

# Multipass orbital welding of pipe

## A primer for the prospective first-time user

By John Emmerson

First developed about 30 years ago by the aerospace and nuclear power industries, orbital mechanized welding is now a mature technology that is applied in almost every industry that uses welded tubes and pipes.

It is used in industries from semiconductor manufacture to shipbuilding, power plant construction to marine gas pipelines, chemical plant maintenance to food processing.

Relevant applications for orbital gas tungsten arc welding (GTAW) in this article are those in which the pipe cannot be rotated but must be welded in a fixed position, whether 5G, 2G, or 6G (horizontal, vertical, or at an angle).

This article addresses some of the most common questions and concerns that managers and engineers have about this process.

### **Mechanized GTAW Pipe Welding Versus Manual Welding**

A common misconception is that a machine can weld faster than a human being. This is not always so. The process involves a molten, fluid puddle of metal

influenced by gravity and surface tension forces, and these forces are identical for manual and machine welding.

Mechanized welding can yield high deposition rates and higher torch travel speeds, but ultimately the process limits any substantial improvement in these factors over manual welding. Increased productivity with mechanized welding is primarily the product of duty cycle and reduced defect rates. A machine cannot tire, take coffee breaks, or make mistakes.

Is mechanized pipe welding guaranteed to increase productivity? Not necessarily. Numerous considerations, such as work-flow and workpiece geometry, may not make mechanized welding cost-effective.

For example, if work flow cannot be arranged to allow welding of a number of similarly-sized pipes in uninterrupted succession or if the product requires an assembly sequence in which the pipe size is different for each subsequent weld, re-adjusting the weld head for each pipe size results in lost time.

Given a suitable application, mechanized welding often achieves a 70 percent duty cycle versus 20 to 25 percent for manual welding. Productivity realistically can increase threefold over manual welding. However, this level of improvement cannot be attained unless work flow can be

arranged to maximize arc-on time. If only one weld can be made, followed by an hour of processing before welding can resume, mechanized equipment does little to improve productivity.

This sometimes is the case in field fabrication, when equipment must be moved from one weld site to another. Just the opposite often can be true, however.

For example, physical access to the weld may be a fundamental factor in productivity. Field pipe welds frequently must be made in power plants and chemical manufacturing facilities where a manual weld that takes two hours can be made by a machine in 10 minutes. Frequently, access to welds in both field construction and maintenance is so difficult that manual welds only can be done using mirrors to view the backside of the weld or require two welders on both sides of the joint to make one weld.

Maintaining quality and control of weld parameters also may override duty cycle considerations. For instance, if welding personnel cannot achieve specified quality standards, duty cycle becomes a secondary issue.

Many of the alloys available today require tight control over weld parameters such as heat input. Duplex stainless steel and INCONEL® alloys require tight regulation of heat input to maintain desired metallurgical properties in the weld deposit and heat-affected zone (HAZ) and to avoid defects such as cracking.

If weld quality is not a major concern, investing in mechanized orbital equipment likely will not provide sufficient returns. However, if a company's application requires that welds adhere to codes such as American Society of Mechanical Engineers (ASME) section IX, B31.1 or B31.3, rapid payback can come with reductions in weld defects and subsequent rework.

Most companies can achieve sustained defect rates of less than 1 percent with mechanized welding. Companies frequently benefit from relaxed quality control mandates when they use this technology. For example, 100 percent radiographic inspection may be relaxed to a 10 percent inspection sampling.

## Components of a Pipe Welding System

The systems on the market today generally have the following components:

1. A weld head that carries and manipulates the torch
2. A power source that provides both weld head control and programming, as well as current output programming
3. A remote pendant for system control away from the power source
4. A water recirculator that provides torch and possibly weld head cooling

For the purposes of this article, weld heads and power sources are discussed.

## Weld Heads

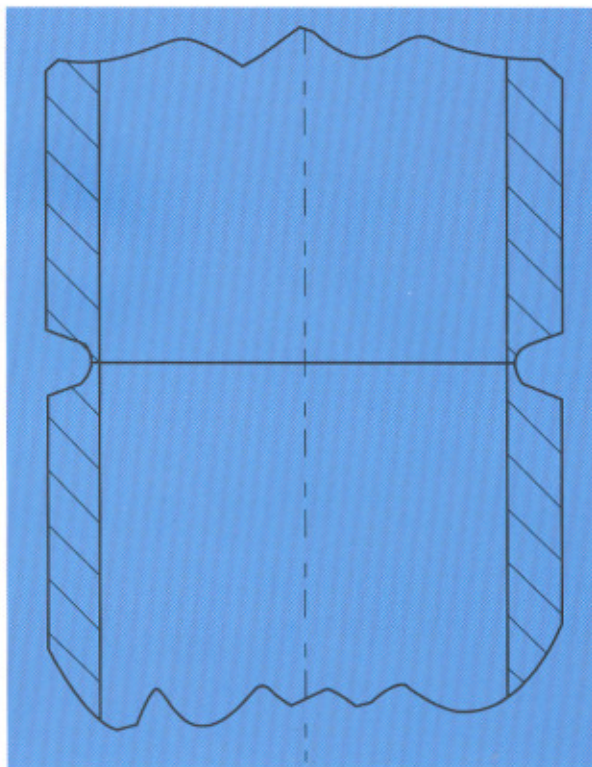
Weld heads for multipass welding typically feature:

1. Torch rotation.
2. Filler wire feed capability
3. Electronic control of arc length (arc voltage control).
4. Torch oscillation (weave) capability with programmable width, speed, and independent end point (sidewall) dwell times.

A variety of weld heads have been developed to meet specific application requirements and constraints. Weld heads fall into one of two categories—full function in place or full function orbital.

**Full Function in Place.** Full function in place heads adjust to clamp on pipes within a specified outside diameter (OD) range. An adjustable, lever-actuated clamp holds the head on the pipe and remains stationary. A torch and other mechanisms mount on a rotating module.

The filler wire feeder may be entirely mounted on the rotary portion of the head, or it may be floor-mounted with a conduit connected to the rotating module. Floor-mounted wire feeds allow the use of larger spools of wire but may sacrifice wire feeding accuracy.



**Figure 1**

*A J-prep, in which two ends of pipe are butted together, is a popular method of preparing pipe for automatic welding.*

These heads incorporate electronic arc-voltage control and electronic torch oscillation. Some models may use a mechanical follower to control arc length, but technically, these are not full function and have limitations for multipass welding.

This type of head installs rapidly on the pipe. Each model welds a finite range of tube and pipe sizes. Radial clearance requirements depend on pipe OD. Head mechanisms cannot be water-cooled, so they are most suitable for alloys that do not require preheating.

This type of head can be installed rapidly on the pipe and generally requires less axial straight length of pipe for mounting. No hand tools are required for mounting the weld head on the pipe. Some models include a clutch for rapid cable unwrapping at weld completion.

**Full Function Orbital.** Full function orbital heads feature torch rotation, filler-wire feed, electronic arc voltage control, and electronic torch oscillation. Unlike the in-place head, however, the entire weld head mechanism rotates around the workpiece.

The head attaches to the pipe using a metal band or guide ring fabricated to match the size of the tube or pipe. Generally, the guide ring attaches to the pipe, and the head is installed on the ring afterward, though some models retain the guide ring and both are installed simultaneously.

It takes slightly more time to install these systems than to install an in-place head. This type also may require a longer straight length of pipe for mounting.

This type can cover numerous pipe sizes within the range of one weld head. Radial clearance remains constant on all pipe sizes, and head design permits water cooling of the body, which allows it to be used on alloys requiring preheat.

## Power Sources

The physical size and weight of the system power supply may be an important consideration. Some systems that are not very portable might be perfectly acceptable for a fabrication shop. On the other hand, portability is key for field use. Many inverter-based power sources can be moved by one or two people without equipment.

Input voltage for the power source is another important consideration. Fabricators generally have access to any input voltage, but a field contractor may need a specific, three-phase voltage at a job site. If a motor generator provides the power, a single-phase power source may be in order. Some power sources operate on one specific voltage, while others can operate with a range of input levels, single- or three-phase.

A power source output of 200 to 300 amps generally suffices for conventional mechanical welding.

An *orbital welding* power source integrates the controls that operate the various weld head functions with the power source. A *standard power* source can provide output power only and cannot be used for mechanized orbital welding. In addition, multipass welding requires

multipass programming, which usually is done with an integrated microprocessor and custom software.

**Analog Power Sources.** Analog power sources are programmed by entering the desired speed, amperage, and other parameters on dials and putting the machine into motion with mechanical switches.

The units allow one pass (one orbit around the pipe) to be programmed. When multiple passes are required, welders must stop the machine, reset the dials for the next pass, and restart the weld. The alternative is to change dial settings on the fly.

Features on analog power sources include:

1. Easy-to-understand operation.
2. Good tolerance of environmental extremes.
3. Simple maintenance requirements.

However, analog power sources cannot lock out unauthorized changes in critical parameters, and they do not store programs.

**Microprocessor-Based Power Sources.** Microprocessor-based systems have the following features, among others:

1. Many levels of programming for all parameters
2. Multiple passes possible without stopping
3. Weld program storage
4. Solid-state data cards that allow program transfer between systems or off-line programming on personal computers
5. Programmable limits that prevent changes to critical weld program parameters

Microprocessor-based units require a longer learning curve than do analog power sources. Most weld programming is done by the welder using the equipment, so most programs use simple prompts that require little computer literacy.

### Creating New WPS/PQRs

Many people believe, falsely, that substituting mechanized pipe welding for manual techniques means that a new Procedure Qualification Record (PQR) and Weld Procedure Specification (WPS) must be done.

The ASME code, section IX, defines

welding variables under section QW-250. Nonessential variables are subsequently defined in section QW-251.3.

Variables for GTAW are listed under QW-256 with nonessential variables listed under subheading 256.2. By definition, a nonessential variable is one that may be changed without requiring a rewriting and subsequent requalification of the WPS/PQR. The code specifically states that a change from manual to machine welding is a nonessential variable.

In addition, joint design—including bevel geometry and fit-up gap—are nonessential variables and may be changed to accommodate machine welding.

### Bevel Geometry

In mechanized welding, three tools are critical—pipe beveling equipment to help ensure repeatable pipe end geometry, fit-up tools to help ensure reasonable fit-up for tack welding, and mechanized pipe welders to help ensure a repeatable weld process.

Some shops may purchase an orbital welding system but balk at spending additional money on pipe-prepping tools that can help ensure repeatable, accurate bevel geometry.

Computerized pipe welding systems are essentially simple machine tools. They unerringly repeat the programmed motions and change functions at the proper moment. They cannot, however, compensate for a changing bevel geometry and poor fit-up.

If shops are unwilling to spend money on pipe end-prep tools, they probably will not achieve code-acceptable machine welds. To meet the need, numerous manufacturers offer portable pipe-prepping tools with electric, pneumatic, and hydraulic drives.

Pipes with wall thicknesses up to .125 inch (3 millimeters) can be welded in a single pass. If wall thickness is greater than this, a multipass technique usually is required.

For smaller pipes and boiler tubing, a standard V-bevel with a slight gap is adequate, if not optimal, for welding most materials. However, the most suitable prep for automatic welding is a J-prep (see **Figure 1**) with the pipe ends butted together.

An extremely skilled welder can use a

standard V-bevel with an orbital head, but this ignores the most common rationale for mechanized welding—lack of skilled welders. Equipment manufacturers generally recommend using a J-prep.

### Training

One of the most common mistakes is purchasing equipment to meet an ongoing contract deadline and expecting welders to become instant experts.

Three to five days of direct instructions by a factory technical specialist are usually required for multipass mechanized welding systems. Welders typically need several weeks after that to reach full proficiency.

Welders must have time to learn the limits of the machine's capability and make some inevitable mistakes. Too frequently, welders are expected to immediately begin using the equipment in production, which can lead to mistakes on expensive production workpieces. Just as in learning to drive a car or operate a new software program, it takes time before operation becomes second nature.

Pipe should be fit up and tack welded with care, but some variability is to be expected. Welders learning to use the machine must develop a sense of just how much variability that orbital pipe welding system can be expected to accommodate.

Bypassing the learning curve is impossible. Unfortunately, many first-time users do not realize the importance of training and the length of the associated learning curve that allows welders to become proficient and achieve the productivity possible with these welding tools.

### Recommendations

Manufacturers should weigh the costs and benefits of a mechanized welding system the same way they would for a new computer system or machine tool. Waiting for the start of a big job as the impetus for evaluating this kind of equipment is a mistake.

All of the orbital multipass pipe welding systems on the market today are equally capable of making repetitive welds that meet code standards. However, buyers

should beware of claims of "higher welding speeds" or "superior productivity." Weld speed ultimately is determined by physical forces and not a unique capability of the weld head or power source.

Prospective buyers should compare equipment according to features and ease of use in specific applications. They also should determine that a vendor can provide rapid response if service is required and how much local support can be expect-

ed from the factory sales representative.

For companies uncertain whether machine welding is appropriate for their applications, renting before purchasing is a good option. Many manufacturers offer rental programs with purchase options, allowing first-time users to evaluate machine welding without making a purchase commitment.

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