Reducing the Ecological Impact of Arc Welding

Practical strategies are offered for reducing energy consumption when using various arc welding processes

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Arc welding processes consume a great deal of energy and are widely used in manufacturing. Practical strategies for reducing energy consumption are particularly important considering the need to create more eco-friendly manufacturing environments. This article explores practical strategies relating to arc welding power source efficiency, equipment setup, and welding technique to reduce the ecological impact of widely employed arc welding processes.

Improved Power Source Efficiency

Power source technology has matured significantly in recent decades. Modern power supplies use significantly less energy when welding as well as when sitting idle with the power on. Older transformer/rectifier power supplies have poor energy conversion rates during welding and have high idle power. Inverter power supplies require less energy when welding and have significantly lower idle power. Inverter power supplies with transistor technology are the most efficient when welding and when idling, and provide faster response times and higher pulse frequencies. Figure 1 shows power consumption while idling for three different power supply types (Ref. 1).

Typical utilization for manual or semi-automatic arc welding processes is 25%, meaning the power supply is idling 75% of the time. For a facility running three shifts per day, five days a week, and 52 weeks per year at this utilization, a trans-
former-rectifier power supply will consume 6177 kWh of power while idling. At a cost of $0.11 per kWh, this results in a yearly cost of $680 per power supply. An inverter/transistor power supply will consume only 749 kWh, resulting in a yearly cost of $82 per power supply. In this example, changing to a more efficient inverter/transistor power supply will result in a yearly savings of $598 per power supply during idle time. For a facility with 25 power supplies, this savings is $14,925 per year.

In addition to using power supplies that consume less power while idling, turning power supplies off when not in use is a simple method of reducing energy consumption. This can be accomplished by equipping power supplies with an idle time-out feature. Newer power supplies reduce power use by turning the cooling fans on only when they are needed.

Power Supply Rating

It is commonly believed that operating a power supply at or near its maximum rated load will cause damage or cause it to operate less efficiently; however, the opposite is true. Operating a power supply at a load below its rating can significantly reduce its efficiency. As indicated in Fig. 2, operating an 81% efficient power supply at only 25% of its rated load decreases the operating efficiency to approximately 65% (Ref. 2). By using power supplies with a maximum rated load closer to the expected operating parameters, manufacturers can take better advantage of increased-efficiency power sources and reduce energy consumption.

Parameter Optimization

Parameters can be optimized to improve the electrode melt-off efficiency, allowing more material to be deposited for a given amount of power consumed. This can be accomplished by increasing the welding current. While increasing the current alone may not be an option due to heat-input limitations, material thickness, or an open-root joint preparation, increasing the travel speed to maintain a consistent current/travel-speed ratio may resolve these issues. Figure 3 illustrates the increase in pounds of filler metal consumed per kWh of welding power at three different current settings for submerged arc welding in constant current mode with a 3⁄32-in.-diameter electrode.

Increasing the welding current from 250 to 425 A resulted in a 21.4% increase in the amount of steel filler metal consumed per kWh of welding power. This means that for the same amount of power, a greater amount of filler metal will be deposited.

Since no currently available welding power supply is 100% efficient, typical power supply efficiency ranges must be used to convert the data provided in Fig. 3 into something more meaningful. Figure 4 provides pounds of steel filler metal consumed per kWh of power at four different power supply efficiencies. These data can be used to estimate a cost per pound of filler metal deposited using the appropriate deposition efficiency number and power cost per kWh.
Table 1 provides a comparison between a submerged arc welding power supply operated at 250 vs. 425 A for one year in a facility running three shifts per day, five days a week, and 52 weeks per year. By increasing the welding current to 425 A, power consumption would be decreased by 3656 kWh, the cost of power would be decreased by $402, and the utilization required to deposit the same amount of steel filler metal would be reduced from 50% to less than 25%. For a facility with 25 power supplies, this represents a savings of $10,054 in power costs and the required arc-on time to do the same amount of welding would be reduced by 39,000 hours.

Deposition Efficiency

Table 2 provides typical deposition efficiency ranges for four consumable-electrode arc welding processes. Ranges are provided as deposition efficiency is dependent on spatter level and/or stub loss [shielded metal arc welding (SMAW)]. Process parameters can have a significant effect on the former, and welder technique can impact the latter.

A straightforward method of decreasing energy consumption is to change to a process that has an inherently higher deposition efficiency. There are, of course, trade-offs for any such change that must be considered. For instance, gas metal arc welding (GMAW) has a higher deposition efficiency than flux cored arc welding (FCAW); however, it is generally less tolerant to contaminants, is more challenging to use out of position, and requires a higher level of welder skill.

Another method of decreasing energy consumption is to increase the deposition efficiency of the arc welding process currently being used. Since the deposition efficiency of a process determines the percentage of filler material that is actually deposited into the weld pool, increasing it will increase productivity for the same level of power consumption. This can be accomplished by optimizing parameters for improved arc stability and droplet transfer to reduce spatter generation. A 5% increase in deposition efficiency will result in at least a 5% increase in the amount of consumed filler material that is deposited into the weld joint.

Pulse vs. Constant Voltage

Pulsed GMAW waveforms are used to achieve spray transfer at a lower average current than welding in constant voltage (CV) mode by employing a peak current and a background current. The peak current promotes spray transfer while the background current maintains the arc between pulses. Figure 5 illustrates the difference in current/wire-feed-speed ratios for 0.045-in.-diameter wire for the GMAW process in pulsed and CV welding modes.

At a wire feed speed of 350 in./min, the welding current in CV mode was 265 A, while the welding current in pulse mode was 235 A. This represents an 11.3% reduction in arc power.

Table 3 provides a comparison between robotic welding using CV GMAW vs. pulsed GMAW for one year in a facility running three shifts per day, five days a week, and 52 weeks per year. Due to the reduction in average current, the cost of power to operate one power supply was decreased by $695. For a facility with 25 power supplies, this represents a savings of $13,900 in power costs.

Resistive Heating of the Electrode

For a given wire-feed speed, the current output of the power supply is affected by the contact tip-to-work distance (CTWD). Due to the effect of resistive (IR) heating, increasing the CTWD will decrease the current needed to melt the electrode or increase the deposition rate for a given current. The effect is greater for smaller-diameter wires since they have a higher electrical resistance.

Figure 6 illustrates the effect of resistive heating on 0.063-in.-diameter solid...
wire using the GMAW process. In weld trials conducted at EWI, at a CTWD of 0.75 in., the current output of the power supply was 300 A. Increasing the CTWD to 1.125 in. reduced the current output by 23% to 230 A. Figure 6 also illustrates that welding in CV mode with the extended CTWD still required 300 A, which supports previous conclusions on the reduction in average current when using pulsed GMAW.

Table 4 provides a comparison between a single robotic welding operation with a 0.75-in. vs. 1.125-in. CTWD for one year in a facility running three shifts per day, five days a week, and 52 weeks per year. Due to the reduction in average current, the cost of power was decreased by $1441. For a facility with 25 power supplies, this represents a savings of $36,035 in power costs.

### Power Loss Associated with Cable Length and Gauge

For the purpose of clarity, the previous examples have been calculated assuming zero power loss through the welding cables; however, some amount of power loss is inevitable. Using an incorrect cable gauge can contribute significantly to power loss, as can excessive cable length. It can be calculated that at a welding current of 300 A using 4/0 gauge cable, a set-up with 10-ft-long lead and ground cables will result in approximately a 1.2% power loss. Increasing both cables to 50 ft will increase the power loss more than four times to approximately 6.1%. If the current-carrying capacity of the cable gauge is exceeded, this effect becomes more significant, as illustrated in Fig. 7.

Using the same parameters as the example above with a 0.75-in. CTWD, the power loss associated with 10-ft-long cable lengths will require an additional 682 kWh of power. The power loss associated with 50-ft-long cable lengths will require an additional 3648 kWh of power. This represents an additional $401 of power cost per power supply. For a facility with 25 power supplies, this represents a savings of $10,033 in additional power costs per year.

### Conclusions

This article provides a number of practical strategies for reducing energy consumption for arc welding processes. In addition to using more energy-efficient power supplies that use less power during welding and while idling, significant improvements can be made by implementing changes in equipment setup and welding technique to reduce the ecological impact of widely employed arc welding processes.

### Table 4 — 0.75-in. vs. 1.125-in. CTWD

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<th>CTWD</th>
<th>0.75 in.</th>
<th>1.125 in.</th>
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<tr>
<td>Average current</td>
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<td>230 A</td>
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<td>Voltage</td>
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<td>30 V</td>
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<td>Power supply efficiency</td>
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<td>Utilization</td>
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### References