# INVESTIGATION OF TIG WELDING ON DISSIMILAR METERIALS USING NON DESTRUCTIVE TESTING (NDT) AND RADIOGRAPHY TESTING (RT)

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## ABSTRACT

*Aluminum, Copper and mild steels are popular materials in industrial and constructional applications. Of late, joining of these metals with lesser defects and higher strength is gaining more and more importance. Welding is an efficient way of joining two metals in order to get a high strength and permanent joint. In the current work, an investigation is carried out to study the effect of TIG (Tungsten Inert Gas) welding processes, when Aluminum is welded with mild steel. The scope of the current work also includes, when Copper is welded with mild steel investigating the effect of filler material on weld quality, strength and hardness of the joint by silicon bronze and Copper Filler materials are used. Further, micro structural analysis using Non-destructive Testing, Porosity analysis using Radiography Testing and Analysis of Mechanical properties is also taken up on the weld zone to study the quality of the joint. It was observed that a satisfactory bonding for steels can be achieved by TIG welding processes. However higher strength and superior quality joint can be achieved with TIG welding process using silicon bronze as filler metal.*

**Keyword: -** *Al,Cu,MS,TIG,NTD,RT,Mechanical properties.*

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## 1. INTRODUCTION

The modern age demands light weight, high strength structures with desired product properties which leads to the joining of dissimilar materials. Many industries relay on metals for manufacturing of desired products and joining of dissimilar metals is an important application in industries. So coming to metal joining processes welding is an efficient process for joining dissimilar metals and to achieve a high strength and permanent joint .The joining of dissimilar metals with welding will only work if both the metals to be weld are mutually soluble with each other or else as an alternative a third metal which is soluble with both the metals is used to get a joint. The Aluminum, Copper and mild steel metals are the most widely used metals in industries for manufacturing products. The joining of mild steel, with mild steel has been widely attempted for applications in power industries, steam generators, nuclear applications, and in small products like hydraulic valves. Dissimilar metal welds involving mild steel can be done using most full fusion weld methods, including TIG (Tungsten Inert Gas) .

Weld procedures using filler (consumable) enable better control of joint corrosion resistance and mechanical properties.Weldability normally decreases with increasing carbon content, special precautions such as preheating, controlling heat input, and post weld heat treating are normally required for steel with a carbon content reaching 0.30%. The dissimilar metal consists of distinct chemical composition and the major problem arises when welding dissimilar metal is formation of intermetallic compound in the welded region. In welding of dissimilar steels welding process and welding parameters plays a important role in formation of a good welded joint. In order to get a high strength joint free from weld defects an appropriate welding process and weld parameters should be selected.

TIG welding process is an arc welding process uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere with a shielding gas generally Argon or Helium or sometimes mixture of Argon and Helium. A filler metal may also feed manually for proper welding.

## 2. EXPERIMENTAL DETAILS

### 2.1 Operation of TIG welding

Similar to torch welding, GTAW normally requires two hands, since most applications require that the welder manually feed a filler metal into the weld area with one hand while manipulating the welding torch in the other. Some GTAW equipment is capable of a mode called "touch start" or "lift arc"; here the equipment reduces the voltage on the electrode to only a few volts, with a current limit of one or two amps.When the GTAW equipment detects that the electrode has left the surface and a spark is present, it immediately (within microseconds) increases power, converting the spark to a full arc

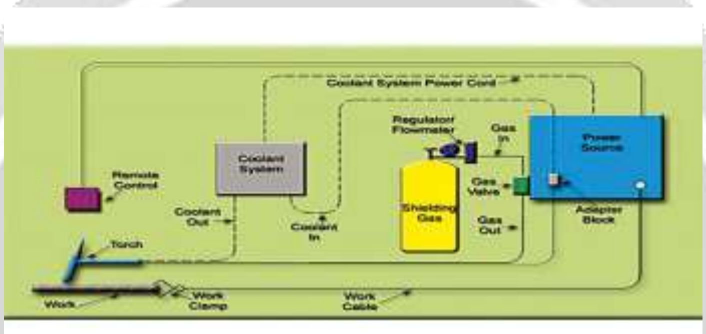


**Fig -1:** TIG Welding System Setup

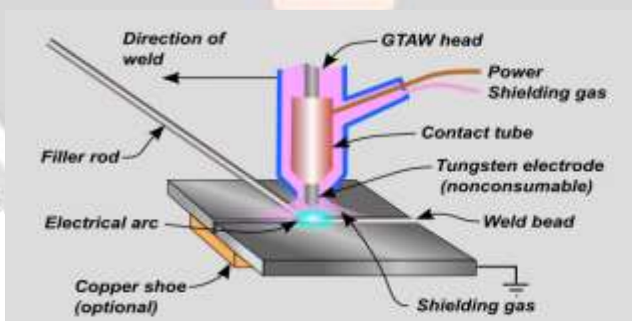


**Fig -2:** TIG Welding

### 2.2 Operation modes

GTAW can use a positive direct current, negative direct current or an alternating current, depending on the power supply set up. A negative direct current from the electrode causes a stream of electrons to collide with the surface, generating large amounts of heat at the weld region, This creates a deep, narrow weld. In the opposite process where the electrode is connected to the positive power supply terminal, positively charged ions flow from the part being welded to the tip of the electrode instead, so the heating action of the electrons is mostly on the electrode. This mode also helps to remove oxide layers from the surface of the region to be welded, which is good for metals such as Aluminium or Magnesium. A shallow, wide weld is produced from this mode, with minimum heat input. Alternating current gives a combination of negative and positive modes, giving a cleaning effect and imparts a lot of heat as well.

**2.3 Selection of Electrode for TIG Welding**

The electrode used in GTAW is made of tungsten or a tungsten alloy, because tungsten has the highest melting temperature among pure metals, at 3,422 °C (6,192 °F). As a result, the electrode is not consumed during welding, though some erosion (called burn-off) can occur. The diameter of the electrode can vary between 0.5 and 6.4 millimetres (0.02 and 0.25 in), and their length can range from 75 to 610 millimetres (3.0 to 24.0 in).Thorium oxide (or thoria) alloy electrodes were designed for DC applications and can withstand somewhat higher temperatures while providing many of the benefits of other alloys.Electrodes containing zirconium oxide (or zirconia) increase the current capacity while improving arc stability and increasing electrode life.

**2.4 TIG Welding of Dissimilar metals**

Welding dissimilar metals often introduces new difficulties to GTAW welding, because most materials do not easily fuse to form a strong bond. However, welds of dissimilar materials have numerous applications in manufacturing, repair work, and the prevention of corrosion and oxidation. In some joints, a compatible filler metal is chosen to help form the bond, and this filler metal can be the same as one of the base materials During dissimilar welding proper gap and bevel angle are maintained and mostly pulsed current.

**2.5 Need for Dissimilar Welding**

Dissimilar Welding has the following Application in the Industries

- Food service and kitchen equipment, Aerospace components, Surgical and pharmaceutical components, Automotive exhaust and other components, Nuclear piping and components,
- Truck boxes, Castings, Aerospace ducting and other components, Wheels, Boats and boat props, Tanker trucks,
- Neural bronze marine components and boat propellers, Aluminum bronze valve bodies**.**

**2.6 Advantages of TIG-Welding**

- High quality and a precision weld
- Pin-point control
- Aesthetic weld beads
- No spark or weld spatter
- Ability to weld more metals and alloys

**2.7 Dissimilar TIG welding**

- Aluminium and Mild Steel
- Copper and Mild Steel

The base material used in this investigation is AA2024-T3 grade Aluminium and 308L grade Mild Steel of plate thickness 6mm have been used for TIG welding and the behavior is noted.

**Table-1:**Properties of Base metal

| PROPERTIES | ALUMINIUM | MILDSTEEL |
|---|---|---|
| Atomic Number | 13 | 26 |
| Atomic Weight (g/mol) | 26.98 | 54.938 |
| Melting Point (°C) | 660.2 | 1538 |
| Boiling Point (°C) | 2480 | 2861 |
| Thermal Conductivity (cal/cm. °C) | 0.57 | 0.82 |

**2.8 Specification of the Al-MS Weld**

Welded without using any Filler rod and Preheating of Weldment

- Type of Joint – Butt Joint
- Weld Length – 100 mm
- Plate Thickness – 6 mm
- Motion of Torch – Curvilinear Motion
- welding current -70–90 A
- arc length - 3.0–4.0 mm

**Fig-3:** Al-Mild Steel TIG Weld:

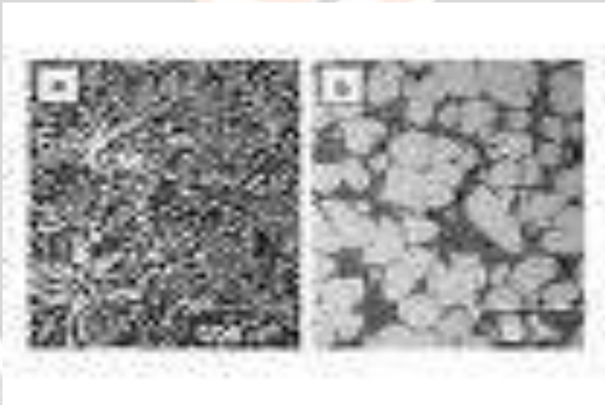

**Fig-4:** Microstructure of Mildsteel and Aluminium base Metal

**Fig-5:** Heat affected zone of Aluminium and Mild Steel

**2.9 Problems in Aluminium and Mild Steel TIG Welding**

In Aluminium Weld Alternating current source is used where as in Mild Steel Direct Current Source is used. We made an attempt to fuse the material without using any Filler rod on the pulsed D.C Power for obtaining the TIG welding, But welding is not properly fused. Initially the welding was done by the Linear propagation of the Torch, But the welding did not fuse completely, when the Torch was moved in Curvilinear Propagation the fusage of Aluminium and Mild Steel was high compared to the weld obtained from the Linear propagation of the Torch**.**

**2.10 Reason for Poor Al-MS Welding:**

The Major factor that is responsible for the Improper fusage of two metals are:

- High Heat affected zone at the Juncture of two plates.
- Large amount of heat is transferred in Aluminium as the heat conductivity of the metal is very high compared to that of the Mild Steel.
- The melting point of Aluminium is also very less compared to that of the Mild Steel.

**2.11 Possible Solution of Al-MS Welding:**

- Heat affected zone and the amount of heat transferred the weld plate Should be reduced with the help of Suitable Coolant .
- Aluminium and Mild Steel can be welded together using Al-4043 L in the Under water welding.

**2.12 Selection of Filler Rod:**

- In dissimilar welding of Copper and Mild steel, Technically silicon bronze is used as filler rod.
- There are some problem which occur during welding, silicon bronze filler rod.
- To overcome some problem occurs in the above process we use copper as a filler rod.
- In TIG welding the same base metal is used for the welding which has good property , so the copper filler metal is used.

**Table-2:** Specification of Universal Testing Machine

| | |
|---|---|
| Make | FIE Pvt Ltd,Yadraw |
| Model | UNITEK-94100 |
| Range of testing | 0 KN to 100 KN |
| Maximum crosshead stroke | 100mm |
| Clearance between columns | 650mm |
| Power supply | Single phase,230 V A.C,50 Hz |

**2.13 Hardness Property**

- The hardness at the weld center has been measured using Rockwell hardness tester with a load of 60 kg. the steel ball of 1/16 in diameter is used to apply the load by impressing over the specimen and readings are measured from the B scale of the Rockwell hardness machine.
- The ball which is used in the Rockwell hardness machine is diamond because of high hardness when compared to other.

**Table-3:** Specification of Hardness Machine

| | |
|---|---|
| Make | Blue star |
| Indenter | diamond |
| Load | 60 kgf |
| Type | Direct mass loading |

**Table-4:** Typical Properties of Silicon bronze and copper

| Properties | Silicon bronze | copper |
|---|---|---|
| Atomic Number | 14 | 29 |
| Atomic Weight | 28.086 | 63.546 |
| Atomic Diameter | $2.240 \times 10^{-10}$m | $2.551 \times 10^{-10}$m |
| Melting Point | 970 - 1025 °C | 1356 K |
| Boiling Point | 2,355°C | 2868 K |
| Density | 8.53 g/cc | 8.94 x 103 kg/$m^3$ |
| Thermal Conductivity | 36 W/m-K | 147-370W/m.k |
| Annealing Temperature | 475 - 700 °C | 400-650°C |
| Tensile yield strength | 105-415Mpa | 210-390 Mpa |
| Modulus of Elasticity | 115Gpa | 130-145Gpa |
| Compressive strength | 30-280Mpa | 45-330Mpa |
| Hardness | 60-95 | 235-878Gpa |
| Machinability | 30-60% | 40-70% |

### 2.14 Specification of the Al-MS Weld

Welded without using Silicon bronze and copper Filler rod

- Type of Joint – Butt Joint
- Weld Length – 100 mm
- Plate Thickness – 6 mm
- Motion of Torch – Curvilinear Motion
- welding current -70–90 A
- arc length - 3.0–4.0 mm
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## 3.RESULTS:

**Fig -6:** Cu and MS TIG Welding Using Silicon Bronze Filler Rod:

**Fig -7:** Cu and MS TIG Welding Using Copper Filler Rod:

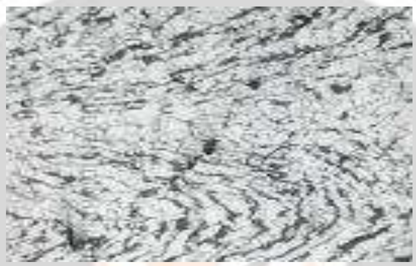

**Fig -8:** Microstructure of Silicon Bronze Weldment

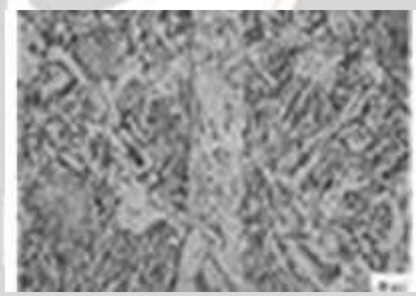

**Fig -9:** Microstructure of Copper Weldment

**Table-5:**Mechanical Properties of Silicon bronze

| Properties | Theoretical | Practical |
|---|---|---|
| Tensile strength | 255N/mm | 240N/mm |
| Yield strength | 185N/mm | 169 N/mm |
| Hardness | 150 HB | 130HB |

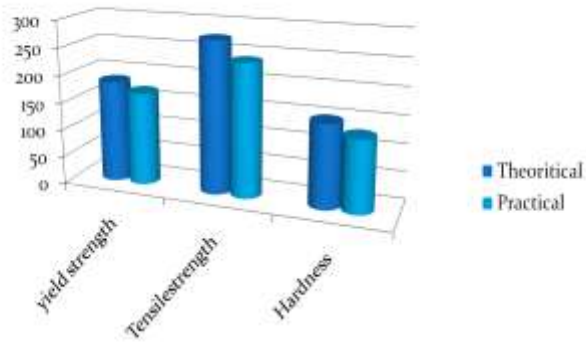


**Chart-1:** silicon bronze

**Table-6:** Mechanical Properties of Copper

| Properties | Theoretical | Practical |
|---|---|---|
| Tensile strength | 200N/mm | 190N/mm |
| Yield strength | 150N/mm | 142 N/mm |
| Hardness | 80-120 HB | 90HB |

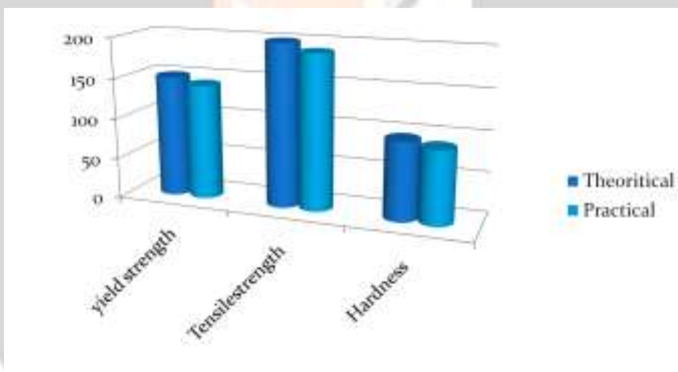


**Chart-2:** Copper

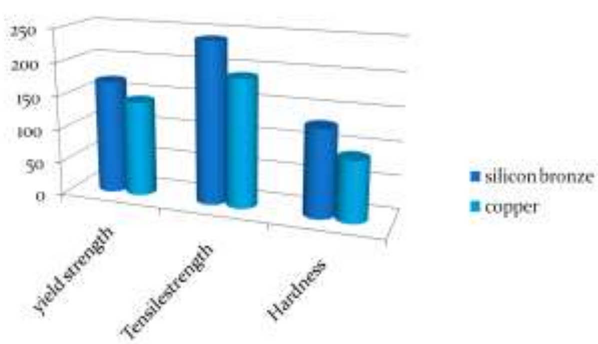


**Chart-3:** Comparison of silicon bronze and Copper

**3.1 Non-destructive Testing:**

- Non-destructive Testing is the Method of identifying the defects with out causing any damage to the test material.
- These tests are performed in a manner that does not affect the future usefulness of the object or material.
- In that NDT we take radiography method to identify the defect in our welding piece

**3.2 Radiography Testing - (RT):**

- Radiographic technique involves the use of penetrating gamma or X-radiation to examine parts and products for imperfections.
- An X-ray machine or radioactive isotope is used as a source of radiation.
- Because of penetration and absorption capabilities of x-ray & gamma radiation.
- Radiography is used to test variety of products such as welds, casting, forging &fabrications.
- It is sensitive for 3D defect like gas hole, porosity , slag, lack of penetration these are the defect which occur commonly in welding.
- The crack also can find above 250 microns.
- The metal thickness up to (cobalt)225mm or 9” can be detected using radiography imaging.

**3.3 Radiography Imaging:**

The density of the exposed image can be maintained 2-3 for clarity visibility

% of sensitivity = $\frac{100}{x}\sqrt{(T \times H)}/2$

| METAL THICKNESS(mm) | Ug(mm) |
|---|---|
| Upto 25 | 0.25 |
| 50 | 0.50 |
| 75 | 0.75 |
| 100 | 1 |
| Above 100 | 1.8 |

**3.4 Geometric Unsharpness/ug:**

- The geometric un-sharpness is varies depending upon the thickness of the specimen
- Ug=s*t/ (sfd-t)
- Step1:1.8=3*6/ (sfd-6)
- Step2: sfd=16/2=8mm
- The distance between the source and specimen is maintained at 16mm to obtain perfect image

**3.5 Radiation Maintenance:**

Iridium source is enough for the thickness we have

- 1hr for Ir192-500MR
- 1hr for Ir60-300MR
- Formula : $I_1/I_2= (D_2)^2/ (D_1)^2$

The above formula is from inverse square law.

The law states that, the radiation intensity varies inversely as the square of distance from the source.

- Step1 :$500/I_2= (0.008)^2 / (1)^2$
- Step 2 :$I_2$=7812 MR/hr

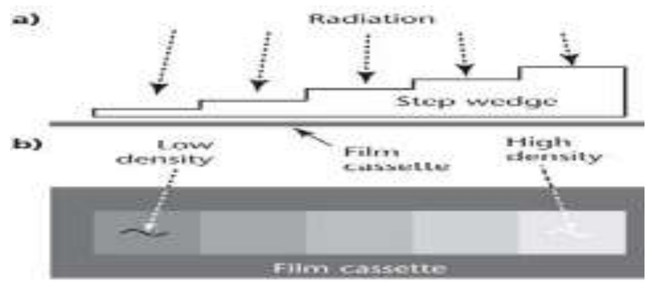


**Fig-10:** Transmission of radiation

### 3.6 Radiography Interpretation – Welds:

- In addition to producing high quality radiographs, the radiographer must also be skilled in radiographic interpretation. Interpretation of radiographs takes place in three basic steps: (1) detection, (2) interpretation, and (3) evaluation. All of these steps make use of the radiographer's visual acuity.
- Visual acuity is the ability to resolve a spatial pattern in an image. The ability of an individual to detect discontinuities in radiography is also affected by the lighting condition in the place of viewing, and the experience level for recognizing various features in the image.

**Discontinuities:**

- Discontinuities are interruptions in the typical structure of a material. These interruptions may occur in the base metal, weld material or "heat affected" zones. Discontinuities, which do not meet the requirements of the codes or specifications used to invoke and control an inspection, are referred to as defects.

### 3.7 Results of Radiography

- Porosity is the result of gas entrapment in the solidifying metal. Porosity can take many shapes on a radiograph but often appears as dark round or irregular spots or specks appearing singularly, in clusters, or in rows.
- Sometimes, porosity is elongated and may appear to have a tail. This is the result of gas attempting to escape while the metal is still in a liquid state and is called wormhole porosity. All porosity is a void in the material and it will have a higher radiographic density than the surrounding area.

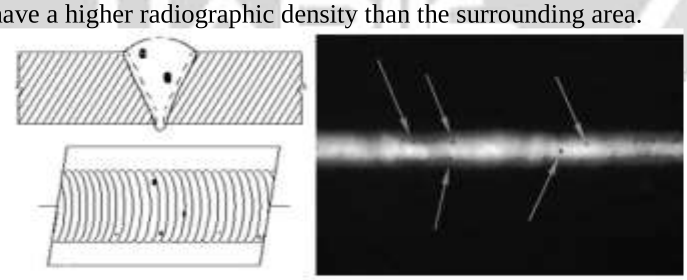

**Fig-10:**Porosity image

| METHOD | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| X-RAY RADIOGRAPHY | Detects surface and internal flaws Can inspect hidden areas Permanent test record obtained Minimum part preparation | Safety hazard Very expensive (slow process) Highly directional, sensitive to flaw orientation High degree of skill and experience required for exposure and interpretation Depth of discontinuity not indicated |

## 4. CONCLUSION AND DISCUSSION:

- A Possible solution is obtained for the Welding of Aluminium and Mild Steel. It can be Welded by the Curvilinear Motion of the Torch.
- The Welding of Aluminium and Mild Steel requires removal of Heat from the Weldment Continously,Due to the higher Heat conductivity of Aluminium.
- There is a large probability of Welding Aluminium and Mild Steel in the Under Water Welding as the Heat is Continuously removed from the weldment by Water.
- The Welding Speed is Very low when Silicon Bronze filler rod is used in the TIG welding for Copper and Mild Steel, It can be replaced by the Copper Filler rod which has high Welding Speed.
- A layer of Silica is deposited during the repeated cycles of Welding when the Silicon Bronze filler rod is used, which affect the Character of weld and requires frequent flux removal.

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