

Q: Which type of transformer is better for the resistance spot welding of sheet metal, alternating current (AC) or mid-frequency direct current (MFDC)? I am mostly concerned with automotive sheet metal applications but would welcome any thoughts on this subject.

A: The decision to utilize either a MFDC power supply or AC transformer for resistance spot welding is as much a processing question as it is a welding question. To help illustrate this, the following discussion of which power supply may be better for a particular application can be broken down into several parts, including processing, facilities, and welding. I also think it is important to have some historical perspective on this topic for it actually has a part in answering the question. Finally, this topic has historically generated more than a little debate within the resistance welding community so do not expect everyone to agree with this answer.

The MFDC technology was originally developed for automotive resistance spot welding in the late 1970s as a joint effort by Square D and Goodrich. Square D focused on the weld control while Goodrich concentrated on the MFDC power supply. At that point in time, General Motors was a major customer of Square D and was heavily involved in the development process of this new technology. The major motivating factor in the technology development was a reduction in the weight of the transformer. That period in time within the automotive body construction arena witnessed the migration away from traditional manually operated handguns toward robot-mounted weld guns, particularly integrated resistance welding guns called transguns. As the robots of the day were rather limited in their capacity (figure about 60 kg for that time period), the only way to incorporate a larger weld gun design was to reduce the weight of other welding system components, specifically the transformer. A secondary motivation was that MFDC permitted weld guns with large secondary loop areas to achieve higher secondary currents, in some cases in excess of 20 kA. This level of secondary current was difficult to achieve even with the utilization of hip-mounted AC transformers.

When the new MFDC power supplies were released to the plants there was little, if any, discussion concerning the benefits of lower primary power demand, nor was there any mention of the effect MFDC had on material weldability. There are most likely two reasons for this. The



Examples of both an MFDC power supply (blue) and an AC transformer (green). The MFDC unit is rated at 170 kVA while the AC is rated at 65 kVA. The weight and external dimensions are similar; however, the potential electrical outputs are very different. The MFDC unit has an approximate current range of 5–45 kA (capable of welding aluminum) but the AC transformer would struggle to achieve a secondary current greater than 20 kA, mostly due to impedance limitations.

first is that the majority of body shops back then were electrically oversized with regard to primary power. Why? They were equipped to handle portable gun transformers. The primary electrical demand for portable gun transformers is huge (potentially ten times that of MFDC), and since these electrical systems were already in place, a capital cost reduction was not possible unless a “greenfield” facility was being launched. As a result, there was very little cost savings attached to the actual power system equipment side. The second reason had to do with the fact that the MFDC technology was in its infancy and the facilities engineer was not going to risk downsizing a plant power system on this new technology. The same thinking applied to the welding engineer with respect to weld quality and process robustness. Since the initial goal was mass reduction and increased secondary weld current capability, folks were not looking for, nor expecting, an improvement in material weldability.

The selection of AC vs. MFDC with regard to facilities and tooling is based on its own unique acceptance criteria. As with all choices, it is not entirely a black and white issue and some knowledge of the potential compromises and pitfalls is essential to achieve an accurate decision. From a facility perspective, the use of MFDC represents a major change in thinking as compared to AC. The following points should help illustrate the differences, and highlight both possible advantages and disadvantages for each type of power supply.

- MFDC permits equal three-phase current distribution and thus a more bal-

anced primary loading condition. An AC welding system only taps into two of the three primary bus legs and requires a fair amount of facility planning to ensure that each leg on the bus is subjected to relatively the same load. Also, because the single-phase loads are not synchronized, balancing the load on a three-phase distribution is nearly impossible.

- The selection of MFDC for a large volume installation, such as a new bodyshop, can result in reduced overall primary demand. This lower primary demand can translate into savings due to the lower costs associated with primary power distribution equipment (smaller circuit breakers, wire, etc.). But since switching from AC to MFDC requires changing from single-phase breakers and two-wire systems to three-phase breakers and three-wire systems, the true electrical facility cost may be negated. Another important consideration is that the typical AC installation requires primary cable rated at 600 V while an MFDC system generally needs higher rated primary cable between the weld control and the power supply.
- MFDC power supplies possess a broader current range than do their AC counterparts, so fewer transformer models are required to cover the full welding current spectrum. With MFDC it is possible to equip an entire body shop with two sizes of power supplies while it might take as many as ten different AC transformer models to cover the same current range.
- Within the world of general automotive

applications (up to ~25 kA) the cost of AC transgun transformers vary in price from \$800 to \$1500 while the equivalent MFDC units run from \$2000 to \$3500, depending on features. The same disparity can be seen in the weld controls required for each power supply with the MFDC suffering an approximate 20% cost penalty. A cautionary note on costs: This is one area where the application and volume can have a huge impact. Prices for the MFDC equipment used to be in excess of 2:1 over the comparable AC device, but that gap has narrowed considerably due to the economies of scale. That being said, the inherent complexity of a MFDC resistance welding power supply or weld control will most likely keep it more expensive than its AC equivalent for the immediate future.

- MFDC power supply water cooling requirements are significantly higher when compared to an equivalent AC unit, with the typical flow rate requirements twice those required of AC. The sophisticated internal water paths also dictate a higher differential pressure, and the physical conditioning (i.e., mechanical filtration, etc.) of the water must be better to prevent sediment buildup due to the tortuous water flow path. Conversely, the AC transformer is much more durable and less prone to failure with respect to water issues.
- The MFDC power supply has a much shorter life expectancy than its AC counterpart. This is due to the characteristics of a diode when it is thermally cycled and the resultant movement between the wafers in the rectifier packs. In essence the 'moving parts' of the MFDC power supply wear out. The typical life span averages 10–12 million thermal cycles, but can be higher. Additionally, the MFDC power supply is more susceptible to failure due to low water flow rates or excessive kVA demand. While these same afflictions are harmful to an AC transformer, the magnitude of the degradation is much less.
- The higher operating frequency of the MFDC power supply permits for a more controllable situation for the weld control, and results in the delivery of a more accurate weld schedule. MFDC is also less susceptible to the primary power oscillations in plants due to the output being derived from three-phase power rather than on a single-phase.

The selection of AC vs. MFDC with regard to weld quality is also based on differences between the two types of power delivery systems. However, unlike the items mentioned in the facilities discussion above, the effect of these differences on welding is not always clear. The subtle

nature of the differences between AC and MFDC and their possible effects on weld quality and process robustness really forces each application to be evaluated on its own merits.

There have been multiple peer reviewed papers published in many forums regarding the different welding characteristics of AC vs. MFDC, and the results are not always conclusive or consistent in determining which process is capable of producing better weld quality. These studies, which included advanced high-strength steels (AHSS), looked at many aspects of the two welding processes and ranged in scope from the physical properties of the weld to the effect of weld current conduction angle and its direct effect on the inherent inter-cycle cooling associated with AC power vs. the lack of inter-cycle cooling with MFDC. One auto company performed an in-house study to determine whether the polarity effects of MFDC current were significant. The responses studied included weld range comparisons, electrode life evaluations, and static and dynamic mechanical studies of weld strength. Despite all this hard work and analysis, an all-inclusive answer still has not been found. Put another way, while a particular application or specific material may benefit from utilizing either AC or MFDC, the results to date do not permit anyone to make broad statements with regard to material weldability such as "all galvanized materials weld better with AC" or that "all stack-up ratios in excess of 4:1 weld better with MFDC."

At the end of the day, there are not many automotive resistance spot welds that cannot be made with either AC or MFDC, and the selection of either of the two is going to be driven much more by facility and tooling considerations than welding. Bottom line, asking if AC or MFDC is better is like asking if a car is better than a truck. Without clarifying the criteria for a particular application the answer is really hard to determine.◆

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