than used on most CD welders
5. Welder can be re-used/re-purposed for other resistance welding applications
6. Generally, less expensive than CD welders



Other Significant Differences Between the Two

In many cases RoMan FRT-MFDC technology can achieve faster rise times compared to CDW. RoMan FRT-MFDC technology allows welds to be made every half second. CDW generally requires one to two seconds between weld to allow charging of the capacitors. Capacitors also have a limited life based on number of charges.

This graph shows **RoMan FRT MFDC** (**Red**) and **CDW** (**Blue**) and time to current peak and hold levels.



Note: These wave shapes were taken from the **SAME** production machine.

LET'S DISCUSS THE PROCESS

If you are still frustrated with trying to conquer this beast of welding projections to Hot Stamped Boron Steel, call T.J. Snow Company –

The Leader in Resistance Welding!

800-NOW SNOW (800-669-7669)

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