"ADVANCED WELDING EQUIPMENT & CONTROLS FOR THIN SHEET STAINLESS STEEL FABRICATION"

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Stainless Steels in the thickness range 0.5 mm to 3.0 mm find extensive usage in the manufacture of dairy and food processing equipment. With ready availability of such steels indigenously, we can expect an exponential growth in their usage in the coming years.

Fabrication of thin sheets to form equipment, mainly involves cutting and welding operations. Conventional techniques like shearing or nibbling and manual welding procedures are totally inadequate to handle thin sheets of stainless steel due to problems like distortion, warping, lack of heat input control, need for high level of operator skill and so on. In the recent years advanced processes and controls like programmable Pulsed TIG welding, Pulsed MIG welding and programmable Air plasma profile cutting equipment have helped in overcoming the above problems and make thin sheet stainless steel fabrication simple to handle.

Stainless Steel welding also calls for careful selection and matching of filler materials and pre- and post-weld cleaning procedures to retain the "Stainlessness". Some of the key features of such equipment and controls and selection criteria for filler materials is highlighted in this article.

INTRODUCTION

The world production of Stainless steel is reaching new peaks year after year and this trend is bound to continue, with more and more applications being found. Stainless steels are also the subject of continuing extensive development to improve the types of alloys, the manufacturing process and the quality.

At present a large variety of stainless steels with different properties are available: properties such as toughness at very low temperatures and high temperature strength. The most important property is, of course, resistance to corrosion in many different types of environment. Stainless steels can be classified according to their microstructure, as shown in Table 1. Their weldability varies from excellent to poor, as graded in Table 2. The most common type employed in food and beverage industry is the austenitic types and to some extent ferritic types. Both these are easily weldable.

WELDING OF THIN SHEETS OF STAINLESS STEEL

In the past, stainless steel has been welded most often with covered electrodes, *i.e.,* Manual Metal Arc welding. The improvement in filler wire compositions and welding equipment in recent years has resulted in the increased use of TIG (Tungsten Inert Gas) and the highly productive MIG (Metal Inert Gas) welding process. Usage of these processes is a necessity in handling fabrication of thin section of stainless steel to take care of problems like distortion, lack of heat input control, etc., present in the manual welding methods.

TIG WELDING

The TIG welding method is characterised by high welding quality, clean weld metal and good surface finish. It is therefore extensively used in the process industries as well as within the food industry. TIG welding is particularly suitable for lighter materials -

Table 1: Composition Range of various types of Stainless Steel.

Type of steel	C	Cr	Ni	Mo	Properties	Users
Austenitic Typical example	<0.25 0.03	12-30 18	6-40 12	0-5 3	Not hardenable; Generally good weldability	Heat exchangers vessels and pipelines within chemical, food and power industries
Martensitic Typical example	0.10-0.30 0.2	11-17 13	0-3	0-2	Hardenable; Poor weldability	Tools and machine parts
Ferritic Typical example	<0.25 0.03	12-30 17	0-5	0-5	Nothardenable; relatively good weldability	Household machines, automotive, chemical industry (ELI-steel).
Ferrite-Austenitic Typical example	<0.15 0.02	18-30 25	4-10 5	0-2 1.5	Nothardenable; relatively good weldability.	Machine parts
Ferrite-Martensitic Typical example	0.10-0.15 0.1	12.15 13	0-1	0.2	Hardenable; Poor weldability.	Machine parts

metal as thin as 0.5 mm thick - the TIG method is used to make root runs followed by filling with MIG process.

Stainless Steel is TIG welded with direct current. The arc is generated between the work piece and the tungsten electrode. For thin sheet welding (0.3 mm to 4 mm) square butt joints can be made without any filler materials. Filler metal if needed is fed into the arc and the molten pool from the side. Fig. 1a to 1b gives the principles of TIG welding.

Salient Features of TIG Method:

- High quality weld metal
- Even and smooth finish
- No spatter
- No slag formation
- No welding fumes
- Easily adaptable for mechanised/automated welding
- Easily programmable.

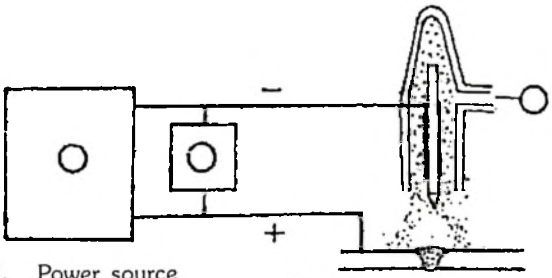
Conventional TIG welding plants based on Rectifiers or Generators are not ideally suited for thin sheet applications since such power sources are not programmable. Recent developments in electronics has helped in building totally programmable TIG equipments based on Thyristor or transistor controls.

Thanks to such programmable control equipment, it is now possible to monitor a number of functions and parameters, which are critical to achieve first class welding results:

- automatic pre- and post-flow of gas
- start-, welding- and root shielding gas
- welding current with stepless up- and down-slope
- welding speed
- wire feed for filler material
- pulsing : current, wire feed, system movement, etc.

A typical programme representation for a mechanised welding application will be as shown in Fig. 2. As is clear from the figure, the welding current can be modulated to achieve the desired end results. In practice, the pulsation parameters are adjusted to control:

- degree of penetration in the weld
- apply precise heat input to minimise distortions



1. Power source
2. HF generator
3. Shielding gas (argon)

Fig. 1A

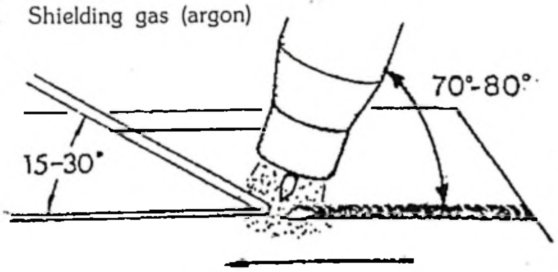


Fig. 1B

– have beneficial influence on grain coarsening in the base metal and in the transition zones.

Programmable TIG welders both for manual and mechanised welding applications are available in a wide range to cover the entire gamut of stainless steel welding. While simpler welding equipment for manual welding is available locally, special purpose machines *viz.*, programmable pipe or duct welders, mechanised stations for freeze drying plants, etc., need to be imported.

Table 2: Weldability of stainless steels.

Steel type	Weldability
Austenitic	Good-Excellent
Ferritic	Relatively good
Martensitic	Poor
Martensitic-austenitic	Relatively good
Ferrite-austenitic	Relatively good-Good

Shielding Gas for TIG Welding

Argon is the ideal shielding gas for TIG welding because it is:

– Easily ionised

– insensitive to variations in arc length.

As an inert gas, Argon does not combine with other substances or react chemically with the weld pool. It protects the weld pool from the detrimental effects of the surrounding air.

For manual welding, pure argon is recommended. For mechanised TIG welding, pure Helium gas is used. Argon may also be mixed with helium or Hydrogen. Gases containing hydrogen must only be used, if the Stainless Steel is austenitic.

Filler Materials for TIG Welding

A wide range of filler materials with compositions matching those of the base metal are available. Normally the filler wires have slightly higher silicon content to compensate for burn-off and act as a deoxidising agent. For manual applications, normally wires of dia 1.6 mm to 3.2 mm is used with lengths of 700 mm -1000 mm. For mechanised applications, wires wound on spools is employed.

Note

The alloy constituents of these wires are specifically designed for TIG welding. They should not be used for MIG welding or oxy-acetylene welding, or *vice-versa*.

MIG WELDING

The MIG welding method is productive, economic and easily applied. The schematic of a MIG welding station is shown in Fig. 3.

In the case of conventional MIG-welding one usually differentiates between two types of arcs-short arc and spray arc.

In short arc welding a short circuit is always obtained between the molten pool and the end of the heated electrode. During every short circuit the welding current rises and this increases the electromagnetic forces so that the droplet which forms on the electrode is pinched off.

If the welding current is increased, however, the material is transported without short circuits. The droplets are transferred into the molten pool in the form of a spray - so called spray arc welding.

Short arc welding is primarily used on thin material, while the spray arc, which is a hotter type of arc because of the higher current and voltage, is used of thicker material.

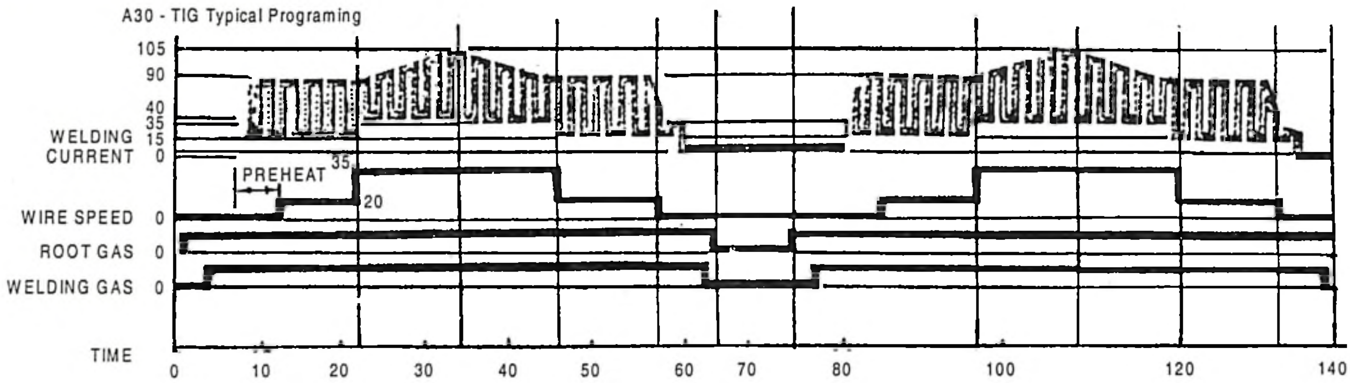


Fig. 2

MIG-welding of stainless steels is usually performed in thin materials. For this application a

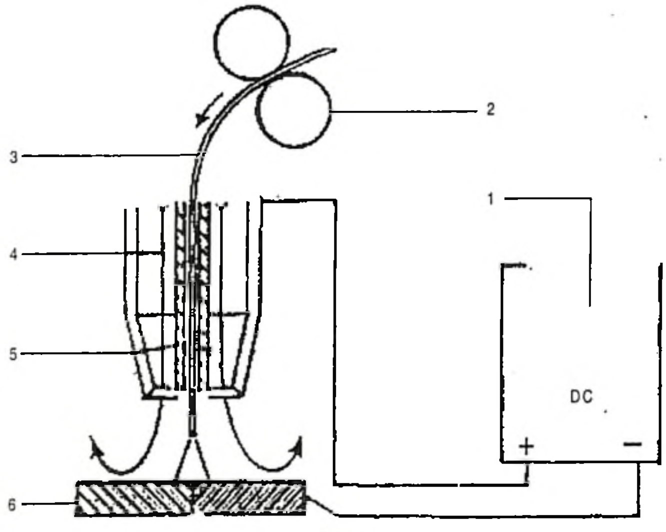


Figure 3

1. Power Source, 2. Electrode feed unit, 3. Electrode (wire), 4. Shielding gas, 5. Contact tip, 6. Workpiece.

method, which gives the benefits of the spray arc, in other words a minimum of spatter, would be desirable.

Pulsed Arc is a method which makes this possible.

Pulsed Arc

In pulsed arc, a low current is used, the so called background current (1b), which is set just high enough to keep the arc alive, but without any migration of filler metal. At regular intervals a current impulse (1p) is sent out, which melts the tip of the wire and a molten droplet is transferred to the molten pool without any of the short circuiting which takes place in conventional short arc welding. Since the pulsing mode eliminates short-circuiting, the result is a steady and consistent droplet-per-pulse transference of material. This can be termed an artificial spray arc operating within the short arc range or in the area between the shot arc region and the spray arc region, the so called mixed arc region as seen from Fig. 4 & 5.

Advantages of the Pulsed Arc Method

The main advantages of the Pulsed Arc method can be summarised as follows:

* Minimum spatter - Less post-weld-treatment.
* Stable arc - More uniform welding results.
* Lower heat input compared with the spray arc method - Less deformation in conjunction with thin plate welding and less risk of intergranular corrosion.

Synergic Control

In order to save the welder the trouble of setting all these parameters himself, Synergic machines are now available. Synergic control means using a key process parameter to calculate and control the remaining parameters in the process. In practice this means that the welder chooses a preselected option on a rotary switch, keyboard, etc., to programme the wire types, wire diameter and shielding gas to be used.

The welder only needs to set the correct wire feed speed after taking account the plate thickness to be welded. In this case the wire feed speed is used as key parameter. The control equipment in the power source (for instance a computer) then calculates the other suitable pulse parameters automatically.

Shielding Gas for MIG Welding

When welding stainless steels mixtures of the following gases are used:

Argon	Ar	inert
Helium	He	inert
Oxygen	O_2	oxidizing
Carbon dioxide	CO_2	oxidizing
Hydrogen	H_2	reducing

The gases have different properties, which affect welding in a highly complex manner. The thermal conductivity ionization energy density and chemical activity of the gases vary and this can affect factors like:

* Arc stability
* Bead appearance (wetting, fluidity)
* Weld geometry
* Porosity
* Chemical composition of the weld

(Weld speed, penetration, need for preheating, transition amperage for spray arc, gas flow.)

Argon and helium are inert gases *i.e.,* they do not influence the chemical composition of the weld metal, which is a great advantage. However, when MIG-welding stainless steel the arc is very unstable with inert gas alone. The arc wanders on the plate and a non-uniform weld is produced. This is, due to some extent, to variations in the amount of iron oxide on the plate surface.

When a small quantity of oxygen or carbon dioxide is introduced into the argon shield a uniformly oxidized surface is developed and the position of the arc root (cathode) is hereby stabilized. Argon with 1-3% oxygen or 2-5% carbon dioxide is most commonly used. Both types of gas mixture improve the fluidity and wetting of the weld metal. The addition also minimizes undercut, which is a problem when welding with argon alone. The stabilizing effect of oxygen is stronger than that of carbon dioxide.

Argon with 1-3% oxygen is recommended for the spray arc welding of stainless steels.

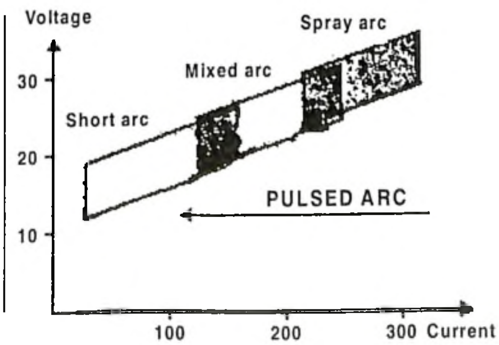
Filler Wires for MIG Welding

A wide range of solid wires for gas shielded welding is available.

Consumables for austenitic stainless are usually of about the same composition as the base metal. The MIG-wires have a higher silicon content which results in better fluidity and arc stability.

These austenitic consumables can also be used for welding ferritic or martensitic grades of stainless steel if the welded structure is to be used in a sulphur free environment. Titanium and Nb-stabilized wires are particularly recommended if the welded structure is

Figure 4



Picture 1. Pulsed Arc, an artificial spray arc which works within the normal mixed and short arc

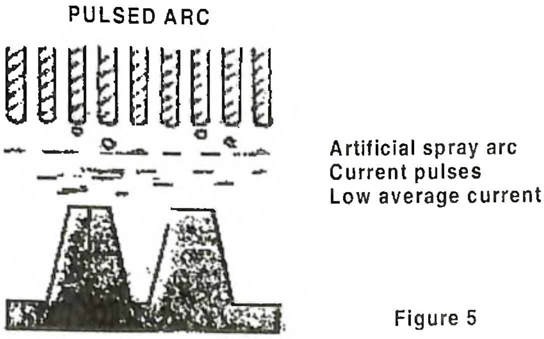


Figure 5

Picture 2. Droplet transfer and current wave from during pulsed arc welding.

going to be used at high temperature (above 400 degrees Centigrade). Stabilized steels can also be welded with the above mentioned low carbon types if the operating temperature is lower.

WELDING PRACTICE

To achieve the best results when welding stainless steel, more is required than just good equipment and the correct filler materials. One must also be proficient and have adequate knowledge of the material properties.

Cleanliness

Clean joint surfaces and clean filler material are important. In precision work, it may be necessary to clean the joint surfaces by brushing and degreasing. Only stainless steel wire brushes should be used. If grinding is used, make sure the discs are clean. Never use a hammer on stainless steel without some kind of spacer in between, or use a copper mallet.

Deformation

Austenitic steel is liable to deform. Its thermal coefficient of expansion is greater and its thermal conductivity is less than non-alloyed steel.

When welding thin materials, a welding fixture should be used to reduce the risk of deformation. Alternatively, tack welding can be used with less space between the welds than required on non-alloyed steel.

Welding

Spray arc is recommended for horizontal MIG welding of heavier materials. When welding thin materials or when positional welding, the weld pool is too fluid when the spray arc method is used. Use short arc instead, which means less heat is applied. The pulsed arc technique can be used in all positions and provides good control of heat input. This is particularly beneficial in positional welding.

TIG welding of stainless steel upto 3 mm thick can be done with or without filler material. For thicker plate, filler material is used. The TIG method is often used for root runs when quality demands are high and only one side is accessible for welding.

Post Weld Treatments

With suitable post-treatment, the service life of a stainless steel product used in a corrosive environment can be increased. The oxide coating adjacent to the weld must be removed. This is best done with a pickling paste. After pickling, it is essential to rinse away all residual pickling acid with water. The oxide coating can also be removed by brushing, grinding or peening.

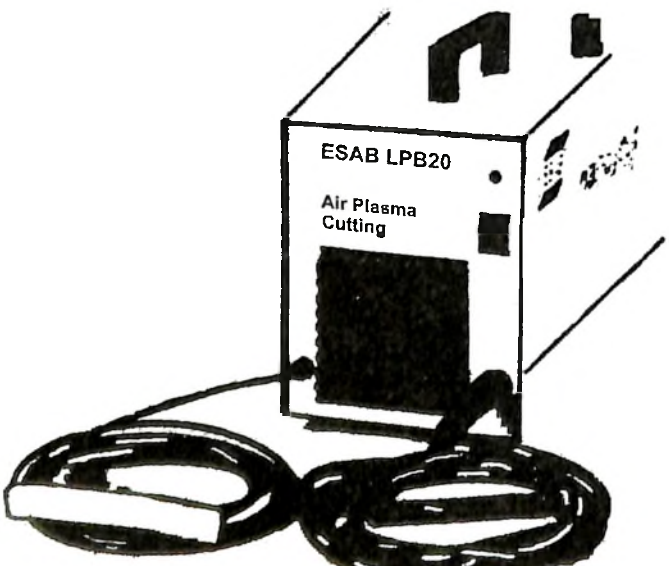


Fig. 6

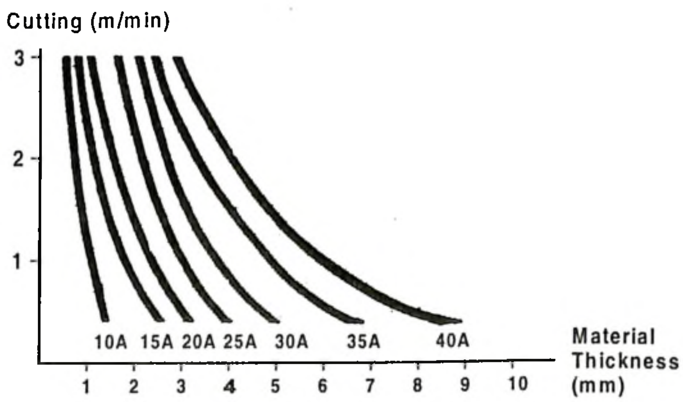


Fig. 7

Plasma Arc Cutting

For cutting stainless steels, plasma-cutting technique has been in use for a number of years. Conventional plasma cutters employed expensive gases like Argon for cutting and hence the process was totally uneconomical. Particularly, for thin sheet cutting, mechanical methods were preferred although they were inaccurate and called for operator skill.

Recent developments in the area of plasma technology combined with high reliability electronics has resulted in the introduction of simple to use, inexpensive, portable plasma cutting machines. Such machines employ ordinary compressed air as the cutting gas and also to cool the torch and nozzle. Bulky bottles of gas are no longer necessary for plasma arc cutting, all that one needs to do is connect the unit to a suitable power supply and compresed air supply and it is ready to use.

A 40 ampere capacity plasma cutter weighing approximately 20 kgs., is shown in the Fig. 6. This machine can handle cutting from 1 mm to 10 mm thick plates of stainless steel. Both manual and mechanised cutting modes are possible. The cutting speeds achievabte for various thicknesses are shown in Fig. 7.

By combining the mechanised mode with a suitable software, one can also achieve profile cutting like ducts, an important need for food processing industry.

What is Super Duplex Stainless Steels

The distinction between duplex and super duplex stainless steel is some what arbitrary. A duplex stainless steel is generally an Fe-Cr-Ni-Mo-N alloy whose composition is balanced to obtain approximately equal amounts of ferrite and austenite in the microstructure. It has been experimentally observed that alloys higher in chromium, molybdenum and nitrogen have improved resistance to pitting corrosion in chloride-containing environments, as compared to their leaner counterparts. Pitting resistance, such as measured by determining a critical pitting temperature (CPT) in the ASTM G48 Method. A ferrite chloride test has been found to correlate reasonably well with a Pitting Resistance index (PREN), which is defined as follows:

$$PREN = \%\,Cr + 3.3\,C\,\%\,Mo + 16\,C\,\%\,N.$$

The convention today is to refer to duplex stainless steels whose PREN is greater than 40 as super duplex stainless steels. Practically, this generally means a duplex stainless steel containing about 25% Cr, nearly 4% Mo and nearly 0.3% N.

CONCLUSIONS

Handling fabrication of thin sheets of stainless steel used in food processing and beverage industry calls for modern welding and cutting equipment with electronic controls and matching filler materials. Added to these the welding practice itself plays a key role in achieving reliable welds. With the availability of advanced equipment and controls locally, fabrication of stainless steel should become far more simple and straightforward.

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