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Experimental Analysis on Mechanical Properties with Microstructures on Aluminium alloy 6070 Welds with H14 Steel

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Abstract: TIG welding stands out as a highly precise and efficient welding technique, proficient in joining both ferrous and non-ferrous metals. This method offers exceptional control, produces minimal fumes and spatter, and results in a clean weld that often requires little to no finishing. The focus of the current research is on determining the optimal combination of welding parameters for TIG welding of Al6070 and H14 materials. The literature survey reveals the inherent difficulty of welding aluminium using conventional arc welding processes. A multitude of welding parameters significantly influences both the quality of the welds and their repeatability. This study systematically investigates various parametric ranges and their effects. The TIG welding setup employed in this specific study will weld 10mm thick Al6070 and H14 plates, adhering to the prescribed welding parameters. The impact of these parameters on the tensile and impact strength of the welding joints, as well as the microstructural characteristics, will be thoroughly analysed.
Keywords: TIG welding, Al6070, H14, Welding current, Gas flow rate, Welding speed, Tensile strength, Impact strength.

I. INTRODUCTION

Welding represents a lasting joining technique wherein heat and/or pressure is applied to unite diverse ferrous and nonferrous materials, including metals and alloys, at their points of contact. This method is widely employed, particularly in aluminum welding, where alloys are liquefied at the interface to fuse workpieces, resulting in a durable joint upon solidification. To enhance bonding strength, a filler material is frequently introduced, creating a molten weld pool that solidifies to form a robust connection between the materials. The performance of welded materials is contingent upon factors such as the metal's melting point, thermal conductivity, reactivity, thermal expansion, electrical resistance, and surface conditions. As you embark on your welding journey, the wealth of information on this topic can be overwhelming. It's crucial to delve into the diverse forms of welding, each with its unique characteristics. Some techniques are relatively straightforward to grasp, while others may pose more complexity. The aesthetic appeal and ease of post-weld cleaning vary significantly between different welding styles.

1) *TIG Welding:* TIG welding stands out as an arc welding method employing a tungsten electrode, which remains non-consumable. The electrode is linked to a vital power source, and a shielding gas, typically Argon or Helium, is often utilized to safeguard the welding surface from the atmosphere. The addition of filler metal is optional and depends on the specific weld type or conditioning welding is particularly valuable for joining challenging materials like aluminium and magnesium. This versatile technique has evolved to encompass various metals such as MS, SS, HSS, etc. Tungsten Inert Gas (TIG) welding ensures high-quality welds, achieved through the heat coalescence generated by an electric arc between the non-consumable tungsten electrode and the metal. Throughout the process, gases are created by heating the workpiece and filler pin to facilitate welding. Helium and argon serve as shielding gases due to their non-reactive nature. These inert gases shield the welding area, preventing dust, minimizing oxidation, facilitating heat transfer during welding, and aiding in the initiation and maintenance of a stable arc, thanks to their low ionization potential.

- TIG welding is known for its remarkable flexibility, although mastering it can be challenging. Lincoln Electric TIG welders are renowned professionals in the field.
- TIG welding demands the use of two hands. One hand feeds the rod, while the other handles the TIG torch, responsible for generating the required heat and arc. This torch is versatile enough to weld a variety of conventional metals, including copper, steel, nickel alloys, cobalt, and titanium alloys.

Figure (1.1): TIG Welding

2) *Mechanism of TIG Welding:* Various mechanisms contribute to the efficiency of TIG welding, including the Marangoni Effect, Buoyancy force, Electromagnetic force, Arc constriction due to active flux, and Arc constriction due to negative ions. The Arc concentration effect, illustrated in Figure 1.7, highlights the localized arc's regulation of the workpiece's heat input, resulting in a smaller influenced heat region. This advantage prevents base metal distortion during the welding process, attributed to arc overheating and rapid cooling rates

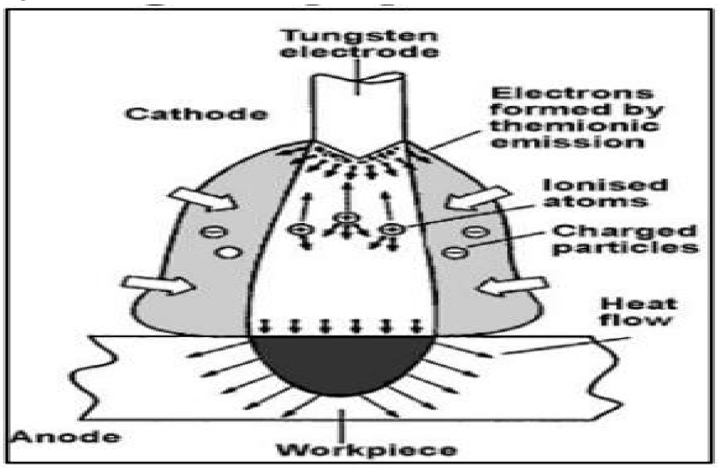

Figure (1.2): Arc constriction

3) *TIG Welding Process Parameters:* The effect on the weld and its efficiency of the various welding parameters is discussed below. Voltage controls the welding arc length as well as subsequent arc cone diameter and thickness. When voltage increases arc length gets longer (and arc cone wider), even as it reduces, the arc length gets shorter (and arc cone narrower) A high initial voltage allows easy arc initiation and enables greater range of working tip width. Penetration range diminishes as voltage increases. Filler feeding or Filler melt off rate should be kept constant in GTAW welding process since it is manual process. Voltage is a control variable in manual processes as it is very difficult to retain the same arc length continuously during manual process. Hence, GTAW is the output form of constant current (CC).The welding current refers to the amount of heat applied to the welding component and it depends on the welding material, the thickness of the steel, the welding speed and the shield air. The goal is to achieve the necessary penetration of defect-free welds. Current has significant impact on weld bead form, welding velocity and weld efficiency. Most GTAW welds use direct current on the negative electrode (DCEN) (straight

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polarity), since it provides greater weld penetration depth and faster moving speed than on the positive electrode (DCEP) (reverse polarity).

II. MATERIALS AND METHODS

A In the welding of the Tungsten Inert Gas, an arc between a tungsten electrode and the work piece is carried. This arc and the weld pool are secured from atmospheric pollution by an inert-gas gaseous shield such as argon, helium, or argon-helium blend. Optionally, the filler metal is used according to the welding criteria. This filler metal can be manually or automatically applied irrespective of process forms. The TIG welding process itself may be manual or automatic, depending on the heat dissipation needed, the welding power source provides direct or alternate current. TIG welding produces stronger performance when the components are hard to solder. TIG welding has been used for the production of high quality welding materials with the heat coalescence produced by an electro arc formed between a tungsten electromagnetic electrode and the work component, Helium and argon gas and falls below the best suitability for shielding as it is not chemically reactive.

A. TIG welding Procedures

The acronym TIG is a US tungsten inert gas abbreviation. Tungsten also known as wolfram is a metal with a fusion point of over 3300^{0}C, which means that the metals typically sweated more than twice a fusion point. Inert gas is the same as inactive gas, a type of gas that is not expected to interact with other elements. This process in Germany is known as WIG welding, W wolfram. The regional standardized term for this welding technique is TIG welding. This welding method has number in accordance with DS / EN 24063

1) *The Principle of TIG Welding:* TIG welding is a method of electro-arc welding that generates the fusion energy through an electric arc burning between the work piece and the electrode. The electrode, arc and solder pool are shielded by an inert gas during the welding cycle against the harmful effects of ambient air. The gas shielding gas through the gas nozzle leads to the soldering area, where the ambient air substitutes. TIG welding varies in the sense that electrodes like electrodes are not consumed in such procedures as MIG / MAG and MMA from other arc welding methods.

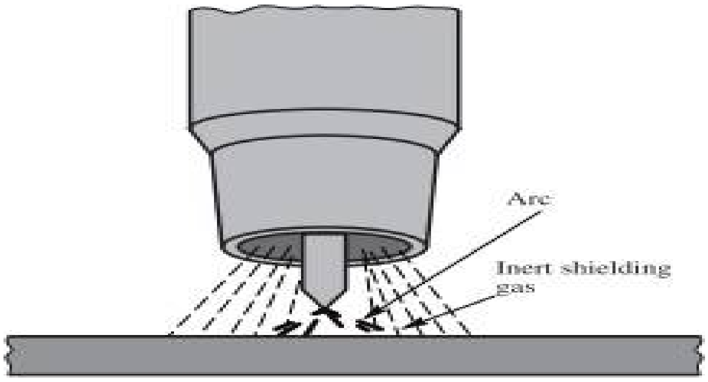


Figure (2.1): TIG welding Principle

2) *Alternating Current:* The alternating power is defined by a number of cycles, normally 100 times per second, voltage shift in polarity.

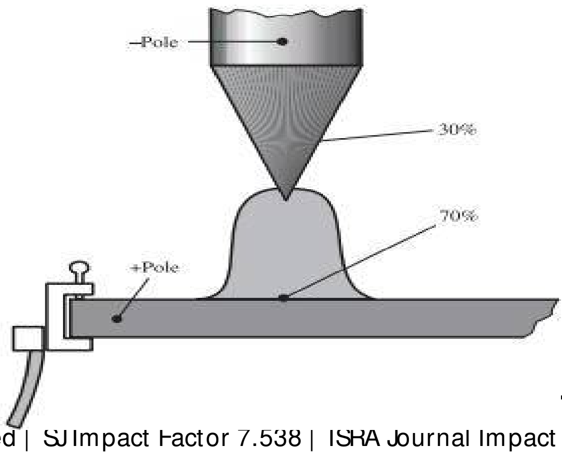


Figure (2.2): Heat distribution at TIG welding

3) *TIG Welding Equipment Configuration:* You need equipment consisting of many components with their own separate functions to handle with make the TIG welding process work to the full degree. The welding unit TIG consists mainly of

A TIG torch which is the arc-control device that the welder uses.

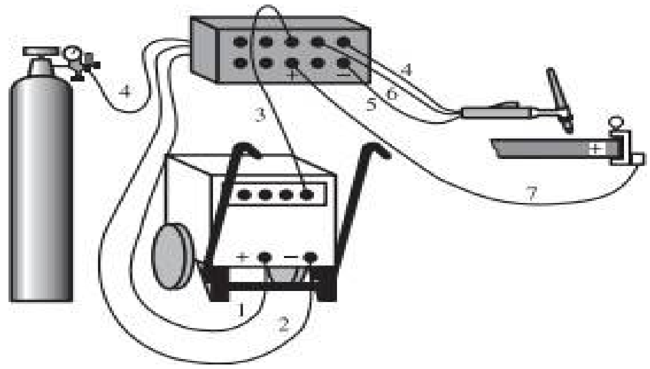


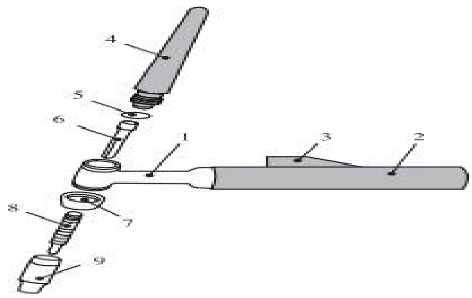
Figure (2.3): Example for configuration of welding equipment

Most TIG welding systems are designed so that a single unit is the power source and the TIG unit

Figure (2.4): Power source and TIG unit in one unit

4) *TIG Torch*

Figure (2.5): TIG Torch Figure



(2.6): TIG welding torch

5) *The Gas Nozzle:* The role of the gas dump is to push the blinding gas down the welding area and remove the air in the atmosphere. The gas pin is screwed to the TIG torch so that it can be switched, where possible. This typically consists of a ceramic substance that holds heat in large quantities. The measurements of the gas pin are often shown by a number referencing the inner diameter of the hole in 1/16. Example The internal 4/16 "diameter of the gas nozzle no. 4 is 6.4 mm Another form of gas dump is the gas lens that is built so that the protective gas passes through a wire grid to make the gas stream more stable over a long distance. The advantage of the long gas flow is that the electromechanics will provide a longer stickout so that a clearer view of the soldering pool is possible. The consumption of protective gas can also be minimized through a gas diffuser.

6) *TIG Boxes:* The TIG interface control system can be very basic or advanced with several different functions. The simplest version only controls the welding stream and switches on / off the shielding gas with a small switch on the TIG torch. The more sophisticated TIG boxes are able to monitor the blinding gas so that it is brought out to the weld until the arc is turned off and the shielding gas is stopped until the welding current is cut off. Which ensures that during the cooling process, the tungsten electrode and the welding pole are both shielded from air. In addition, the TIG box typically has an ignition mechanism to prevent scratching. This ignition device can be an HF unit which increases the frequency to 2 million to 4 million periods a second and the voltage to several thousand volts. The high frequency and voltage allows the spark to be generated between the electrode point and the workpiece surface that transfers the arc.

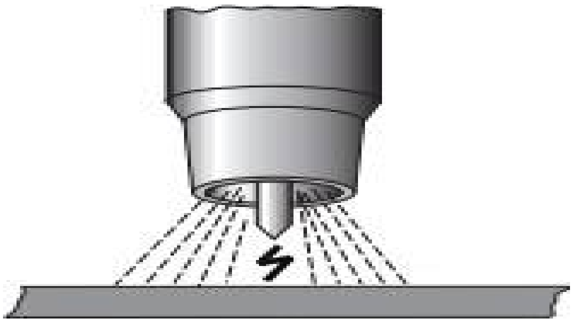


Figure (2.7): High frequency ignition

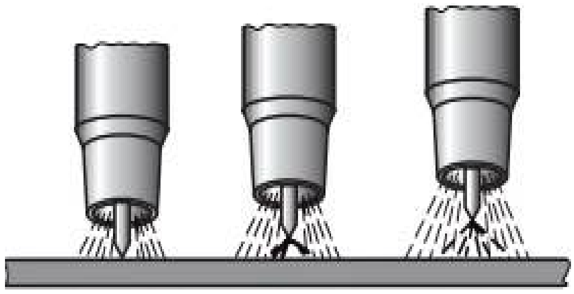


Figure (2.8): Ignition with the LIFT method

7) *Welding of Aluminum Alloys:* Many transport industries, such as the automotive sector, have primarily been concerned with mass cutting, which has become useful due to fuel efficiency, reduction in emissions and recyclability. Thus, the emphasis on lightweight materials such as aluminum and magnesium has become more important. The thermal conductivity of aluminum is very high; thus, heat can be carried away from the surface of the welding region easily. The thermal expansion of aluminum coffee is also strong relative to steel at the melting point 565/650 ° C at a heat supply, so that it can distort or cause stress if the correct welding process is neither foolish nor faded. Aluminum is a reactive metal that easily forms an oxide layer on the surface and the soldering strength is weak. The welding of aluminum is also difficult with conventional arc welding methods. Aluminum and its alloys could easily be soldered by recognizing the welding features and by using correct procedures. DC current, with and without pulse current and permanent tungsten electrode current, are applied to the most common commercial aluminum and alloy soldering method.

B. *Al6070 Material Properties*

Table (2.1): Physical Properties of Al6070

Description of properties	Quantity
Density	2.71g/cc

Table (2.2): Mechanical Properties of Al6070

Mechanical properties	Metric Units
Tensile strength	145Mpa
Yield strength	69Mpa
Shear strength	97Mpa
Fatigue strength	62Mpa
Elastic modulus	70-80Gpa
Poissons ratio	0.33
Elongation	20%
Ratio	35

C. H14 Material

H14 Tool Steel is a flexible hot work stain for the chromium-molybdenum industry, which is commonly used for hot work and cold work equipment. H14 chromium hot-work steel has had tungsten added for improved high-temperature properties and a high heat resistance. It exhibits little size change during hardening and is suitable for long-run die castings dies. The hot hardness of H14 resists thermal fatigue cracking that takes place in hot working tools due to cyclic heating and cooling cycles. H14 is also used for hot tooling applications as any tool steel due to its excellent combination of high toughness. Temperature resistance (also known as heat testing) to break thermal fatigue. H14 is also used in a variety of cold work tooling applications due to its high durability and excellent stability in heat treatment. H14 offers better hardness (through hydration in large chapter thicknesses) and better wear resistance in such applications than common alloy stones like 4140.

They can also be supplied with Electro-Slag-Remelted (ESR) and VA-Products (VAR). The re-melting processes have better chemical homogeneity, carbide size refinement and related mechanical characteristics and fatigue improvement.0750 kg / m3 (0,280 lb / in3) Gravity specific: 7.75

Workability: from 65% to 70% 1% carbon steel

Figure (2.3): Chemistry Data of H14

Carbon	**0.32 – 0.45**
Chromium	**4.75 – 5.5**
Manganese	**0.2 – 0.5**
Molybdenum	**1.1 – 1.75**
Phosphorus	**0.03 max**
Silicon	**0.8 – 1.2**
Sulphur	**0.03 max**
Vanadium	**0.8 – 1.2**

III. RESULTS AND DISCUSSIONS

A. Experimental Results

Various experiments were undertaken involving the TIG welding of Al6070 and H14 metal plates, focusing on hardness and microstructural aspects.

1) Tensile Test

The Tensile Testing of Al6070 and H14 metal plates commenced with the external surfaces. Universal testing machine was employed for conducting the tests, revealing elongation percentages. The Al6070 and H14 metal plates displayed ultimate tensile strength (Mpa) and UTS values. The strengths were calculated within the spectral range of 3.6–5.1 mg, with a digital frame rate of 170 Hz. The IR camera used had a pixel resolution of 25 µm and a pixel pitch of 30 µm. The standard camera calibration range for measurement was 5°C to 1000°C. The Al6061 MMC were affixed vertically to the top and bottom of the UTM grip, and environmental control was maintained by enclosing the test space with air conditioning. The instrument featured a front visible opening for continuous monitoring of temperature variations.

Table (3.1): Tensile Specimens test results of Al6061 and H13 material

S.no	Load applied (N)	Ultimate tensile strength (MPa)	Modules of elasticity	% Elongation
1	500	1123.37	37.22	3.8
2	750	1263.97	52.37	5.1

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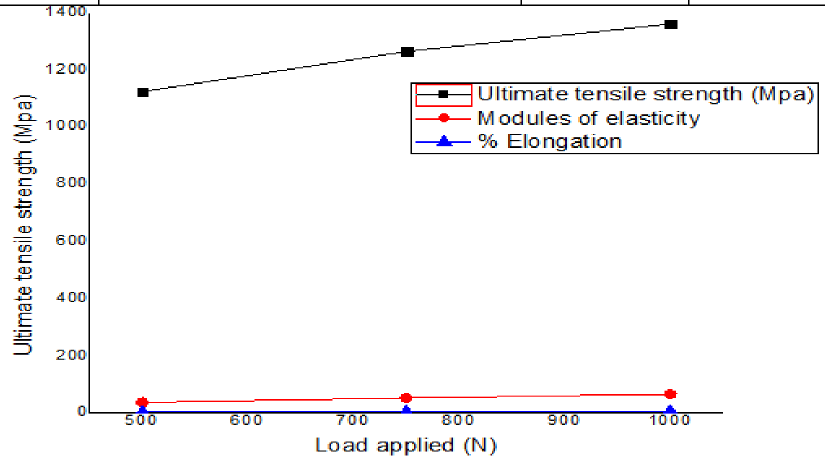
3	1000	1359.84	66.29	6.6



Graph (3.1): Tensile Specimens test results of Al6070 and H14 material

2) Micro Structural Results

Al6070 And H14 Material Micro Structure Analysis:

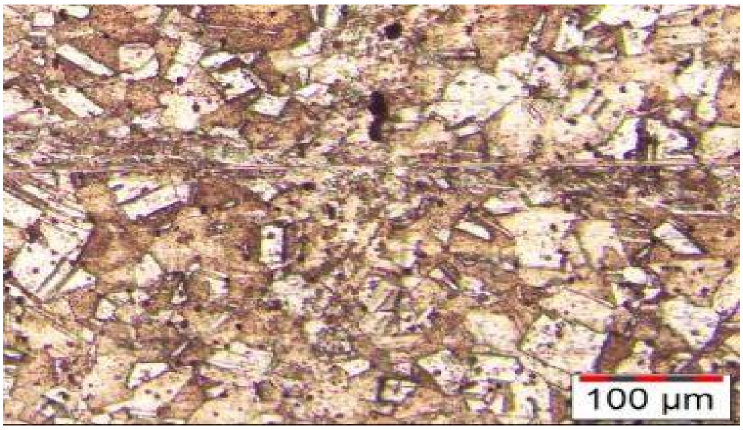


Figure (3.1):100x

The above figure shows clearly the 100xmicro-structural approach at a maximum distance of 210Mpa where the crack propagation rate decreases slowly.

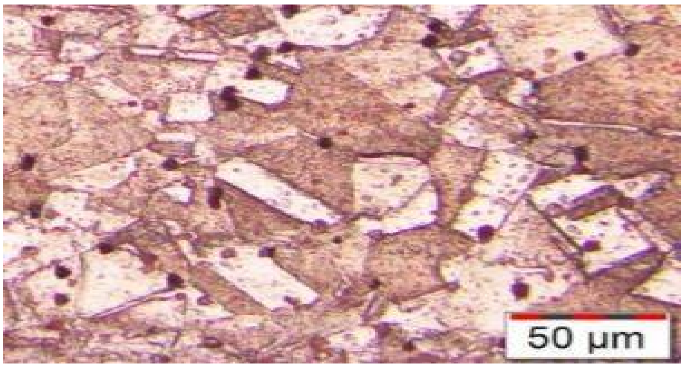


Figure (3.2): 200x

The above figure shows clearly that for Al6070 the 200x micro structural approach has a maximum length of 10 mm and a high strength as compared to 100 km, and the obtained strength is 186Mpa.

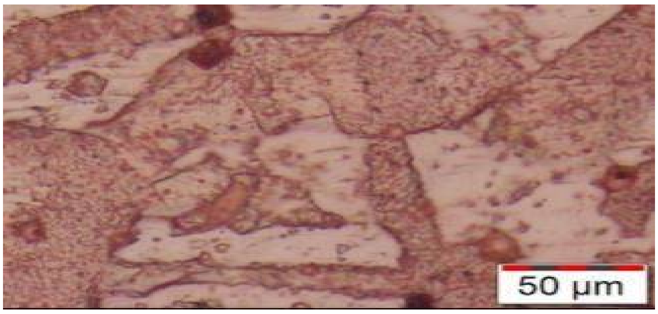


Figure (3.3): 500x

The above figure clearly shows the 500x micro-structural approach of Al6070 with H14 taken at 10 mm maximum and 196Mpa high power, where the split rate is decreasing slowly

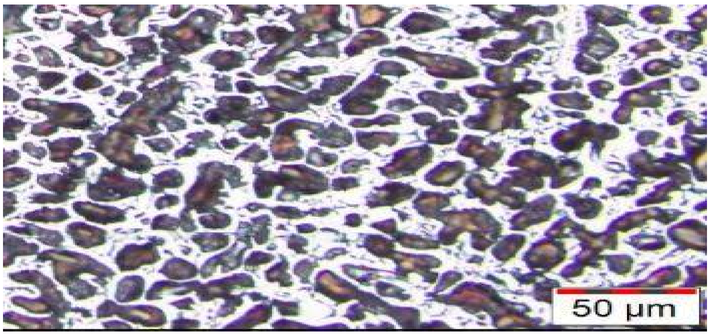


Figure (3.4): weld zone100x

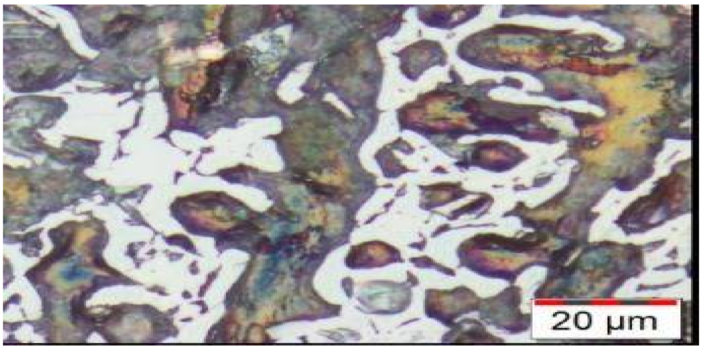


Figure (3.5): weld zone200x

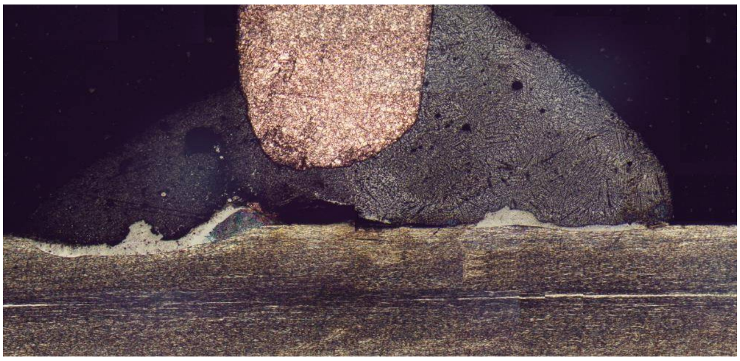


Figure (3.6): weld zone500x
Figure: Weld zone area

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3) *Hardness Test:* The hardness test is a mechanical evaluation of material properties crucial in construction, structural analysis, and material fabrication. Its primary purpose is to determine the suitability of materials or the appropriate treatment required for specific applications. Assessing the ease with which Al6070 and H14 can be processed is a common practice for inspecting metals and alloys. In instances where moving blades operate in wet steam, they are exposed to tiny droplets of steam that lead to erosion of the upper edge of the blade. Hardening the leading edge of the blade enhances material resistance to erosion. The quality of soil in Titanium and Cu-welded plates, employing Butt welding methods, is contingent on various factors such as soiling speed and power.

WELD ZONE:

S.ID	Location	Observed Values in HV				
		Base Material (Al6070)	HAZ (Al)	Weld zone	HAZ (H14)	Base Material (H14)
1		59.3	31.75	118.1	87.5	94.7

Table (3.2)

B. *ANALYTICAL RESULTS:*

1) *Fatigue Analysis:* While several parts can start working well at the beginning, they also fail due to fatigue failures induced by repeated cyclic charges. The object of fatigue analysis is to characterize the capacity of a material for the many cycles of its lifetime. The analysis of the residual stresses in the solder joint includes three different types of fatigue analysis: strain life, stress life and fracture mechanism.

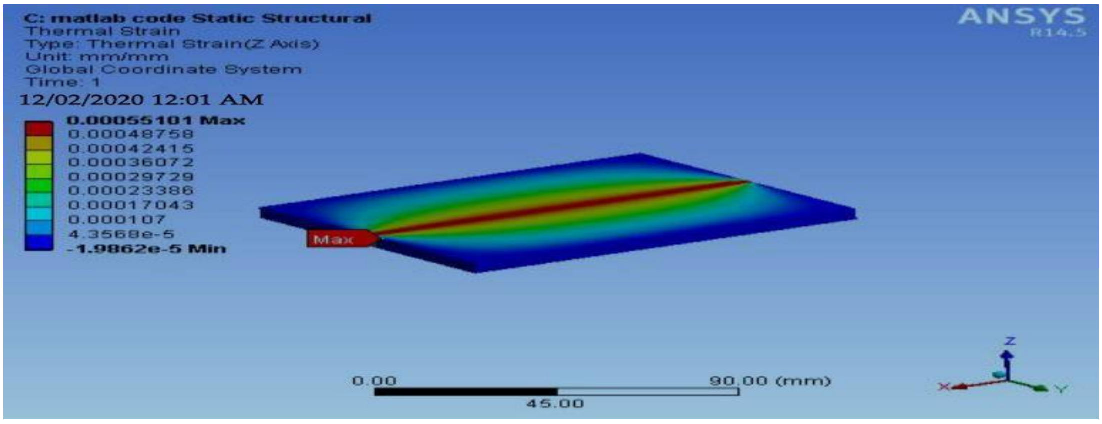

FIGURE (3.7): Thermal strain having in Z- Axis having Maximum of 0.00055101 mm/mm and Minimum of –1.986e-5 mm/mm

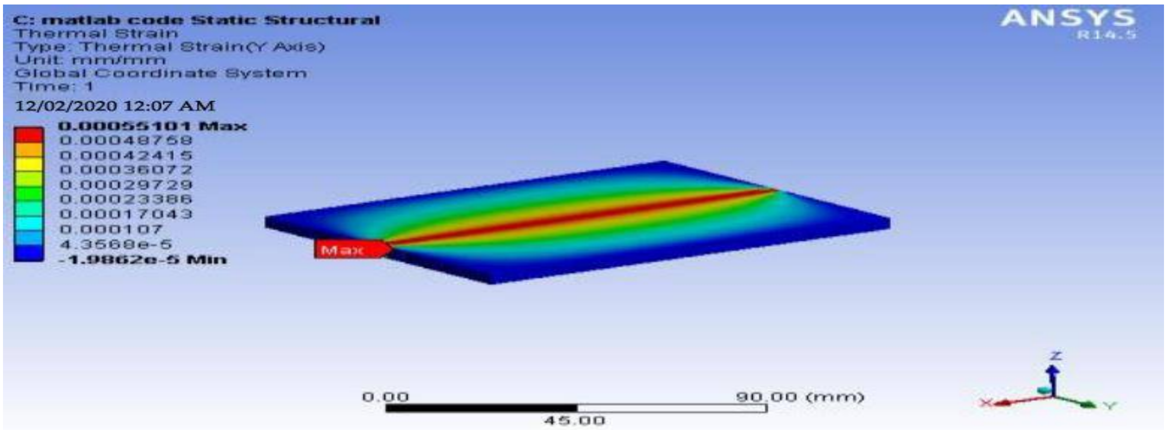

Figure (3.8): Thermal strain having in y- Axis Having Maximum of 0.00055101 mm/mm and minimum of –1.986e-5 mm/mm

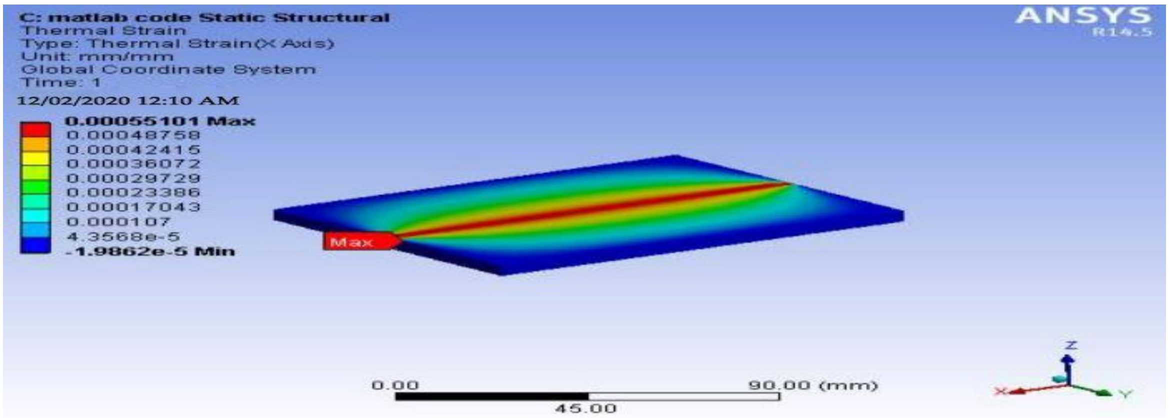

Figure (3.9): Thermal strain having in x- Axis Having Maximum of 0.00055101 mm/mm and Minimum of –1.986e-5mm/mm

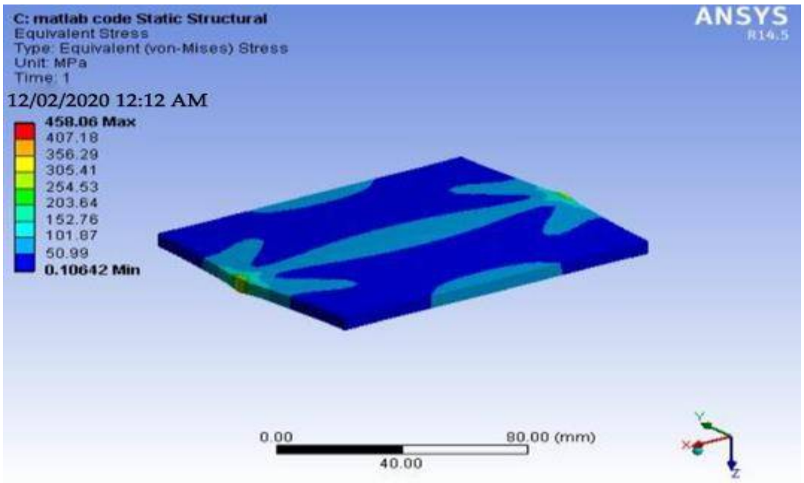

Figure (3.10): Equivalent Stress Having Maximum of 458.06 Mpa and Minimum of 0.10642 Mpa .

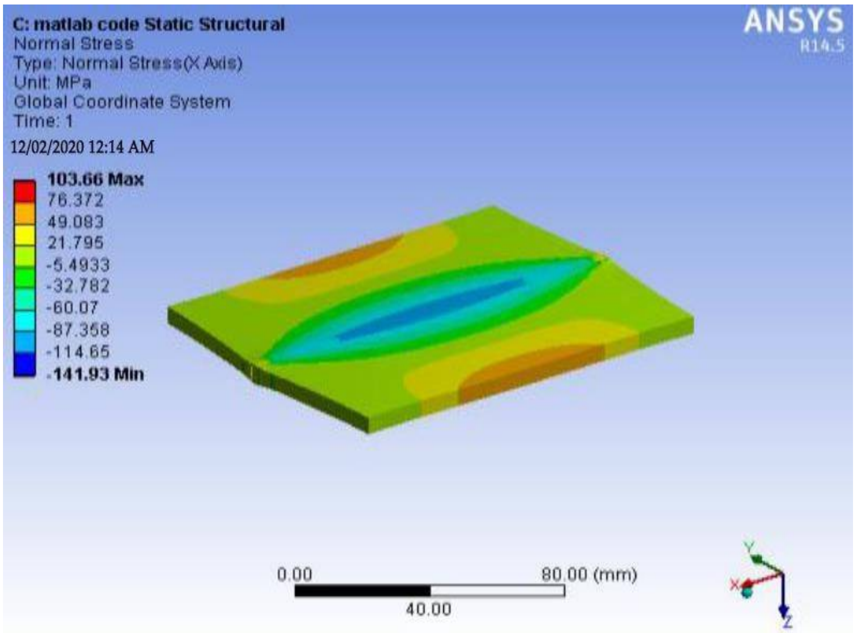

Figure (3.11): Normal stresses in X- Axis Having Maximum of 103.66 Mpa and Minimum of -141.93 Mpa

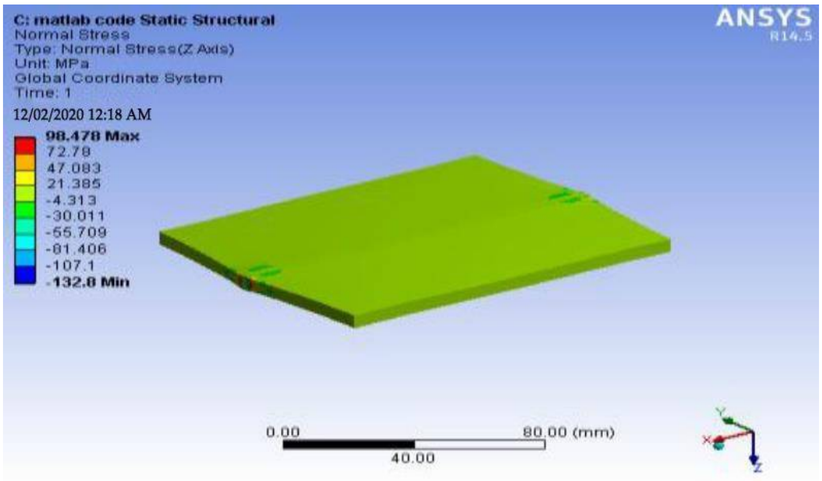

Figure (3.12): residual Normal stress in Z- Axis Having Maximum of 98.478 Mpa and Minimum of -132.8 Mpa

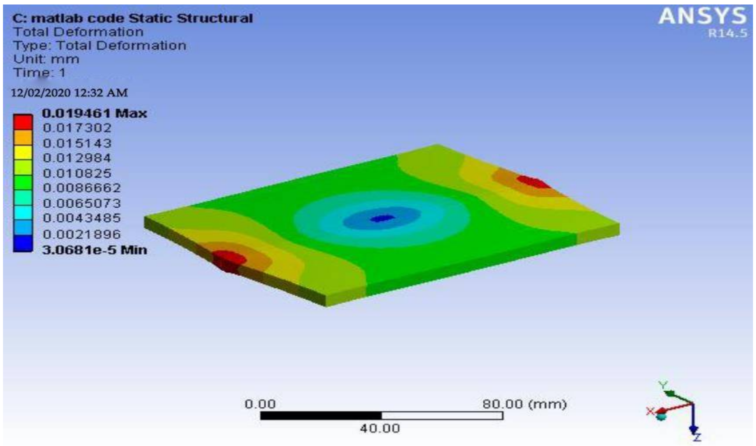

Figure (3.13): Total Deformation Having Maximum of 0.019461 mm and Minimum of 3.0681e-5mm.

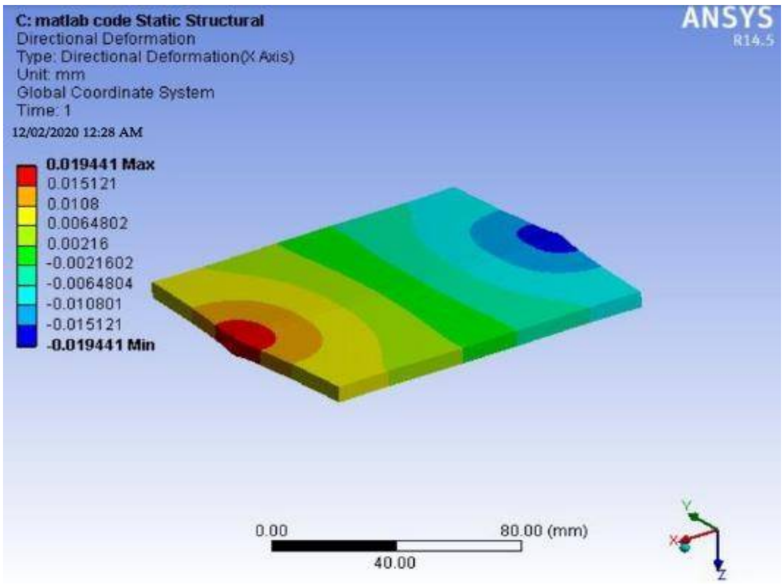

Figure (3.14): Directional deformation in X- axis having Maximum of 0.019441 mm and Minimum of -0.019441 mm

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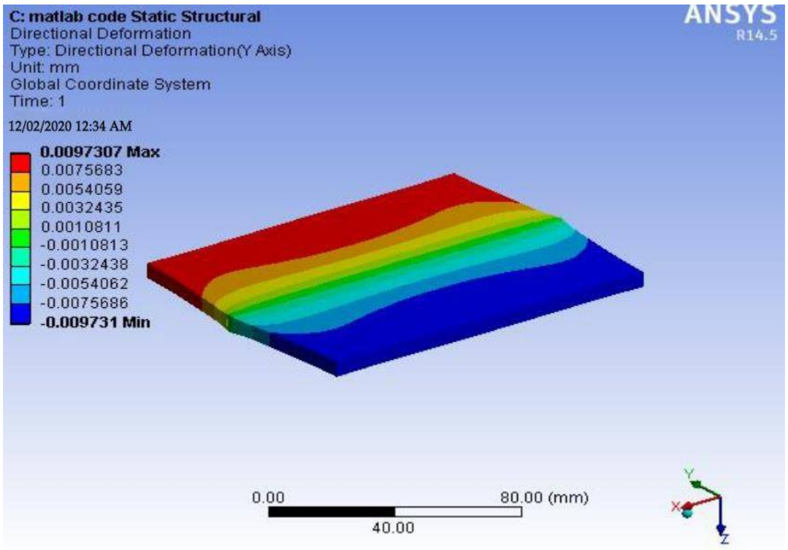


Figure (3.15): Directional deformations in Y- axis having Maximum of 0.0097307 mm and Minimum of 0.009 731 mm.

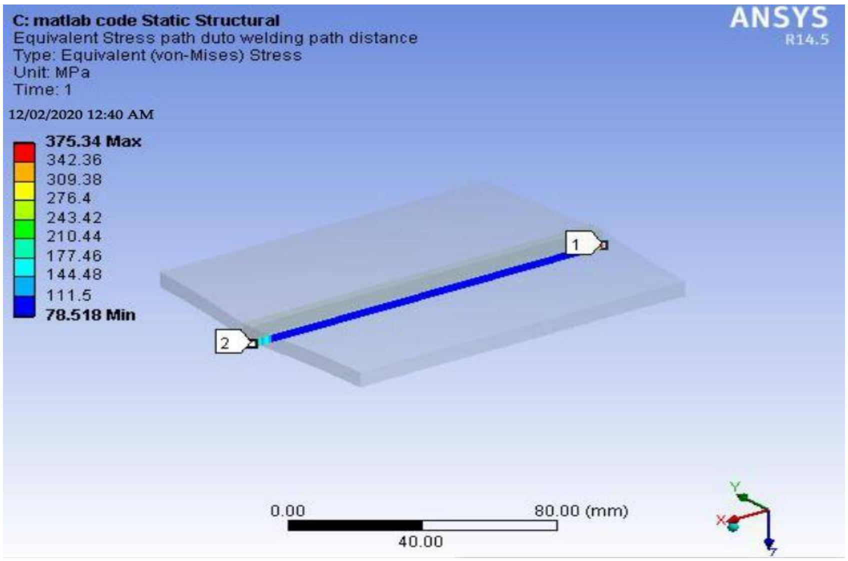
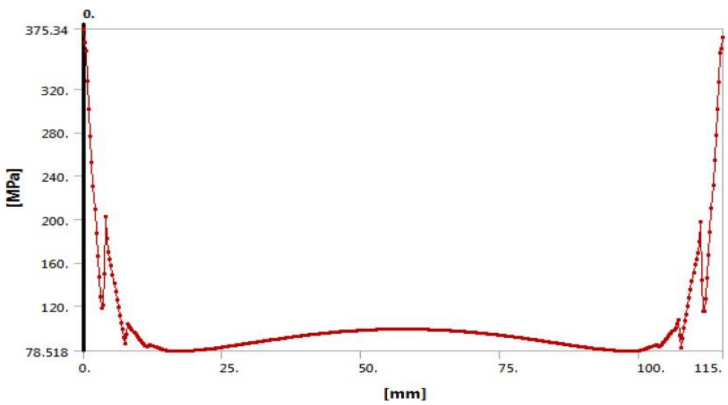


Figure (3.16): Equivalent stress along 1—2 path having Maximum of 375.34 Mpa and Minimum of 78.518 Mpa.



Graph (3.2): Model (C4) > Static Structural (C5) > Solution (C6) > Equivalent Stress path due to welding path distance

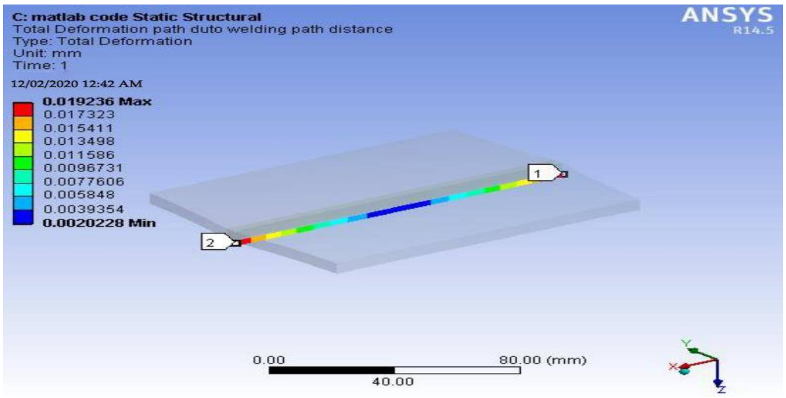
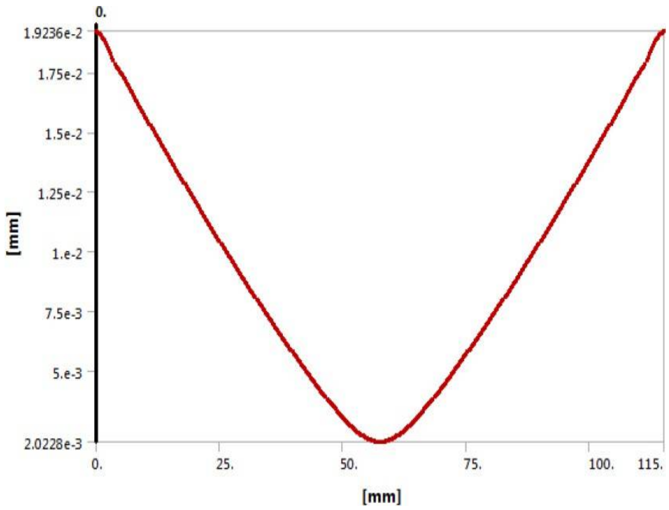
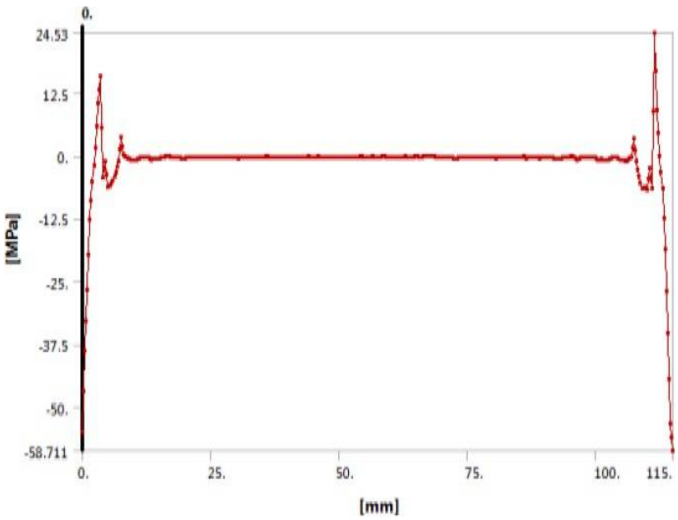


Figure (3.17): Static Structural of total deformation along 1—2 path having Maximum of 0.019236 mm and Minimum of 0.0020228 mm



Graph (3.3): Model (C4) > Static Structural (C5) > Solution (C6) > Total Deformation path duto welding path distance

The above graph indicates the overall total deformation values for the solder track at the top of the welded edges at the start and end edges at 0,019236 mm.



Graph (3.4): Model (C4) > Static Structural (C5) > Solution (C6) > Normal Stress z path duto welding path distance

The above graph shows along the weld path distance and obtained residual stress at the weld bed of the top edges shows the maximum residual Normal stress along z axis values are **24.53 Mpa** of the initial and final edge offset distance of 5mm.

TABLE (3.3): THERMAL RESULTS

THERMAL	MAXIMUM	MINIMUM
Total Heat Flux	18.174 W/mm2	5.7533e-14 W/mm2
Directional Heat Flux x axis	18.095 W/mm2	-18.099 W/mm2
Directional Heat Flux y axis	3.9805 W/mm2	-3.9748 W/mm2
Directional Heat Flux z-axis	0.18337 W/mm2	-0.14702 W/mm2

TABLE (3.4): THERMAL + STATIC COUPLED WELD RESULTS

STATIC	MAXIMUM	MINIMUM
Equivalent Stress	458.06 Mpa	0.10642 Mpa
Normal stress inX- Axis	103.66 Mpa	-141.93 Mpa
Normal stress inY- Axis	428.69 Mpa	-32.524 Mpa
Normal stress inZ- Axis	98.478 Mpa	-132.8 Mpa
Shear stress inXYPlane	86.039 Mpa	-96.958 Mpa
Shear stress in YZ Plane	79.86 Mpa	-85.842 Mpa
Shear stress in XZ Plane	18.555 Mpa	-18.357 Mpa
Total Deformation	0.019461 mm	3.0681e-5mm
Directional deformation in X-axis	0.019441 mm	-0.019441 mm
Directional deformation in Y-axis	0.0097307 mm	-0.009731mm
Directional deformation in Z-axis	0.0018541 mm	-0.0018539 mm
Equivalent stress	375.34 Mpa	375.34 Mpa

TABLE (3.5): STATIC IN DUE TO PATH WELDING

STATIC	MAXIMUM	MINIMUM
Total Deformation	0.019236 mm	0.0020228 mm
Normal stress InX-Axis	103.66 Mpa	-104.35 Mpa

Normal stress InY- Axis	290.9 Mpa	-13.397 Mpa
Normal stress InZ-Axis	24.53 Mpa	-58.711 Mpa

IV. CONCLUSIONS

The research work has been found in literature for TIG welding of Al 6070 and H14 Materials based on past work the following conclusions are drawn:

1) Welding speed, welding current, welding voltage, electrode diameter and electrode gap, work piece material, shielding gas etc. are important process parameters for TIG welding.
2) Out of the listed parameters welding current, gas flow rate and welding speed play a vital role to perform precise and uniform welding of welded materials.
3) The range and selection of parameters depend upon type of material, strength required and specifications of welding machine used.
4) Welding strength and welding profile is greatly influenced by selection of welding material and welding technique.
5) For better strength and cleanliness in TIG welding of aluminium, AC power source is mostly preferred.
6) Microstructure investigation at different zones of weldment gives an comparative outcome between TIG welding and base material to differentiate the effect of temperature distribution.
7) UTM and Impact Testing Machine can be used for Tensile and Impact testing of TIG welded joints.
8) Welding defects can be eliminated by proper welding precautions and controlling the different welding parameters.
9) Automation of TIG welding process can make it more useful and precise. It can help to achieve faster welding speed less distortion and even thin welding sheets can be easily welded with less skill required.

V. FUTURE SCOPE

Within this study, the TIG welding parameters and their effect on a welded joint are further developed and are useful to understand and select the correct welding parameters. For the highest performance, the impact of the sum of different parameters on the soldering bowl and the solder geometry can be more accurate. Due to its effect on the welding joint and sold quality the behavior of different material parameters may grow into a vast area of research.

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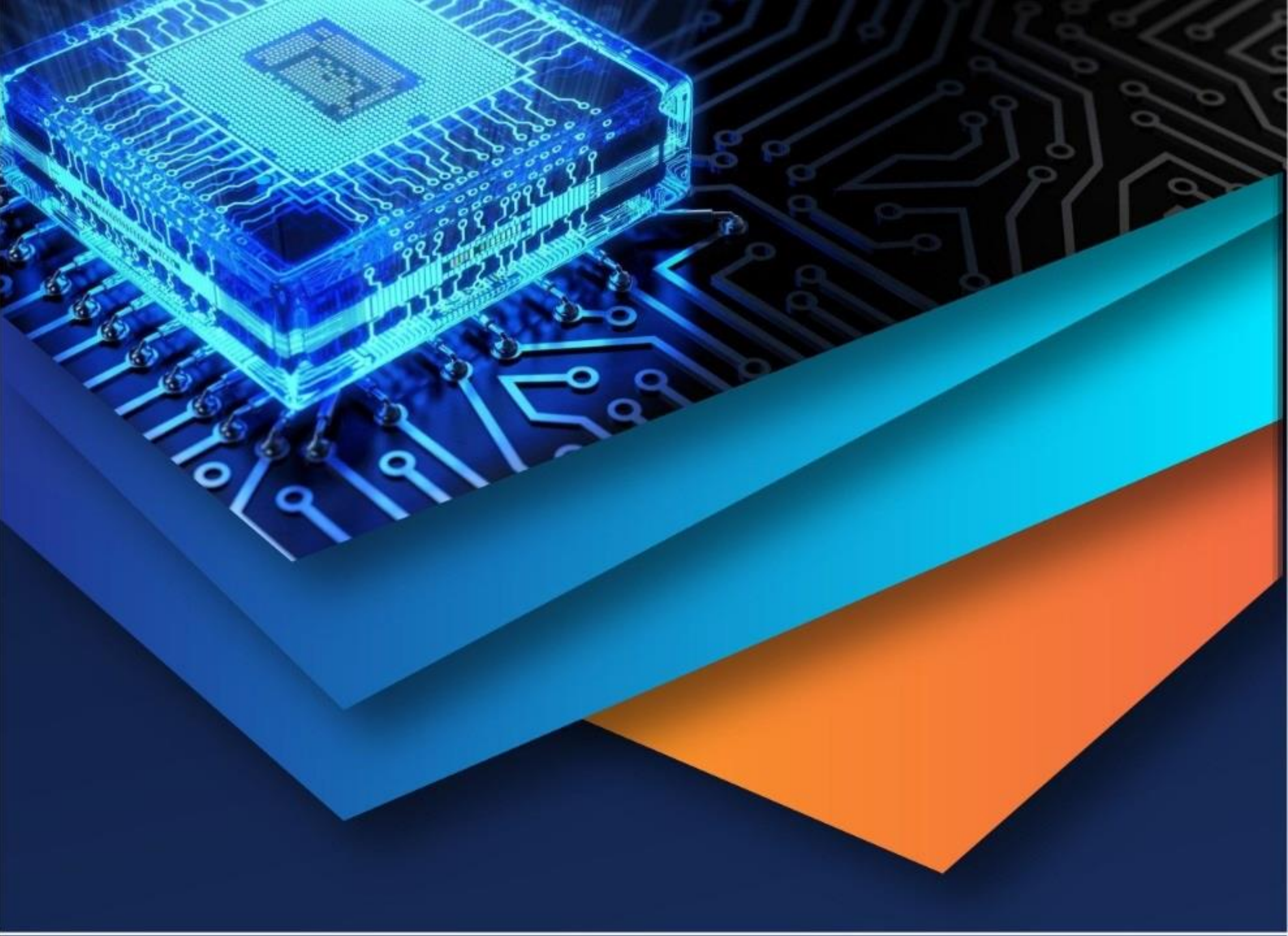

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