Review on Gas Tungsten Arc Welding of Stainless Steel and Mild Steel Plates

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Abstract

Tungsten arc welded plates are commonly used in industries. The Welding of dissimilar metals is particularly useful in structural applications. However, welding such plates is difficult due to the loss of carbon from mild steel and the precipitation of chromium in stainless steel during the welding process. TIG welding is the best process for controlling these issues that arise during welding on base metals. This paper review TIG welding of Stainless steel and mild steel plates.

Keywords: TIG welding, Dissimilar Metal Welding, Carbon Migration

1. Introduction

Welding is a process that involves applying heat and pressure to two or more parts to form a permanent joint. The process produces a mixture of materials by reheating them before they re-crystallize temperature with or without the inclusion of filler material, and with or without pressure. Welding is a method of joining metals permanently.TIG welding is a form of welding that uses a tungsten electrode that is commonly used in modern industries to join materials that are identical or dissimilar. We can easily join by using the TIG welding process. Nuclear reactors, Construction, thermal power plants, vessels, and heat exchangers are all examples of civil engineering, as well as a range of industrial applications, all use stainless steel and mild steel plants.

Gas tungsten arc welding (GTAW), otherwise called tungsten inert gas (TIG) welding, is a sort of a bend welding measure that utilizes a non-consumable tungsten anode to create the weld. The weld region and anode are resistant to oxidation or other barometric pollution by an idle protecting gas (argon or helium). Filler metal is by and large utilized, however a few welds, alluded to as autogenous welds, or combination welds don't need it. At the point when helium is utilized, this is frequently alluded to as heli-arc welding [1].

GTAW welding thin stainless steel and non-ferrous metals like aluminum, magnesium, and copper alloys are a specialty. This approach provides rival methods like welding techniques include shielded metal arc welding and gas metal arc welding. Give you more control over your weld, resulting in quicker, and higher-quality welds. GTAW, on the other hand, is considerably more complex and difficult to track than most other welding methods, as well as significantly slower. Plasma arc welding is a similar method that employs a slightly distinct welding torch to produce a larger weld, extra centered arc welded and is often automated as a consequence [2].

Since it affects electrode burn-off rate, fusion depth, and weldment geometry, welding current is the most important variable in the arc welding process. Weld bead shape, welding speed, and weld efficiency are all affected by current. Since DC on electrode negative (DCEN) (straight polarity) produces greater results, Weld penetration depth and travel speed are greater on the electrode positive (DCEP), and it is used in the majority of GTAW welds (reverse polarity). Reverse polarity allows the electrode tip to heat up rapidly and degrade in gas tungsten. Since the anode heats up faster than the cathode. A higher current in gas tungsten arc welding can cause spatter and damage to the workpiece. Again, in gas tungsten arc welding, a lower current setting causes the filler wire to stick. To deposit an equal amount of filling content, high temperatures must be applied for long periods. So greater heat-affected areas are often seen for lower welding current. The voltage is adjusted in fixed current mode to keep the arc current steady [3,4]. Generally, we achieved defect-free joints by tungsten inert gas welding, as compared to other welding processes. Give you more control over your weld, resulting in quicker, and higher-quality welds. GTAW, on the other hand, is considerably more complex and difficult to track than most other welding methods, as well as significantly slower. Filler metal is by and large utilized, however a few welds, alluded to as autogenous welds, or combination welds don't need it. This approach provides rival methods like welding techniques include shielded metal arc welding and gas metal arc welding.

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2. Working Principal of TIG Welding

It operates in the same way as arc welding does between the tungsten and the work object, a powerful arc is formed. Heat is created by the arc, which is used to fuse the sample. Shielding gas is often used to stop oxidation of the weld surface [5].

The gas is ionized as it is supplied by the tank, an arc forms between the electrode and the work object as a result. Heat is produced, causing the Welding of base metal and filler rod to fail and the filler metal to fall onto the heated joint. One of the workpiece is formed by a DC source with positive polarity. The negative polarity is applied to the electrodes. The power source may be a negative electrode and a continuous voltage AC or DC power source that produces a smooth metal transfer and a steady arc with minimal splatter all over the existing spectrum [6].

Power sources for welding, high-frequency unit, and cables are the main components of the TIG operation. To complete the TIG welding process, we required a welding torch, tungsten electrode, and filler metals. We also needed an inner gas cylinder, a pressure regulator, and a flow meter to get the best welding efficiency. Inert gas is commonly used to protect against contamination of welded joints and ambient gases. TIG welding often necessitates the use of cooling water to keep the device cold, as well as a gas valve [7].

2.1. Mechanism

The weld is made with a non-consumable Tungsten electrode. Electrodes with a diameter of 0.5 mm to 6.4 mm and a length of 150 mm to 200 mm are widely available. Depending on whether they are connected to a positive or negative terminal, electrodes have different current-carrying capacities. Thorium and zirconium are used to keep the electrode from melting since the arc length varies, to hold the current steady, a constant current power source is used. The welding torch receives power from the power source and delivers it to the electrode, which is housed within the torch holder. For Aluminum and Magnesium, an AC power supply is usually favored because the cleaning action of AC eliminates oxides and enhances joint consistency. A constant-current welding power supply creates an electrical arc between the tungsten electrode and the workpiece.

Noble gas, typically Argon or Helium or a combination of both, the tungsten electrode, and thus the welding zone, is shielded from the ambient air. Temperatures of up to 20,000°C are formed, which are used to join two separate materials. The electrical arc is fed with filler metal either manually or automatically. Depending on the type of fabric or alloy we're welding, the filler rod we use is critical [8].

2.2. TIG Welding Process Parameters

The following operating variables influence the weld bead geometry, penetration depth, and overall weld efficiency. Tungsten inert gas welding produces excellent weld efficiency, but welding parameters and joint geometry have a significant impact on weld deposition rate. For a good and best outcome, proper process execution and control of a large number of parameters are critical. Normally, various combinations of welding parameters and joint geometries are used to create a welded joint.

2.2.1 Welding Current

The most important variable in the arc welding technique welding current regulates the level of electrode decomposition, fusion depth, and weldments geometry. Current has a direct impact on a welded bead form, welding weld, and pace efficiency. Since DC on the electrode negative (DCEN) (straight polarity) achieves the greater depth of penetration and movement speed of the weld DC on electrode positive (DCEP), it is used in the majority of GTAW welds (reverse polarity). Furthermore, since the anode is more heated than the cathode in a gas tungsten discharge, polarity inversion causes the electrode tip to heats up quickly and degrades. In GTA welding, a higher current will cause splatter and damage to the workpiece. Again, in GTA welding, a lower current setting causes the filler wire to adhere. Since high temperatures must be applied for long-term limits for deposits and a similar quantity of filling products, lower welding current also results in larger heat-affected areas. The voltage is varied in fixed current mode to maintain a steady arc current [9].

2.2.2 Welding Voltage

The electrical potential between the welding wire's tip and the ground, as a result, the molten weld pool's seeming. Depending on the GTA welding voltage, welding equipment is often set or adjustable. It defines the fusion zone's shape as well as the reinforcement with welds. Arc initiation is aided by a high initial voltage and permits for a superior working tip distance series. It does, however, generate larger, Low welding voltages that produce flatter, less deeply penetrating welds; At maximum arc voltage, the penetration depth is greatest, on the other hand, high welding voltage causes significant variations in welding efficiency [10].

2.2.3 Welding Speed

The rate at which the electrode is moved along the seam or the rate is increased at which a job done with an electrode travels along the seam, determines welding speed [11]. Weld Travel Speed is measured in millimeters per minute of electrode/arc travel. Welding speed is an essential factor in GTAW welding. Accelerating for a given current and voltage, the welding speed has the effect of reducing the warmth input. Since they're connected to the current, the electromagnetic force is unaffected by welding speed and hence the arc strain. As weld speed increases, the region of the weld cross-section shrinks. The D/W ratio, including penetration depth (D) and weld width (W), has only a small impact on travel speed. These findings indicate that the travel speed has no impact on the processes involved in the creation of the weld pool, rather than the amount of material that has melted as a function of current, material form, and other variables, welding speeds vary from 100 to 500 mm per minute and thickness of the plate [12].

2.2.4 Shielding Gases

There are numerous shielding gas applications in the GTAW process. Since it protects the weldment from atmospheric pollution, shielding gas is very necessary for the form of tungsten inert gas welding. The presence of oxygen and hydrogen in the atmosphere causes our weldments to heat up, which is why we use shielding gas as a protective layer on the weldments. Argon, helium, and argon + helium are also Gases that are used as shielding agents.

Helium is recommended for welding thick aluminum workpieces since it has a higher ionization potential than other high-conductive materials like copper alloys than argon, requiring arc initiation and maintenance at a higher voltage, but with more heat output [13, 14].

2.2.5 Filler Metal

Filler metals, which have a content creation in the same vein as the parent material, are commonly used for plate thicknesses greater than 2 mm. Filler metal is usually applied cold from a roll or a loop in programmed frameworks and ranges in thickness from 1.6 to 3.2 mm. Austenitic steels come in a variety of forms, but not all of them are austenitic hardened steels that are welded without the use of filler metal or additional heat treatment regularly. To achieve adequate erosion resistance of the weld, the vast majority of very austenitic mixtures necessitate the use of filler metal. Frequently, the weld metal is in a position to meet the reinforced base material's fundamental yield and durability requirements. The welds' malleability isn't quite as good as base metal, but they're still bendable. Filler metals with low carbon grades (L-grades) are commonly used in consumption-safe assistance. The upper metals of carbon filler will stimulate higher-temperature output administration for high-temperature administration. A large number of the 300 filler metals have had their structures changed to ensure that the cement with a sufficient total of ferrite to avoid hot breaking during hardening. This takes into account higher warmth sources of information and, as a result, greater welding speeds. The existence of a specific volume of ferrite denotes that the Welds have a ferromagnetic property. Welding should be done with lower heat inputs for compounds that are set fully or nearly completely austenitic. An express ferrite weld metal is appealing for certain applications, and convinced filler metals are shipped for that determination. The most popular filler metal used in most 300 arrangement tempered sheets of steel is coordinating with filler metal [15, 16].

2.3. Advantages, limitations and applications of Gas Tungsten Arc welding

Advantages:

- TIG welding necessitates the use of a tungsten electrode that is not consumable.
- Filler metal is applied by hand when necessary.
- To secure the weld and the tungsten, shielding gas is used.
- Welds a greater number of metals than any other process [17].

Limitations:

- TIG fusing is a labour-intensive process. They are more time-consuming than the other welding methods.
- TIG welding is more difficult because it needs highly qualified and experienced personnel.
- Health and safety concerns Welders are exposed to high levels of light, which can cause eye damage.
- The initial cost of TIG welding is extremely high [17].
- TIG welding is more difficult because it require costly equipment.

Applications:

- TIG welding is reasonable in steel welding situations where quality and visual part of weld crease are the principal significant issue With the assistance of TIG welding we can join a wide range of steel grades.
- General applications for creases that need a great visual look.
- Metal furniture, machine building, bikes, and so forth. The chemical industry needs smooth weld profiles. Lines, tanks, and so forth Aviation and flying corps use TIG welding for its unwavering quality.
- Thin sheet industry, Automotive and vehicle industry, transport industry, and so on repair welding of all sort of steel.
- Machinery, support, and so on X-beam quality root passes.

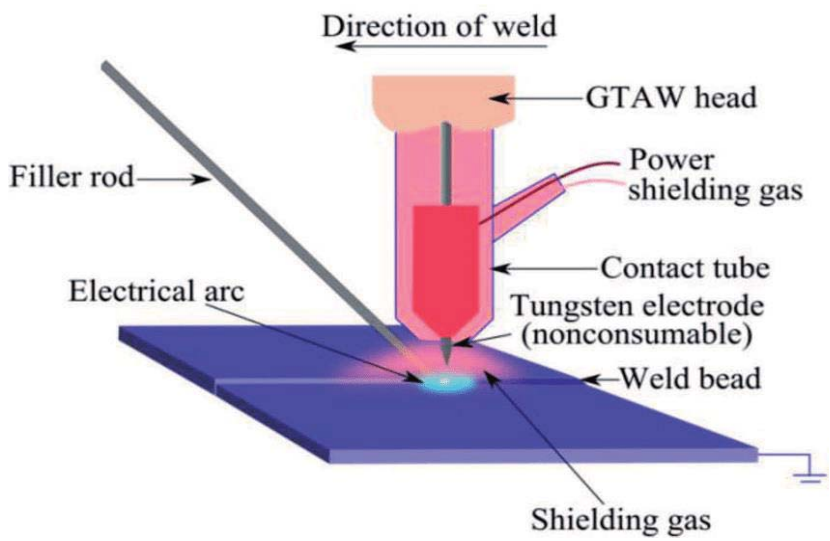


Fig. 1: TIG Welding [18]

3. Dissimilar Metal Welding

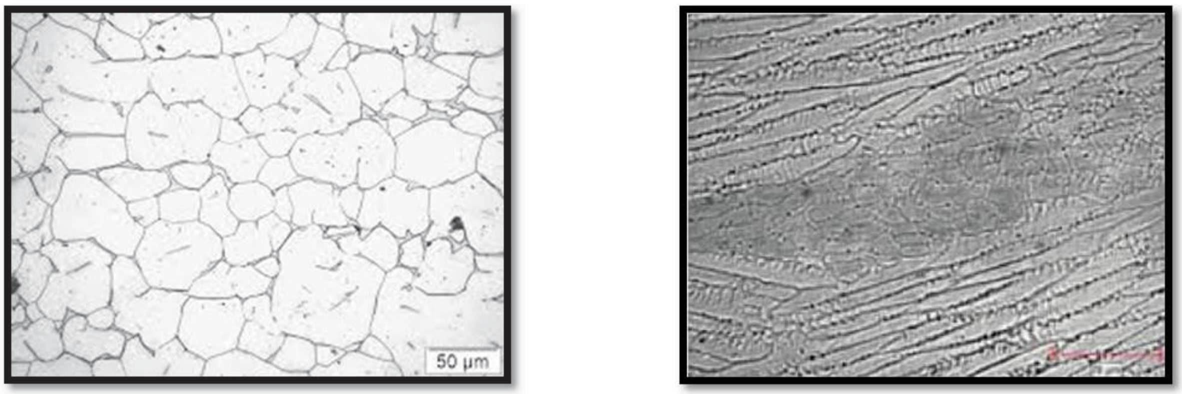
This is a method of joining two metals that have different chemical or mechanical properties and aren't a good match. Since it consists of more than two different metals, such as aluminum and steel, the word can be a little confusing at times. Infect, two metals of the same name are often welded together, but if they need different core properties, they are referred to as dissimilar metals. You could weld two steel metals together, for example, they will, however, vary enough to be considered dissimilar.

This Welding establishes a solid, long-lasting bond between the two metals, resulting in a single finished product. In the section below, we go through the procedure in greater detail. This welding method functions almost identically to that of joining two similar metals together using a beam that is precisely centered on the metals; you melt each of the metals together until they form a single linked joint. If the two metals aren't welded differently, such as if you're using two austenitic sheets of steel, as we discussed earlier, the two will frequently come together seamlessly. Different Factors that should consider are:-

- Solubility – This is the tendency of a metal to dissolve in a solvent. Both metals must be able to dissolve in each other.
- Intermetallic compounds – During the welding process and exhibition metallic bonding, these will be formed in the conversion region.
- Weldability – Dependent on the solubility of two metals and their Intermetallic compounds.
- Thermal expansion –Temperature rise determines how much the form of your metals changes.
- Melting rates –The stage at which metal begins to melt.
- Corrosion –Corrosion is characterized as the occurrence of corrosion when two metals have different electrochemical scales.
- End–service conditions – Regardless of the circumstances under which your dissimilar metals will be used.

The GTAW (TIG) welding measure was first evolved in quite a while in the mid-1940by Russell Meredith of Northrop Aircraft Corporation. Around then Northrop required an approach to weld aluminium and magnesium and current welding measures were not satisfactory to weld these combinations. President Roosevelt, in a letter to Winston Churchill, would later flaunt about the disclosure of new welding strategies that empowered America to assemble ships with a speed unparalleled throughout the entire existence of shipbuilding. TIG or GTAW (Heli arc) was created to join light amalgams utilized in airframe producing, explicitly, Magnesium. The TIG cycle gave a steady, reasonable approach to rapidly accomplish top-notch welds [19].

Stainless steel is a category of iron-based alloys with at least 11% chromium, a composition that prevents rusting and provides heat resistance. Stainless steel contains nitrogen, aluminium, silicon, sulphur, titanium, nickel, copper, selenium, niobium, and molybdenum, among other elements (ranging from 0.03 percent to greater than 1.00 percent) [20, 21].



(a) (b)

Fig. 2: (a) 304 L Stainless Steel microstructure [22] and (b) Microstructure of 304 L Stainless Steel by TIG Welding [23].

Table 1:- Effect of TIG welding on various Stainless steel-grades

Reference No.	Materials	Type of welding	Parameters	Outcomes
[24]	SS 304	TIG	308 stainless steel filler wire	HAZ has a dendritic structure and a coarse-grained structure. Tensile power, yield strength, and elongation are all 1800 MPa, 75 MPa, and 25%,correspondingly.
[25]	SS 316L	TIG	Ar Gas with H2 [H2 concentrations of 0 percent, 1.5 percent, and 5%]	1.5 percent H–Ar has a higher tensile power. With increasing H2 content, penetration depth and weld bead width increase.
[26]	SS 304L	TIG	Multipass TIG 304 SS filler metal	The welds had a dendritic microstructure, which is -ferrite. The optimum hardness value is obtained for three pass specimens.

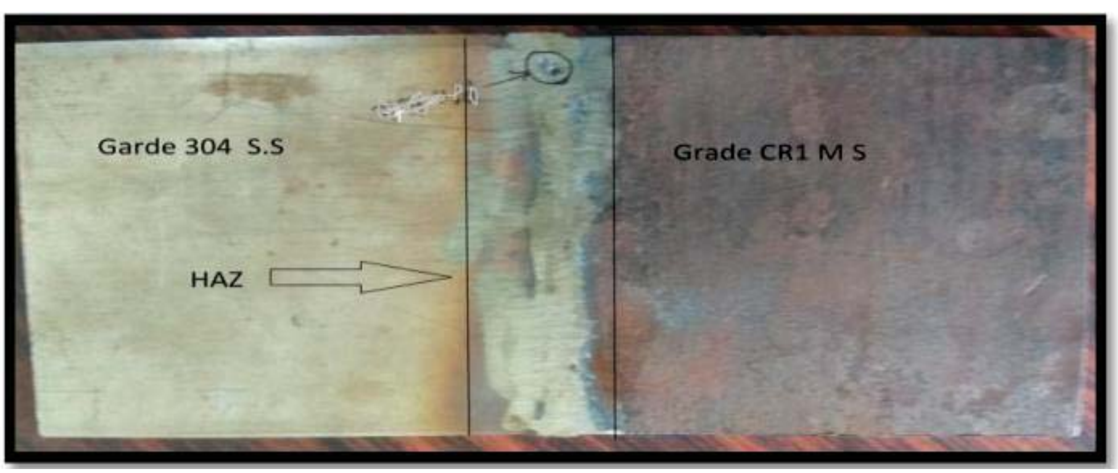


Fig. 3: TIG welded plates

Table 2:- Chemical composition of grade 304 and CRI

Element	ASTM A 240 GRADE 304	IS 513GRADE-CR1
Carbon	0.048	0.042
Sulphur	0.014	0.004
Phosphorous	0.030	0.020
Manganese	1.090	0.189
Silicon	0.406	-
Chromium	19.12	-
Nickel	8.01	-
Nitrogen	0.052	-

When used on stainless steels and mild steels, the key benefits of this process are often summarised as follows:

1. A localized heat source that leads to a small fusion zone.
2. 2. A small welding pool with a very stable arc and a calm environment. Spatter isn't a problem, and the oxidation method doesn't require any flux.As a result of the removal of residues, any final cleaning process is greatly simplified.
3. A high level of metallurgical efficiency, with a focus on penetration and weld form in all positions.
4. Welds that are sound and pore-free.
5. Electrode wear resistance is extremely poor[27].

To join mild steel and a stainless steel standard, TIG welding was used. Elasticity welded joint weakening, hardness, and curve analysis were all looked at. The weld properties are largely determined by the collection of various evaluations of processed steel used for welding. For S.S. and MS plate joints welding with tungsten inert gas is the best option. In the welding industry, we can see there isn't anything deformity found because of welding like porosity, breaks, and so on likewise twist test demonstrated the best outcome for this work. The result was fulfilled and clears a pondered welding under twist load. Since the deficiency of Cr from S.S. during TIG welding is extremely low, it resists erosion in the field. Furthermore, welding is performed in an inactive environment to protect the weld from hydrogen and other environmental hazards. According to the article, the strength of various metals welded by TIG welding is incredible. Hardness esteem at the motivation behind filler metal is at an all-time high, which simply the result of form exploration is progressing. When we add up all of the test results, we find that TIG welding on similar metal plates produces the best results [1].

Differing welding was done with SS-316 and MS-E350BR, both of which were ostensibly 8 mm thick. Tables 3 and 4 show the compound structures of the SS-316 and MS-E350BR combinations, respectively.

Table 3:- Chemical composition of SS- 316.

%	C	Mn	Si	P	S	Cr	Mo	Ni	N
SS 316	0.08	2.0	0.75	0.045	0.03	18.0	3.0	14.0	0.10

Table 4- Chemical composition of E350BR.

%	C	Mn	S	P	Si	Nb +V+Ti	N	CE Value
E 350BR	0.20	1.50	0.045	0.045	0.45	0.25	-	0.42

Disparate metal SS 316 and E350BR are welded by TIG welding. On a variety of comparable and dissimilar materials, there has been some work on TIG welding with gases. Done to consider and advance the welding yield such as elasticity, the tensile strength of weld joints, and so on shifting the information boundaries such as welding current, gas stream rate, welding speed, and so on.

Karpagaraj et al. [30] suggested that Drop geometry, reinforcements, and weld depositions are of particular concern to the majority of the investigators. Micro-hardness, impact strength, and corrosion studies are among the other outcomes that need further focus. New and hybrid techniques can also allow for improved optimization and calculation. Rattana Borrisutthekula et al. [31] concluded that at a given heat input, increasing welding speed or current did not affect the welding width and thickness of the intermetallic reaction sheet. Wider welds and narrower welding windows resulted from increasing the arc length, however, it was not discovered to be a factor in the height and width variance of the Layer of intermetallic reaction. The strength of the intermetallic reaction layer is affected by changes in welding speed and arc length. K.C. Ganesh et al. [32] suggested that since most recent studies on activated TIG welded joints have based on it is dynamics of molten weld pools, this study provides insight into the thermo-mechanical behavior of A-TIG welded joints compared to MP TIG-welded joints. The mechanical-thermal behavior of Welded joints made of 316LN stainless steel was investigated by the MP TIG and A-TIG fusing processes. Himanshu Garg et al. [33] reviewed the TIG and A-TIG joining methods. Estimates for TIG and A-TIG welding procedure variables, as well as Microstructure, mechanical, penetration depth, and weld bead consistency are examples of weld outcomes, have also been given. In comparison to TIG welding, activated TIG welding has greater hardness and mechanical properties. The microstructure, mechanical properties, and comparisons between the two weld developments are all extensively explored, as are the weld characteristics of stainless steel in TIG and A-TIG. A-TIG welding possesses a higher weld penetration than conventional TIG welding, resulting in different welding properties. The effects of depth penetration and the ratio of depth to width differed as different fluxes were used.

A. Karpagaraj et al. [34] identifies the most widely used optimization techniques for the GTAW process. Each GTAW procedure parameter's contribution is recognized. The graph shows that the most important parameters in GTAW are WC and WS. Peak current and back current in the pulsed GTAW action are the most energetic limits. To measure the GTAW process parameters, hybrid techniques were introduced. Bead geometry, reinforcements, and weld depositions are of particular concern to the majority of the researchers. Micro toughness, impact strength, and corrosion studies are some of the other outcomes that need further focus. Other GTAW parameters will be studied in the future, and the results will be interesting. Techniques that are modern or hybrid. According to YasuoSuga et al. [35], sudden changes occur in welding conditions, similar to root hole, welding speed then on, the welding framework can optimally control the welding conditions. The built framework is tried and situated to be successful for entrance control in programmed butt welding of slight low-carbon steel plates. A smart welding robot framework with vision sensors that notice the structure and measurements of the weld liquid pool, including length, width, and the region was built. A versatile framework utilizing Artificial Neural networks was proposed. It's an Input layer of six units for length, width, region, welding speed, welding current, and root hole of welding line, a yield layer of seven units that show change of welding current, and a secret layer of eight units. Naishadh P. Patel et al. [36] reviewed Effect of Activated Fluxes on Weld Penetration and Mechanism Responsible for Deeper Penetration of Stainless Steels.

4. Summary:-

• In the arc welding process of gas tungsten arc welding, also known as tungsten noble gas welding, a non-consumable tungsten electrode is used to supply the weld. As compared to rival methods like shielded metal arc welding and gas metal arc welding, this method is superior, the process allows for more control over the weld, resulting in cleaner, higher-quality joints.

• Low-carbon steel plates up to 6 mm thick are usually joined using TIG welding.TIG welding produces a more accurate and safer low-carbon steel weld than other arc welding techniques such as manual arc welding or metal noble gas joining. Low-carbon steel is a ductile metal that can be machined quickly. TIG welding machines are available in two current ratings: high and low.TIG welding has a current range of 150 A to 350 A, which is ideal for welding thick low-carbon steel plates. We can see that there are no defects found due to welding, such as porosity, cracks, and so on. TIG welding creates a stronger bond between metals that aren't compatible.

5. Conclusion:-

TIG welding effect on stainless and mild steel plates was studied in this paper, with various welding speeds, welding current, voltage, and other parameters and others influencing the results. Mild steel and stainless steel plates were joined using the TIG welding method. In which defects such as porosity and cracks cannot be detected using this welding technique. TIG welding of stainless steel and mild steel produces superior properties as compared to other welding processes.

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