

AUTOMATED NARROW GAP GAS TUNGSTEN ARC WELDING (GTAW) – DRIVING DOWN THE COST OF ENERGY

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INTRODUCTION:

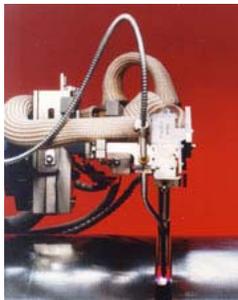
While the increasing cost of energy is a constant concern, there is little doubt that the need for electrical power will increase over the next several decades. The Department of Energy predicts that the demand for electricity will increase 50% by 2030. Despite recent events in Japan, at least some of this energy will be supplied by nuclear power generation. Existing U.S. nuclear power plants were constructed using 1960's and 1970's technologies, relying mostly on manual techniques. New nuclear power plants overseas have incorporated automated GTAW and other higher deposition welding processes. In order to be competitive, U.S. commercial nuclear component manufacturers and construction firms can take advantage of current advances in automated welding technology. Automated GTAW narrow gap technology is now sufficiently advanced that the next generation of power plants are being designed to incorporate this technology which reduces the cost of components and assemblies of the most critical parts of the power plants.



Heavy-duty nuclear component
Babcock & Wilcox

Babcock & Wilcox (B&W), the only manufacturer of commercial nuclear heavy components in the United States, has successfully incorporated narrow groove Gas Tungsten Arc Welding (GTAW) into the component manufacturing process. High quality weld deposits with excellent properties have been achieved while reducing heat input, shrinkage and residual stresses that are specific problem areas for more traditional joint preparations in thick-wall weldments. The capabilities of modern GTAW power supplies, new developments in torch design, in conjunction with narrow groove geometries, enable B&W to provide precise control over the process, while avoiding the lack of sidewall fusion defects that have been the common drawback to narrow gap welding.

NARROW GAP TORCH DEVELOPMENT



Narrow gap torch. *Arc Machines, Inc.*

Although narrow gap welding has been around for a long time, prior to the development of the rotating tungsten narrow gap torch (RT-NGT) in the early 1990s by Arc Machines, Inc. and Arc Applications, Inc., lack of sidewall fusion was a common problem in extremely narrow groove widths. A prototype RT-NGT that rotated a tungsten electrode with a 15 degree lead angle from side to side during welding with an associated synchronizing mechanism allowing the wire feed nozzle to move with the electrode, was built, tested, and delivered to B&W in the early 1990s. From this beginning, technical obstacles were gradually overcome so that narrow gap technology can now be used routinely with some torch configurations in groove widths as narrow as 0.375" at depths up to 6.00" and other designs for grooves approximately 0.6" wide up to 12" depths.

The accepted approach for narrow gap weld development has been to design custom torches for each application. The end user, the equipment manufacturer, and the welding application company have all worked together to design and develop equipment, troubleshoot, and implement the process. Special torches have been designed for applications at various depths and widths of the groove and several different torches may be used on a single heavy-wall weld. At depths of 3.00" or less a more conventional narrow groove GTAW torch has been designed by Arc Machines that does not utilize the RT-NGT process.

Because the cost of a set of equipment rises with increasing levels of automation, each application should be reviewed for critical needs. At the most basic level, a conventional narrow groove torch with manual tilt and wire manipulator is the simplest and least costly. At the top level are remotely operated RT-NGT and conventional narrow groove GTAW torches with motorized tilt and wire manipulators that are dedicated to the most critical welds. Various combinations of manual and motorized axes are available for intermediate applications.

Within the confines of a narrow gap groove, gas coverage requires special attention to insure weld quality particularly when welding out of position. There must be adequate screening in the torch gas cup design to seal properly around the tungsten and achieve good coverage with laminar flow. Initially, developed torches have been modified to improve shielding by adding screening and sealing around the periphery of the cup. Auxiliary shielding is beneficial when welding near the top of the narrow groove.

REMOTE VISION SYSTEMS

Application of automated narrow groove technology would not have been feasible without a concomitant development of remote vision systems which provide a clear view of the weld pool while filtering the arc. The deeper and narrower the weld groove, the more critical it is to have a clear view of the welding arc and surrounding area. The challenge to achieving adequate viewing of the entire weld area including the arc is the very large dynamic range between the lightest and darkest regions in the welding area. The extreme contrast ratio is such that there were no video cameras capable of delivering usable images within this range.

AMI has reduced the contrast ratio by 4 orders of magnitude using a patented camera and lens system to bring the complete image within camera range. This system reduces the lens brightness by 75-95% while permitting visible light from the surrounding region to pass the camera with very little differential attenuation. Currently, remote viewing systems on the narrow groove and RT-NGT torches feature very small digital cameras mounted on the weld head coupled to monitors located at a convenient distance. When two cameras are used, both the leading and trailing edges of the weld pool can be viewed, permitting the welding operator to accurately monitor the weld in progress. The vision system has no moving parts which eliminates maintenance problems, and the camera is water cooled which is essential when used in preheat temperatures of 120° F or more.

HEAVY-DUTY WELD HEADS

B&W worked with AMI to develop a new heavy duty weld head, the Model 52, to support the weight of the accessories, motors, cameras, etc. used with the RT-NGT torch. The head provides more responsive and reliable voltage control which is critical with the narrow groove process. On larger diameter weld joints, multiple weld heads equipped with narrow gap torches can often be positioned and run on the same track to increase productivity and there is some evidence that the use of this technique results in less distortion.

ADVANCED MICROPROCESSOR-BASED GTAW POWER SUPPLIES

B&W purchased newer model advanced microprocessor-based GTAW power supplies, the Model 415, more than 5 years ago. B&W also use power supplies and controls from other manufacturers in conjunction with AMI NG torches. The newer Model 415 GTAW power supplies are designed to be versatile automation position control and power supply systems. The basic system includes a complete complement of welding controls, as well as water cooling for the torches and cameras. The programmable Windows[®]-based power supply/controller provides up to 400 amps of welding current. The machine is easy to operate and almost all of its function ranges and modes can be defined by the user to exactly match the weld head or fixture being used. It can also be used to turn on and control ancillary equipment such as turn tables, positioners, side beams and hot wire power supplies.

MANIPULATOR-BASED SYSTEMS

While many applications with these power supplies and NG torches involve the use of orbital weld heads, additional optional closed-loop motor servos and/or open-loop motor manipulator controls make it possible to use the power supplies for work-cell manufacturing environments or for use with custom weld heads having unique functions.

Downhand welding is always easier to accomplish than out-of-position welding but it is not possible to do this with nozzles or joints that are eccentric to the part. Eccentric joints must be welded orbitally, but large vessels and components that can be rotated and that have a concentric circular weld joint, can be welded down-hand in the flat position or in the horizontal position using turning rolls, lowboys or positioners which may be controlled by the welding power supply. The manipulator-mounted system, the AMI Model 2, uses a series of standardized motion stages for functions such as AVC (Arc Voltage Control) which controls the arc gap, and torch oscillation together with onboard wire feed for the variety of torches. The system is typically mounted on a beam or manipulator that is moved into position on the weld joint.

SPECIFICALLY DESIGNED GROOVE GEOMETRIES

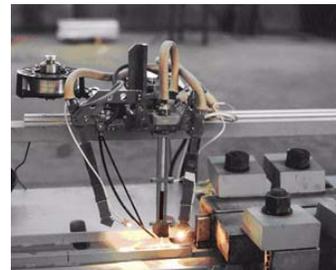
The narrow groove weld joint using the rotating tungsten narrow gap torch was originally developed using a single bead per layer technique with the weld bead going across the entire joint from sidewall to sidewall. This technique is usually applied with grooves less than 0.60 inches across the root and included angles of 0 to 2° at thicknesses up to 12". With the more conventional NG torch, similar groove widths with a groove included angle of 8° at thicknesses up to 4.25" were developed. This torch used a two bead per layer welding technique to insure weld bead side wall tie-in quality as well as the desired deposit properties.

In certain materials the single bead technique was found to result in strong directional grain growth patterns that could result in some reduction of deposit properties. To counteract these affects, another approach was developed using a split bead deposit technique. The split bead technique can be performed with the rotating tungsten NGT using a narrower oscillation width or simply using a fixed tungsten torch with narrow or no oscillation. While both single bead or split bead techniques are used for welding out of position, split bead techniques are better suited for 2G horizontal applications.

Several bead deposition techniques were developed to achieve and maintain the desired weld deposit profile in the 2G (pipe vertical) position. The effects of gravity with the single bead technique resulted in sagging and bowing out at the lower sidewall which also affected lower sidewall penetration. Arc Applications developed a series of techniques depositing a bead against the lower side wall before running single or double thinner beads above the first in order to maintain the desired weld profile and to achieve consistent weld quality. Thinner upper beads were also effective at tempering the underlying weld metal and heat affected zone when welding high strength low alloy steel.

LIMITATIONS AND BENEFITS OF NARROW GROOVE WELDING

Automated narrow groove technology is very efficient for out-of-position applications and is the process of choice if reduced distortion with high quality is required. Narrow gap techniques and the associated equipment can be utilized daily in production manufacturing environments resulting in repeatable high-quality welds. Using a single or split bead per layer deposit, narrow groove welding techniques nearly eliminates weld bead positioning subjectivity by the operator that has often resulted in lack of fusion defects with conventional welding geometries.



Narrow gap torch for 12" thickness.
Arc Applications, Inc.

An additional bonus is the low volume of filler materials needed to fill a narrow gap joint compared to more standard joint preparation for thick-wall weldments. With the use of more and more engineered materials, filler material cost is a significant factor and another reason for the increasing application of narrow gap welding.

FUTURE APPLICATIONS OF NARROW GAP TECHNOLOGY

Among the next generation of power plants will be a scalable, modular, passively safe, self-contained Advanced Light Water Reactor (ALWR) system in which the nuclear core and steam generators are contained within a single vessel. B&W is currently designing the mPower™ small modular reactor (SMR). The mPower™ small modular reactor can be built in the factory and shipped to a customer's site greatly reducing field erection time. The modules

will be installed underground to assure safety. Single modules that generate 125 MWe can be paired as multiple units to meet customer demand.

The next generation power plants will use all high strength low alloy steel and with this material, heat input is a concern. Since a high quality deposit with excellent strength and toughness is required for nuclear welds, one of the processes being considered for the mPower™ small modular reactor is RT-NGT as well as conventional narrow groove GTAW. The reduced cost of welding made possible with NGT will reduce the cost of the mPower™ reactor manufacturing.

Automated narrow gap technology has also been used in the ITER international thermonuclear research and engineering project for development of electricity producing fusion power plants. As part of the initial project for the Fusion Reactor Segment assembly in Japan and Magnet Coil Casing in Italy, Arc Applications, Inc., and Arc Machines, Inc., developed an extended rotating tungsten narrow gap hot wire GTAW for welding up to 12” wall thicknesses. Feasibility of out-of-position welds with the extended range hot wire torch including horizontal, and both vertical up and vertical down positions were demonstrated.

The ITER project is a consortium of members from the European Union, India, Japan, People’s Republic of China, Russia, South Korea and the United States. The fusion reactor has been designed to produce 500 MW of output power for 50 MW of input power, a ratio of 10 to one which has not been achieved with previous fusion reactors. Nuclear fusion taps energy from reactions like those that heat the Sun and is seen as a cleaner approach to power production than nuclear fission and fossil fuels.

CONCLUSIONS

Application of automatic narrow groove welding systems has resulted in high quality weldments with consistently low repair rates while increasing productivity. In B&W’s commercial nuclear manufacturing facilities in the United States, narrow gap welding has essentially replaced conventional wide-angle welds in sections of one inch and greater thickness with the result of driving down costs. Use of this technology in power generation, offshore and other applications demanding high quality coupled with lower cost, has the potential to significantly reduce the cost of energy. Other fabrication sectors, with similar requirements, are also taking advantage of these capabilities and benefiting from this industry-leading work.

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