WELDWELL

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SERVICE TO THE WELDING COMMUNITY

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SPECTRUM

"Mr.P.B.Hegde, a Pune based consultant, raising a point during the Annual Welding Seminar organized by IIW - India, Mumbai Branch, on 23rd November, 2013 at Vashi, Navi Mumbai"

INSIDE

HIGHLIGHTS

- Strip Clading
- Persistent five myths about welding
- High-Quality Welds Using Hybrid Welding process

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Editorial

Dear Reader,

One more year has passed by. Indian economy and consequently welding business has not shown any significant improvement. The only rays of hopes are recent clearance of a number of power plants by the Govt. and the start of fabrication for RIL Jamnagar plant expansion. Welding industry is today largely depending on these positive indicators.

Talking of cladding at this juncture is apt. Wherever chemical or petrochemical plants exist, pipes and valves are needed to transport fluids or gases. Over the last decade, the use of noble materials for the entire valve has shifted to the cladding on a forged or cast C-Mn steel load-bearing bodies with a resistant alloy. The lead article covers the various technologies and aspects of strip cladding for chemical and petrochemical plant applications. In the last few years, several groups have worked on the development of hybrid laser / GMAW welding (HLAW), for various segments of the industry. Depending on the intended application, the objectives are significantly different. Nevertheless, new HLAW applications usually benefit from the ability of the process to produce deep welds in one pass without having to chamfer the parts. Development of a performing HLAW process requires particular care and knowledge, and its implementation can be quite costly. But once this process is in production, it can bring huge benefits in terms of productivity as well as savings in consumables and labor cost. The Technical section provides a glimpse of what a Hybrid technology can offer. There are few persistent myths about welding. To improve the image of welding as a profession these myths need to be countered. In the education section we have attempted to do so. Successful launching of Mars Orbital Mission, Mangalyaan, by India has generated considerable interest on how it was fabricated and what are the materials used. Though, mostly confidential the review section has gathered some information and presented them for you.

The Editorial Board wishes you and your family a Very Happy and Prosperous New Year 2014.

Dr.S.Bhattacharya
Editor

Event

The National Welding Meet - 2013

The National Welding Meet - 2013 was hosted by the Indian Institute of Welding, Baroda Branch, on 31st August, 2013 at Vadodara. The theme of the meet was “Challenges in dissimilar welding”. The Meet was inaugurated by the Chief Guest Mr. Y.S.Trivedi, Executive Vice President & Member of the Board of L&T. In his inaugural address he highlighted the importance of joining dissimilar materials. He also underlined the growing needs of the industry and the advances in the joining technology. He emphasized the role professional organizations, such as IIW – India, can play to fulfill the dreams of the industries in the field of welding. In his presidential address Mr. P.K.Das, President, IIW-India, elaborated various activities of the Institute and mentioned the forthcoming international event, International Welding Congress 2014 from 9th to 11th April, 2014 and a concurrent International welding exhibition, Weld India 2014, from 10th to 12th April, 2014 at the Pragati Maidan, New Delhi. The theme of the Congress will be “Advances in Welding, Cutting & Surfacing Technologies for Improved Economy, Reliability & Sustainable Environment”.

A total of ten technical papers were presented in three sessions covering a wide range of subjects related to dissimilar metal welding. Mr. R.G.Rangasamy of DAE, Kalpakkam, received an award of ₹.10,000/- for the “Best Paper” sponsored by the Association of Welding Products Manufacturers. The Meet was attended by 162 delegates including 26 student delegate which is a very heartening sign for the welding fraternity. The Meet ended with a very lively valedictory function which was chaired by Mr.R.Srinivasan, Vice President, IIW-India. Mr.Gautam Gohil, Hon. Jt. Secretary, Baroda Branch, presented the vote of thanks.

The Meet was sponsored by a number of industries including Weldwell Speciality Pvt. Ltd., Mumbai, who hosted the evening tea for the delegates.

Strip cladding*

INTRODUCTION

Wherever chemical or petrochemical plants exist, pipes and valves are needed to transport fluids or gases and control flows. Over the last decade, the use of noble materials for the entire valve has shifted to the cladding on a forged or cast C-Mn steel load-bearing bodies with a resistant alloy. The quality of the facing material varies with the application.

Cladding of load bearing base metals with noble metals offers various benefits such as high cost benefit, desired chemical composition at the surface, high quality overlay finish, lower dilution levels, allowing reduced number of layers and many more.

PRINCIPLE OF STRIP CLADDING

The principle of strip cladding is essentially the same as weld cladding with wire. The main difference is the use of a wide strip instead of a wire.

There are two most productive processes for surfacing large components viz. submerged arc and electroslag cladding processes. Both processes are characterized by a high deposition rate and low dilution and are suitable for surfacing flat and curved objects such as heat exchangers, tubes, tube sheets and various pressure vessels. Submerged arc welding (SAW) is the more frequently used, but if higher productivity and restricted dilution rates are required, then electroslag welding (ESW) is recommended.

Schematic diagrams of the two processes are given in Fig. 1 and 2.

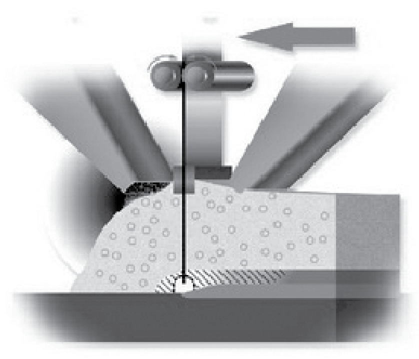

Fig. 1 Submerged Arc Welding

Fig. 2 Electroslag Welding

SAW PROCESS

The well-known SAW method has been widely used with strip electrodes since the mid-1950s. A strip electrode, normally measuring 60 x 0.5 mm or 90 x 0.5 mm, is used as the (usually positive) electrode and an electric arc is formed between the strip and the workpiece. Flux is used to form a molten slag to protect the weld pool from the atmosphere and helps to form a smooth weld bead surface (Ref.Fig.1).

FLUXES FOR SAW STRIP CLADDING

SAW fluxes are though mostly agglomerated type but they may differ based on its basicity and whether they are alloying or non-alloying type.

Aluminate basic type of flux is used for submerged strip cladding of Cr, Cr-Ni,Cr-Ni-Mo and stabilized stainless strips of the 300 classification. It is also used for duplex stainless steels. A neutral Cr-compensating flux is also designed for strip cladding 300 types. Neutral Cr, Ni and Mo-alloying type flux is designed for cladding at high welding speed with an 309L strip, producing a 316L overlay weld metal in one layer e.g. for internal overlay welding of a paper fibre digester drum. A neutral, agglomerated, slightly molybdenum alloyed flux is suitable for strip cladding with unalloyed C-Mn-steel strips. Weld metal in one layer on non-alloyed plate shows that the flux adds nominally about 0.4% Mo. The well balanced flux composition minimizes silicon transfer from the flux to the weld metal, reducing the risk of hot cracking. These are suitable for cladding with all grades of Ni-based strips. A neutral moderately silicon alloying flux designed for strip cladding with Monel strips. The flux is primarily suitable for strip cladding NiCu7 or with CuNi30 strip used as buffer layer.

ESW STRIP CLADDING

This method was developed in the early seventies to increase productivity by increasing the deposition rate and decreasing the dilution compared to SAW process. Due to the properties of ESW often only one layer is needed to fulfill the cladding requirements and further the consumption of consumables is significantly reduced. ESW strip cladding relates to the resistance welding processes and is based on the ohmic resistance heating of a molten electrically conductive slag. There is no arc between the strip electrode and the parent material. The heat generated by the molten slag melts the surface of the base material, and the edge of the strip electrode is submerged in the slag and flux. The penetration achieved with ESW is less than that with SAW because the molten slag pool is used to melt the strip and some of the parent material. The temperature of the slag pool is about 2300°C, making it to water-cool the contact jaws. ESW uses higher welding currents than SAW strip cladding so the welding heads used are more heavy duty.

The following shows the features of ESW compared with the SAW strip cladding process:

- Increased deposition rate of 60% to 80%.
- Only half of the dilution (10% - 15%) from the base material due to less penetration.
- Lower arc voltage (24 - 26 V).
- Higher amperage and current density (about 1000 - 1250 A with strips of 60 mm width.)
- Increased welding speed (50% to 200%).
- Comparable heat input.
- Lower flux consumption (about 0.5 kg/kg strip).
- The solidification rate of the ESW weld metal is lower, aids de-gassing and increases resistance to porosity.

FLUXES FOR ESW

The ESW-process requires a slag pool with an ohmic resistance behaviour. In comparison to SAW cladding the electrical conductance must be higher to avoid arc flash, which is a disturbance of the process. The composition of the welding flux influences the conductivity, the solidification range and the viscosity of the molten slag. To increase the cladding speed at corresponding high welding currents, it is necessary to use fluxes with high electrical conductivity and low viscosity. High basicity flux used with the electroslag process, is designed for single-layer or multilayer cladding in combination with austenitic strips at very high deposition rates. A high power intensity (up to 45 cm/min with 60 x 0.5mm strip) can be used.

CLADDING EQUIPMENT

Strip cladding processes whether SAW or ESAW practically are all automated processes. The equipment required for cladding thus essentially contains:- Power sources, Strip cladding head, Magnetic weld pool control, Reliable strip feeding, Water chillers, Flux recycling system, Rotators, turntables, Columns and booms and Full digital control.

1. Power sources

Strip cladding requires power source of higher capacity. The current requirement for ESAW is higher than that required for SAW process. The processed usually run for a long time at a single go and hence the rated duty cycle should also be higher. To achieve the higher current some time parallel connections are used.

2. Strip cladding head

The head is the feeding point of the strip. There are certain standard widths of strip which are in use. The most common is 60 mm and 0.5 mm thick. The heads are water cooled.

3. Magnetic steering system

The system is intended for stainless electroslag strip cladding in order to get a more consistent and straight weld pool. The magnets are placed on either side of the welding head to provide the desired magnetic flow. This is recommended for strips over 60 mm in order to obtain an optimal bead shape during strip cladding. One must use a magnetic steering device to control the magnetic influences of the high currents flowing through the strip.

4. Strip feeding

Cladding strip is supplied in coil in varying weights. It may be as less as 30 kg to as high as 700 kg. Weights of up to 50 kg are very popular. The commonly supplied coils have an inner diameter of 305 mm.

5. Water chillers

In both the processes a considerable amount of heat is generated. It is therefore, necessary to cool the system. The head is also water cooled. To conserve water it is required to chill the water and reuse.

6. Flux recycling system

The amount of flux added in both the processes is more than that gets consumed. The excess flux is recycled through a recycling system which consists of collecting the excess flux, processing and feeding back into the system.

7. Welding positioners / Turntables / Rotators

To orient the job the above accessories are required. The job is either rotated or positioned suitably to facilitate easy cladding. In rare occasion the welding head is repositioned for the purpose.

8. Column and Boom

Strip cladding is commonly performed on large jobs and may need considerable material handling activities. In fabrication shops which regularly handle heavy jobs require column and boom.

9. Control automation for automatic welding

As already mentioned that these processes are automatic and hence control system is important. It includes control panel, necessary measuring device, recording of data etc.

RECENT DEVELOPMENTS

In order to increase productivity, two possibilities were considered, namely higher deposition rates and welding fewer layers. From this point of view, two main developments took place:

High speed fluxes

To increase the deposition rate the speed and the current must be increased. If the welding speed remain constant, the thickness of the deposit will increase. The key is to create a flux that melts fast enough, so that the weld pool can follow the travel speed of the strip.

The solution is to decrease the viscosity of the molten flux, which facilitates flow of the pool. This way the pool is able to follow the strip, even at higher travel speed. High speed fluxes allow to clad twice the surface per unit cladded with normal speed fluxes. This has helped in cladding on minimal thickness of base metal. Cladding on 5 mm thick plates have also been reported.

Single layer fluxes

Single layer fluxes give an answer to the demand of higher productivity by depositing an alloy in one single layer. The amount of certain elements lost by dilution is compensated by adding them to the flux. This way, it is possible to obtain the nominal analysis of the overlay in the first deposited layer itself. It also allows to clad with standard strip compositions instead of the more expensive over-alloyed ones.

It is important to notice that the flux is designed for a specific strip and for specific parameters. One cannot deviate too much from the parameters indicated, since dilution levels and flux consumption will differ and result in another end analysis.

CONCLUSON

With the recent developments strip cladding of forged or cast C-Mn steel load-bearing bodies with a resistant alloy to severe corrosive environments is becoming popular. Amongst the two popular processes ESW is gaining more acceptance due to its higher productivity, lower dilution and other technical benefits.

COMPARISON BETWEEN SAW AND ESW CLADDING PROCESSES

The difference in deposition rate between the methods is illustrated in the table below.

... continued on Page 10

Myths and Facts

Persistent five myths about welding

In one form or another welders have had to deal with some pretty interesting attitudes towards the welding profession. Some people think welding is a low-paying job. Others think there isn't much diversity to being a welder. Even more interesting for women welders is this common remark: "Really? You're a welder?" It seems no matter how much the profession has progressed, there are at the very least 5 persistent myths about welding.

Welding is a low-paying profession

This myth suffers from the stigma surrounding all blue-collar jobs. Despite evidence to the contrary there is still the idea that working with your hands earns less money than working with your head (although trade work requires working with both hands and head). Possibly it originated from the roaring '90s, the glittering lights of financial market, the computers, the cellphones — it was such an economic boom, it was unbelievable. The scenario has changed. It is time to go back to the basics. Availability of persons working with computer and cellphones etc. are now in excess. The earnings of this category of people have come down significantly whereas those working with hands whose earnings have improved.

Welding is a man's job

Jobs that require more manual labor are typically thought of as "men's work." With approximately 6% of the welders' population made up of women, that perception is slowly but surely changing.

Though 6% is still a significantly low number, the percentage of women welders continues to grow. Even today, more women are looking to welding as a profession and have started to establish themselves successfully.

Welding jobs are scarce

The problem here is that the demand for welders cannot be measured on a universal scale. Heavy manufacturing areas will typically need more welders than areas where manufacturing does not play a major role in the company. There is a big shortage of skilled welders all over the world.

The myth is further muddled because even if the jobs are plentiful, employers are often looking for a specific type of welder: those with experience. This leaves those new to the trade and fresh out of welding school still looking for work. To counter this problem Prime Minister's Office in India has initiated skill development programmes in a big way in which training of welders is one of the key vocations. They have set a target of more than one lakh employable welders.

Welding is a one-note profession

"Welder" brings up the image of someone doing some work with sparks coming out of it – that's it. People fail to see the versatility of being a welder, not just in the act of welding but also in what welding can produce and the many different areas of the welding profession. In fact welding is probably one of the most diversified profession where each job is a new experience. To be a good welding engineer or a welder knowledge of disciplines such a mechanical, metallurgy, electrical and now electronics, chemistry and physics are required since welding profession utilizes all of them. Today the welding profession is more knowledge based than ever before.

There's little/no advancement in the welding field

Career advancement in any industry is dependent on the employers as well as how much effort the employee puts in. It is true that for a maintenance welder the scope of advancement is limited but for a welder or a welding engineer in a fabrication shop the scope of advancement is practically unlimited. In addition a welder who works independently has more leeway in charting his own destiny.

"It would be possible to describe everything scientifically, but it would make no sense; it would be without meaning, as if you described a Beethoven symphony as a variation of wave pressure." - Albert Einstein

High-Quality Welds Using Hybrid Laser/ GMAW process*

In the last years, several groups have worked on the development of hybrid laser/GMAW welding (HLAW), for various segments of the industry. Depending on the intended application, the objectives are significantly different, and the definition of quality itself can differ a lot. Nevertheless, new HLAW applications usually benefit from the ability of the process to produce deep welds in one pass without having to chamfer the parts. As shown on Figure 1, the HLAW welds are drastically smaller than GMAW welds, going from several passes (six on the picture on the left) with chamfer and back gouging to a single pass without chamfer.

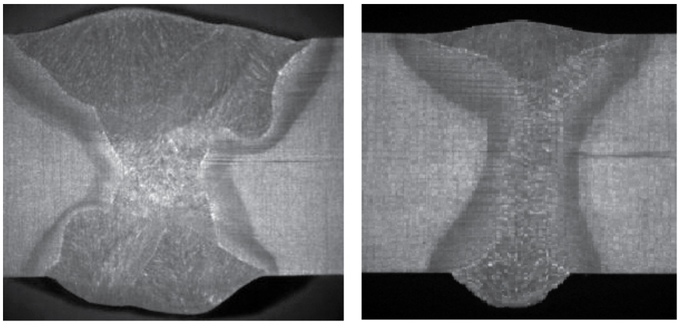

Fig. 1: GMAW weld vs HLAW weld on 12mm HSLA steel.

Recent tests showed that, when compared to manual GMAW, HLAW brings a 90% diminution in welding time and consumables (see table below).

Table 1: Consumables and time savings for 12 mm HSLA steel

	GMAW	HLAW
Wire (kg/m of weld)	0.57	0.05
Gas (l/m of weld)	248	31
Welding time (min/m of weld)	15.0	1.3

However, to survive the transition from laboratory to production floor, the process must perform in the following ways:

- Produce welds showing good mechanical properties, as defined by the application
- Produce these quality welds repeatedly despite the variations inherent to the industrial environment
- Minimize operation costs.

Here below is a brief discussion on the points to consider in order to meet these results.

PARTS PREPARATION

Although HLAW is less demanding than autogenous laser welding when it comes to parts fit-up, it still often requires improvements in the quality of the joints, when compared to standard arc or resistance welding processes. HLAW is particularly interesting for the realization of long welds for which machining may be necessary to ensure a constant fit-up, thus reducing important preparation costs.

Working on the process to make it more tolerant to variations, it is possible to reduce the tolerance requirements so that laser-cut parts can be used directly, without having to machine the edges. However, the joint fit-up still needs to be sufficiently good to maintain the gap below a certain limit, e.g. 2mm maximum gap for 12mm thick steel parts. These looser precision requirements combined to the ability of the HLAW to weld thick material in one pass, without chamfering, lead to huge savings in term of machining.

ADAPTIVE WELDING

To reduce the requirements related to machining and positioning, the preferred avenue is the use of adaptive welding. Unless one is able to tolerate low quality or justify investing heavily in the precision of the primary parts, making HLAW an adaptive process becomes necessary, in order to ensure the profitability of the process. This is achieved by determining the welding parameters in real-time, according to the actual configuration of the joints – and not their theoretical position.

A camera placed right in front of the welding head evaluates the relative position of the workpieces: the

** Adapted from Laser Editorials, February 13, 2013* controller (PLC, PC) selects the welding parameters to match the actual gaps and applies them automatically. The welding parameters are stored in a database, allowing automatic selection of proper parameters for all acceptable configurations, i.e. all configurations for which it is possible to obtain welds that meet the quality requirements. This allows maintaining the quality of the welds in an economically beneficial way, using reasonable dimensional tolerances for the parts and their positioning.

CONTROL OF THE COOLING RATE

Everyone wants to weld fast to achieve a high productivity. However, success rarely lies in excess speed. Very fast welding, as permitted by processes using lasers, leads to high cooling rates, which can cause the formation of fragile metallic phases. In contrast, slow cooling rates can lead to a coarse lamellar grain structure, conducive to cracks propagation. The use of a CCT diagram may be essential to develop good HLAW welding parameters, producing welds having the desired mechanical characteristics.

Thus, a 12mm deep HLAW weld on HSLA steel (full penetration in one pass) led to the formation of coarse lamellar ferrite, responsible for bad performances in Charpy testing. By reducing the wire feed speed, the cooling rate decreased sufficiently so that the absorbed energy at -30°C went up from 40J to100J. Hardness remained at all times lower than that produced by GMAW (see Figure 2 below)

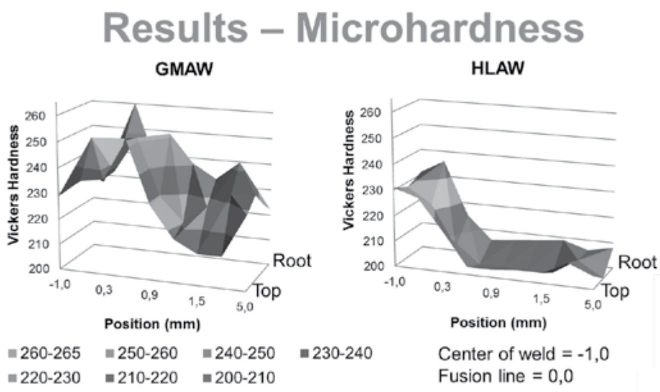

Figure 2: Micro-hardness measurements.

On the other hand, a 19mm deep HLAW weld on alloyed steel (partial penetration, one pass) experienced high cooling rates leading to the formation of very hard and brittle martensite. Preheating the parts allowed controlling the metallic phases formed during cooling and obtaining resilient sound welds.

CONTROL OF THE PLUME

High power laser welding causes the formation of a partially ionized cloud, having a high density of fine particles which remain suspended between the laser optics and the material to be welded. This laser-generated plume scatters part of the laser beam, reducing significantly the efficiency and the stability of HLAW.

To overcome this problem, it is necessary to get rid of suspended particles, either by blowing them off or by extracting them. Tests performed at Novika showed that at 15kW of laser power, the addition of a plume management system brought a 77% decrease in the average attenuation of the laser beam, helping to improve efficiency and stability of the HLAW process. While implementing such a system, care should be taken not to interfere with the GMAW shielding gas while being close enough to the torch and laser beam to extract the fume.

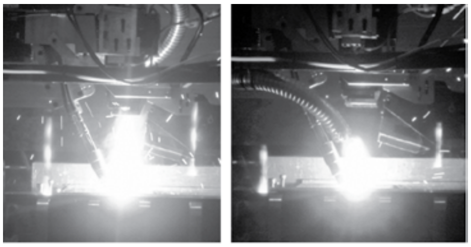

Figure 3: HLAW welding without (left) and with (right) plume management.

CONCLUSION

Development of a performing HLAW process requires particular care and knowledge, and its implementation can be quite costly. But once this process is in production, it can bring huge benefits in terms of productivity as well as savings in consumables and labor cost. And with the great performances and decreasing cost of the high power fiber and disk lasers, one can expect better and better ROI's, and stronger presence of the HLAW process on the shop floors.

Sandvik 24.13.LHF

Sandvik Materials Technology, a leading manufacturer and supplier of stainless steels, has introduced Sandvik 24.13.LHF welding wire particularly suitable for overlay welding and joining dissimilar steels, for example austenitic stainless steels to low alloyed or non-alloyed steels. It has excellent resistance to hot cracking due to its enhanced ferrite content. The wire may be used for TIG, plasma arc, MIG and submerged arc welding processes.

The product meets AWS specification ASME/AWS SFA5.9 ER309L and EN ISO 14343 number 23 12 L. The product also has CE and TÜV approvals.

PROPERTIES OF THE WIRE

Chemical Composition

The chemical composition of the filler metal is as under.

C max	0.015
Si	0.3
Mn	1.8
P *max*	0.015
S *max*	0.015
Cr	24
Ni	13
Mo *max*	0.3
Co *max*	0.05
Cu *max*	0.10
N *max*	0.05

Whereas the all weld metal chemistry for non-heat treated all weld metal made by MIG welding with a shielding gas of Ar + 2%O_2 and TIG or plasma arc welding with argon as shielding gas is

C max	0.015
Si	0.4
Mn	1.6
P max	0.015
S max	0.015
Cr	24
Ni	13

Ferrite content

The ferrite number according to the DeLong diagram, based on the aim composition is 16 FN.

Microstructure - All-Weld Metal

Austenitic matrix with a ferrite content of about 15 FN according to DeLong.

Mechanical Properties - All-Weld Metal

Temperature	°C	20
Yield strength	RP	0.2
Yield strength	MPa	410
Tensile strength	Rm	
Tensile strength	MPa	600
Elongation, A	%	41
Reduction in area, Z	%	71
Impact strength, Charpy V	J	140
Hardness, Vickers	H V	160

Corrosion Resistance - All-Weld Metal

Sandvik 24.13.LHF is normally used for joints between non-alloyed or low alloyed steels and stainless steels, where resistance to corrosion is of secondary importance.

RECOMMENDED WELDING DATA

MIG welding

Electrode positive is used to give good penetration in all types of welded joint. The following table shows recommended conditions for MIG welding.

1 Short arc welding is used with light gauge material of less than about 3 mm, in depositing root runs, and in welding out-of-flat positions.

2 Pulse parameters: Peak current 300 400A, Background current 50 150A,

Frequency 80 - 120Hz

The higher the inductance in short arc welding, the higher the fluidity of the molten pool. Spray arc welding is normally used for heavier gauge material.

Wire diameter mm	Wire feed m/min	Current A	Voltage V	Recommended Gas flow l/min
Short arc welding 1				
0.8	48	40 - 120	15 -19	12
1.0	48	60 - 140	15 - 21	12
Spray arc welding				
1.0	6 -12	140 - 220	23 - 28	18
1.2	59	180 - 260	24 - 29	18
1.6	35	230 - 350	25 - 30	18
Pulsed arc welding 2				
1.2	3 - 10	150 - 250	23 - 31	18

TIG welding

The parameters for TIG welding depend largely upon the base metal thickness and the welding application as given in the following table. Electrode negative and a shielding gas of argon or helium should be used to prevent oxidation of the weld metal.

Submerged-arc welding

Electrode positive is suggested for joint welding to give good penetration.

Wire diameter (mm)	Current (A)	Voltage (V)
2.0	200 - 350	28 -32
2.4	250- 450	28 -32
3.2	300 - 500	29 - 34
4.0	400 - 600	30 - 35

...continued from Page 5

Table 1: Comparison SAW and ESW

		SAW	ESW
Electric Arc		Yes	No
Source of heat		Electric arc	Joule-effect in molten slag
Typical welding parameter for 60 X 0.5 mm strip	Current	750 A	1250 A
	Voltage	24 V	24 V
	velocity	10 cm / min	16 cm / min
Current density in strip		25 A / mm^2	42 A / mm^2
Dilution		18 %	10 %
Magnetic control		No	Yes

Mars Orbiter Mission - Mission Overview and Spacecraft fabrication

The Mars Orbiter Mission (MOM) or Mangalyaan (Hindi for "Mars Craft") is designed to study Mars from its orbit. The scientific objectives are to explore Mars' surface features, morphology, mineralogy, and atmosphere. To achieve these objectives, the 1,337-Kilogram spacecraft is equipped with five scientific instruments and will nominally spend 6-10 months orbiting and making measurements at Mars. Most importantly, the mission serves as a demonstration mission with the main objective of placing Mangalyaan in orbit around Mars as a study for future spacecraft and mission design.

MOM was launched aboard a Polar Satellite Launch Vehicle on 05 November, 2013, from the island of Shriharikota. The satellite's thrusters will then begin a series of six small fuel burns, moving it into higher orbit before it slingshots toward the Red Planet for an arrival at Mars on Sept. 24, 2014 and will be joined above Mars by MAVEN (Mars Atmosphere and Volatile Evolution mission of NASA). MOM catapulted from earth orbit on December 1, clearing an important hurdle on its 300-day, 780 million-kilometer journey to Mars and putting it on course to be the first Asian mission to reach the red planet.

The mission was put together on rather a short notice of just 15 months to go until the Interplanetary Launch Window (from October 28, 2013 to November 19, 2013) that comes once every 26 months. Mangalyaan was approved for a total project cost of $69 million. In 2012, roughly one-tenth the cost of MAVEN. The individual components of the orbiter began assembly before the spacecraft came together in March 2013.

SPACECRAFT AND SUBSYSTEMS

The Mangalyaan spacecraft is based on a modified IRS/INSAT/Chandrayaan-1 bus. The main body of Mangalyaan is cuboid in shape featuring composite and metallic honeycomb sandwich panels and a central composite cylinder. It is roughly 1.5 m cube constructed of aluminum and composite fiber reinforced plastic sandwich material. Total mass is about 1,340 kg, of which 852 kg. is fuel. A 1.4 x 1.8 m solar array wing consisting of three panels which can generate 800 W power at Mars. The bus is built around a thruster and propellant tanks with 390 liter capacity. The thruster uses a Titanium alloy injector and a Columbium alloy combustion chamber. The engine's injector is also made of titanium while the thrust chamber is constructed of Columbium alloy. Electron welding technique is used to mate the injector to the combustion chamber.

The Indian Space Research Organisation, or ISRO, has worked to keep import costs low by designing most of the parts that were then outsourced to the domestic private sector. Two-thirds of the parts for the Indian probe and rocket were made by domestic firms like Larsen & Toubro, the country's largest engineering firm, Godrej & Boyce, Walchand Nagar Industries and state plane-maker Hindustan Aeronautics Ltd. ISRO still has to import some metal alloys used in the space programme that it then given to its contractors and Indian companies. "Thanks to the space work, the company's engineers now know how to handle the specific metal alloys and the high-precision welding needed for aircraft and missiles as well as rockets," said S. M. Vaidya, the business head of Godrej's aerospace division, which made the rocket's engine and fuel-powered thrusters for the Indian Mars probe.

CONCLUSION

India's space enthusiasts say the $70 million Martian mission will be a step toward understanding the natural world, inspiring children to go into research science and advancing science and technology in ways that help common people cope with a changing environment. Learning more about alien weather systems, for example, might reveal more about our own. Finding evidence for life on other planets might help scientists discover new life forms in places on Earth previously thought inhospitable.

"To visit another planet is a fantastic thing, the biggest thing," said space scientist Yash Pal, former chairman of the country's University Grants Commission.