TIG WELDING AND EFFECT OF VARIOUS PARAMETERS ON TIG WELDING: A REVIEW

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Abstract: This paper represents a review on TIG welding and effect of various process parameters on TIG welding process. GTAW plays an important role in those industries where it is important to control the metallurgical properties and weld bead shape. TIG welding process compared to other arc welding process, low heat affected zone, no slag, in a single pass its productivity is relatively low and high heat concentration. Knowledge of process variables is important and necessary to produce weld of satisfactory quality. The parameters such as welding speed, current, voltage, gas flow rate etc. affects the weld strength in the form of weld bead geometry and mechanical strength. Various techniques are proposed in literature to achieve the better optimization of these parameters.

Keywords: **TIG welding, process parameters, welding current, speed, voltage**

• Introduction

TIG welding is a type of welding process and these types of welding is widely used in modern industries for joining the similar or dissimilar materials. TIG welding is also called gas tungsten arc welding (GTAW). The main advantages of TIG welding process it require low heat affected zone, absence of slag, joining of similar and dissimilar metals at very high quality weld. The quality and accuracy of joints mainly depends upon welding speed, shielding gas, power supply, gas flow rate, voltage. TIG welding techniques is relatively a high strength welding techniques as compared to others. TIG welding process has been a most popular choice of welding process when a considerable precision welding operation and a high level of weld quality is required. In the TIG welding process the main problem is limited thickness of material which can be welded in single pass, weak tolerance to some material composition and the low productivity. In TIG welding uses a separate filler metal and a non-consumable electrode with an inert shielding gas (Ar, He). It is a manual welding process in which welder uses both hands to weld, one hand is used to adding the filler rod to the weld joint and other hands for holding the TIG torch that is produce the arc.

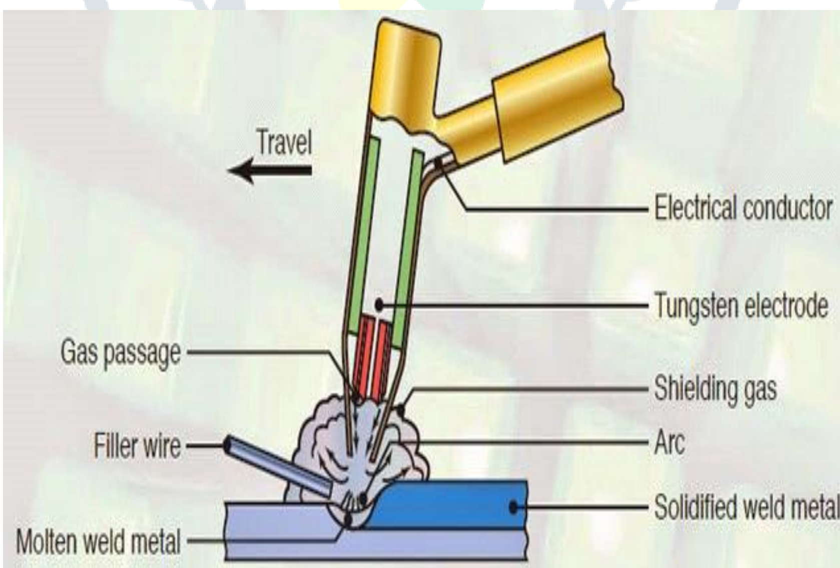

Fig.1 TIG welding process

The setup of TIG welding is consists of a cylinder of argon gas, welding torch, cable for current supply, a suitable power sources, tubing for gas supply and water tubing for cooling the torch. The shape of welding torch having a cap type at one end to protect the rather long tungsten electrode against emergency or accident breakage, In TIG welding tungsten is used because it is very hard, brittle and radioactive material. This is used limited as compared to others metals. TIG welding requires three main things the first one is heat which is produced by electricity passing through the tungsten electrode by creating an arc to the weld. The second things is shielding gas comes from a cylinder of gas flow to the weld area to protect from air and the last things is filler rod or metal that is added by hand into the arc and melted. A small section of stainless steel, mild steels and non-ferrous metals such as magnesium, aluminium, and copper alloys are mainly welded by TIG welding. The process gives the operator greater control and safety over the weld as compared to metal inert gas welding, allowing for stronger and higher quality welds. However, GTAW being significantly slower than most other welding techniques is comparatively more complex, hazardous and difficult to master.

- **problem statement and formulation**
  - Gurram et al., [2013] studied the effect of copper and aluminium addition on mechanical properties and corrosion behavior of AISI 430 ferritic stainless steel gas tungsten arc welds. Authors welded stainless steel plates by TIG welding process. The plates of 5 mm thickness are used for preparing the welded butt joint. Authors evaluated the mechanical and corrosion behaviour of TIG welded joints. They conclude that the ferritic stainless steel joints fabricated by the addition of 2 gm Al in post-weld annealed condition resulted in better tensile properties compared to all other joints, They also concluded that there is a marginal improvement in the ductility of ferritic stainless steel weldments by the addition of 2 gm Cu in post-weld annealed condition compared to all other joints and base metal.

  - Abdalla et al., [2015] studied the analysis of the mechanical behaviour of AISI 4130 steel after TIG and laser welding process. Authors welded stainless steel AISI 4130 plate by TIG and laser welding process. The plates of 1 mm thickness are used for preparing the welded butt joint for each test. Authors evaluated the mechanical behaviour of TIG and laser welded joints on such parameters power 750W (LASER), 148W (TIG), speed 60mm/sec (LASER), 1.65mm/sec (TIG), voltage 7.4V (TIG), current 20A (TIG). They concluded that laser welding process easily automated and produces phase transformation area about ten times smaller than TIG welding process. The hardness in the fusion zone is quite high for both processes, but it was reduced to about 200 HV for the laser welded steel and about 100 HV in TIG process after tempering. The tempering applied after welding process improved the ductility of the steel, transforming the martensite and enhance the compatibility between the phases.

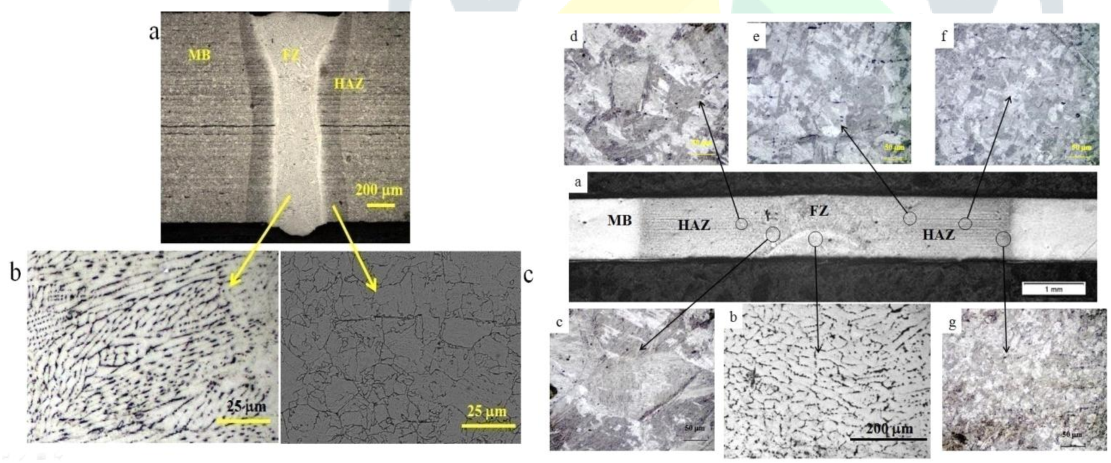

Fig.2 LASER and TIG welding microstructure view

  - Baddu and Raole, [2014] studied the mechanical properties and microstructural investigations of TIG welded 40 mm and 60 mm thick SS316l samples for fusion reactor vacuum vessel applications. They welded stainless steel 316l plates by TIG welding process for fusion reactor vacuum application. The plates of 40 mm and 60 mm thickness are used for preparing the double V groove welded joint. Authors evaluated the mechanical and microstructure behaviour of TIG welded joints. They concluded that the samples have exhibited the higher tensile strength in both the 40 mm and 60 mm thick plates compared with base metal. Impact fracture energy of the WZ was less as compared to BM and HAZ.

- Zou et al., [2015] studied the mechanical properties of advanced active-TIG welded duplex stainless steel and ferrite steel. They welded duplex stainless steel and ferrite steel plates by TIG welding process. The plate of 1 mm thickness and 0.2 mm notch is used for preparing the welded joint. They used welding speed, current, arc length, electrode diameter, shielding gas as input parameters. Authors evaluated the mechanical properties of TIG welded joints. They concluded that the weld oxygen content played a significant role in affecting the weld shape of both steels, which could be controlled by adjusting the oxygen content and the shielding gas of the AA-TIG welding process. They also concluded that with the increase in the weld oxygen content, the weld shape became narrow and deep for both steels. The Vickers hardness of the weld metals of both steels was not affected by the oxygen content in the shielding gas.

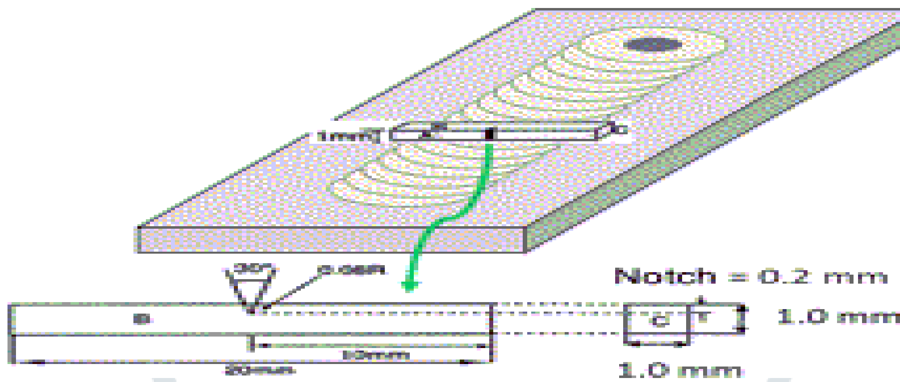

Fig.3 Active-TIG welding process

- Lei et al., [2011] studied the microstructure and mechanical properties in TIG welding of CLAM steel. Authors welded CLAM steel plates by TIG welding process. The plate of 0.5 mm thickness is used for preparing the welded joint. Authors evaluated the mechanical and microstructure behaviour of TIG welded joints. They used a1, a2 original CLAM composite filler as filler material. They concluded that the tensile strength was reduced when the PWHT temperature rise, tensile strength of WM is higher than that of HAZ and BM. The microstructure of the weld metal for every specimen was found to be tempered martensite with a little of delta ferrite. Hardening at WM and softening in HAZ is detected in the TIG weld joint. Microhardness in WM decreased when the temperature of PWHT increased. The ultimate tensile stress of weld metal is higher than that of HAZ and BM. Absorbed energy increased with PWHT temperature rising, until PWHT was done at 760◦C/30min, the specimen ductile fractured in local area

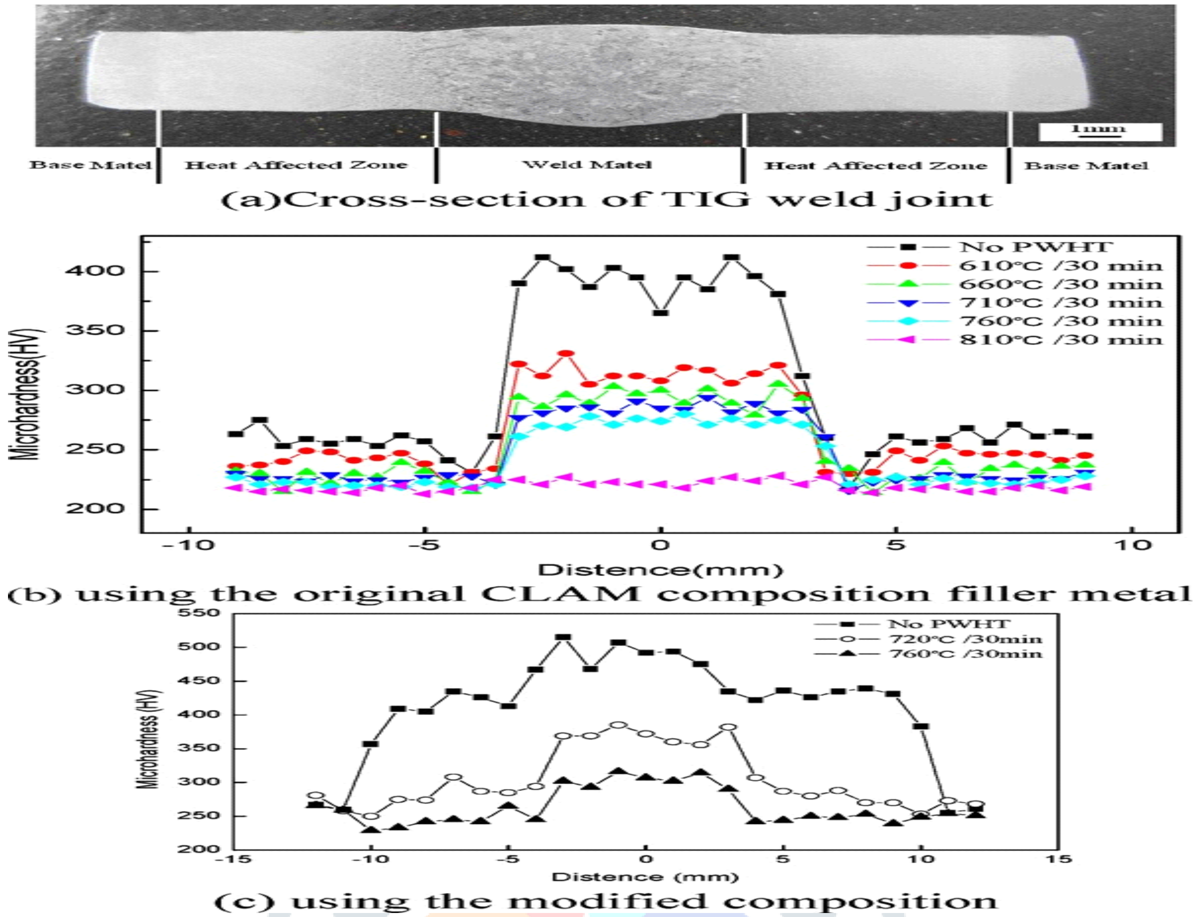

Fig.4 Micro hardness distributions on TIG weld joints (a) cross-section of TIG weld joint (b) using the original CLAM composition filler metal (c) using the modified composition.

- Sathiya et al., [2015] studied the comparative study on transverse shrinkage, mechanical and metallurgical properties of AA2219 aluminium weld joints prepared by gas tungsten arc and gas metal arc welding processes. They welded AA2219 alloy by TIG and MIG welding process. The plate of 25 mm thickness is used for preparing the welded butt joint. Authors evaluated transverse shrinkage, mechanical and metallurgical properties of TIG and MIG welded joint. They used welding current 185A (MIG) and 195A (TIG), voltage 28V (MIG) and 10.5V (TIG), groove design V shaped, speed 25 cm/min. (MIG) and 10 cm/min. (MIG), polarity and gas flow rate as input parameters. They concluded that the transverse shrinkage generated in GTAW weld joint is comparatively lower that in GMAW weld joint. The tensile strength of GTAW weld joint is higher than that of the GMAW weld joint. The hardness values of TIG and MIG welds are lesser than heat affected zone and base metal.

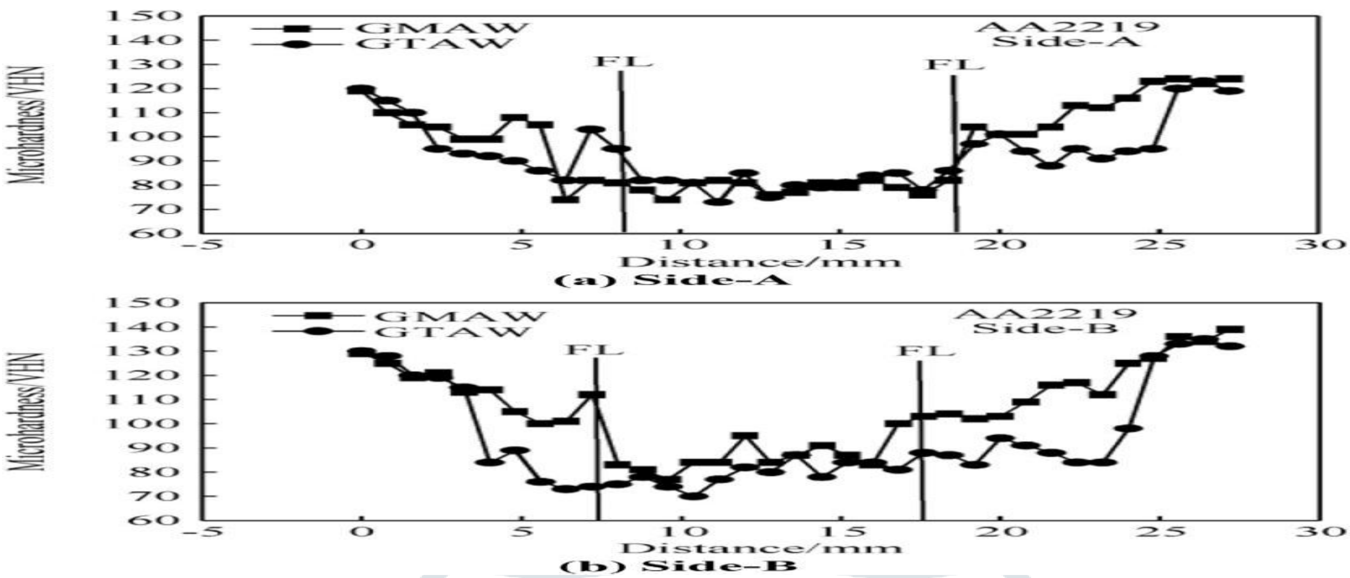

Fig.5 Hardness distribution across the transverse section of weld joints

- Ahmadi and Ebrahimi, [2015] studied the welding of 316L austenitic stainless steel with activated tungsten inert gas process. Authors welded stainless steel 316L plates by activated TIG welding process. The plate of 9 mm thickness is used for preparing the welded joint. Authors evaluated the mechanical and morphology properties of TIG welded joints. They used a flux from 0.1 to 8 mg/cm^2 were carried out to study the effects of coating density of flux on the weld penetration. The process parameters are electrode diameters3.2 mm, current 150A, and arc length 3 mm, gas flow rate 12L/MIN. They concluded that the weld penetration is increased while the weld metal width decreased; among the fluxes SiO2 flux had a significant effect on enhancing the weld penetration in A-TIG. A-TIG welding can increase ultimate tensile strength of weldment because of increasing the retained delta ferrite content of stainless steel welds.

- Kah and Martikainen, [2013] studied the influence of shielding gases in the welding of metals. They welded stainless steel plates by TIG and laser welding process. The plate of 5 mm thickness is used for preparing the welded joint. Authors evaluated the mechanical properties and microstructure of TIG welded joints. They used helium, argon, hydrogen as shielding gas. They concluded that for carbon steel, increasing the oxidation potential of the shielding gas decreases the toughness and tensile strength of the weld deposit. For ferritic stainless steel, increasing the amount of carbon dioxide in shielding gases can increase the martensite content at the grain boundary.

- Liu et al., [2015] studied the activated flux inert gas welding of 8 mm-thick AISI 304 austenitic stainless steel. They welded stainless steel AISI 304 plates by activated TIG welding process. The plate of 8 mm thickness is used for preparing the welded joint. Authors evaluated the mechanical properties of TIG welded joints. They used welding current 150A, voltage 25V, speed 60-75mm/min, gas flow rate 10-15 l/min. as input parameters and ER304 as filler material. Authors concluded that activated flux powder in TIG welding can increase the content of delta-ferrite in weld metal, but does not significantly change the microstructure and chemical components of A-TIG weld compared with those of C-TIG weld. The tensile strength and elongation of A-TIG weld joints are superior to those of C-TIG welding and no crack or defect with single length more than 3 mm is detected on the surface of bended welds after bending test.

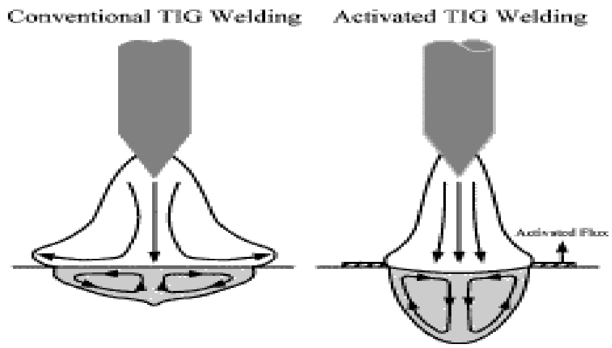

Fig.6 Activated flux inert TIG welding

- Atapour et al., [2014] studied the microstructure and corrosion behaviour of multipass gas tungsten arc welding 304L stainless steel. Authors welded stainless steel 304L plates by TIG welding process. The plate of 6 mm thickness is used for preparing the welded joint. Authors evaluated the mechanical and corrosion properties of TIG welded joints. They used ER 308 filler rod as filler material. They concluded that all the weld were essentially austenitic with the presence of a small amount of ferrite. The hardness values from the weld zone towards the base metal increased in all weldments while the maximum values obtained for three passes welded specimen due to the increase in the ferrite content and grain. The corrosion resistance also increased.

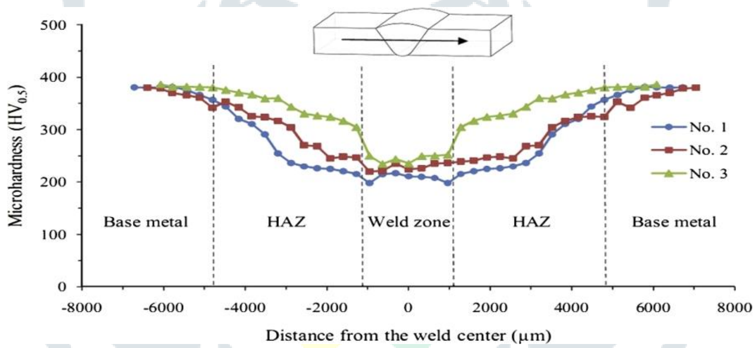

Fig.7 microhardness profile showing the hardness values at different zone

- Molak et al., [2009] studied the Measurement of mechanical properties in a 316L stainless steel welded joint. Authors welded stainless steel 316L plates by TIG welding process. The plate of 8 mm thickness is used for preparing the welded joint. The authors evaluated the mechanical properties and microstructure or image correlation study of TIG welded joints. They concluded that Optical strain measurements based on Digital Image Correlation can be very helpful for strain measurements during the static tensile test of a micro sample. The differences in mechanical properties of the material examined with the use of micro samples and standard samples are significant. Especially for the case of yield strength and elongation to failure values.

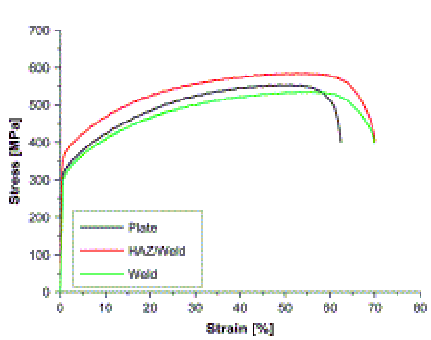

Fig.8 stress- strain diagram for different weld zone

- Kumar et al., [2015] studied the experimental process of TIG welding of a stainless steel plate. They welded stainless steel 304 plates by TIG welding process. The plate of 6 mm thickness is used for preparing the welded joint. Authors evaluated the metal deposition rate of TIG welded joints by using orthogonal array (L9). They used DOE (design of experiment) approach to find out the final results. They used current, gas flow rate, root face, and welding time as input parameters. Authors concluded that the current and root face affect the metal deposition rate very significantly. They found that optimal input parameter current, gas flow rate, root face and welding time are 90A, 2.0 ltr/min, 20mm and 95 second.

- Ghosh et al., [2016] studied the parametric optimization of MIG welding on 316L austenitic stainless steel by grey-based taguchi method. Authors welded stainless steel 316L by MIG welding process. The plate of 3 mm thickness is used for preparing the welded butt joint. Authors evaluated the mechanical properties of MIG welded joint. They used welding current, gas flow rate and nozzle length as input parameters. They concluded that the x ray test result shows that lack of penetration and visual inspection indicate the undercut, spatter and blow holes in some sample. The optimum parameters founded by taguchi method are current 10A, gas flow rate 20l/min and nozzle distance 15 mm and current is more significant as compared to gas flow rate and nozzle distance.

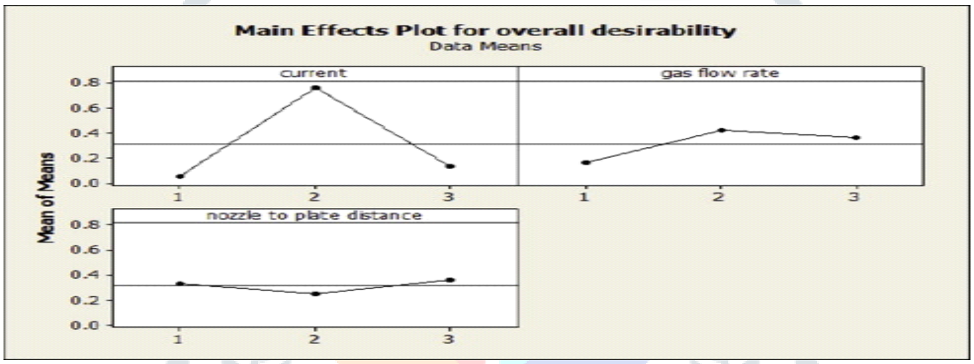

Fig.9 Response graph for mean desirability

- Gulenc et al., [2005] studied the experimental study of hydrogen in argon as a shielding gas in MIG welding of austenite stainless steel. Authors welded stainless steel 304L by MIG welding process. The plate of 10 mm thickness is used for preparing the welded joint. Authors evaluated the mechanical and microstructure properties of MIG welded joint. They used welding current and shielding gas as input parameters. They concluded that the sample welded at 240A current and with 1.5% H_2-Ar shielding media had shown good tensile property. When the amount of hydrogen in Ar is increase, then toughness of welding joint is increased. The hardness value is higher at base metal as compared to heat affected and weld zone.

- **PROCESS PARAMETERS**

In TIG and MIG welding process variables play an important role in the quality, bead geometry and weld penetration. Knowledge of process variables is important and necessary to produce weld of satisfactory quality. The process variables are changing from one range to other to produce desired results and that are not completely independent.

The following parameters affect the quality of the weld:

- **Welding current**
  When the current is high, TIG welding leads to splatter and work piece gets damaged. When the current is low, TIG welding leads to sticking of the filler wire. Fixed current mode is used to the voltage to maintain a constant arc current. Larger heat affected zone (HAZ) can be found for lower welding current.
- **Welding voltage**
  Welding voltage may be fixed or adjusted. It depends upon the TIG welding equipment. A high initial voltage allows for easy arc initiation. Too high voltage, can lead to a large variable in welding quality.
- **Welding speed**
  When the welding speed is increased, heat input per unit length of weld decreases and penetration of weld decreases. Welding speed controls the bead size and penetration of weld. It does not depend on current. Excessive high welding speed causes the uneven bead shapes, increase the tendency to porosity.

- **Gas flow rate**
  Gas flow rate is important factor which is affected the results and output. Flow rate range generally is 6-7 litre/min. In TIG uses a lot of shielding gas so it pays to set up the gas flow accuracy for obtains proper results.
- **Welding current**
  When the current is high, TIG welding leads to splatter and work piece gets damaged. When the current is low, TIG welding leads to sticking of the filler wire. Fixed current mode is used to the voltage to maintain a constant arc current. Larger heat affected zone (HAZ) can be found for lower welding current.

• ADVANTAGES AND DISADVANTAGES

Advantages of TIG welding:

- Electrode is non-consumable used in process and thin section is easily welded.
- Welds can be made with or without filler metal.
- Better control on welding variable and no slag and splatter problem.
- In TIG welding low distortion of work piece because of the small heat effected zone.
- The TIG process has many applications and uses because it can be used to make high quality welds in almost any metals and alloys.
- It can be done by both automatic and manual techniques and can be applied in all positions.
- TIG may be used on a wide range of metal thickness.

Disadvantages of TIG welding:

- The UV rays is brighter as compared to others welding process.
- It is a slower process than consumable electrode arc welding process.
- Overall expensive is more. Welding supplies is expensive as compared to others because the arc travel speed and metal deposition rate is slow and tungsten electrode is also expensive
- The contamination comes during the transfer of molten tungsten from the weld. Exposure of the hot filler rod to air using wrong welding techniques causes weld metal contamination.

• CONCLUSION

Various parameters like welding current, speed, voltage, gas flow rate, electrode diameter etc. are important to achieve the better quality. Microstructure properties will be studied at different zone of welding and founded that how the temperature distribution affected the base metal, heat affected zone and weld zone. The joints fabricated by TIG process exhibited higher tensile strength as compared to GMAW joints. The superior tensile properties of TIG joints are due to the formation of uniformly distributed and very fine strengthening precipitates in the weld region. TIG welding parameters affects the weld strength in the form of weld bead geometry and mechanical strength. TIG welding specimen can bear higher elongation and yield strength.

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