Trend in Arc Welding Equipment Development and Present Status

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Among the various fusion welding processes "arc welding processes" are dominant in terms of their popularity, usage and weight of weld metal deposited. A weldment is the result of interaction of parent metal, filler metal, equipment, process, parameters and operator skill and/or knowledge. While for a given fabrication, parent metal, filler metal, operator skill and/or knowledge cannot be varied, the welding equipment provides an opportunity for varying the electrical welding parameters to obtain the desired deposited metal characteristics such as contour, finish and burn-off rates etc.

The design and development of welding equipment for metal arc welding processes are, therefore, critical. The electrical characteristics of the equipment will have to match the requirement of the different processes and to possess controls to vary the variable welding parameters to adjust the deposition condition for giving optimum output and quality. The design and development of arc welding equipment is, therefore, a highly specialised branch of electrical design.

In this article, a brief review of the trends in developments of arc welding equipment as applied to the following metal arc welding processes is made: (i) manual metal arc welding (MMA): (ii) tungsten inert gas shielded arc welding (TIG); (iii) plasma arc welding; (iv) metal inert gas shielded arc welding (MIG); and (v) submerged arc welding (SAW).

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Manual metal arc welding (MMA)

Among the above processes, the most popular and widely used one is manual metal arc welding which employs a consumable flux-covered stick electrode and necessary electric power is derived from either a transformer or a transformer rectifier or a motor generator or engine driven generator. Fifty years ago, electric arc welding would mean only a basic stick electrode and a hand-cranked transformer and an operator. Since then, tremendous progress has been made in widening the field of application of welding technology both with respect to the different types of metals and alloys which can be joined and also newer and more sophisticated welding processes.

Manual metal arc welding continues to enjoy the dominant position in terms of the total weld metal deposited. The designs and shapes of equipment have also undergone revolutionary changes in catering for the ever-increasing demands of weld quality—hence the advent of various types of transformers, transformer/rectifiers and rotating machines like motor generators and engine driven generators.

Transformer

Manual metal arc welding power sources are constant current type which means a minimum variation in welding current with arc length changes. Depending upon the type of materials to be welded and their thickness the, current has to be varied. Broadly, the following types of transformers are available today: (a) Oil-cooled transformers with tapped chokes or moving core, and (b) air-cooled transformers with moving core chokes. While oil-cooled sets are certainly preferred for their longer life are consistent and reliable performance, improved designs have rendered the air-cooled sets also equally attractive today. Greater care is, of course, necessary in designing the moving systems.

With a single operator transformer, only one welder can weld at a particular time. To cater the demands of the ship building and other heavy industries, multiple operator sets have been developed where a number of welders may carry on simultaneous welding from the same power source with individual current regulators at the welders' disposal. Up to 12-operators multiple operator sets are available, and this has led to considerable economy in capital investment. Remote control device for current variation when the are point is situated far away from the power source is a useful innovation so far as the shipping and construction industries are concerned.

Apart form the changes in the types of transformers over the years, there has been substantial re-thinking in the basic designs particularly in achieving greater economy and reliability.

In developed countries like the USA, Europe and Japan, cold rolled grain oriented stalloy sheets are essentially used in manufacturing transformer cores and they are die punched. This alone gives rise to considerable economy of manufacture in scale with the added advantage of better magnetic characteristics. Another trend is to go in for higher class insultation materials which retain insulation properties at relatively higher temperatures and over longer periods.

In India today, the core materials are mostly imported and that, too, not always from the same source. Obviously, this poses a problem in obtaining identieal characteristics with a frozen design of a transformer when core material varies from supply to supply in its magnetic properties. Again the uptake or the volume of manufacture does not probably make it a lucrative proposition for the manufacturers to go in for punched cores. Various insulated conductors that are manufactured today are also not freely available in sections and shapes required. Again the most efficient and popular conductor material, copper, is scarce. Aluminium is being extensively used in replacement ; jointing problems have largely been solved. Since aluminium resources are in abundance in India, its usage as conductor material is bound to increase in the coming years.

Manual metal arc welding transformers both oil-cooled and air-cooled with natural or forced cooling in hand-welding ratings i.e. 60% duty cycle, of 100 to 500 Amps are manufactured in the country and are available freely. To meet the specific needs of ship building and repair industry, site construction of power plants etc. electronic/electrical devices for controlling welding current from a distance as well as reducing the open circuit voltage to a low level when the arc is not struck are available as accessories. To satisfy the needs of the above industries when preference for multi-operator transformers is shown, such equipment for 3, 6, 9 and 12 operators with necessary power factor compensating capacitors and regulators with safety inter-locking devices are available from indigenous manufacturers.

Transformer/Rectifier

While in earlier days, selenium metal plates were mainly used as rectifier elements, these have since given place to the comparatively new silicon devices. Successful development and indigenous manufacture, coupled with satisfactory availability of good quality silicon diodes, have made it possible to make the transformer/rectifier welding power sources more compact and less cumbersome. As was the case in developed nations, here also people did have inhibitions and reservations in putting silicon diodes to welding loads which produce transients. Selenium plates as such have decidedly better transient characteristics but with proper design configurations and protective elements in the circuit, silicon diodes are observed to be equally efficient. Once this problem was taken care of, on all other considerations silicon diodes score over selenium plates in their usage in welding power sources.

Here again, easier configuration of the stacks could be achieved if reverse polarity diodes were freely available. The modern trend is also to use transistorised or thyristorised circuits for current control in power sources. There is also work going on to bring in pulsing techniques in manual metal arc welding power sources.

While all the four types viz. transformer, transformer/rectifier, motor generators or engine generators are in use in arc welding, each has its advantages and disadvantages.

Transformer and transformer/rectifier sets are static in nature requiring very little maintenance, and capital investment is much less when compared to motor generator or engine driven generators of similar capacities. But at the same time power factors are comparatively low. Furthermore, a motor generator can take in supply voltage fluctuations in its stride with great tolerance without any perceptible reflection in weld quality ; but rotary equipment do require much more maintenance. With input voltage compensators put in the circuit, which means additional cost not too easily justified for general purpose welding, static power sources can also eliminate the problem of supply voltage fluctuations. But each variety would continue to have its share in its own specific area of application along with some areas where any of them would do.

Transformer rectifiers in capacities ranging from 300-1200 Amps are indigenously produced for meeting the needs of manual metal arc welding applications as well as arc air gouging. Developments of multi-operator transformer rectifiers to satisfy the special needs of customers engaged in submarine and other critical fabrication works has also been undertaken by indigenous equipment manufacturers.

Generator sets, engine driven or otherwise, in capacities ranging from 200 Amps to 1200 Amps are produced by two major equipment manufacturers in the country.

Tungsten inert gas shielded arc welding (TIG)

In manual metal arc welding, the flux covering on the electrodes provides stabilisation of the welding arc and also shield the molten metal from atomospheric contamination. In TIG welding, a non-consumable electrode which is usually thoriated or zirconiated tungsten, is used to strike an arc and the shielding is provided by an inert gas like helium or argon. A filler rod, when needed, is externally added. The TIG process produces the finest quality welds on all weldable metals and alloys. Starting from the Second World War when the TIG process was first introduced to weld magnesium, a variety of materials is being welded with this process today.

Sophistication

While D.C. is used for welding almost all materials like stainless steel, heat-resistant steel, high tensile and ultra-high-tensile steels, nickel, copper and their alloys, A.C. is required for welding aluminium, magnesium and their alloys. A TIG welding set generally comprises (a) power source, (b) high frequency unit, (c) d.c. suppressor (for Al and Mg alloys) and (d) torch. The power source can give either A.C. or D.C. output. There are also sets which provide choice of A.C. and D.C. output from the same unit. The high frequency unit, in case of A.C. is required to strike an arc without actual physical contact between the non-consumable electrode and workpiece and to maintain the arc. In the case of D.C. welding, this is required only for arc striking. The D.C. suppressors are used for greater arc stability while welding refractory materials.

A variety of TIG equipment is available in developed countries starting from modular components mounted on a frame to single units having A.C./D.C. power as well as other associated equipment. The latest equipment has incorporated facilities like spot weld, pre-and-post-gas purge, soft start, crater filling, and pulsing. These extra facilities have given a huge dimension to the sophistication and precision with which TIG process can be applied.

Indigenous manufacture of basic TIG equipment started in the early sixties. Today with an estimated population of around 1,500 TIG equipment in the country and with an envisaged growth rate of 10 per cent, TIG is expected to play a dominant role in precision and high quality welding. This will be true only when its proven potential and capability are fully exploited. To meet this challenge, although some improvements in designs and some additional facilities are being incorporated gradually in the indigenous equipment, a lot of work is yet to be done to make available equipment with all the facilities built in.

With the increase in fabrication needing high quality and reliable welds in non-ferrous, stainless steel and other low and high alloy material and high pressure pipelines as in thermal and nuclear power plants, the adoption of tungsten inert gas metal arc welding, manual, semi-automatic and automatic has registered a sudden upward trend. Complete equipment either as composite unit or as separate units of power source, d.c. suppressor and H. F. unit in different capacity ranging from 300-500 A, 300-600 A are available in the country to meet a variety of requirements. Special composite equipment for tackling low thickness areas in these materials with capacity from 2A to 15A are also indigenously available. The composite units are offered by manufacturers with sophistication such as slope-in, slope-out controls, pulsing and pre-and-post-gas flow controls. The arc welding equipment manufacturing industry in the country is today poised for taking on custom-built TIG equipment to meet specific needs incorporating varying degrees in sophistication.

Plasma arc

Plasma arc technology has made substantial progress in utilising the high heat energy of an ionised gas stream. For conventional shielded metal arc welding, temperatures up to approximately 10,000 degrees Fahrenheit (6,000°K) may be obtained in the arc. TIG arc temperature may be up to 35,000 degrees Fahrenheit (20,000 degrees K) and plasma jet temperatures can be as high as 90,000 degrees Fahrenheit (50,000 degrees K). The welding equipment required for plasma arc welding consists basically of a power source, a high frequency generator and a torch. In the USA and Europe, equipment is available for operation at 450 Amps. The comparatively recent extension of this process to weld foil thicknesses up to 0.01 mm has opened a new chapter in the metal joining technology. The full potential of this process is yet to be tapped.

Very recently both plasma and microplasma equipment have been successfully developed in India and with the expansion of activities in electronic, aeronautic, nuclear, space and other associated industries, plasma welding technology will be adopted more and more in joining difficult metals.

Metal inert gas shielded arc welding (MIG)

Although Tungsten inert gas shielded arc welding produces highest quality welds, it is a slow and expensive process. MIG, on the other hand, is an economic as well as a faster process. Metal inert gas welding implies a continuous consumable electrode fed at a pre-determined rate and melted in the weld pool which is protected by a shroud of an inert gas usually argon. The MIG process was invented in the USA in 1948. In 1957, CO_2 was introduced as shielding gas for welding mild steel. Because of higher penetration and the semi-automatic nature of application, the CO_2 process has quickly caught on and carved for itself the rightful place in production welding.

A complete range of MIG equipment which basically comprises—a D.C. power source, wire feeding device and a torch, is available in the advanced countries. Currents required are up to a maximum of 600 amps. But with the development of flux cored wires and gas mixtures, this current requirement is reduced with better weldment properties.

Modern trends

The power sources are essentially constant voltage type unlike the manual metal arc and TIG welding power sources. These may have provisions for slope control. Power sources of different power capacities are available depending upon the materials, type and thickness and modes of metal transfer (dip, spray or dip-spray) expected. Sophistication in the design can provide facilities like soft start, inching, pre-and-post-gas purge and spot welding.

The wire feeding device is a critical link in the chain between input power and weld metal deposition in the MIG welding system. Starting with a modest form with provisions for just basic needs, modern models have incorporated inching, purging, electrode feed adjustment, solenoid for gas and water flow and pre-and-post-gas facilities. The most important factor is speed control which initially was achieved through electro-mechanical governors. Today they are mostly controlled by solid state devices ensuring more precision and greater reliability.

Indigenous wire feeders are yet to be fully built in with all the above facilities for consistent performance. It is again the lack of availability of components coupled with the perennial problem of low volume that has stood in the way of the development of the more sophisticated versions.

Torches are either straight neck or curved neck type. They can be natural air cooled or water cooled. Curved neck torches are most fashionable at the moment and are, in fact, essential for out of position welding and for joints having restricted access. Modern trends in designs of torch tend to favour use of integrated cables housing all the service lines in one single cable for greater operator ease and efficiency.

All the types and ranges of torches are available in India today and the qualities are comparable to international standards.

It was, however, realised that traditional MIG welding equipment generally called for operators with higher capabilities in selecting and adjusting various welding parameters. This led to the revolutionary concept of "single knobber" equipment wherein a single knob sets welding conditions to accommodate variations in metal thicknesses and changes in welding positions. This became immediately popular with people who had initial reservations against handling complicated equipment.

India saw the first indigenous MIG equipment rolling out around 1970. Since then new ranges have been added to cover the entire spectrum of MIG welding applications. But somehow or other mainly because of lack of knowledge and lack of free availability of different MIG consumables, MIG equipment production has not grown to the expected level. It is hoped with its tremendous potential, MIG is going to cater for around 6 to 10 per cent of total weld metal deposited in about five years' time.

Another extension of MIG welding is pulsed MIG which produces far superior weld properties with less distortion compared to conventional MIG. This is yet to come in India.

Plasma-MIG

This new welding process invented by Philips Research Laboratories, Eindhoven, can be regarded as a synthesis of plasma and MIG welding. The consumable electrode and the welding arc are shrouded by thermally ionised gas or plasma. This is claimed to produce better control of metal transfer. This process is yet to get established and get wider usage.

Submerged arc welding (SAW)

All the processes like TIG, Plasma and MIG can be used successfully for either semi-automatic or automatic or automated applications with the individual process derivatives, but they are all open arc processes where radiation and comparatively poor metal recovery put a limit on using high currents. High productivity and good quality welds achieved by submerged arc welding process have made it the most popular automatic welding process. Here the arc is submerged in welding flux and wire is continuously fed. The slag provides the shielding of the weld pool with provision for additions of alloying elements, if necessary. There are generally two types of systems adopted for variation of welding parameters. The more popular models employ arc voltage control where the wire feed motor is fed from the arc voltage and the power source is obviously of drooping characteristic type. The other models use a constant potential power source with independently variable wire feed motor. Both designs are equally acceptable.

Motor generators as well as transformers and transformer/rectifiers are available since 1969 in various ratings to cover a wide application range. In advanced countries, this process has been fully exploited by developing new techniques like twin wire and tandem wire systems to achieve higher deposition rates along with positioning equipment like booms, roller beds etc. Although a start has been made in this direction in India, a lot of scope still exists to widen the field of application of this process with indigenous equipment. Strip cladding equipment, for example, is not yet available in the country.

Automation

Constant developments are taking place in advanced countries to bring in components in the equipment which would improve productivity and weld quality with provisions to monitor it as and when necessary. Total automation in welding is still a far cry. There is a misconception that mechanisation of welding and automation will cut down employment potential. It is an illusion. When looked at comprehensively, these innovations only take away the manual/personal skill as we go from manual to semi-automatic and then towards mechanisation to total automation but instead demand more mental capabilities and understanding of the process controls on the part of the operator. In this process, elements of human error come down while weld quality, consistency and reliability automatically improve. Again mechanisation and automation would necessarily lead to completion of the project in a shorter period making for substantial economic advantages and giving opportunity for more sustained secondary and tertiary employment potential than the higher employment potential offered by manual metal arc welding processes during just the construction period.

In India, while the status of development in the field of arc welding equipment for manual metal arc welding can be considered satisfactory, much remains to be done in increasing the efficiency of the equipment and the economic utilisation of major materials of construction viz. stalloy, conductor and insulation. In the area of TIG, MIG and SAW and their process derivatives the gap to be bridged to tap the full potential of the processes in aiding faster production and industrial development is wide. There is an urgent need to adopt a "system approach" to licensing, manufacturing, selling and servicing of welding technology requirements of Indian industry. The sooner this concept is implemented all along the line, the better it would be for Indian industry.