ANALYSIS AND EXPERIMENTAL INVESTIGATIONS OF WELD CHARACTERISTICS FOR A TIG WELDING WITH SS316L

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ABSTRACT

Austenitic stainless steel is widely used materials in the current industrial area including higher and lower temperature applications such as storage tanks, pressure cups, furnace equipment's etc. Using ratio of those materials is increasing constantly due to having superior corrosion resistance and mechanical properties, GTAW&GMAW process are widely used for stainless steel welding, especially for full penetration welds in thin gage materials. Selection of shielding gas and filler material is crucial parameter for the quality, the microstructure and properties of weldments. The weldments properties strongly depended on the shielding gas, since it dominates the mode of metal transfer.

Shielding gas not only affects the properties of weld but also determines weld ability, the appearance, the shape and penetration of bead as well. Pure argon is mainly used for GTAW as shielding gas at present. The most common shielding gases are argon riches mixtures, such as argon with a few percent helium, carbon dioxide, hydrogen, oxygen, nitrogen for GTAW&GMAW process. In this project the austenitic stainless steel (316L) is welded by GTAW process and its mechanical property were studied and the process welding parameters like CURRENT, VOLTAGE AND GAS FLOW RATE of TIG for getting maximum weldments, best mechanical properties and min HAZ. The analysis of the test results is conducted and the combination of welding parameter ranges that gives best result is found. This combination can be considered as good working ranges for TIG welding of SS316L material and conduct the study of temperature distribution and total heat flux of welding area using ANSYS.

INTRODUCTION: MATERIALS USED - TYPE SS316L

Grade 316L, the low carbon version of 316 and is immune from sensitisation (grain boundary carbide precipitation). Thus it is extensively used in heavy gauge welded components (over about 6mm). There is commonly no appreciable price difference between 316 and 316L stainless steel. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures. Compared to chromium-nickel austenitic stainless steels, 316L stainless steel offers higher creep, stress to rupture and tensile strength at elevated temperatures. Type

316L offers improved weldability and also reduces the possibility of lower corrosion resistance around welded areas

Characteristics

- Higher creep resistance
- Excellent formability.
- Rupture and tensile strength at high temperatures
- Corrosion and pitting resistance

WELDING VARIABLES

The major process variables in the approximate order of importance are,

- Welding current
- Arc voltage
- Arc Travel speed (or) chuck speed
- Electrode Extension (or) stick out
- Gas flow rate

GTAW WELDING BENEFITS

- ✓ Superior quality welds
- ✓ Welds can be made with or without filler metal
- ✓ Precise control of welding variables (heat)
- ✓ Free of spatter
- ✓ Low distortion
- ✓ Slag removal is not required (no slag)

GTAW WELDING LIMITATIONS

- ✓ Requires greater welder dexterity than MIG or stick welding
- ✓ Lower deposition rates
- ✓ More costly for welding thick sections

AIM AND SCOPE

Gas tungsten arc welding is one of the widely used techniques for joining ferrous and non ferrous metals. TIG welding offers several advantages like joining of dissimilar metals, low heat affected zone, there is no slag to clean off after welding because no flux used. TIG weld quality is strongly characterized by weld bead geometry. From the experiments to study the effect of process parameters on tensile test, hardness, Impact, Micro, salt spray corrosion and Ultrasonic tests. And, conduct the thermal analysis to find the total heat flux and temperature distributions of the SS316L material.

The main objective of this project is to investigate the weld characteristics of the SS316L material. Conducting the experiment using various welding parameter to find the maximum strength.

EXPERIMENTAL METHODOLOGY

WORK METHODOLOGY:

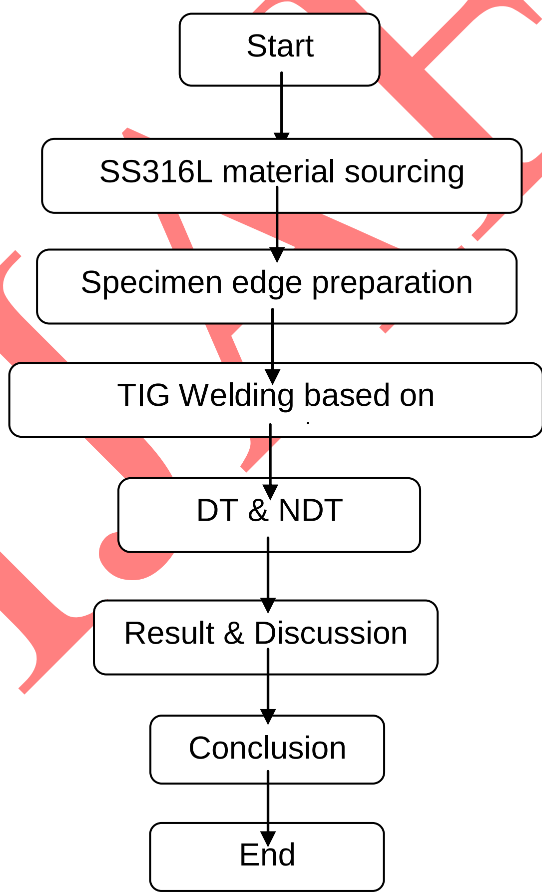


Fig 1: Block Diagram Of Process

EXPERIMENTAL WORK

DOE is a technique of defining and investigating all the possible combinations in an experiment involving multiple factors and to identify the best combination. In this, different factors and their levels are identified. Design of experiments is also useful to combine factors at appropriate levels, each within the respective acceptable range to produce the best results and yet exhibit minimum variation around the optimum results. The design of experiment is used to develop a layout of the different conditions to be studied. An experiment design must satisfy two objectives: first the number of trails must be determined and second the conditions for each trail must be specified. Before designing an experiment, the knowledge of the product/process under investigation is prime importance for identifying the factors likely to influence the outcome. The Design of Experiments (DOE) is a method to identify the important factors in a process, identify and fix the problem in a process, and also identify the possibility of estimation interactions.

Process Parameters

In this study three level process parameters i.e. welding current, voltage, and shielding gas flow rate are considered.

Constant parameter:
1. Work Piece Thickness
2. Wire rod diameter
3. Welding speed
4. Welding technique (Down hand welding)

Input Parameter:
1. Factor A: Welding Current
2. Factor B: Welding Voltage
3. Factor C: Gas Flow Rate

Table 1: Process Parameters and their Level

Thickness	Parameters	Level1	Level2	Level3
10mm	Welding Current	160	180	200
	Welding Voltage	40	50	60
	Gas Flow Rate	4.0	4.5	5.0

Table 2: L9 Orthogonal array after assignment of parameters

Welding Current (Amps)	Welding Voltage (Volt)	Gas Flow Rate (LPM)
160	40	4.0
160	50	4.5
160	60	5.0
180	40	4.5
180	50	5.0
180	60	4.0
200	40	5.0
200	50	4.0
200	60	4.5

Specimen Preparation

The edges of the specimen are prepared using a wire cutting machine. The edge preparations are arranged to make the weld joint. A gap (1 mm to 2 mm) is maintained between the pieces to ensure proper penetration of the weld. Specimens of dimensions 200 mm × 100 mm× 10 mm are prepared, then closed butt joint are made by these specimens. Before welding, edges of the work pieces are suitably prepared. The edges and the area adjoining them is cleared of dust using wire brush. Afterwards, the work pieces to be welded were positioned with respect to each other and welding process was performed under constant speed and wire diameter in flat (down hand) position. But the welding current, voltage and gas flow rate varies for each test.

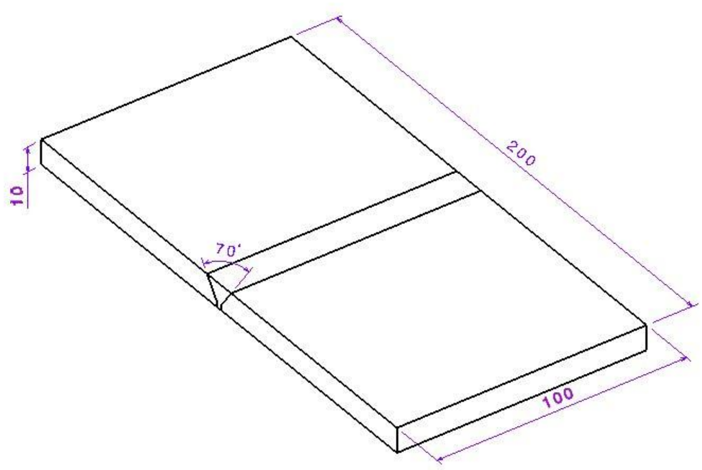


Fig 2: Joint Preparation

Fig 3: welded specimens

RESULT & DISCUSSION

This chapter deals with the results and discussions of the experimental findings of welded joints prepared at constant work piece thickness, wire rod diameter, welding speed and welding technique (Down hand welding). The welded specimens prepared under varying current, voltage and Gas Flow Rate is having different effects. The experimental results were displayed below in the Table.

Table 3: Experimental Results

Sample	Rockwell Hardness in HRB	Tensile Load in N	Tensile Stress in N/mm²	Energy absorbed in J	Impact strength in J/mm²
T1	61.33	83.55	422.61	116	4.64

T2	67.67	59.31	311.34	100	4.00
T3	66.67	71.91	360.32	118	4.72
T4	69.67	74.49	400.59	102	4.08
T5	76.33	84.6	425.98	52	2.08
T6	57.33	67.87	355.38	180	7.20
T7	65.67	78.99	402.83	160	6.40
T8	63.00	83.46	420.45	132	5.28
T9	67.67	71.49	368.09	54	2.16

EXPERIMENTAL OBSERVATIONS

Tensile Test:

The tensile strength of the SS316L welded joints are measured in Universal Testing Machine (UTM) and the results are found. The specimens are machined according to ASTM-E8 standard.

Table 4: Tensile test experimental observations

Welding Current (Amps)	Welding Voltage (Volt)	Gas Flow Rate (LPM)	Tensile Load in N	Tensile Stress in N/mm²
160	40	4	83.55	422.61
160	50	4.5	59.31	311.34
160	60	5	71.91	360.32
180	40	4.5	74.49	400.59
180	50	5	84.6	425.98

180	60	4	67.87	355.38
200	40	5	78.99	402.83
200	50	4	83.46	420.45
200	60	4.5	71.49	368.09

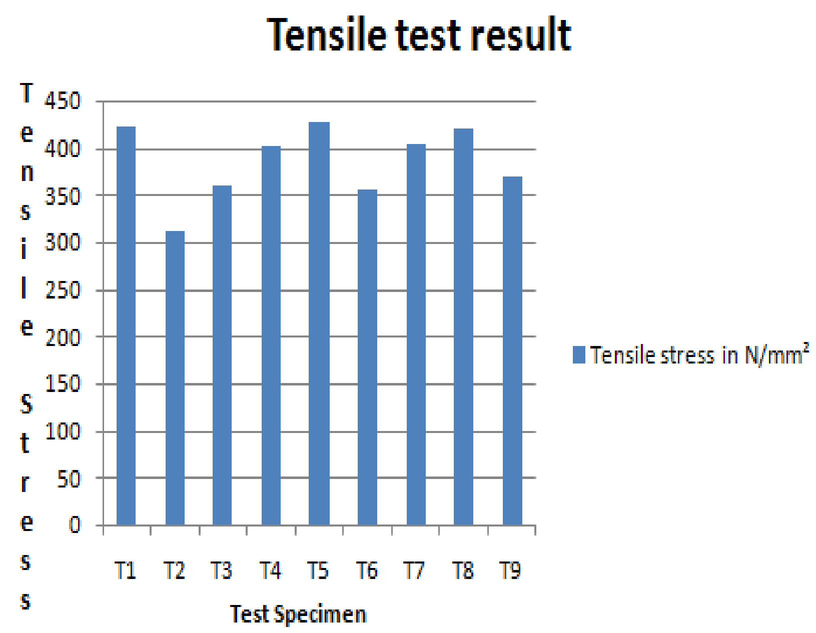


Fig 4: Tensile test specimen after test

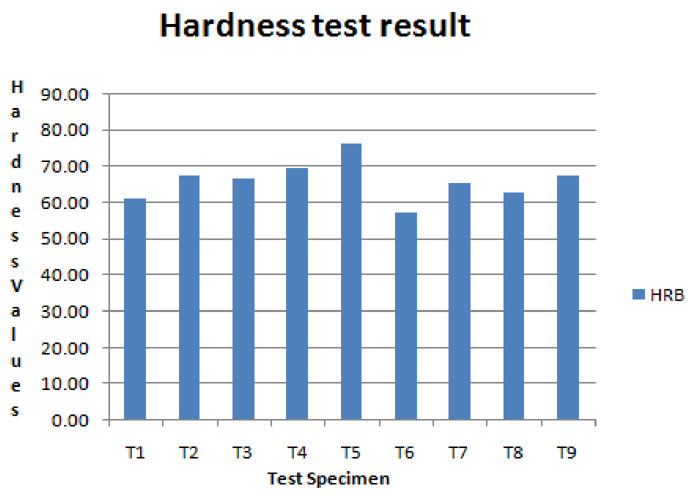
The tensile strengths of all joints were evaluated. Nine specimens were tested and from this nine results were obtained the tensile strength. The tensile test results of the SS316L material jointed by TIG welding were given in Table. From this table T1, T5, T8 will give maximum value of tensile stress. The failure was occurred in weld metal zone.

Rockwell Hardness Test:

The hardness measurements were performed to determine the strength.

Table 5: Hardness test experimental observations

Welding Current (Amps)	Welding Voltage (Volt)	Gas Flow Rate (LPM)	Rockwell hardness in HRB
160	40	4	61.33
160	50	4.5	67.67
160	60	5	66.67
180	40	4.5	69.67
180	50	5	76.33
180	60	4	57.33
200	40	5	65.67
200	50	4	63.00
200	60	4.5	67.67



The hardness measurements were performed to determine the strength. Microhardness test is performed by using Rockwell hardness tester. The hardness of the weld metal is measured and it is shown in the Table. There is some variation in the hardness of weld zone due to varying welding parameter combination. We will get higher strength value is T5 specimen.

Charpy Impact test:

The following basic parameters are used in Charpy impact testing.

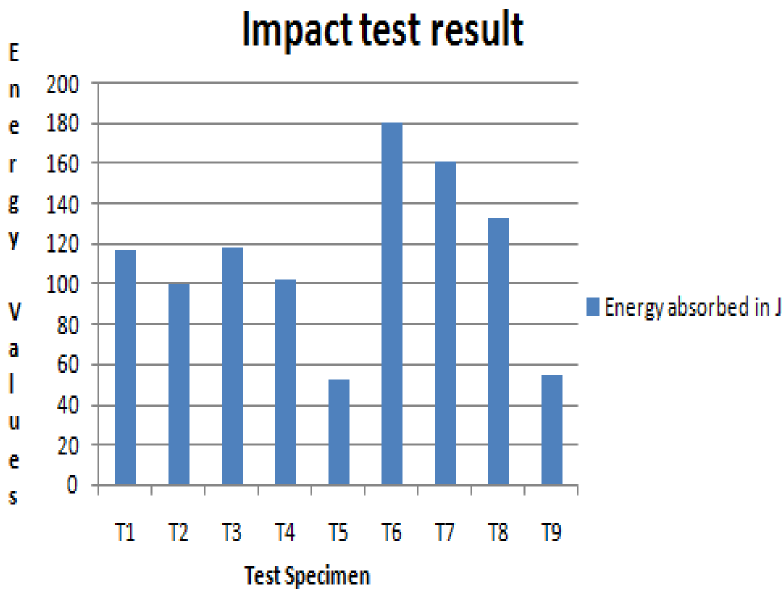
Table 6: Impact test parameters

Parameters	Values
Energy range	0 - 300
Specimen length	55 mm
Size	10 sq mm
Notch	U Notch
Fall angle	141° 12'
Notch depth	5 mm
Material	SS316L

The impact strength of the SS316L welded joints are measured in Charpy impact testing machine and the results are found. The specimens are machined according to ASTM-E23 standards.

Table 7: Charpy Impact test experimental observations

Welding Current (Amps)	Welding Voltage (Volt)	Gas Flow Rate (LPM)	Energy absorbed in J	Impact strength J/mm²
160	40	4	116	4.64
160	50	4.5	100	4.00
160	60	5	118	4.72
180	40	4.5	102	4.08
180	50	5	52	2.08
180	60	4	180	7.20
200	40	5	160	6.40
200	50	4	132	5.28
200	60	4.5	54	2.16



Nine specimens were Impact tested and from this nine results were obtained the energy level. The impact test results of the SS316L material jointed by TIG welding were given in Table 5.5. From this table T6 will stored maximum value of energy.

Salt Spray corrosion test:

The salt spray of the SS316L welded joints are measured in salt spray testing chamber and the results are found.

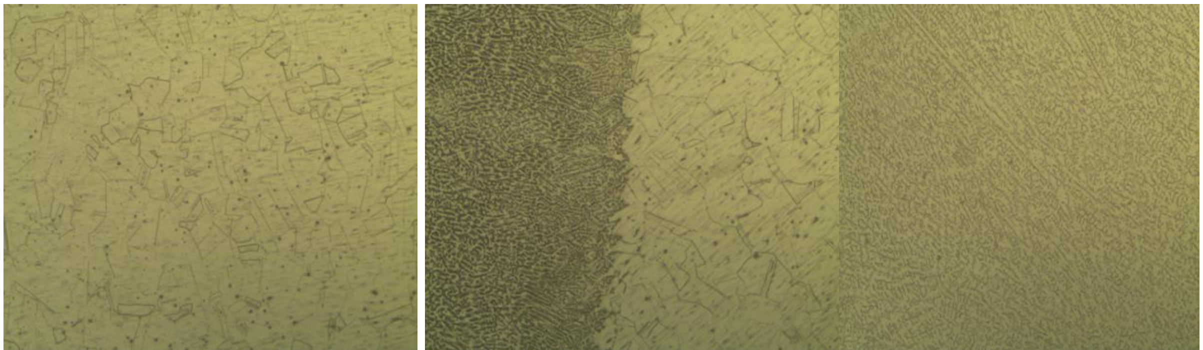
Test parameters,

- ✓ Chamber temperature: 34.50 - 35.5ºC
- ✓ pH value: 6.65 - 6.85
- ✓ volume of salt solution collected: 1.0 - 1.5 ml/hr
- ✓ concentration of solution: 4.80 - 5.30% of Nacl
- ✓ Air pressure: 14 - 18 Psi
- ✓ Component loading in the chamber position: 30 dec angle

Observations: No red rust formation up to 24 hours. so there is no corrosion impact on the SS316L material within 24 hours of time.

Macrostructure Examination:

Microstructural characterization studies were conducted on metallographically polished and chemically etched samples to investigate morphological characteristics of grains and secondary phases. The images were captured in base metal, HAZ and weld metal.

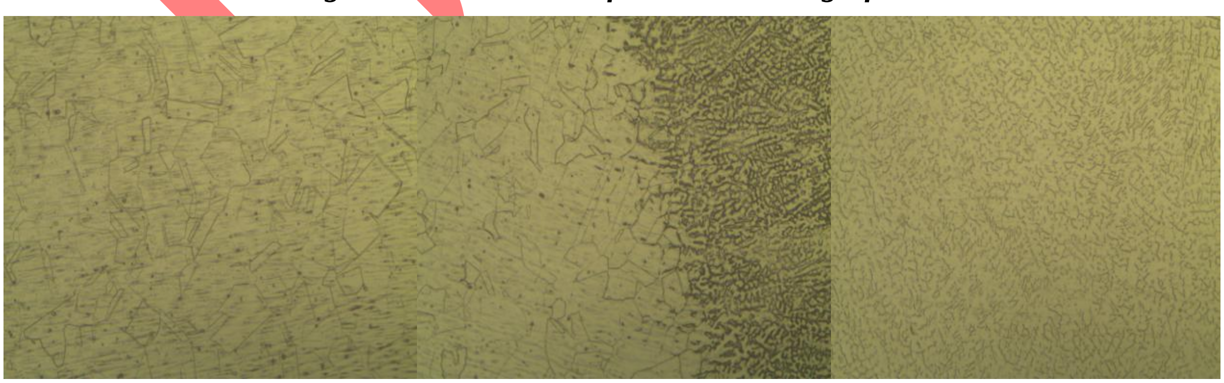


Base metal HAZ Weld zone

Fig 5: Microstructure of T1 in 200X magnification

Base metal HAZ Weld zone

Fig 6: Microstructure of T5 in 200X magnification



Base metal HAZ Weld zone

Fig 7: Microstructure of T9 in 200X magnification

Microstructural characterization studies were conducted on metallographically polished and chemically etched samples to investigate morphological characteristics of grains and secondary phases. The microstructure of base metal, HAZ, weld zone is shown in the Fig 5.6, 5.7, 5.8. These three microstructure examinations were studied in T1, T5 and T9 specimen.

Ultrasonic testing:

The ultrasonic test of the SS316L welded joints is measured and the results are found.

Table 8: Ultrasonic test parameters

Test sample	Indications
T1	Incomplete penetration
T2	Porosity
T3	Slag
T4	No indication
T5	No indication
T6	Excess penetration
T7	No indication
T8	No indication
T9	Porosity

Thermal Analysis:

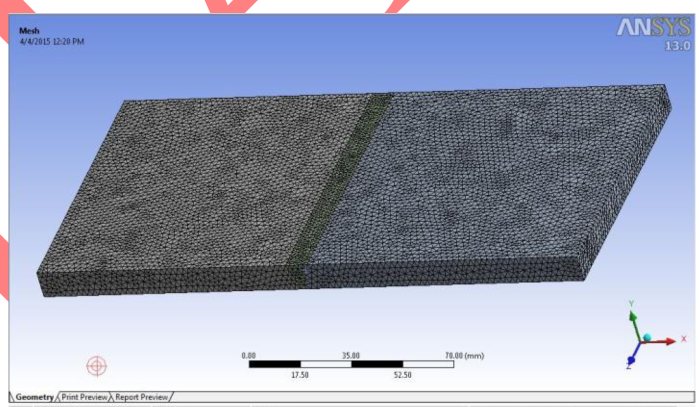


Fig 8: Meshed model used in the analysis

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TOTAL HEAT FLUX

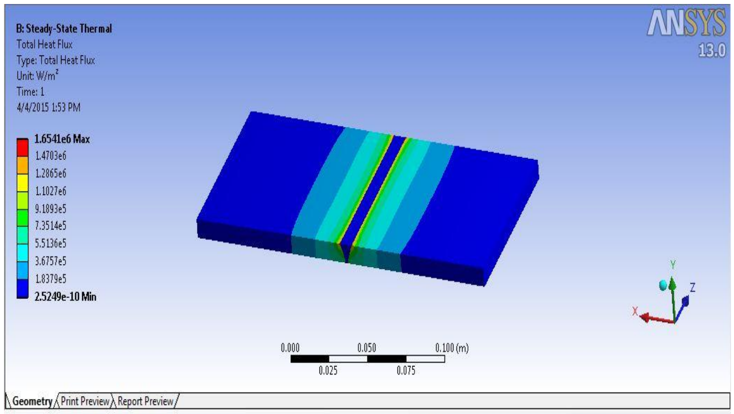

Fig 9: Total heat flux

Heat input and friction coefficients were adjusted during the welding process to keep the calculated temperature below the melting point of base metal material. From fig shows total heat flux rate, the heat input was a moving heat source with a linear distribution of heat flux at the contact surface. The heat flux values will decrease in transverse movement in the work specimen. The major heat flux is available near to the weld zone.

TEMPERATURE DISTRIUBUTION

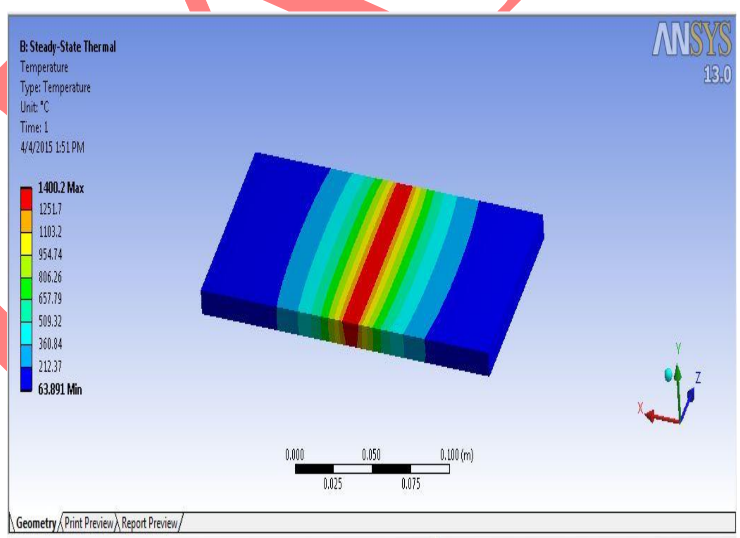

Fig 10: Temperature distribution

Fig shows the temperature distributions for the SS316L material during the welding process. As anticipated, the peak temperatures are observed at the heat source location. Steep temperature gradients are observed ahead of the heat source, showing the least significance of heat flow ahead of the welding torch. The gradients behind the torch show the cooling phenomenon after peak temperature achieved, as the torch moves ahead from certain point. The temperature distribution when the weldments are cooled to almost uniform temperature followed by some more time steps further simulating the cooling phase.

CONCLUSION AND FUTURE SCOPE

The various destructive and nondestructive tests are conducted in this experiment, from the analysis of all experimental trials it was found that the great effect of welding parameters such as welding current, voltage and gas flow rate on weld joint. It is clear from the results phase that the following conclusions are drawn from the analysis of collected data of input and output parameters. For this Amps and voltage maximum depth of penetration is obtained with minimum failure is occurred.

From the expected values the following parameters are considering best for the TIG welding on SS316L.

For tensile test: T1, T5 and T8 the corresponding parameters are

Welding Current (Amps)	Welding Voltage (Volt)	Gas Flow Rate (LPM)
160	40	4.0
180	50	5.0
200	50	4.0

The best hardness values are obtained from sample T5 as it compare to all other samples.

For hardness test: T5 the corresponding parameters are

Welding Current (Amps)	Welding Voltage (Volt)	Gas Flow Rate (LPM)
180	50	5.0

When considering the Impact test, which is developed the more Joules in the parameter of T6 s

For Impact test: T6 the corresponding parameters are

Welding Current (Amps)	Welding Voltage (Volt)	Gas Flow Rate (LPM)
180	60	4.0

FUTURE SCOPE

Attempt has been made to get continuous temperature distribution. But one could get so only in the images which are captured after the welding. If continuous temperature distribution in the images which are captured during the welding would accessible then HAZ (heat affected zone) width would have easily been calculated. Heat affected zone is the region of the base metal generated in the vicinity of the welded zone and where the microstructure is significantly different from microstructure of the base metal. Heat affected zone is the region heated from recrystallization temperature to the temperature just below the melting point. HAZ width is generally calculated from transient temp distribution which is a roundabout process. Hence future scope of the project is to get continuous temp distribution during the welding to calculate HAZ width.

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