EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF TIG WELDING PARAMETERS ON DUPLEX STAINLESS STEEL: A REVIEW

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Abstract— Abstract— Tungsten Inert Gas welding is also known as Gas Tungsten Arc Welding (GTAW), has an advanced arc welding process become a popular choice when a high level of weld quality or considerable precision welding is required. However, the major problems of the TIG welding process are its slow welding speed and limited to lower thickness material in a single pass. In this work, autogenous TIG welding has been performed on 5 mm thick Duplex Stainless Steel 2205 plate without using any filler material. The wide selection of welding current and scan speed has been tested for getting full penetration welding. Activated flux has conjointly been used to improve the weld depth. After performing welding by maintaining the different gap between the plates to be welded, weld bead geometry and tensile strength of the weld has been investigated. It is observed that by maintaining an appropriate gap full penetration welding of the plate is possible which gives strength almost similar to the base material.

Keywords - Tungsten Inert Gas welding, Activated flux, Tensile test, Hardness test and A - TIG welding process etc.

I. INTRODUCTION

Welding is a process of joining two similar or dissimilar metals by fusion, with or without application of pressure and with or without use of filler metal. Weld ability of the material depends upon various factors like the metallurgical changes that occur due to welding, change in hardness of material, in and around the weld and the extent of cracking tendency of the joint. A range of welding processes have been developed so far using single or combination of factors like pressure, heat and filler material used [1].

1.1 Classification of Welding processes

- Homogeneous welding
- Heterogeneous welding
- Autogenous welding

Homogeneous welding – Welding of thick plates using filler metal used as per needs according to thickness of plate. The filler material used to provide better strength to the joint. In this proce is same as base metal. Different types of homogeneous welding process commonly used are

a)Arc welding – Filler material generally used as consumable electrode for manual arc welding and metal inert gas welding. b) Gas welding – An external filler rod is required for gas welding.
c) Plasma arc welding – In case of Plasma arc welding also an external filler rod is necessary for welding.
d) Thermit welding – In case of Thermit welding a molten material from some chemical reaction is added.

In case of homogeneous welding solidification occurs directly by growth mechanism without nucleation stage.

Heterogeneous welding – A filler material different from the base material is used for welding. The solidification in heterogeneous weld takes place in two stages i.e. nucleation and growth

1.2 Various types of Autogenous welding process

a) Resistance welding – Among these process resistance welding is limited for specific application and not useful for thick plate and complicated shape. Further for welding different thickness plate different diameter electrode is required.
b) Laser beam welding – Laser Beam Welding process is very expensive process not for small industry.
c) Electron Beam Welding – Similar to Laser Beam Welding process, Electron Beam Welding process is also very expensive process.
d) Friction Stir Welding – Friction Stir welding is mainly limited to low melting temperature and soft material.
e) Gas welding without filler rod
f) TIG welding without filler rod

II TUNGSTEN INERT GAS WELDING

Tungsten Inert Gas welding is also known as Gas tungsten arc welding (GTAW), is an arc welding process that uses a non-consumable tungsten electrode to produce an arc. The welded area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler is normally used to weld thick plate. The electrode is no consumable since it is melting point is about 3400ºC. In tungsten electrode, 1 to 2% thorium and zirconium are added to boost electron improve electron emission, arc stability, and current-carrying capacity. A constant-current welding power offer produces energy that is conducted across the arc through a column of extremely ionized gas and metal vapors called plasma. Heat input in GTAW does not depend on the filler material rate. Consequently, the process allows precise control of heat addiction and the production of superior quality welds, with low distortion and free of spatter [1].

2.1 Principle of TIG welding

In the TIG welding process, the electrode is non-consumable and purpose of it only to create an arc. The HAZ(heat-affected zone), liquified metal, and tungsten conductor are all secure area atmospheric contamination by a blanket of argonon fed through the GTAW torch. Fig. 1 shows a schematic diagram of the working principle of the TIG welding process. Welding torch consists of a lightweight handle, with provision for holding a stationary tungsten electrode.within the welding torch, the shielding gas flows by or along the electrode through a nozzle into arc region. An electric arc is created between the electrode and the workpiece material using a constant current welding power source to produce energy and conducted across the arc through a column of highly ionized gas and metal vapors. The electric arc produces high temperature and heat can be focused on malt and join two different parts of the workpiece [2].

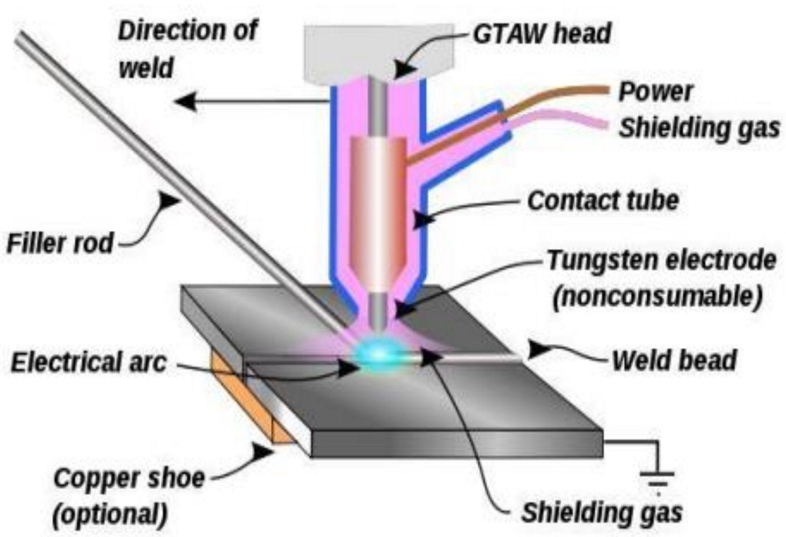


Fig. 1 Schematic diagram of working principle of TIG welding

2.2 Different types of welding current

Both the direct current (DC) and alternating current (AC) may be used for TIG welding. When the work is connected to the positive terminal of DC welding machine and the negative terminal to an electrode the welding set up is said to have straight polarity. When work is connected to negative and electrode to positive terminal then the welding set up is said to have reversed polarity [3].

Table 1 Comparison of different welding current polarities

Sl. No.	Property	DC, electrode positive	DC, electrode negative	AC
1	Penetration	shallow	Deep	Intermediate
2	Heat generation	2/3rd at electrode, 1/3rd at workpiece	1/3rd at electrode, 2/3rd at workpiece	50% on both
3	Metal deposition rate	High	Low	Intermediate
4	Thickness of work	Thin sheets	Thick sheets	Intermediate
5	Stable smaller arc	Easier	Easier	Difficult
6	Arc blow	serve	Serve	Intermediate

2.3 Advantages of TIG welding process

1 Concentrated arc produced for control heat input to the work piece. It resulting in a narrow heat-affected zone.
2 This process is done without the use of flux, therefore no slag formation during the welding process.
3 No Sparks or Spatter because of no transfer of metal across the arc during TIG welding.
4 Compared to other arc welding processes like flux-cored welding, fewer amounts of fumes or smokes are produced.
5 Welding of thin material is possible [3]

2.4 Disadvantages of TIG welding process

1. Low travel speeds than other welding processes to make the process slow.
2. Low filler material deposition during welding compare to other arc welding process.
3. High skills are required for the manual welding process.
4. Welding equipment cost is higher than other arc welding process

2.5 Areas of application of TIG welding

TIG welding is often used for jobs that demand high quality welding such as for instance.

1. The offshore industry
2. The petrochemical industry
3. Power plants
4. The chemical industry
5. The food industry
6. The nuclear industry
7. Automobile
8. Aerospace

III WELDING PROCESS PARAMETERS OF WELDING

1 welding current – Constant current type of power supply is used for TIG welding process. The popular polarity for TIG welding method depends upon the type of piece of work material being welded. DC (DC) with straight polarity is employed for Cu alloy and stainless-steel. DC with reverse polarity is employed for magnesium. The AC (AC) is a lot of versatile in welding for steel and aluminum. Fixed current mode varies the voltage to take care of a continuing arc current [4].

2. Arc voltage - this could be fastened or adjustable reckoning on the instrumentation used for TIG attachment. Some metals need a particular voltage to vary for attachment. A high initial voltage is needed for straightforward arc initiation. It additionally permits for a bigger vary of operating tip distance between conductor and piece of work. Overlarge voltage will result in bigger variability in piece of work quality.

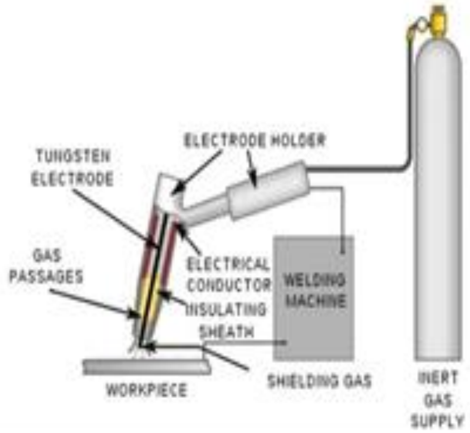
3. Shielding Gas – Shielding gas is needed for TIG welding to shield the weld area from atmospherically contamination. If atmospherically gases (oxygen and nitrogen) have are available in contact with tungsten electrode, arc or welding metal cause fusion defect, and porosity. Numerous shielding gases area unit on the market as well as mixtures of Ar, helium, and H. principally Ar is employed as a shielding gas for TIG welding. The alternatives of shielding gas affect the depth of penetration, surface weld profile, strength, bearableness, and hardness.

4. Gas rate of flow – a uniform flow of noble gas is needed to defend the liquefied metal. Gas rate of flow will vary, the correct choice of the rate of flow is needed to make sure weld quality and improve efficiency. The worth of the gas rate of flow efficiency on the thickness of the piece of work material to be welded. Lower rate of flow needed for manual welding than automatic welding method [4].

5. Welding speed – the quantity of energy transferred per unit length of the weld is inversely proportional to the welding speed. Most value of welding current with low speed provides maximum welding to the weld. Compare with the high welding speed in TIG welding low attachment speed reduces the tendency of porousness

IV AUTOGENOUSLY TIG WELDING

A weld joint made by melting the contact edge surfaces and after hardening it at temperature (without Addition of any filler metal) is named “autogenous weld”. Thus, the composition of the autogenous weld metal corresponds to the bottom metal solely. However, AN autogenous weld is crack sensitive once hardening temperature varies of the base metal to be welded is considerably high. TIG welding method performed while not application of filler material is understood as an autogenous TIG welding method. Autogenous TIG welding is most popular particularly for fewer than 5-millimeter thick plate. The benefits of this method are that it is economical to method as compare to heterogeneous or the same welding method as no edge preparation and filler material are needed. Figure 2 shows the schematic diagram of autogenous TIG welding method [4].



V TIG WELDING ON MILD STEEL

TIG welding is widely used for the fabrication of various types of materials like aluminum, low-carbon steel, and stainless steel. Maximum 6 mm thick low-carbon steel plate is often weld by TIG welding. Low-carbon steel weld by TIG welding is more precise and cleaner than other arc welding processes like manual arc welding or metal inert gas welding. Mild steel is ductile material and can be easily machined. Welding of mild steel plate required to give different structural form to provide numerous machine elements. TIG welding is capable of achieving the best qualities weld and most versatile. TIG attachment provides high integrity that's needed at the basis and in conjunction with weld speed. TIG welding machine is accessible in high current rating also like the low current rating. TIG welding provides 150 A to 350 a variety of current which is beneficial for attachment of thick low-carbon steel plate. Table 2 and 3 shows mechanical properties and percentage composition of low-carbon steel respectively.

Table 2 Mechanical properties of Mild Steel

Mechanical Property	Mild Steel
Density	7.85 g/cc
Young's Modules	190 - 210 GPa
Tensile strength	394.7 MPa
Carbon percentage	< 1.5 % C
Hardness	111 HB
Yield strength	294.8 MPa

Table 3 Percentage composition in Mild Steel

Alloy	Percentage (%)
Chromium	0.069
Nickel	0.01
Carbon	0.18
Manganese	0.8
Sulphur	0.04
Phosphorus	0.04
Silicon	0.4
Fe	Balance

1.1 Applications of Mild steel

- Mild steel materials are available in a variety of structural shapes and easily welded into tube, tubing and pipe. Mild steel pipes are used for pipelines in gas and oil industry.
- Mild steel has balance strength and ductility and good wear resistance so used in automobile industries, large structures, forging, nozzle and automotive components.
- Mild steel is used to produce dissimilar joint with stainless steel, application of this dissimilar joint in thermal power industry [5].

VI. LITERATURE SURVEY

TIG welding is widely used for various types of metal & alloy and still uncountable a lot of work goes for higher performance by TIG welding process.

Abhulimen I.U., Achebo J.I et al. [2014] experimented to investigate the microstructure and oxidization resistance at different regions within the low-carbon steel weld by TIG welding. Throughout the welding process, a pointy modification in the microstructure because of complicated thermal cycle and rapid solidification was discovered. This micro-structure change additionally affects the mechanical properties and oxidization resistance of the low-carbon steel weld. Autogenous TIG welding was performed on 12 mm thick low-carbon steel with 200 A current, 19 V voltage and 100 mm/min welding speed. The finer grain size was obtained at weld metal and heat affected zone [6].

Mishra R., Tiwari V., Rajesh S et al. [2014] performed experiments to identify the economical welding parameters using Response surface methodology (RSM) throughout TIG welding of low-carbon steel pipe. Welding Parameters considered were gas rate 25 to 30 l/min, welding current 130 to 180 A, arc voltage 10.5 to 13.5 volt and Ar as shielding gas. Results showed that by using TIG welding of low-carbon steel maximum tensile and yield strength of 542 MPa and 547 MPa was achieved respectively [7].

Fujii H., Sato T., Lua S., Nogi K. et al. [2014] have done a comparison of mechanical properties between TIG and MIG welded dissimilar joints. Low-carbon steel and stainless-steel dissimilar material joints are quite common structural application. These dissimilar joints give a smart combination of mechanical properties like corrosive resistance and tensile strength with lower price. Welding parameters thought-about for MIG welding were welding current 80-400 A and voltage 26-56 volt. TIG welding was performed with 50-76 A current & 10-14-volt voltage. TIG-welded dissimilar joint provides higher tensile strength because of less porosity. Each dissimilar joints have the most effective ductility & yield strength for TIG and MIG welding [8].

Kuo C., Tseng K., Chou C et al. [2012] developed an advanced activated TIG welding technique for deep penetration of weld joint. Marangoni convection induced on the liquefied pool by surface tension gradient. To manage Marangoni convection small amount of oxidizing gas was used. The welding method is done with welding current 160A, welding speed 0.75 mm/s, electrode gap of 1mm and Ar-O2 shielding gas. They discovered that Marangoni convection changes from inward to outward and weld form become wide and shallow [9].

Vikesh, Randhawa J., Suri N.M et al. [2011] investigate the result of oxide fluxes during TIG welding of 6 millimeters thick dissimilar joint between low-carbon steel and stainless steel. The CaO, Fe_2O_3, Cr_2O_3 and SiO_2 fluxes were used in powder form. These powders were mixed with acetone to supply the paint. Before welding, a thin layer of flux was brushed onto the surface of the joint to be welded. TIG welding was performed with welding speed 150 mm/min, welding current 200 A and gas flow of 12 l/min. The result indicates that the surface appearance of TIG welds produced with oxide flux formed residual slag. TIG fastening with SiO_2 flux powder can increase joint penetration and weld to depth ratio [10].

Pal K., Kumar V et al. [2013] studied the effect of activated flux on the TIG welding method. They focused on the effect of penetration in low-carbon steel by the TIG welding method. Compare to other arc welding method it having a small depth of penetration. An activating flux powder is employed to avoid this drawback. Taguchi improvement is employed to optimize welding method parameters exploitation activating TIG welding technique on low-carbon steel. They observe from the experimental result that improves within the depth of penetration at weld zone with increase weld current. Depth of penetration is inversely proportional to the travel speed [11].

Nayee G., Badheka V. et al. [2013] studied the result of activated TIG welding on wear properties and dilution proportion in medium carbon steel welds of 12-millimeter thick plate. TiO_2 and Cr_2O_3 fluxes were employed in powder type. Flux powder was uniformly mixed with acetone and brushed onto the surface of the joint to be welded. DC and also the straight polarity were used with constant welding speed. A single-pass TIG welding was performed with 180A welding current. The result indicated that TiO_2 flux coated weld increased the dilution on base metal as compare to Cr_2O_3 flux coated weld [12].

Ruckert G., Perry N., Sire S., Marya S et al. [2014] studied the effect of oxide-based fluxes on metallurgical and mechanical properties of the weld joint. Tungsten inert gas welding method is employed to provide welds between 6mm thick low-carbon steel and stainless steel plate with activating flux. During this investigation ZnO, TiO2 and MnO2 powder were used. welding method performed with welding current 200 A, arc voltage 12.5 V and welding speed of 5 mm/min. Highest width to depth ratio gets below

$TiO_2$and ZnO fluxes compare to standard TIG welding method. Among all three fluxes, TiO_2 shows lowest angular deformation [13].

Dhandha K.H., Badheka V.J et al. [2014] show that in the TIG welding method application of activated fluxes improves weld penetration and method competitiveness. They summaries the investigations on TIG welding of stainless steel, plain carbon steel, Al and Ti victimization activating flux. Welding method performed with 150 A & 175 A current and 15 cm/min welding speed. It was disclosed that fluxes supported fluorides contribute to increased weld penetrations of Ti and SiO_2 flux for stainless steel, plain carbon steel, and Al. The importance of flux homogeneity, flux composition and profile are shown to be primordial in determining the width to depth ratio of weld [14].

Zuber M., Chaudhri V., Suri V.K., Patil S.B et al. [2014] done an experiment to show the effect of activated fluxes on mild steel welds. Maximum 2 to 3-millimeter-thick plates of stainless-steel and steel will be weld with TIG welding under autogenous mode. The activating flux welding process is considered a feasible alternative to increase process productivity. Grade 91 steel is used as workpiece material. A TIG welding was applied on P91 steel in which oxide powders CaO, ZnO, Fe_2O_3, TiO_2, MnO_2, and CrO_3 were used as flux material to produce a bead on plate weld. This method is responsible for an increase in depth of penetration and also reduction in weld width. Heat input was increased with the use of activated fluxes [15].

VII. MOTIVATIONAL AND OBJECTIVE OF PRESENT WORKS

From the literature review, it's discovered that, though TIG welding is especially performed on stainless-steel and other top quality Materials, but for exactness quality welding to be done on mild steel component this method is going to be helpful when welding Performed within the automated system as well as without using any filler rod. throughout autogenous TIG welding for not using any filler material, it's found that penetration depth or melt depth restricted to a definite depth once welding performed on the thick plate. Using activated flux some work was reported for TIG welding on dissimilar materials as well as for stainless-steel which improves the penetration of welding to some extent. any during autogenous TIG welding without using filler rod, when plates are kept side by side and no gap provided between them, the depth of penetration or melting depth is also restricted to a particular value since liquefied material doesn't flow towards the bottom side of the joint. Therefore, for proper flow of liquefied material towards very cheap of the joint, a suitable gap should be maintained for autogenous TIG welding. Supported the above observation, within the present work, autogenous TIG welding has been performed conventionally and using activated flux. further to get further optimum gap between the plates for TIG welding of 4 mm thick steel plate different gap price has been considered. Following are the detailed objective of this work.

- To perform autogenous TIG attachment of 4 mm thick mild steel plate using mistreatment any filler rod and study the effect of welding current and more speed.
- To study the weld depth and width and microstructure of the weld area obtained after TIG welding for different welding condition
- To study the effect of various welding parameter like arc voltage, welding current and welding speed.
- To perform TIG welding of 4 mm thick mild steel plate using a layer of TiO_2 coating (activated flux).
- To perform TIG welding of 4 mm thick steel plate by maintaining the various gap between the plates to be welded.
- To measure the tensile strength of the weld joint.
- To measure macro-hardness of welding zone.

VIII CONCLUSIONS

Findings of the present investigation can be summarized in the following points

- The results of the conventional TIG welding process performed show that, maximum depth of penetration was obtained with parametric combination of minimum welding speed and maximum current.
- When the same procedure is repeated with additional utilization of TiO_2 flux, depth of penetration increases in comparison to the conventional welding, but some crack on the weld zone was observed for using flux.
- With constant welding speed, another set of experiments were done by maintaining a gap between work piece to be welded. It is observed that, with a gap of 1 mm, defect free welding with proper material flow obtained throughout the joint for higher welding current.
- Comparing the three methods of TIG welding, depth of penetration and tensile strength of weld joint is maximum when adequate gap is maintained between the components to be welded.
- From the graphs plotted, it can be inferred that welding width and depth increases with increase in welding current and gap maintained between the components to be welded.

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