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PUBLISHED BY THE AMERICAN WELDING SOCIETY TO ADVANCE THE SCIENCE, TECHNOLOGY, AND APPLICATION OF WELDING AND ALLIED JOINING AND CUTTING PROCESSES WORLDWIDE, INCLUDING BRAZING, SOLDERING, AND THERMAL SPRAYING

BY TOM SNOW, DON DECORTE, AND ROGER HIRSCH

Q: We supply stampings to the automotive industry, and when one of our customers required us to switch to high-strength steel sheet metal, the nuts we've successfully resistance projection welded to mild steel stampings for many years did not meet the required torque and push-out weld strength specifications. We're using the same machine settings as before. Do you have any suggestions?

A: We've heard about this problem from several customers. High-strength low-alloy steel (HSLA), press hardened or hot stamped, is specified more often these days to help reduce the weight of automotive parts. However, these alloys are not as easy to spot and projection weld as standard low carbon steel, which can be welded with a relatively wide range of settings.

Challenges with resistance welding high-strength steels are caused by in-die heat treating processes and base metallurgy transformations that result in extra hardness and inconsistent surface conditions.

When there is a wide difference in hardness between the high-strength sheet metal and the projections of the weld nut, it is difficult to forge the projections into the sheet metal without severe expulsion and inconsistent weld strength.

Resistance welding problems begin when the hardness of sheet metal exceeds 700 MPa. Some boron and Usibor steels present even more welding challenges because they can reach a hardness level of 1200 MPa. Unfortunately, good welding charts are not yet readily available for welding projection nuts to high-strength steel.

Although you may be tempted to shortcut the process, we recommend undertaking a thorough research and development procedure to identify and optimize the three most important variables in resistance welding: weld force (tip pressure), weld current (secondary amperage), and weld time (the duration of current flow).

When resistance welding nuts to high-strength steel, a combination of high weld current and short weld time is recommended because it creates intense heat at the projections, allowing the welding/forging process to take place fast before the projections are "blown out." Whether connected to a pneumatic or servo-actuated ram, the importance of using a fast follow-up device in the force delivery system cannot be overemphasized — Fig. 1.

In our resistance welding seminars, we teach the concept of determining a proper weld lobe during this research and development process. A weld lobe is a graphical representation of all the machine settings that will produce results that meet your customer's specifications — Fig. 2A–G.

There may be some allowable variations, but the window of interactive parameters for successfully welding

Fig. 1 — Photo of a fast follow-up spring installed in the ram of a projection welding machine.

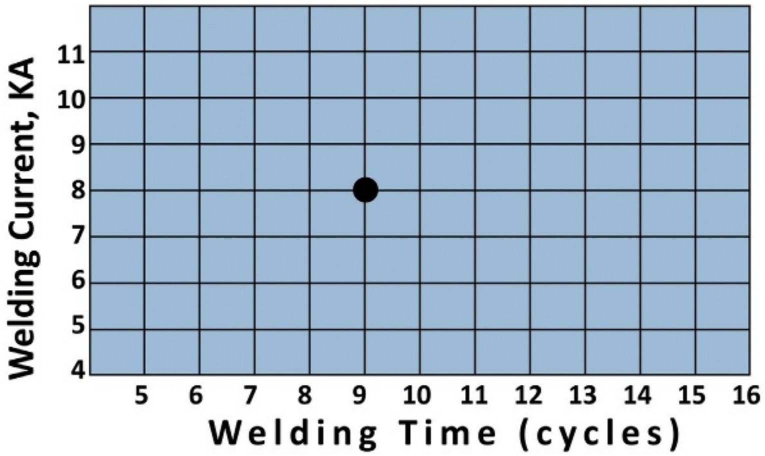

Fig. 2A — Seven-step series of weld lobe development graphs: Step 1. Make a weld that meets test requirements. Use a standard welding chart for the most similar alloy available and adjust as needed. Put a dot at the intersection of the welding current and the welding time.

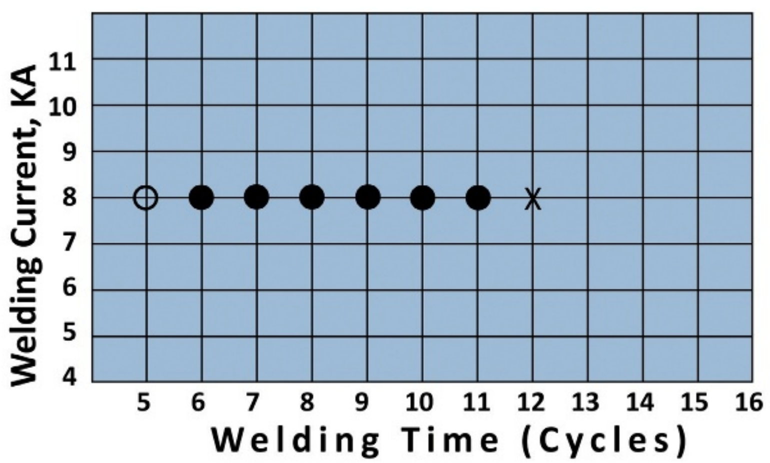

Fig. 2B — Step 2. Increase the welding time one cycle at a time until you see the start of metal expulsion and put an X at that intersect. Then decrease weld time until the weld result is just on the edge of being acceptable and put an O at that intersect.

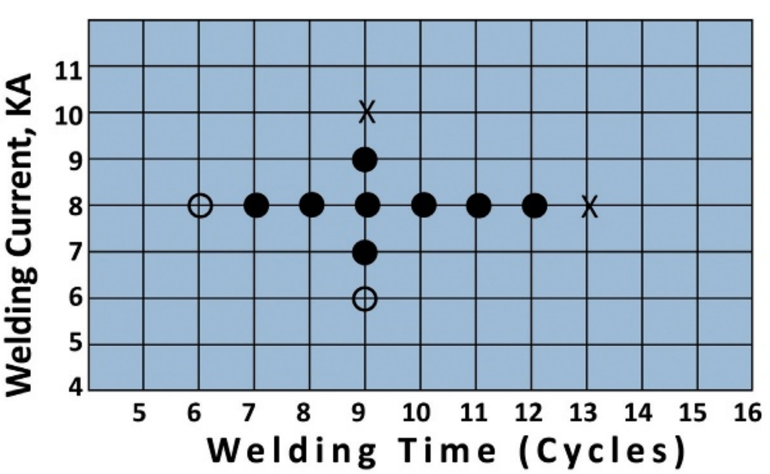

Fig. 2C — Step 3. Increase the welding current until you see the start of metal expulsion and put an X at the intersect. Decrease the welding current until the weld result is just on the edge of being acceptable and put an O at that intersect.

nuts to high-strength steel will be much smaller than for mild steel. During your testing process, be sure to use the same procedure that will be utilized by your customer to test production welds — Fig. 3.

If you've chosen a properly sized press-type resistance welding machine (not a rocker arm spot welding machine) that has fast follow-up and a set of electrodes suitable for your nut welding application, you should get the best results from a mid-to-high weld force setting, high weld current, and a very short weld time. Best results usually come from setting the machine to weld "hot and fast."

Once these parameters are established, it's important to start the production run with settings that fall in the center of the weld lobe; in other words, your proven optimum settings. With these settings dialed in, the machine should produce consistently successful welds throughout the shift. However, if one or more of the variables starts to drift, at least you have some margin available before the welds fail. To avoid rejects, it's advisable to test the welds every hour or so.

It's also important to note that the squeeze time setting on the welder control needs to be set properly. This function, which would be better understood if called "Tip Travel Time," is the delay time measured in cycles (one cycle = 1⁄60 of a second) between machine initiation and the start of current flow.

In an effort to speed up production, squeeze time is sometimes set so short that it times out and turns on the welding transformer before the upper electrode tip has a chance to apply full force to the nut. This results in the projections being "blown out" due to inadequate force.

On an air-operated welding machine, this problem can be avoided by installing a pressure switch, that will not allow the control to fire the transformer until full weld force is achieved.

Once proper squeeze time is assured, choosing the correct welding force is critical to avoid weld expulsion. A force setting that's too low will cause the projections to blow out, and a force setting that's too high could collapse the projections before a strong weld is accomplished. In either case, the resulting welds will be very low in strength and ductility.

If proper machine and settings are used, a standard single-phase alternating current (AC) resistance welding unit should be able to weld projection weld nuts to some high-strength steels. However, as mentioned previously, the window of settings that give successful results is relatively small.

Many automotive parts suppliers are opting to invest in resistance welding machines with three-phase mid-frequency direct current (MFDC) technology. Because it's more controllable than single-phase AC welders, it would seem logical to assume that this technology would help when welding high-strength metals. However, most standard MFDC welders don't have a fast enough current rise time to optimize the process. To address this problem, a new MFDC "Fast Rise Time" technology is now being offered that can produce 30–70 kA pulses in 3–10 ms. That's around a quarter of a half cycle.

Another recent trend for projection welding nuts and studs to high-strength steel is to use a resistance welding machine with a large capacitor discharge (CD) power supply. Miniature resistance welders with small-capacity CD power supplies have been used to weld small electronic parts for decades. Over the last 10 years or so, larger-capacity machines using newer technology have become available, and they are well suited for projection welding nuts and similar applications.

Rated in kilojoules (kJ), these high output machines offer the advantage of instantaneous delivery of a short burst of high welding current. And because the current flow is over quickly, parts welded with CD technology have virtually no heat distortion.

Another advantage of large-output CD resistance welding machines is that they require a relatively small primary power supply to charge the capacitors. Although usually not a problem due to part handling constraints, recharge

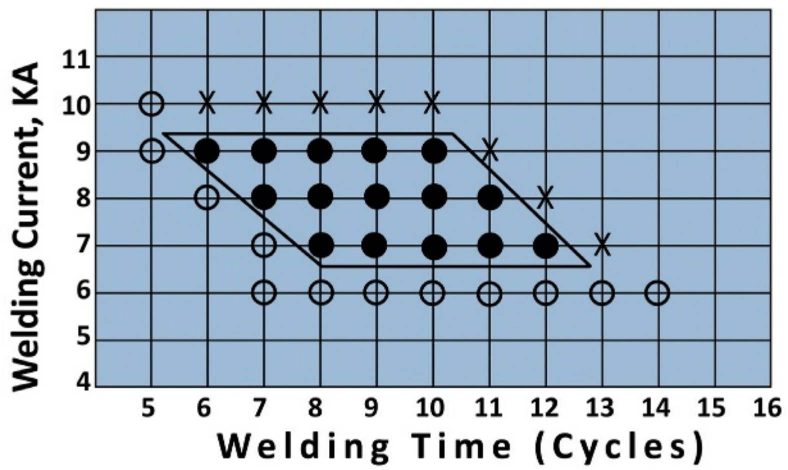

Fig. 2D — Step 4. Drop the welding current to the lowest point that produced a weld just on the edge of acceptance (6 kA in this example) and make welds for the same group of weld time. Repeat for each line of welding current up to the current that produces expulsion (10,000 kA in this example). This creates a finished welding lobe for this particular electrode force.

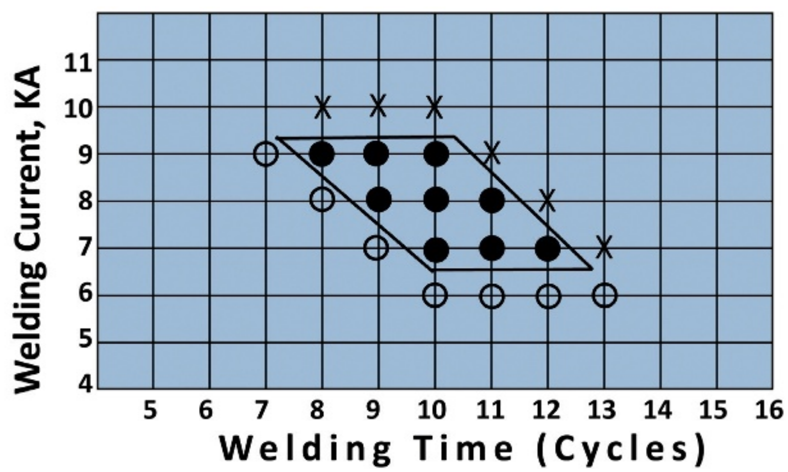

Fig. 2E — Step 5. Increase the electrode force and repeat the same process for each line of welding current. The resulting lobe will be smaller and shift to the right.

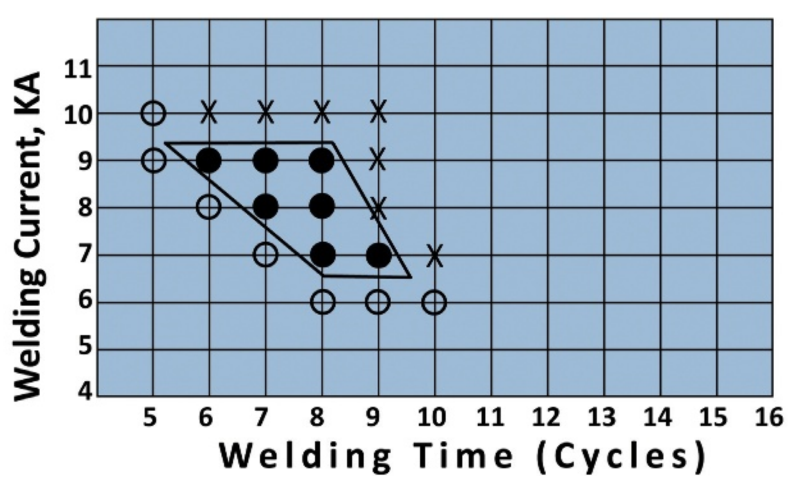

Fig. 2F — Step 6. Lower the electrode force and repeat the same process for each line. The resulting lobe will be smaller and shift to the left.

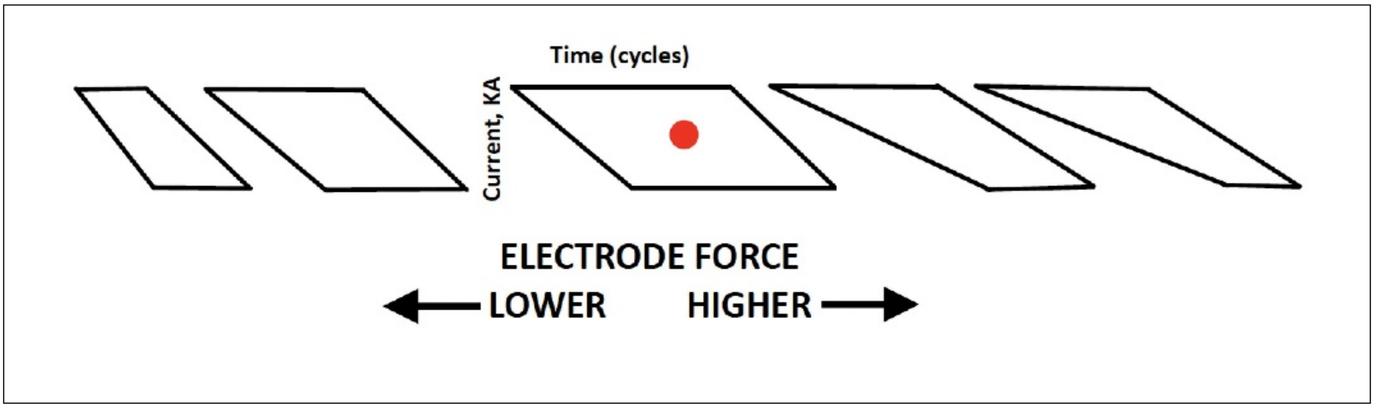

Fig. 2G — Step 7. Find the electrode force setting that develops the largest size welding lobe. Then set the welding machine for the weld time and welding current that is in the middle of the lobe. (Graphs courtesy of Unitrol.)

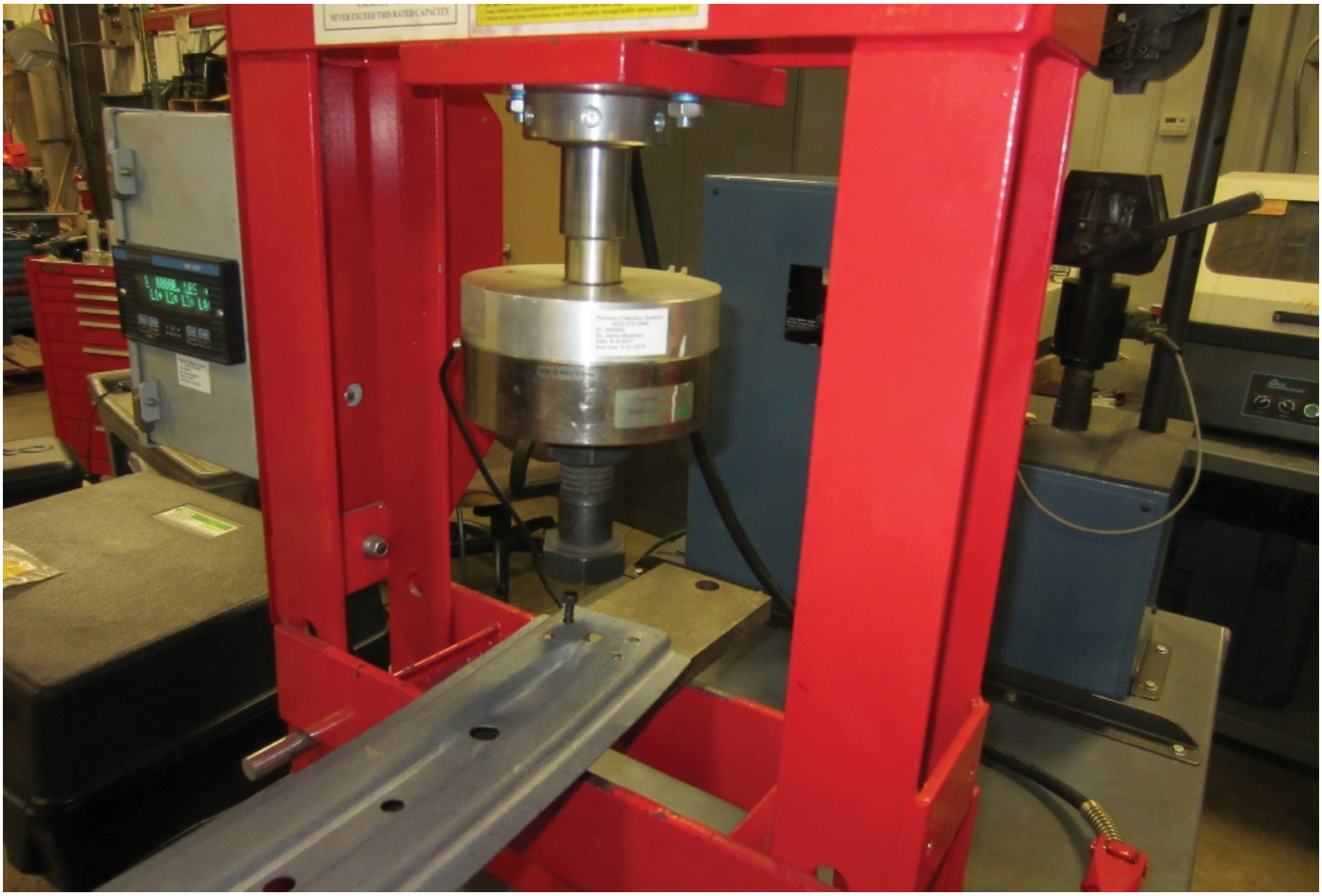

Fig. 3 — Photo of the push-out weld test procedure.

time between welds can limit production speeds.

It's important to note that maintenance work on a CD welding machine requires special safety precautions. Unless properly discharged, the capacitor banks typically store between 1000 and 3000 V.

Regardless of the power supply type you choose, resistance projection welding nuts to high-strength steel is becoming the "new normal" and we must adapt. As always, the trick is to use the right machine, understand the process variables, and optimize the settings for best results. WJ

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