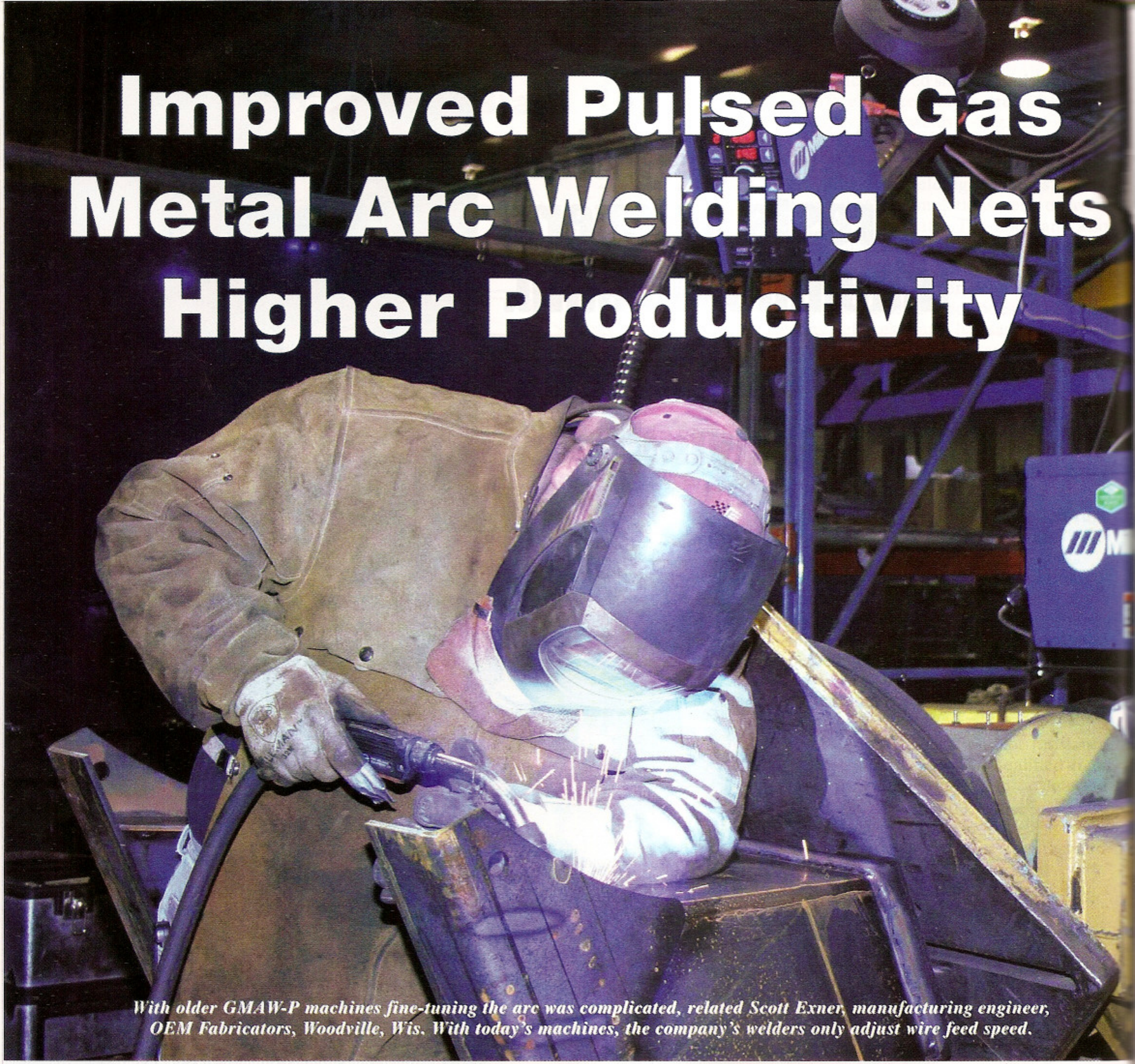
Improved Pulsed Gas Metal Arc Welding Nets Higher Productivity



With older GMAW-P machines fine-tuning the arc was complicated, related Scott Exner, manufacturing engineer, OEM Fabricators, Woodville, Wis. With today's machines, the company's welders only adjust wire feed speed.

Of all the recent advances in welding technology, some of the most exciting and beneficial are in the area of pulsed gas metal arc welding (GMAW-P). In GMAW-P, as the name implies, the welding current transitions or "pulses" between a high peak current, where metal transfer occurs, to a low background current, which maintains the arc but allows the pool to cool — Fig. 1. This creates a welding capability with increased deposition rates and decreased spatter.

Good applications for GMAW-P include those prone to such problems as incomplete fusion, warpage, melt-through, spatter, lack of pool control, and poor bead appearance. It really shines on thin materials, aluminum, and highly alloyed metals where precise heat control prevents melt-through or metal dilution. In many cases, it can replace gas tungsten arc welding (GTAW) yet provide a similar appearance, while providing the faster travel speeds and decreased training time associated with gas metal arc welding (GMAW).

Unfortunately, many of those who tried GMAW-P in the 1990s dismissed the process as too complex — and it was — often requiring a welding engineer to make it work. That has changed.

GMAW-P has now become accessible for most companies, with solutions available from out-of-the-box, all-in-one machines for small fabricating shops to multi-GMA process systems with programs optimized for mass production or more specialized applications, such as pipe fabrication and power plant construction.

Additionally, the complex interface of yesterday has been replaced by much simpler interfaces. Today's welding operator only needs to know a wire type, size, gas, and preferred arc setting, and then adjust wire feed speed to weld different thicknesses. This synergic or "one-knob" control, along with the ability to maintain arc length regardless of electrode extension,

CHRIS ROEHL and KEN STANZEL are with Miller Electric Mfg. Co. (www.millerwelds.com)*, Appleton, Wis.*

Today's pulsed welding technology enables welders to easily create weld beads of just the right size to eliminate excess heat input, overwelding, and postweld grinding

BY CHRIS ROEHL AND KEN STANZEL

has made it much easier to train new welders and for those new welders to achieve quality results quicker. For many employers facing the welder shortage, this capability alone is sufficient to turn to GMAW-P.

This, however, is only one of the benefits of current GMAW-P technology. Others include the following:

• **Decreased waste and rework.** Because GMAW-P allows precise control of the heat put into a weld, it eliminates excess heat that can lead to melt-through or warping on thin materials, especially aluminum, and provides better control for less-than-optimal fitup — Fig. 2.

• **Eliminate spatter and associated costs.** Today's systems monitor arc conditions thousands of times per second and can detect and clear a short before it becomes a problem or causes spatter — Fig. 3. This eliminates the need to apply and remove antispatter material. Parts can often go to painting without the need for postweld grinding.

• **Allow out-of-position welding.** Unlike spray transfer, which requires welding in the flat or horizontal positions, GMAW-P allows the pool to freeze slightly between current peaks. This means it can be used in out-of-position welding and eliminates the need to reposition weldments, as one would with spray transfer.

• **More productive aluminum welding.** While it used to require a skilled GTA welder to achieve a good bead appearance on aluminum, GMAW-P rivals gas tungsten arc welding in appearance and can replace that process in many applications, increasing travel speeds by 30% and reducing heat by 50% — Fig. 4. Additionally, becoming proficient in GMAW-P requires less training than with GTAW. Compared to short-circuit gas metal arc welding, GMAW-P ensures good fusion.

• **Maintain base metal chemistry.** Many applications, such as cladding with Inconel®, require precise control over the heat in order to maintain the chemistry and properties of the alloy — Fig. 5. The precision of GMAW-P provides this level of control. Systems optimized for these applications, both in manufacturing and construction, will contain programs for each alloy, shielding gas, and wire diameter likely to be encountered. This eliminates operator guesswork and helps less skilled welders become productive quicker.

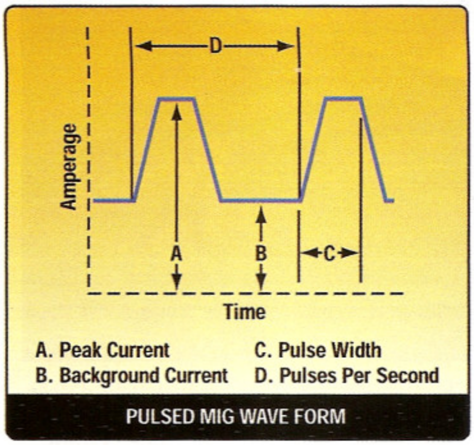


Fig. 1 — The components of a GMAW-P waveform.

• **Larger wires — less cost.** GMAW-P can also allow the operator to use larger-diameter wires. Larger-diameter wires are usually less expensive per pound than thinner wires. In the case of aluminum, larger wire is easier to feed and less prone to birdnesting.

• **Decreased training time.** Today's GMAW-P technology enables new operators to start making production-quality welds in less time, and it gives experienced operators even more control over bead appearance. It allows operators to hold a short (⅜- to ½-in.) electrode extension for better control over the weld pool. Further, it automatically compensates for contact tip-to-work-distance variations, maintaining a constant electrode extension to ensure a consistent weld.

Origins of GMAW-P

Pulsed gas metal arc welding was developed as an alternative to short circuit and spray transfer modes in the shipbuilding industry.

In short circuit transfer, the welding wire shorts against the base metal many times each second to deposit metal into the weld pool. Wire feed speeds, deposition rates, and voltages are typically lower than in other modes. It is also prone to producing spatter. One of its advantages is that, because it produces a smaller, cooler weld pool that solidifies quickly, it can weld in all positions.

In spray transfer mode, the wire does not short against the base metal. Instead, with higher heat input, the arc sprays a stream of molten metal across the arc, achieving higher deposition rates, but also producing a larger weld pool that limits its use to horizontal and flat position welding. With its higher heat, it is prone to melt-through on materials thinner than ⅛ in.

In pulsed spray transfer, commonly called GMAW-P, the current switches between a high peak current and a low background current. At the current's peak, a droplet is pinched off the wire and sprayed toward the weldment. The current then drops to a background level. During this period the pool is allowed to freeze slightly, providing the out-of position capabilities. Yet the process maintains many benefits of spray transfer, such as good fusion, high deposition rates, and/or fast travel speeds.

First and Second Generation GMAW-P

In general, there are several parameters considered when an engineer creates a pulsed waveform, as listed below.

1. **Peak current (heat).** Increasing peak current increases melt-off rate and arc length, and slightly increases average amperage and heat input.

2. **Background current (arc stability).** Increasing background current increases arc length, average amperage, heat input, penetration, and pool fluidity.

3. **Pulse frequency.** Increasing the pulses per second increases arc length, average amperage, and heat input.

4. **Pulse width.** Increasing pulse width increases arc length, heat input, and penetration and cone width.

5. **Pulse rise and falloff time.** Adjusting these can affect the sound and feel of the arc. Some of today's high-end machines tailor these values for specific applications.

These parameters will vary according to wire size and alloy, metal thickness, po-

Fig. 2 — With GMAW-P, operators at Metal Shark Aluminum Boats, Jeanerette, La., can make long welds without having ribs in place because the welding process does not cause any heat-related distortion.

sition of weldment, type of gas, desired bead profile, and operator preference.

In the preinverter days, however, when GMAW-P was introduced, very few of these parameters could be adjusted. Operators were limited to setting the frequency to 60, 120, and, in some cases, 180 Hz (multiples of input frequency) and peak amperage.

The introduction of inverters gave much more control over the pulse parameters. An inverter takes input power, filters it, and creates an output that is independent of input. They are lighter than conventional power sources, and some continue to provide a stable output regardless of wide fluctuations in input power.

Unfortunately, the ability to set all of the pulse parameters added a layer of complexity to the equipment that usually required a welding engineer to operate. There were no formulas. Typically, a welding engineer would set up the equipment in a lab and develop programs, each based on material, gas, and wire diameter. At 15 "teach points" in the wire feed speed spectrum, the engineer would adjust pulse parameters for optimal results. These results were then stored. If the operator chose a wire feed speed between the teach points (based on material thickness), the inverter would interpolate the nearest teach points to arrive at the parameters.

This was a laborious process, and most manufacturers developed a library of common welding programs. If the user was fortunate, the programs worked as intended; however, field conditions often didn't match the lab conditions and could necessitate altering the programs. This could mean having a welding engineer or the manufacturer reprogram each of the teach points. Or it could mean flying in a welding engineer to change the programs on site.

In addition, response times were much slower than with today's technology. Overshoots and undershoots, which refer to the control circuit's going beyond the targeted peak or background current, were difficult to control and could lead to arc outages. If a short circuit did occur, it could take several cycles to clear it. The responsiveness of the technology has been likened to driving a car and trying to adjust your direction by looking in the rearview mirror and only opening your eyes once every minute.

Unfortunately, this generation of GMAW-P machines turned off many companies to the possibilities GMAW-P offered.

Taking Today's Pulse

With current technology, response times have vastly improved to thousands of times per second, and the programs are more robust. Although top-line machines give the option to easily write one's own programs, today's user is freed from setting pulse parameters and is able to take immediate advantage of the benefits

Fig. 3 — By switching to a GMAW-P system for its mild steel, welded barbells, Iron Grip Barbell Co., Santa Ana, Calif., was able to eliminate the need to apply antispatter, while increasing productivity by 16%.

GMAW-P offers.

For example, one popular all-in-one GMA/GMAW-P machine contains pulse programs for mild steel, stainless steel, 4000 and 5000 series aluminum, and metal cored wire in various wire sizes and gas combinations. The user only has to dial in the wire size, type and gas, and adjust wire feed speed based on material thickness. An arc control switch allows the user to set arc preferences, such as length and width.

More advanced equipment contains more programs and is optimized for use in high-volume manufacturing, pipe fabrication, shipbuilding, power plants, and other applications where special alloys are used. It does this without sacrificing ease of operation. For instance, a welder who wants to lay down Inconel® cladding can simply turn to that program, set the desired arc length and wire feed speed, and start welding.

Today's technology offers adaptive GMAW-P, which will maintain arc length even if the electrode extension changes.

Fig. 4 — Pulsed GMAW (top) improves bead appearance and pool control so much that pulsed GMAW can substitute for AC GTAW (bottom) in many applications. Switching processes often increases travel speeds by 30% or more.

Fig. 5 — Welders become productive more quickly with the newer pulsed equipment because setup is quicker, less complicated, and requires less training, noted Brad Hooper, supervisor, Northeast Regional Maintenance, Covanta Energy.

As an example, when welding into a corner, adaptive GMAW-P machines will sense the voltage change and immediately increase or decrease power to maintain the arc length. This gives the user the ability to hold a shorter arc length for more control without fear of shorting the wire. This benefits both the novice welder who may vary electrode extension and the experienced welder who wants more pool control.

Constant Voltage (CV)

While some GMAW-P machines adapt to changes in arc length by varying the pulse parameters, the technology found in today's top-line machines also changes how they regulate voltage and current in the peak and background phases to optimize travel speed and pool control on different materials. The regulation of voltage in both the peak and background phases of the pulse cycle is ideal for increasing travel speed. While the need for speed is universal, materials such as aluminum and stainless steel require a softer arc to remain stable. The softening is added with a slope or curve to the fall edge of the pulse transition.

These systems may be optimized for specific uses, such as fixed automation, flexible automation, and semiautomatic and pipe fabrication, as well as specialized programs for aluminum and stainless welding and high-speed, out-of-position welding ideal for automated systems. New programs can easily be developed and shared, across the plant or across the country, and uploaded with a standard Personal Data Assistant (PDA).

Because of the sophisticated software in today's units, programs for controlling craters or for providing better arc starts are easily built in. On some of today's top-line models, a series of programs can be chosen ahead of time to be available at the click of the gun's trigger (or instruction from the robot controller), allowing an easy switch between preferred settings for various weld configurations.

Another feature found in some top models is the ability to switch between various GMA processes on the fly. Software-driven GMAW-P programs allow the user to use one wire and one gas for several processes and eliminate the need and time to switch between machines for multipass welding procedures.

Take Your Pulse Again

If your view of GMAW-P was shaped by experiences with the earlier technology, it's time to take another look. You no longer have to be a welding engineer to take advantage of the benefits GMAW-P has to offer. It's not a cure all. Conventional gas metal arc welding will always have a place. But for those who can take advantage of GMAW-P, from small fabrication shops to large manufacturers, double-digit productivity increases are the norm and not the exception.◆