BY ALLEN M. AGIN

Q: I weld nuts to hot-stamped parts and am having difficulty getting consistent results. This includes parts where the nuts appear welded to the part, but sometimes pop off in transit to our customer. We also get inconsistent push-out test results. How come? I have asked this question many times and have gotten many different answers.

A: This is a great question. It also raises additional questions and challenges to be considered when making consistently good fastener welds on stampings with an aluminum silicate (AlSi) coating.

First, we should touch on two different types of steel processing: mill processing and in-plant processing. Understanding these are different processes is the key to some of the major reasons for inconsistent weld results.

Mill processing is the processing done at the steel mill, prior to shipment to the supplier or end user. Many conventional metals are stamped and welded just as they come in from the mill, with no additional treatment. Mill-processed steel is malleable and can be shaped using conventional stamping presses and processes. Hot-stamped boron steel is not malleable and requires in-plant processing to stamp it.

In-plant processing is done at an end-user plant, or sometimes at a supplier plant, where they have furnaces and stamping presses to form stampings after they come out of the oven. Hot-stamped or press-hardened materials must be formed using in-plant processing. During in-plant processing, the metal blanks are heated beyond 900°C prior to being formed in a press with water-cooled dies. The blanks are heated to increase the ductility of the steel, reducing springback during the stamping process. In-plant processing changes the metallurgical composition, multiplying the hardness from 50 kilopounds per square inch (ksi) to around 200 ksi. This new material develops an AlSi coating in the process. Welding fasteners to this material is much more difficult than to conventional steels. Think of it like pressing a ripe banana into tempered glass.

Why are my stampings different colors?

At first glance, this may seem like an unusual question until you look in your tote bin. Figure 1 shows an obvious difference in surface color (AlSi coating). This color inconsistency exists due to the variability of in-plant processing with normal everyday work schedules and adjustments. The color difference is caused by changes in the coating thickness due to deviations in line speed, furnace temperature, or die cooling from the ideal process parameters.

Does the color affect weldability?

Absolutely! Normally the steel used in production is processed at a mill, and what you get for production is generally consistent and the same color. However, during in-plant processing, color variations can occur, indicating a change in the thickness of the AlSi layers (see an example of the change in microstructure in Fig. 2). This changes the resistivity of the surface, which directly affects weld quality and repeatability.

What can I do to get consistent weld results?

The “best” textbook answer when using in-plant processing is to make sure there is no deviation from the recommended parameters of time, temperature, and die cooling for the stamping blanks. Even a slight change in the process can create a problem due to the AlSi coating.

The best real-world answer, however, is that holding a process like this to exact settings only seems to occur in laboratory conditions. Like an endangered species, it is almost never found in the real world. This brings us back to your original question.

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

This question comes up quite often. The answer depends on a variety of factors, including the following: in-plant processing, thickness of material, AlSi coating, projection style, nut/stud size, and weld specifications. With variations of any of these, you can get different answers from different people.

Today, the most common welding processes, when it comes to AlSi coated stampings, are capacitive discharge (CD) and medium-frequency direct current (MFDC).

Many years of lab testing and production have identified that a combination of short weld times, high cur-

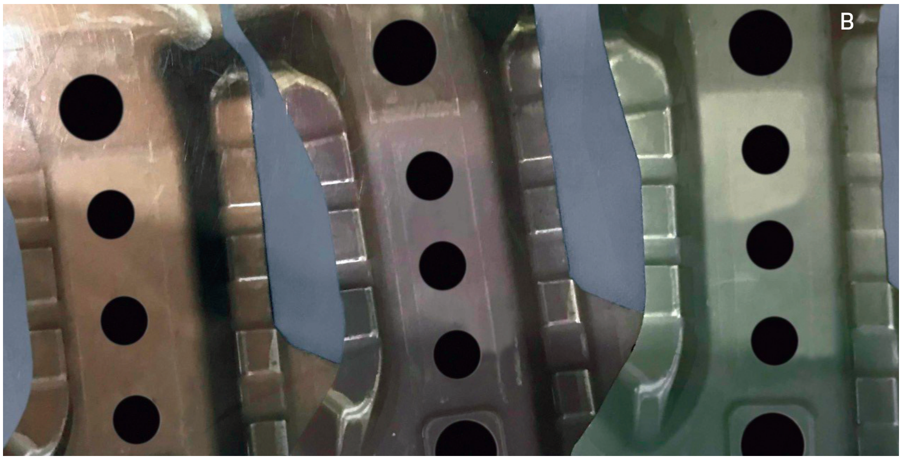

Fig. 1 — A, B — Showing color variations.

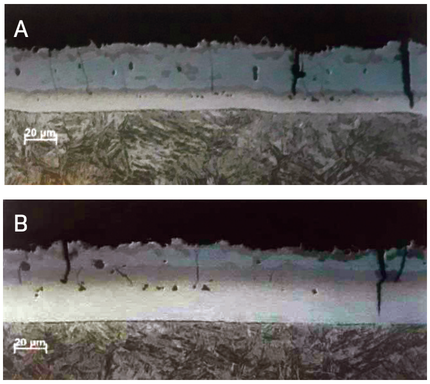

Fig. 2 — A — Thin surface microstructure; B — thick surface microstructure.

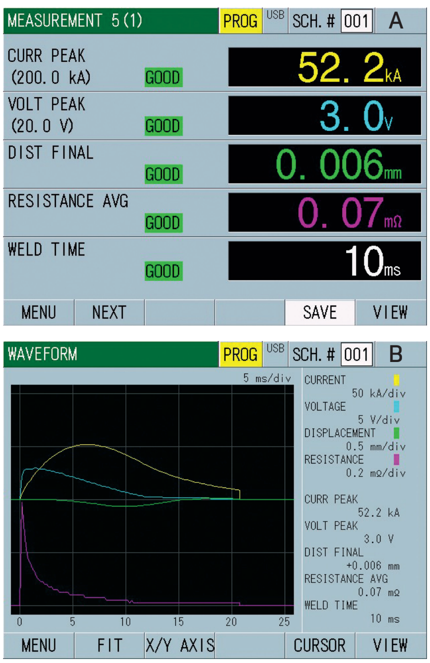

Fig. 3 — A — Weld measurements; B — graphed results.

rent, high force, and fast follow up deliver the greatest consistency. An example of these parameters for welding a M6 flange nut is shown in Fig. 3. Figure 3 shows the current output, time, and displacement when welding a M6 nut onto a 2-mm ALSi-coated material.

While a MFDC process can be ideal for the right application, it does require tight control of in-plant processing. A CD process allows for variations due to in-plant processing in real-world conditions, as described earlier. Figure 4 shows several examples of thickness differences in the multiple AlSi coating layers as slight process changes occurred due to variations in in-house processing control.

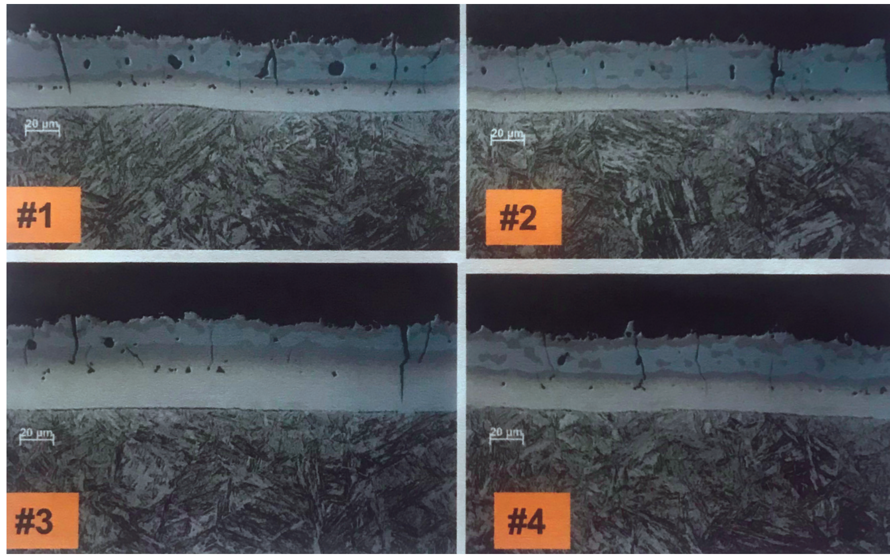

Fig. 4 — Four different microstructure surface thicknesses.

What other factors do I need to consider?

You may want to take the following factors into account:

- Primary power
- Water cooling
- Floor space/footprint
- Air filtration
- Electrode life
- Testing
- Rework
- Capital investment
- Weld quality
- Welder repurposing
- Life cycle cost
- In-plant processing

Expanding on a few of these factors, let's start with power supply. A MFDC system, including the latest "fast-rise time" type of transformer, can require up to 1000 ampere (A) of three-phase power and a 2200 A inverter. CD processes require a small fraction of that power. For example, one manufacturer's CD process only requires 30 A of single-phase 480 volts alternating current. Installation costs of the primary power supply, as well as power cost over the life cycle of the capital equipment, are substantial factors that should be considered.

Supplying chilled water can also be a significant cost to consider. For example, MFDC processes require significant water cooling for the weld control and transformer. A CD welding process that does not require water cooling for the control or transformer saves at least 8 gal per min (30 L per min). In high-duty-cycle CD applications, a small chiller might be recommended to cool the tooling. There are capital cost savings in buying a much smaller chiller, or not buying a chiller at all, not to mention the ongoing power savings from not running a large chiller.

Another often overlooked factor is floor space. Some capacitive storage banks are simply more space efficient. United States-built CD banks are typically much smaller than those sourced overseas. Recently, a large stamping company purchased CD welding machines based on price alone to keep the project cost down. The CD banks were three to five times the size of the domestic units they didn't purchase. The overall footprint of each machine was almost double what it could have been. Put together with the smaller chiller requirements mentioned earlier, the savings in facility investment would have been huge.

Rework is another major cost to consider. In another case, also due to upfront cost-saving measures, two automotive suppliers found themselves reworking lots of parts, and paying more than they had saved on the

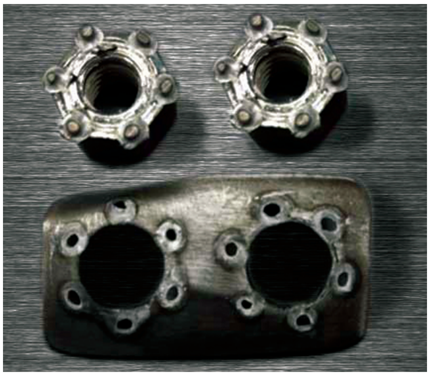

Fig. 5 — Overheated weld showing a large HAZ.

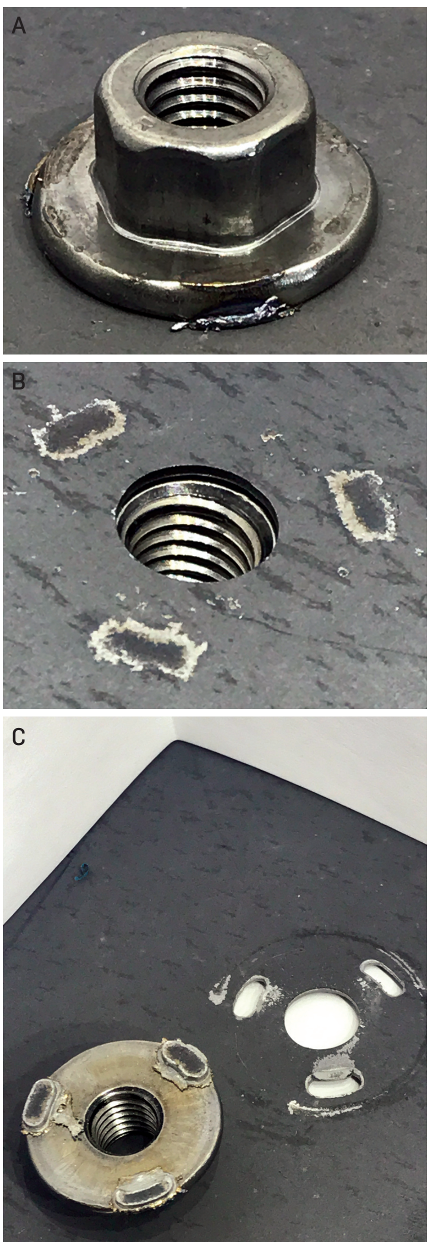

Fig. 6 — A — Showing almost no HAZ; B — showing bottom side again with almost no HAZ; C — showing nugget pull with almost no HAZ.

equipment purchase. They had chosen the MFDC process to weld stampings with AlSi coatings based on equipment price. They didn't recognize a variety of issues with their in-plant processing (some of which I've touched on above), so production welding yielded inconsistent results. Both companies were forced to implement "safety" gas metal arc welds (GMAW) to their fasteners, adding more weight to the vehicle and much greater production cost due to longer processing time, as well as additional personnel, welding gas, and consumables.

There are at least several other factors that I don't have the space to mention here. It is best to discuss all of these with a resistance welding machine builder who has a proven track record on hot-stamped materials. Designing your process for success should also include doing lab welding, testing, and performing a Design of Experiment (DoE) on your stampings before making a major investment.

I've been hearing about the heat-affected zone (HAZ). Why does this matter?

The HAZ is a very important, often critical, factor in all resistance welds. The ideal resistance weld utilizes the highest possible amount of heat for the 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. This may cause a change in hardness in the base material, which can lead to a material failure in the HAZ. Figure 5 shows what appears to be a good weld based on the number of weld nuggets, but with severe overheating leading to a weakened HAZ. In this case, the end user was using a MFDC power supply, and experiencing much lower push-out values than expected. Simply put, the metallurgy changed and the part was weakened due to excessive heating. Had the HAZ been much smaller, push-out values would have been much higher.

On the other hand, Fig. 6 shows examples of the desired HAZ and excellent push-out test results when using high currents and very short weld times. There is no visible HAZ around the projections, or around where they pulled.

As you can see, answering your original question is not simple. It raises many additional concerns that should be taken into account to create consistent and reliable welds.

In conclusion, one of the most important exercises you should consider is partnering with a reputable resistance welding machine builder who has the expertise, experience, and ability to demonstrate a variety of different processes when welding AlSi-coated stampings. While this demonstration can take place in the machine builder's welding lab, this demonstration should use your production parts and a range of their production welding equipment. This equipment should include both CD and MFDC welding machines with all necessary production features. Following this process will supply you with the absolute correct answers for your particular application, enabling you to consistently produce the strongest possible welds. WJ

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