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An Approach to Best Welding Practice. Part – XXI. Section – III- BV-B(i)

ORCID: Samir Kumar Gupta : https://orcid.org/0000-0002-1504-8301

S. K. Gupta, B.E., C.E., FIE., FIIW., MISNT., MAE., MITD.
E-mail : skg1938@gmail.com

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"AN APPROACH TO BEST WELDING PRACTICE. Part – XXI." is the **Twenty First Detail Part** of **"AN APPROACH TO BEST WELDING PRACTICE"** which was written as a General and Overall approach to the subject matter.

AN APPROACH TO BEST WELDING PRACTICE. Part – XXI., Section III –BV-B is particularly focused on the Generation and Computer based Storage of Welding Data on Plasma Welding Processes for Fabrication. It is required as a Working Guideline for Planning Engineers, Welding Coordinators and Quality Managers working in an Engineering Fabrication Plant using welding as the main manufacturing process. This article is the first part of the Section III –BV-B. Other parts will be published in the subsequent issues.

In fact, this is a lengthy process to develop and as each and every step is connected with each other for cross references, none can be eliminated.

In every Fabrication concern where Welding is the major manufacturing process preparation, recording and storage of welding processes must be done.

The Importance of Record Keeping

Record keeping critical in case of Fabrication and Manufacturing concerns employing welding as the main manufacturing process, as because welding is a "Special Process" and the Product acceptance is dependent upon follow up of a number of Procedures, Codes and Standards. Documentation of all these proceedings are to be meticulously prepared and maintained – normally by the "Welding Engineer" or "Welding Coordinator." Again, apart from documentation so many data related to the Power Source, Electrodes, Gases used, Maintenance schedules etc are to be coordinated with variety of data converging for a product to be manufactured and to be accepted by the customer. Normally, most of these are paperwork and the tendency is either to destroy the past records of papers or to dump them somewhere beyond restoration. Even the large volume of information kept in mind of the Welding Engineer or the Welding Coordinator in course of work are irretrievable to any new incumbent or others.

It is an accepted fact now that data collection, storage and retrieval can not be done effectively with human individuals or even by groups and possibilities of distortion of retrievable data cannot be ruled out.

I. What Data are needed ?

It is understood and accepted that in Fabrication and manufacturing Industries where Welding is the main process, classification of Data used and needed is very difficult. We can at best identify the following needs

1. Welding processes
2. Welding Power Sources with Ancillary Equipment
3. Consumables – Electrodes, Wires, Flux Cored Wires
4. Shielding Gases
5. Joint design weldment design and surface preparation
6. Weld location Welding position -

II. How to store and retrieve data ?

A large number of computer softwares have been developed to store data, modify and to retrieve as and when required. This system will eliminate human error, can link and compare past performances with the present one instantly, may even point out optimum use of resources for increased efficiency, effectiveness of resources for ultimate gain of productivity and quality improvement.

An integrated system will include:

- Filler and base metals and their chemical and mechanical properties;
- Histories of welder qualification and the quality of welds by each welder;
- Welding-procedure information, including WPSs, PQRs, and pre- and post weld heat-treatment information;
- Design information, including joint design graphics and welding symbol information; Corrosion-resistant and wear-resistant material information, such as ferrite content and prediction for stainless steel welds.

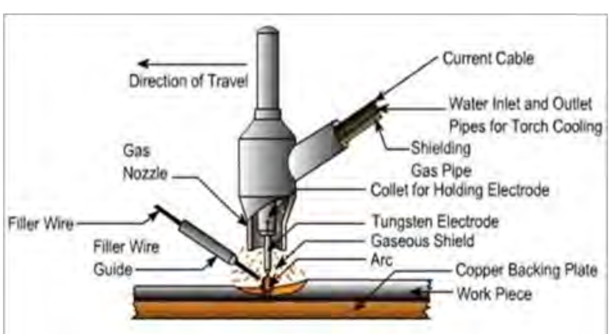
The softwares art all designed to operate in the computing environment of the desktop computer, turning the computer into a welding engineering work station.

Plasma Arc Welding

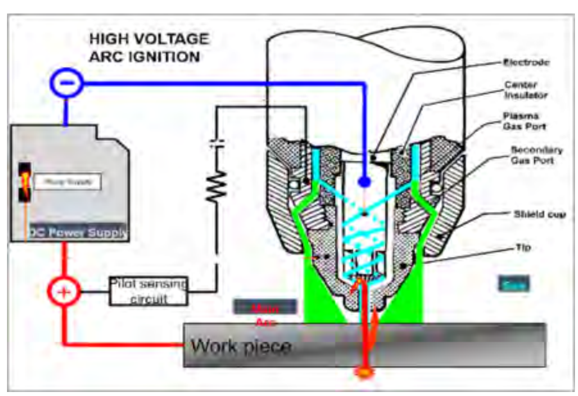
Plasma arc welding (PAW) is a arc welding process using heat produced by a compressed arc between a tungsten non-consumable electrode and the workpiece (transferred arc process) or water-cooled constricting nozzle (non-transferred arc process). The plasma is a gaseous mixture of positive ions, electrons and neutral gas molecules.

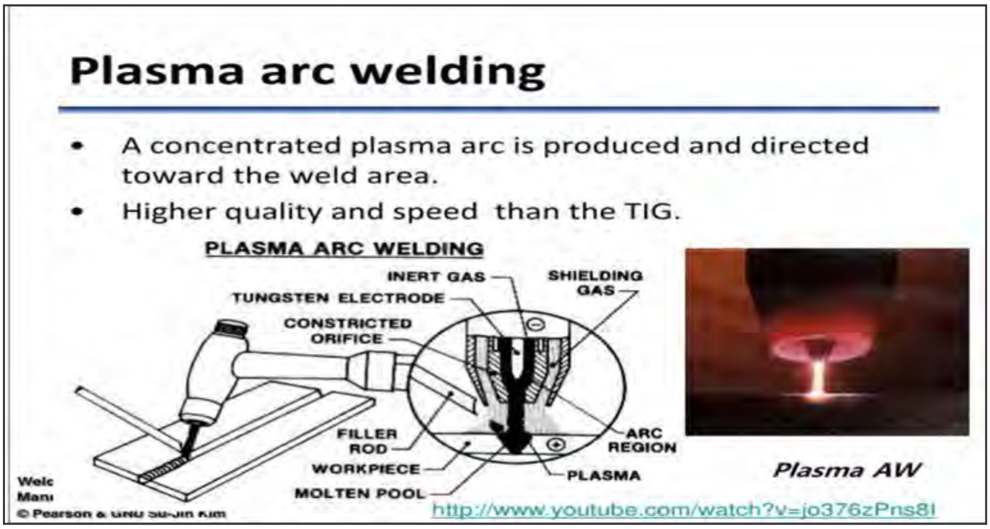
Inert gases used in welding, helium and argon, are made up of loose atoms. At high temperatures the atoms speed up and negatively charged electrons are knocked off the atoms. A plasma is a mixture of fast-moving, negative electrons, neutral atoms, and big, slow-moving, positively charged ions (what's left of an atom after electrons have been knocked off). Plasmas are neutral because the charge of the ions and electrons balance, but because the electrons (especially) and

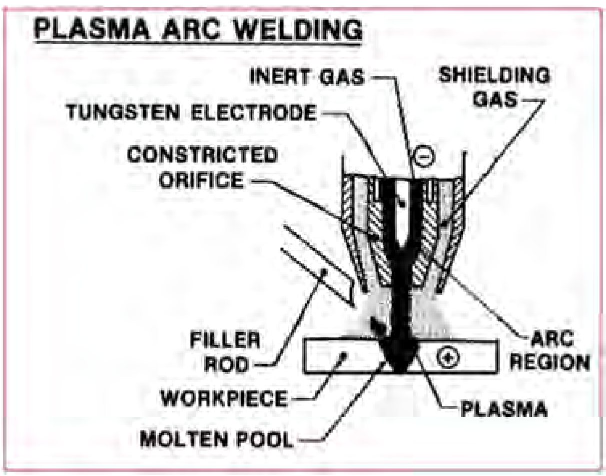
PLASMA ARC WELDING

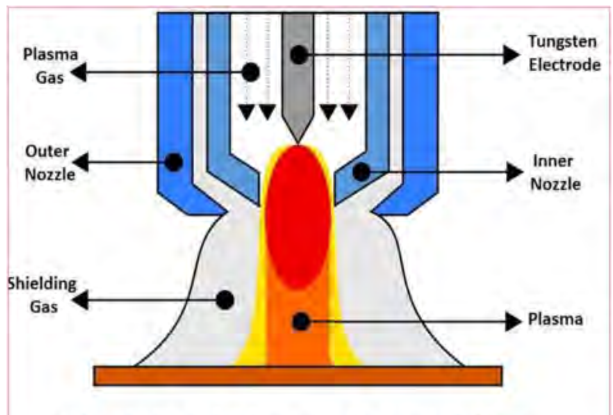


PLASMA ARC WELDING









Principle of Plasma Arc Welding

the ions can move independently, plasmas conduct electricity like metals..

The arc column itself is hot, say 10,000 to 20,000 "C. A voltage drop of around one volt per millimeter is typical for an arc column.

The transferred arc process produces plasma jets of high energy density and can be utilised for high speed welding and cutting ceramics, copper alloys, steels, aluminium, nickel alloys and titanium alloys. The non-transferred arc process produces plasma of relatively low energy density. It is used for welding and plasma spraying (coating) of various metals. Since the workpiece in non-transferred plasma arc welding is not a part of the electric circuit, the plasma arc torch may move from one workpiece to others without extinguishing the arc. Thus if the arc is conducting a 100 amp current, about 100 watts of power is needed to maintain a millimeter of arc column, around the same as alight bulb. The really important voltage drops, through which the electrodes are heated, occur at the electrodes.

PAW: Process Fundamentals

The welding torch used in Plasma Arc Welding (PAW) contains two nozzles an inner nozzle for orifice gas and an outer nozzle for shielding gas. The inner nozzle contains orifice gas which surrounds the electrode. The orifice gas is a neutral gas that gets converted into a plasma state (the fourth state of matter) when an arc is ignited in the chamber. The arc heats the orifice gas to a temperature at which the electrons present in the atoms of orifice gas leave their orbit, due to which, the orifice gas becomes ionized. The ionized gases come out from the orifice of the nozzle as a "plasma jet stream". Plasma is a good conductor of electricity.

Plasma emanates from the nozzle of the orifice at a temperature of about 16,700°C (30,000°F), creating a narrow, constricted arc pattern that provides excellent directional control and produces a very favorable depth-to-width weld profile.

- In PAW the heat source is an arc maintained between a non-consumable electrode and the workpiece

- The arc is constricted by a cooled orifice that surrounds the electrode
- Inert gas is supplied separately to the orifice and to a surrounding low-velocity shielding flow.

Equipment used in PAW

- Power Supply
- Plasma Console
- Water re-circulator
- Plasma Welding Torch
- Torch Accessory Kit (Tips, ceramics, collets, electrodes set-up gages)

1. Power Source

Power Supply The PAW process required a high power DC supply to produce an electric spark between the electrode and welding plates (for the transferred PAW process) either in the tungsten electrode and the discharge nozzle (between the non-transferred PAW process). This welding can weld at a low ampere of about 2 Amp and a maximum current that can control it is about 300 Amp. It requires about 80 volts for proper functioning. Power sources include transformers, rectifiers and control consoles.

2. Plasma Arc Torch

Plasma Arc Torch It consists of four main parts which are tungsten electrode, collets, inner nozzle, and outer nozzle. The tungsten electrode is held by the collet. The internal gas nozzle supplies inert gas to form the plasma inside the torch. The outside nozzle supplies shielding gases that protect the weld area from oxidation. The PAW torches are cooled because the arc is contained inside the torch which produces high heat, so a water jacket is stored outside the torch. Plasma Arc Welding

3. Shielding and Plasma Gas Supply

Shielding and Plasma Gas Supply The plasma gas is similar to a shielding gas supplied by a single source. Mainly inert gases like argon, helium are used as both inert and shielding gases. This gas is provided to both inert and outdoor tubes.

A typical power supply unit charactreristics

Description	Parameter Value	Unit
Rated Supply Voltage	220-230	V
Supply Frequency	50-60	Hz
Rated Input Capacity	6	KVA
Rated Supply Current	30.3	A
No load Voltage	86	V
Welding Current Range	20-180	A
Welding Current Maxm.	220	A
Rated Welding Voltage	27.2	V
Rated Duty Cycle	60	%
Usable Electrode	1.6 - 5.0	mm
Efficiency	85	%
Power Factor	0.9	CoS
Degree of Protection	IP21S	IP
Class of Inulation	H	H
Net weight	4.5	Kg
Machine Size	L340*W150*H1260	mm

4. Filler Metal

Filler Metal Frequently no filler material is used in this welding process. If the filler material is used, it feeds directly into the weld zone

Working Process of PAW

The surfaces of the workpieces are cleaned thoroughly. The power source supplies the power to produce an arc between the tungsten electrode and nozzle, or the tungsten electrode and the workpiece. The tungsten electrode gives a high-intensity arc which is used for ionization of gas particles and then converts the orifice gases into plasma. This hot ionized gas is guided to the welding plates by an orifice. Shielding gases such as argon, helium are supplied through pressure valve and regulating valves to the external nozzle of the welding torch. These gases form a shield around the welding area and protect it from atmospheric gases such as oxygen, nitrogen, etc. The plasma is directed at the plates producing the welding heat. The welding is then carried out. If this welding process requires filler material, it is fed manually.

Three different operating modes can be produced by the choice of the nozzle bore diameter, current level and plasma gas flow rate:

- ❖ Microplasma (0.1 to 15A) is equivalent to microTIG but the columnar arc allows the welder to operate with a much longer arc length. The arc is stable at low welding current levels producing a columnar beam which is suitable for welding very thin section material.
- ❖ Medium current plasma (15 to 100A) similar to conventional TIG, is also used for precision welding operations and when a high level of weld quality is demanded.
- ❖ Keyhole plasma (over 100A) is produced by increasing the current level and the plasma gas flow. It generates a very powerful arc plasma, similar to a laser beam. During welding, the plasma arc slices through the metal producing a keyhole, with the molten weld pool flowing around the keyhole to form the weld. Deep penetration and high welding speeds can be achieved with this operating mode.

Gases used in PAW

Gases (Orifice gas/Shielding gas): Selection of gases for plasma arc welding depends on the following criteria;

- ❖ welding position
- ❖ joint configuration
- ❖ Base metal

Shielding gas is often the same as the orifice gas for many plasma arc welding applications. However, some advantages can be observed when a different gas is used for certain applications.

The orifice gas should be inert with respect to the electrode to avoid the rapid deterioration of the electrode. To enhance the electrode life 99.99% pure orifice gas must be used. Flow rates for orifice gases are generally between 0.1 liters per minute (L/min) to 5 L/min. The most commonly used orifice gases are;

- ❍ Argon
- ❍ Argon – Hydrogen Mixture

Generally inert gases are used as shielding gas. However, an active gas can also be used for shielding if it is not considered to adversely affect weld properties. Following gases are used for shielding the weld pool;

- ❍ Argon
- ❍ Argon – Hydrogen mixture
- ❍ Argon-helium mixture
- ❍ Carbon Dioxide

Flow rates for shielding gases are usually in the range of 5 L/min to 15 L/min for low-current applications and for high-current welding, flow rates of 15 L/min to 32 L/min can be used.

Plasma Arc Welding requires a cooling system. A cooling system should consist of a coolant reservoir, radiator, pump, flow sensor, and control switches.

As in GTAW, tungsten electrodes are used in Plasma Arc Welding (PAW). Tungsten electrodes with small additions of thorium, lanthanum, or cerium can be used for PAW with straight polarity (DCEN). Pure tungsten and zirconiated electrodes are seldom used in plasma arc welding because the electrode tip geometry cannot be maintained..

Comparison of GTAW and PAW Energy Input

The following is from a test made with the GTAW (Tig) and Plasma welding processes on a specific strip of test material in order to establish a comparison of the energy input of poth processes. The test results should be used as a general guideline comparison only.

Test Parameters: Manual welding, no clamping device, Cr/Ni steel, 2.59mm thickness. All values determined with measuring instruments.

GTAW: 125 Amps, 12 Volts, 10.24 I.P.M. (26 cm/min)

PAW : 75 Amps, 18 Volts, 13.38 I.P.M. (34 cm/min)

Heat Input = (V x A x 60) / (SPEED cm / min)

In GTAW Heat Input = (12 x 125 x 60) / (26 cm/min) = 3.46 KJ

In PAW Heat Input = (18 x 75 x 60) /(34 cm/min) = 2.38 KJ

Types of PAW

Following are the main two types of plasma arc welding:

1. **Non-transferred plasma arc welding**

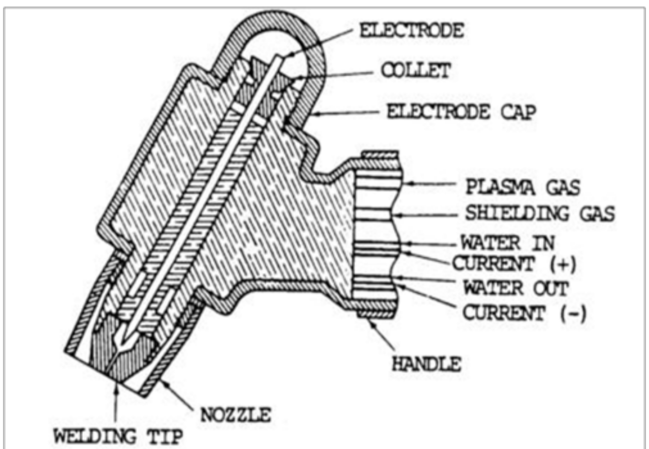
   Non-transferred Plasma Arc Welding In this welding process, DC current is used. In which, the tungsten electrode is attached to the negative and the nozzle is attached to the positive pole. An arc is produced between the tungsten electrode and nozzle inside the torch. This will increase the ionization of the gas inside the torch. The torch transfers this ionized gas for further processing. It is employed to weld thin sheets.

2. **Transferred plasma arc welding**

   Transferred Plasma Arc Welding In this welding process, the tungsten electrode is fixed to the negative terminal and the workpiece is fixed to the positive terminal. It also uses a DC current. An arc is generated between the tungsten electrode and the workpiece. In this process, both plasma and arc are transferred to the workpiece it improves the heating capacity of the process. It is employed to weld thick sheets.

PAW Torch – how it works

The plasma is initiated by a high frequency AC voltage in a chamber inside the torch in an inert "plasma gas." As the plasma gas is fed into the chamber it heats up and expands as well as ionizes. The hot gas rushes out through a water-cooled nozzle as a plasma jet. The plasma jet can be used directly as a heat source, but usually the arc is transferred to the workpiece. The internal "pilot arc" is no longer necessary once the transference takes place. The transferred arc still heats the plasma gas inside the torch and the plasma gas still rushes out as a plasma jet.



Cross section of plasma arc torch head.

Keyholing

The plasma jet makes a particularly stable arc with less tendency to wander erratically and has good concentration as an arc. It is especially useful in its the ability to operate in the "keyhole" mode. The plasma jet has kinetic energy that produces a pressure when it impinges against a weld pool. The pressure is enough to push a centimeter or two into a pool of liquid metal, so that a plasma arc can penetrate into the workpiece like an electron beam or a laser, although the penetration mechanism is not the same. Hence plasma arc welds can be deeper and narrower than GTA welds. The number of weld passes can be reduced in changing from GTAW to PAW. When the PAW process is operated with the arc penetrating all the way through the workpiece the operation is said to be in the "keyholing" mode. The arc impinges on the forward surface of the "keyhole." Melted metal flows around the sides of the keyhole and the streams join behind the keyhole. (The flow of metal is driven by variations in surface tension with temperature, i.e. thermocapillary forces.) In metals that form tenacious oxides, or sometimes due to contamination in spite of the shield gas used to envelope and protect the keyhole, an oxide layer reminiscent of plastic wrap covers the converging streams of molten metal. A lumpy no weld results. But keyholing has a tendency to blow away weld seam contaminants.

Where weld seam contamination is a problem PAW in the keyholing mode might be considered. Porosity in aluminum alloys might be reduced in this way. In the latter case special measures need to be taken to avoid problems from the tenacious oxide on the surface of aluminum.

Applications of PAW

Plasma arc welding is adaptable to both manual and mechanized operation , and can be used to produce either continuous or intermittent welds. Many of the unique advantages of plasma combine to benefit the overall welding process.

Small Part Welding: The plasma process can gently yet consistently start an arc to the tip of wires or other small components and make repeatable welds with very short weld time periods. This is advantageous when welding components such as needles, wires, light bulb filaments, thermocouples, probes and some surgical instruments.

Sealed Components: Medical and electronic components are often hermetically sealed via welding. The plasma process provides the ability to:

1. Reduce the heat input to the part
2. Weld near delicate insulating seals

3. Start the arc without high frequency electrical noise which could be damaging to the electrical , electronic internals

Applications include Pressure and Electrical Sensors, Bellows, Seals, Cans, Enclosures, Microswitches, Valves, Electronic Components, Motors, Batteries, Miniature Tube to Fitting/Flange, Food and Dairy Equipment, Tool Die & Mould Repair .

Metals Welded

Plasma arc welding is used to join most of the metals commonly welded by GTAW. These metals include carbon and low alloy steels, stainless steels, copper alloys, nickel and cobalt based alloys, Titanium alloys.

Welding Positions

Manual PAW generally is considered to be an all position process. Mechanized PAW is done in the flat and horizontal positions.

- These type of welding is used in the marine and aerospace industries.
- It is widely used to weld pipes and tubes of stainless steel or titanium.
- The plasma arc welding often used in electronic industries.
- It is usually employed to repair tools, dyes and moulds.
- It is also used for welding or coating on turbine blades.
- Very thin sheet (down to 0.1 mm), wire and mesh sections in microplasma mode
- Full penetration welding of sheet and prate up to about 5mm thick in single pass keyhole mode.
- Keyhole mode usually in flat position, rarely for tube and pipe welding
- Melt-in mode applications similar to GTAW ar to GTAW

Advantages

- +Higher intensity heat source than GTAW
- -Higher welding speeds
- -Reduced heat input and distortion
- + Insensitive to torch stand-off distance
- + Applicable to almost all metals
- + Adaptable to precision mechanized applications
- Little tolerance for joint misalignment _
- Torch orifice must be well maintained for consistent weld quality
- PAW torches are more bulkier and more difficult to manipulate manually than GTAW
- Requires less operator skill due to good tolerance of arc to misalignments.
- High welding rate.
- It has High penetrating capability (keyhole effect).
- High energy is available for welding. It can easily weld hard and rough workpieces.
- The distance between the tool and the workpiece does not affect the arc formation.
- It has low power consumption for welds of the same size.
- The more stable arc produced by the plasma arc welding.
- It can operate at low amperage.

Disadvantages

- Plasma welding needs two different gas supplies. One, generally pure argon, is needed to form the plasma stream and the other, often an argon/hydrogen mix, is the shielding gas. This involves two sets of gas control equipment and very careful control of the gas flow rates.
- Watercooling of the torch is essential even at low currents to avoid overheating and erosion of the nozzle and orifice.
- Plasma equipment, particularly torches, is more expensive than that for TIG welding and needs more careful maintenance.
- A plasma arc is often too narrow and stiff, which does not compensate for component inaccuracies and leads to need for more accurate and thus more expensive fixturing. The slightly conical TIG arc can be a positive advantage in such cases.
- The plasma process is sometimes slower than TIG and often requires a second weld run, e.g. for bellows manufacture.
- Plasma equipment is generally bulkier and less portable.
- Nearly all bellows manufacturers have abandoned plasma and returned to TIG, particularly pulsed TIG.
- AVC (arc voltage control) cannot be successfully applied to plasma. For autogenous welds this does not always matter but it does if filler wire is being used. Surfacing build-up operations are much more easily carried out using TIG.
- Ninety five per cent of all microwelding can be just as satisfactorily carried out using TIG without the extra complications of plasma
- Standard machine type torches are not readily available for plasma.

v Plasma cannot be easily applied to orbital pipe welding because of the additional complexity of pipework and cables to supply the weld torch with welding current and gas.

- Plasma arc starting nearly always needs HF which can interfere with computers, microprocessors and DC thyristor drives.

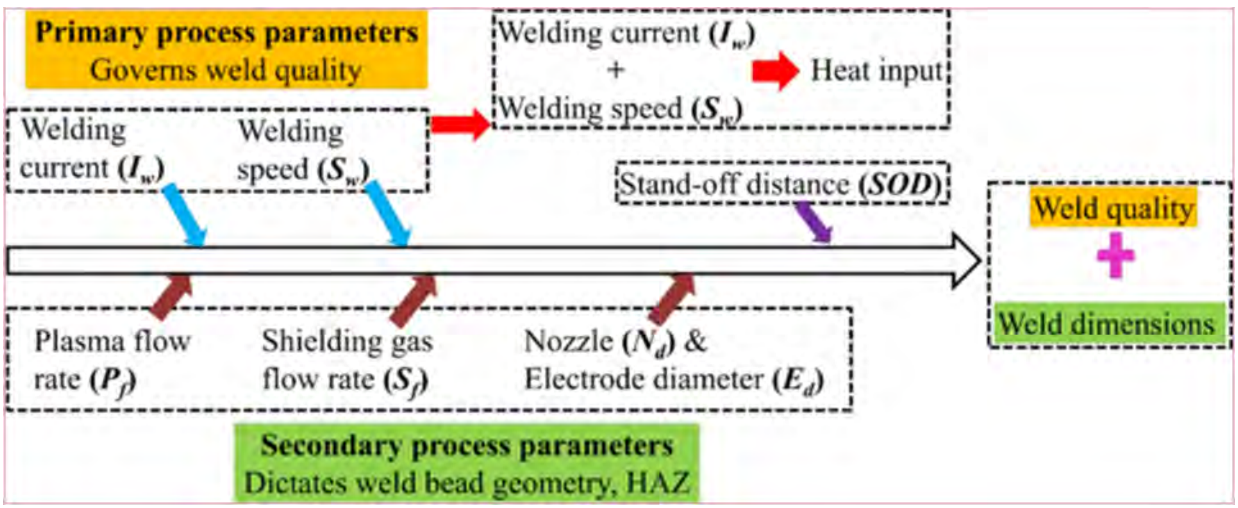
- Note: Neither the TIG nor plasma processes are suitable for outdoor use except in very still air or with the welding arc securely curtained off to avoid draughts.
- Expensive equipment.
- High distortion and wide as a result of high heat input.
- It is a noisy operation so there is a chance of noise pollution. Plasma Arc Welding
- It has more radiation.
- Plasma arc welding is required high skilled labour.
- The maintenance cost is high.

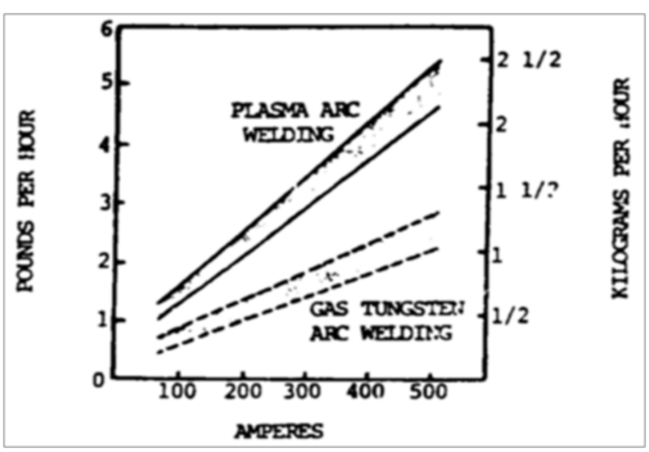
Plasma Arc Welding of Titanium alloys

Welding of titanium can be relatively complex since at high temperatures the material can be very reactive and depending on the inclusion of impurities, they can also have a negative effect on overall weld integrity. Main advantages of PAW compared to TIG include, lower heat inputs, high welding speeds and high metallurgical quality levels.

For successful welding of titanium, some factors need to be considered. Titanium is extremely reactive in temperatures exceeding 500-650°C. It reacts with elements in impurities or air such as C, O, N, and H. These elements strengthen titanium but small amounts also impair ductility and toughness of titanium joints. The effects of the heating and cooling cycles involved in welding processes on the mechanical properties of the alloys and the specific alloy composition also need to be considered.

Development of Microplasma Welding for Different Thicknesses





Sl.No	PAW Parameters	Range
1	Welding Speed	20-100 (mm/min)
2	Welding Current	120-300(A)
3	Gas flow	10-30(l/min)
4	Shielding Gas	Argon
5	Electrode & Dia.	ER4043. 2 mm
6	Nozzle to Plate Distance	1-6 mm

PLASMA ARC WELDING PROCESS CONDITION

Sl	Parameters	Value
1	Diameter Of Wire	1.2 mm
2	Standard Current	220 A
3	Voltage	24 V
4	Shielding, Welding Gases	82% Ar/18% Co_2 98% Ar / 2 & O_2
5	Kind of Tested Microjet Cooling Gas	82% Ar / 18 % Co_2 78 % Ar+ 2% Co_2 + 20 % Helium
6	Gas Pressure	0.4 Mpa , 0.5 Mpa
7	Number Of Microjets	1
8	Cooling Steam Diameter	40µm, 50µm

Sl	Parameters	Value
1	Diameter Of Wire	1.2 mm
1	Dianeter of Wire	1.2 mm
2	Standard Current	220 A
3	Voltage	24 V
4	Shielding MIG Welding Gas	Argon
5	Steam Dia. Of Micro Jet Gas	50µm
6	Micro-jet Cooling Gas	Argon
7	Micro-jet Gas Pressure	0.3 to 0.7 MPa
8	Distance between Welding Head and Microjet Injector	6 cm

OPTIMIZATION OF PROCESS PARAMETERS FOR PAW OF AUSTENITIC STAINLESS STEEL (30-4L) WITH LOW CARBON STEEL.

Parameters	Values
Shielding Gas flow Rate	10 LPM
Purging Gas Flow rate	10 LPM
Plasma Gas Flow Rate	0.5 LPM
Nozzle to Plate distance	6 mm
Filler wire	309 L
Holding Time after welding	1 min
Joint Design	Square Groove
Shielding Gas	High purity Argon
Plasma Gas	High purity Argon
Electrode used	9-1783
Orifice Diameter	0.46 mm
Torch Position	Vertical
Operation tYpe	Automatic
Pilot Arc	5 Amp
Mode of Operation	Fusion Mode
Plate Thicknrss	2 mm

TECHNICAL DATA (EN 60974 -70
ABIPLA* S WELD 150 CT 20

Type of Cooling	Liquid Cooling
Welding Current	80-150 AMP
Duty Cycle	100 %
Welding Speed	Vs up to 4.0 m/min
Electrode Diameter	1.2 - 3.6 mm

ABIPLUS * WELD 250 MT
ABIPLUS* WELD 250 CT 20

Type of Colling	Liquid Cooled
Welding Current	Max. 300 A
Welding Speed	Vs up to 4.0 m/min
Electrode Diameter	3.0 - 4.5 mm
Duty Cycle	100 %