# Thermo-mechanical analysis in TIG welding of S.S 304

Vijay Gohel[1], Jatin Makwana[2], Riteshkumar Ranjan[3]
PG Student, Ipcowala Institute of Engg. & Tech, Dharmaj, Gujarat, India[1]
Assistant Professor, Mechanical Engineering Department, Ipcowala Institute of Engg. & Tech, Dharmaj, Gujarat, India[2,3]

***Abstract* - Tungsten inert gas welding (TIG) is a high quality welding process commonly used to join plates of higher thickness in load bearing components. These processes provide a purer and cleaner high volume weldments. The objective is to study the variation of temperature in TIG welded SS 304 plate of 3 mm work piece thickness. In this work, thermal analysis with the help of ANSYS workbench carried out for butt joint stainless steel base metal (SS 304) using Gas tungsten arc welding (GTAW) process. Thermo - Mechanical simulation is developed. Comparison with the temperature measured by the thermocouples records shows that the results from the present simulation have good agreement with the test data.**

***Keywords* - Thermo-mechanical simulation, temperature distribution, TIG welding.**

## I. INTRODUCTION

In 1890 Electrical arc was first developed by davy in England, but the beginning of arc welding could become possible only with the improvements in generators or electric dynamos between 1877 and 1880. Molten pool and arc shielding with an inert gas (Co) was introduced by Alexander in USA in year 1928 and the patent for TIG welding was received by Devers and Hobart in 1930 in USA. First gas tungsten arc spot welding torch based upon TIG welding was introduced around 1946[1].The process is also called as Gas Tungsten Arc welding and specify as GTAW. In this process, an arc is generated between a non-consumable tungsten electrode and the base metal. The arc is shielding by the inert helium, argon and argon-helium mixture. Although the earliest application of Tig was in aircraft industry for welding of magnesium alloy components but afterward it was successfully used for aluminum and stainless steels in other in industries. The Tig welding is a flux less welding process which opened up new fields for light weighted alloys [2]. In this work, thermal analysis with the help of ANSYS tool carried out for butt joint stainless steel (SS 3304) using Gas tungsten arc welding (GTAW) process. In this work experiment was carried out to measure temperature distribution during the single pass GTAW process used a k type thermocouple attached to the plate. The results of the experiment compared with finite element analysis to confirm the accuracy of finite element analysis. In this work moving heat source model develops in ANSYS workbench for a good agreement between numerical method and experiment results.

## II. LITERATURE REVIEW

**Swapnil S. Ingle et al [1]** The TIG welding (Tungsten Inert Gas) has been widely used for the fabrication of various structures made of metals because of its high weldments. TIG welding is versatile and having less loss of alloying elements which can be protected from the atmosphere by an inert gas such as Helium, Argon and mixture of Helium and Argon. The objective is to study the variation of temperature in TIG welded plate of 5mm work piece thickness. Based on the experimental records of temperature at specific locations during the TIG welding process, Thermo - Mechanical simulation is developed. Comparison with the temperature measured by the thermocouples records shows that the results from the present simulation have good agreement with the test data. **Kundan Kumar et al [20]** The Tig welding is one of the most important material joining processes widely used in industry. An attempt has been made in paper to develop appropriate models for predicting& the Investigation into the Temperature Distribution character of TIG welding. The temperature distribution that occurs during single/multi pass welding affects the material microstructure, hardness, mechanical properties, and the residual stresses that will be present in the welded material. Very limited experimental data regarding temperature distribution during welding of plates is available in the literature. Experimental work will be carried out to find out the temperature distribution during single/multi pass welding of stainless steel plates. **Ch.Indira Priyadarsini et al [2]** today some industries such as shipbuilding and high-speed train guide way, the problem of residual stresses and overall distortion has been and continues to be a major issue. In the last few decades, various research efforts have been directed at the control of the welding process parameters aiming at reducing the distortions and residual stress effects. Yet, in actual practice, large amounts of resources are still being spent in reworking welds, which in turn increases the production cost and delays work completion. It is assumed that in order to reduce the residual stresses and distortions from a welding operation, it is necessary to understand the effects of welding process parameters on the responses. In this thesis, an experimental study has been conducted to assess the effects of heat input, speed rate, wire feed rate, plate thickness, and gap on arc welding responses as applied to steel welding. A butt joint Submerged Arc Welding has been chosen in this study. Submerged Arc Welding (SAW) uses the arc struck between a continuously fed additional filler metal under a blanket of granular flux. The thermal effect of Submerged Arc that specially depends on the electrical arc, flux type and temperature field of its work piece, is the main key of analysis and optimization of this process. The arc welding process is simulated using Finite

Element Method (FEM) program ANSYS. Thermal analysis is carried out and with the above load structural analysis is also performed for analyzing the stability of the structure. The simulations were carried out using a two-step process; non-linear heat transfer that produces the dynamic temperature distribution throughout the weld seam and the plates, and the elasto-plastic analysis, which yields residual stresses, strains, and displacement. Numerical simulation of welding process has been done by analysis tool ANSYS Relationships between the parameters and the responses have been drawn based on the simulation results as well as experimental results. **Abhishek B P et al [3]** in present paper control the metal from the wire rod by develop the arc as well as by control the input process parameter. High heating at a 1 locations during welding and further rapid cooling generate residual stress and distortions in the welding and base metal. In the last few decades, various research's effort have been directed towards the control of welding process parameter aiming at reducing residual stress and distortion they are strongly affected by many parameters like structural, materials and welding parameters. Such welding failures can be minimize by control the weld heat input. The distributions of the temperatures in weld joint of AISI303 grade high strength steel is investigated by Finite Element Method (FEM) using ANSYS software's and experimental has been performed to verify the developed thermo mechanical finite element model using the GMAW process. Basic aim of our paper is to analyze temperatures distributions and residual stresses in dissimilar metal welded plate to avoid future failures in materials because experimental process is costlier. The behavior of welded zone is affected by variation in temperature distributions, microstructures and mechanical properties of the materials. The residual stress gradient near the fusion zones is higher than in any other locations in the surrounding areas. Because of this stress gradient, cold crack at the fusion zones in high strength steel occur. The main objective of this simulation is the determination of temperatures and stresses during and after the process. Temperature distributions define the heat affected zone (HAZ) where materials properties are affected. Stress calculations is necessary because high residual stresses may be caused fracture, fatigue which causes unpredictable failure in regions near the weld bead regions. **Mr. R. Ramachandran [4]** The SS316L 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.

## III. EXPERIMENT PROCEDURE

1) EXPERIMENTAL ANALYSIS

Work material: The work material used for present work is austenitic stainless steel 304 the dimensions of the work piece length 120 mm, width 50 mm, thickness 3 mm. Argon is used as a shielding gas.

Table 1 Composition of stainless steel-304

| **Element** | **C** | **Cr** | **Ni** | **P** | **Mn** | **Si** |
|---|---|---|---|---|---|---|
| **composition** | 0.08 | 20 | 10.5 | 0.45 | 2 | 0.75 |

Table 2 Mechanical properties of s.s-304

| **Material** | **UTS(MPa)** | **Y.S(MPa)** | **%Elongation** | **Density(gm/cm$^3$)** |
|---|---|---|---|---|
| **SS304** | 515 | 205 | 40 | 8.03 |

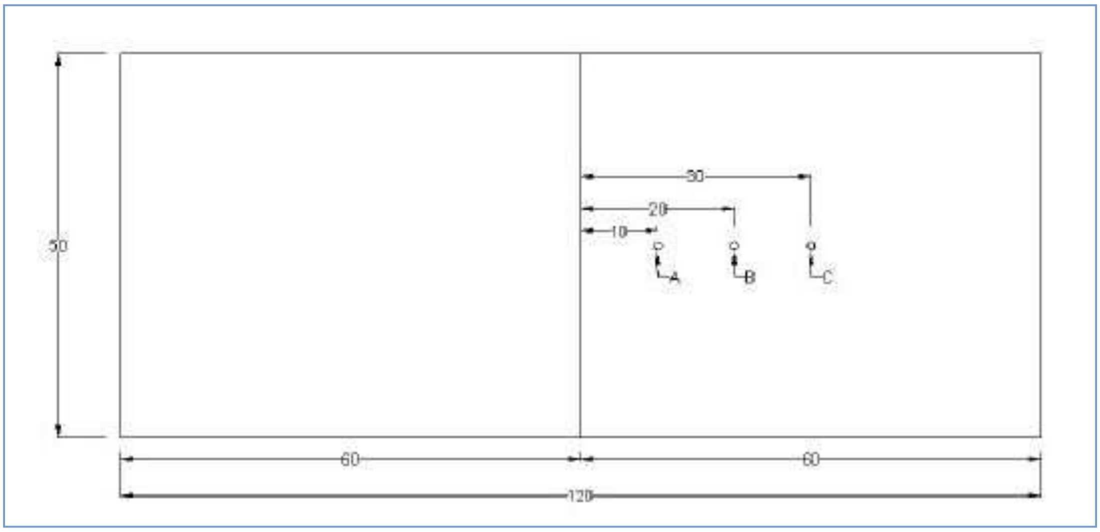


Fig.1 Thermocouple location

The above schematic diagram representation of thermocouple location. The thermocouple location A, B, and C are shown in figure at the distance of 10 mm, 20 mm and 30 mm from centre line of weld joint respectively which attachment for specimen.

Table.3 Range of process parameters

| Serial number | Voltage(v) | Current(amp) | Weld velocity (mm/sec) | Weld efficiency |
|---|---|---|---|---|
| 1. | 20 | 70 | 3.84 | 0.6 |

For the experiment time required to complete the weld is calculate by using stopwatch. Using time and distance travelled by electrode is used to calculate the welding speed. The temperature distribution is measure by K type thermocouple which is connected to temperature indicator. In present work comparison with the temperature measured by the thermocouples records shows that the results from the present simulation have good agreement with the test data. Near the weld bead observed ellipsoidal distribution shape

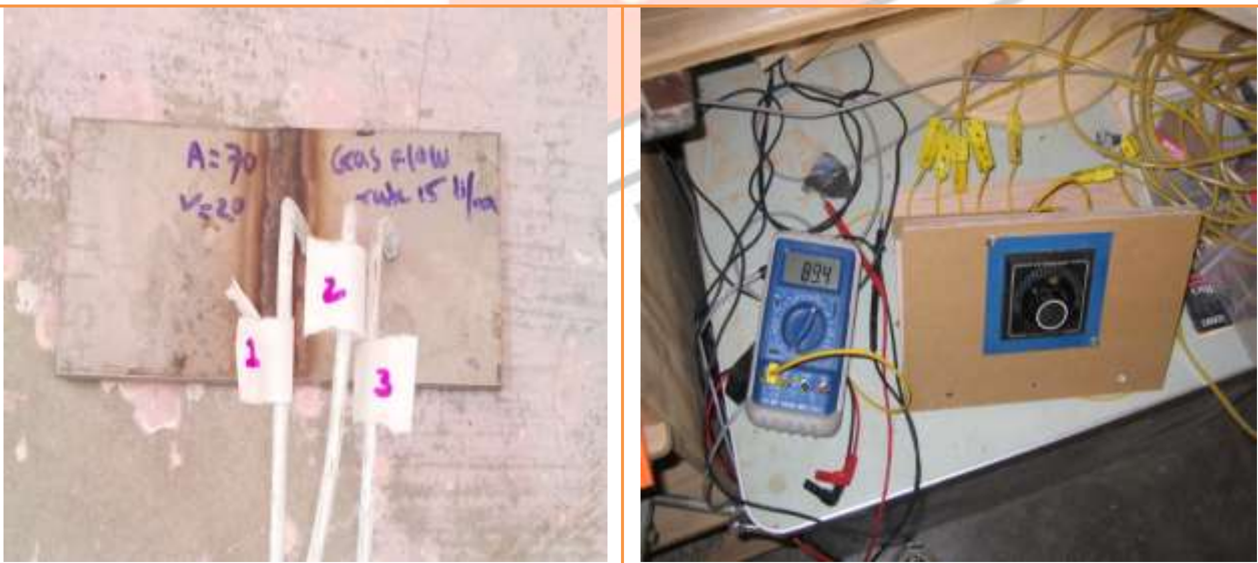

Fig.2 experiment setup

As shown in above figure 2 the experimental setup of welded work piece and temperature measuring instrument. This was performed in Abg engineering works which is in Ankit Udhyognagar, near kailashpati chokadi, v.v.nagar, Anand.

Table.4 Experiment result

| Sr. No. | Distance (mm) | Temp, by exp (max, °C) |
|---|---|---|
| 1. | 10 mm | 168 |

| | | |
|---|---|---|
| 2. | 20 mm | 29.5 |
| 3. | 30 mm | 20 |

2) FEM ANALYSIS

The process of joining butt weld of two stainless steel plate was simulated. The dimension of overall work piece are 120 mm x 50 mm x 3 mm. The welding process takes single pass in this analysis. The welding parameter used in simulation are shown in table 3. In the present study three dimensional symmetrical plate is design to calculate temperature distribution in the plate. In present work consider convection bounder condition and neglected the radiative boundary condition.

The measurement of the temperature at 10 mm, 20 mm, and 30 mm away from the weld centre line in experiment as shown in fig 1.The profile for numerical temperature is validated with the ANSYS result. In the present work we have take I=70 A, V=20 v and welding speed is 3.84 mm/sec. For the plate assume temperature dependant material properties. The heat affected zone and filler weld material were assumed to be same. 3D model of the butt weld joint of two same material plate shown in fig.3 was simulated. In the present work thermal analysis of temperature distribution in butt weld joint plate carried out in the ANSYS Workbench software.

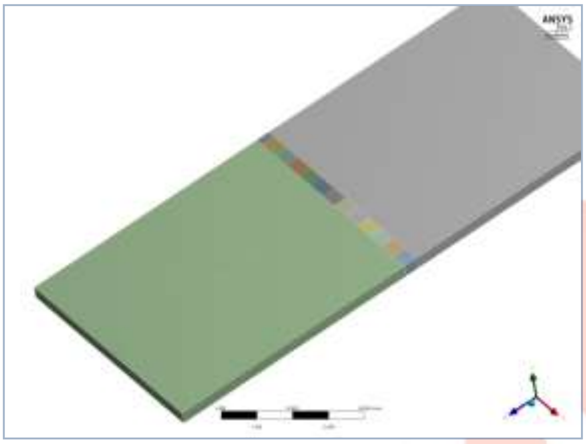


Fig.3 3D model of butt weld joint

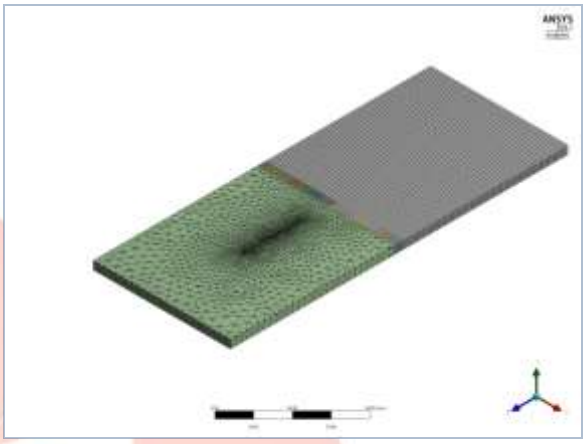


Fig.4 Surface meshing

As shown in fig 3 the geometry of 3D model of butt weld joint this is use in present analysis work. There are mainly four types of geometry entities in the pre processor like key point, areas, lines and volumes. The entities are used to obtain the geometry representation of the structure. The entities are independent and have unique identification labels.

The surface meshing is giving the model to obtain better result as shown in fig 4.The meshing was done between two plates of same material. The mesh is nothing but network of the element. If the meshes are finer then it is adopted to study the effect of the mesh style on the result.

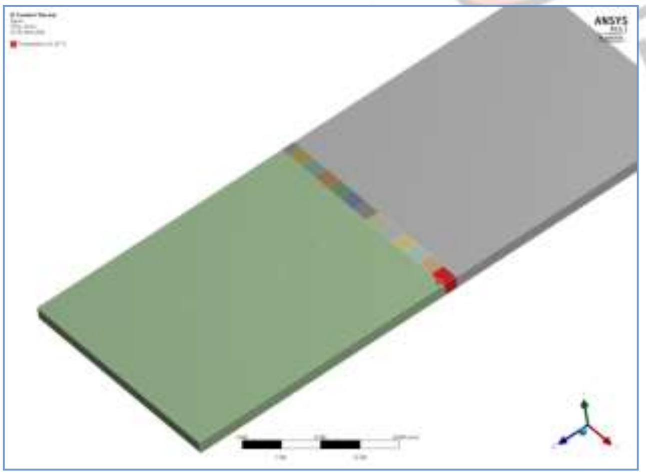


Fig.5 Thermal boundary condition

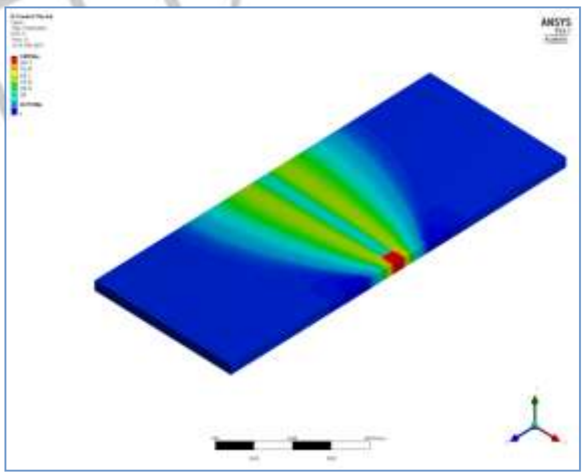


Fig.6 Temperature distribution

The temperature of 1400 $^{0}$C (melting temperature of the filler material rod AWS: ER308L) given at the weld joint that is between the plate along the centre line. The model of thermal boundary condition is shown in fig.5. Room temperature is 31 $^{0}$C was given to remaining areas of plate.

The simulation is carried out for the transient thermal analysis shown in fig.6. The distribution of the temperature for the SS304 during the welding process is shown in figure 6. The peak temperature is shown at the heat source location. Behind the torch indicate cooling after peak temperature achieved as torch move ahead from some point. From the figure the maximum temperature observe 1400 $^{o}$C and minimum temperature observe 18.75 $^{o}$C.

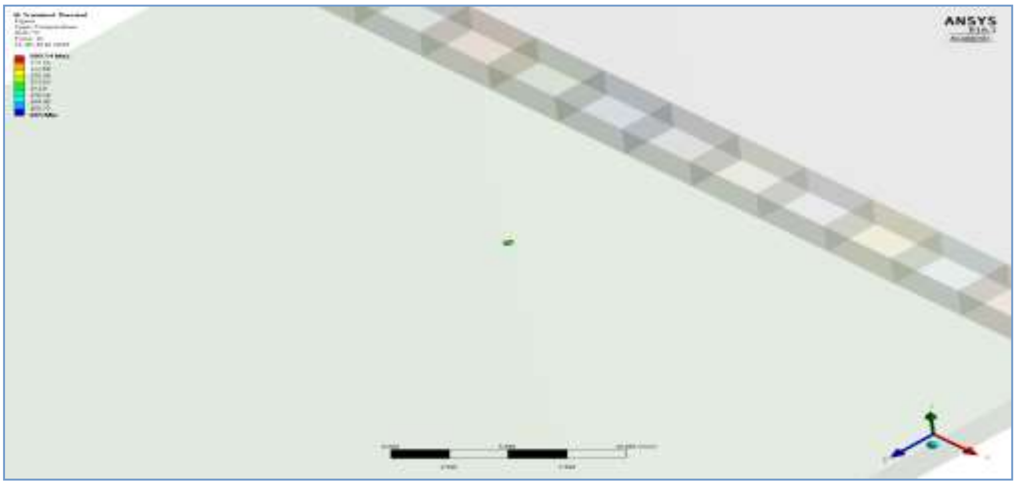


Fig.7 Temperature at 10 mm away from weld center

The fig 7 showed the temperature at the first node 10 mm away from the weld centre line. It is observe that on this node there is effect of two temperatures which one is maximum and second one is minimum temperature. The maximum temperature is obtained 180.54 $^{0}$C and minimum temperature obtained 165 $^{0}$C.

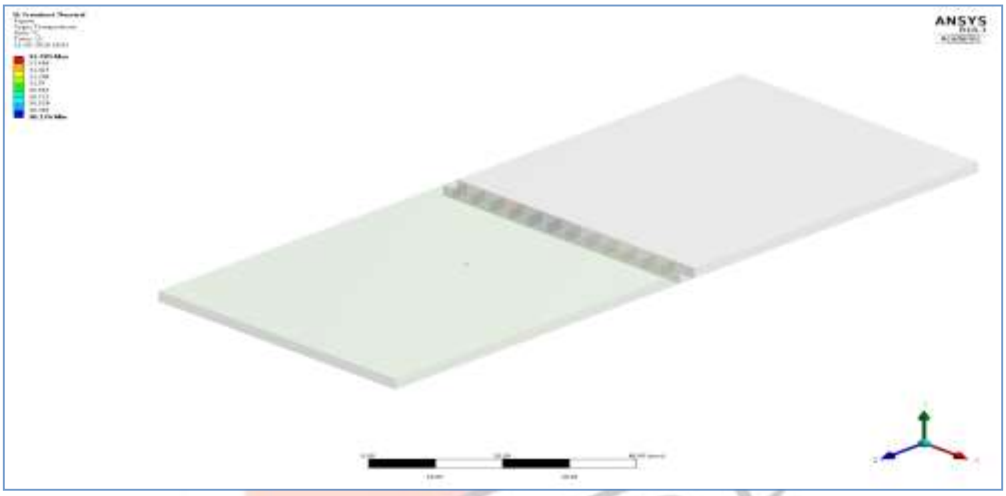


Fig.8 Temperature at 20 mm away from weld center

The fig 8 showed the temperature at the second node 20 mm away from the weld centre line. It is observe that on this node there is also effect of two temperatures which one is maximum and second one is minimum temperature. The maximum temperature is obtained 31.785 $^{0}$C and minimum temperature obtained 30.176 $^{0}$C.

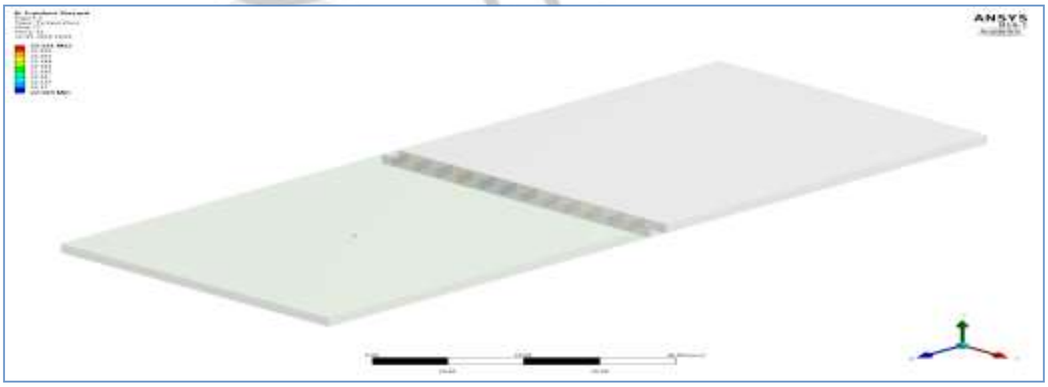


Fig.9 Temperature at 30 mm away from weld center

The figure 9 showed the temperature at the Third node 30 mm away from the weld centre line. It is observe that on this node there is further effect of two temperatures. One is maximum and second one is minimum temperature. The maximum temperature is obtained 22.211 $^{0}$C and minimum temperature obtained 22.165 $^{0}$C. Now combine all three node temperature in tabular form in the range of maximum temperature and minimum temperature.

Table 5 comparison of temperature at different node

| SR. No. | Distance of node | Maximum temperature | Minimum temperature |
|---|---|---|---|
| 1. | 10 mm | 180.54 | 165 |
| 2. | 20 mm | 31.785 | 30.176 |
| 3. | 30 mm | 22.211 | 22.165 |

## IV. RESULTS

From above Experimentation and FEM simulation the result obtained are as follow.

Table.6 Temperature Distribution by experiment and FEM

| Sr. No. | Distance (mm) | Temp by exp ($^0$C) | Temp. by FEM ($^0$c) | Percentage difference |
|---|---|---|---|---|
| 1 | 10 | 168 | 180.54 | 6.94 |
| 2 | 20 | 29.5 | 31.785 | 7.18 |
| 3 | 30 | 20 | 22.211 | 9.95 |

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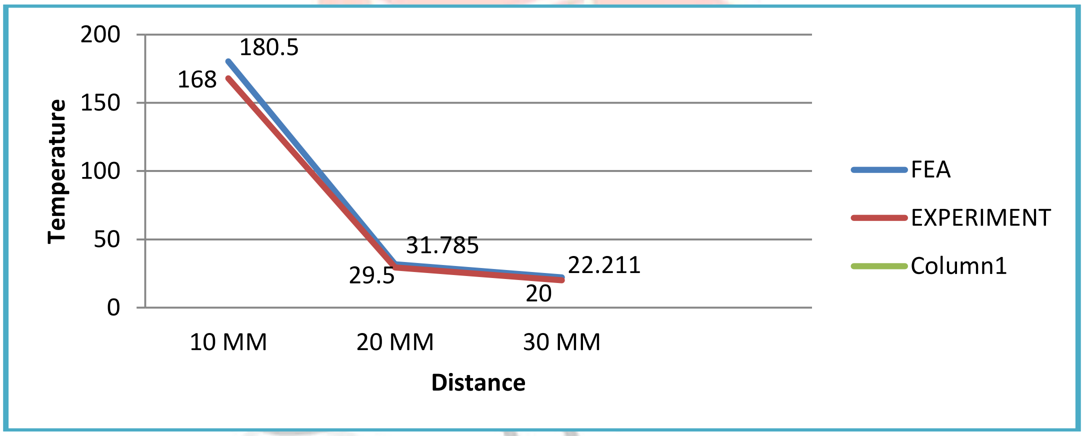
## V. CONCLUSION

According to results the following conclusions can be drawn:

1) There is a close agreement between the simulation and experimental thermal profile. As the simulation thermal Profiles are nearly matching with experimental results as shown in below graph.




2) There are various experimental methods for measuring temperature developed in welded but experimental measurements are costly and time consuming. However, FEM is enough for getting better results with negligible variation to that of experimental results, so simulation process can be carried out where welding applications deals with complex products.

## VI. ACKNOWLEDGEMENT

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