# Thermo-Mechanical Analysis in TIG Welding of Aluminium Alloy 6082

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**Abstract**: ***Tungsten Inert Gas (TIG) welding has been widely used for the fabrication of various structures made of metals because of its high weldment. 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.***

**Keywords:** Alloying element, Thermo-mechanical similation,Temperature distribution,TIG Welding.

## 1. 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. Auguste de meritens described arc welding process in 1882 which was applied to join certain components of electrical storage batteries. Molten pool and arc shielding with an inert gas ($Co_2$) 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. 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 [1].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].

### 1.1 TIG Welding

During TIG welding, an arc is generated between a tungsten electrode and the work piece in an inert atmosphere. Depending on the type of weld preparation and the work piece thickness, it is possible to work with or without filler. The filler can be introduced manually, mechanically without current or mechanically under current. The process can be manual, partly mechanized, fully mechanized or automatic. The power source delivers direct or alternating current (pulsed current or partly with modulated).A major difference between the Tig welding of steel and aluminum is the adhering oxide film on the aluminum surface which influences the welding behavior. These oxide films are removed in order to prevent oxides from being entrapped in the weld. The oxide film can be removed by varying the current type, polarity or also through suitable inert gases. The arc generates high temperature of approximately 6100 C and melts the surface of base metal to form a molten pool. As the molten metal cools, coalescence occurs and the parts are joined. The resulting weld is smooth and requires minimum finish. [3-4].

### 1.2. Importance of Temperature Analysis

In welding some portion of the base metal fuses and forms an integral part of weld metal. Next to it there is an area of the base metal which gets heated to above the upper critical point and cools suddenly. This way it is subjected to a quenching action like hardening. This is called as Heat Affected Zone and it has a different structure and also a higher hardness than original parent metal. During the fusion welding, material close to the weld experiences a large thermal fluctuation. Some metallurgical changes in HAZ do occur. HAZ is that portion of base metal whose mechanical properties and microstructure is changed by the heat of welding and sudden cooling [5]. The HAZ play an important role to determine the weld cold cracking, notch toughness, stress corrosion cracking in severe environmental condition of service. The width of the HAZ can be estimated by the peak temperature obtained at discrete points from weld centre line by experiments, the variation of microstructure at different zones of welding can be examined from micro-graph .Thus it become necessary to make temperature analysis along welding direction [6].In addition, cooling rates and temperatures experienced by the HAZ are lower than the fusion zone. Many kinds of HAZ cracks have been observed. In the partially melted zone, liquation cracks may occur. In the regions of the HAZ subjected to lower peak temperatures, there is a possibility of ductility-dip cracks. Both of these types of cracks can occur in the HAZ of a single-pass weld or in the earlier passes of a multipass weld.

## 2. Procedure

### 2.1 Experimentation for Temperature distribution in welding plate

In this experiment the butt joint made of two similar AA6082 plates. The Aluminum alloy 6082 plates having dimensions 120mm×50mm×5mm are used. The temperature distribution was measured using K-type thermocouples. This method was used during the Tungsten inert gas (TIG) welding of two similar plates. The thermocouples are attached to the welding plate at different distances. The gas flow rate can be adjusted. The values of current and the voltage are set as per trail and run method. The time required to complete weld is measured by using the stopwatch. Using the time and distance travelled by the electrode are used to calculate the welding speed. The temperature distribution is measured by using the thermocouples which is connected to temperature indicator.

Typical welding parameters taken in this study are current 180amp, voltage 25volts, welding speed 114.06 mm/min.

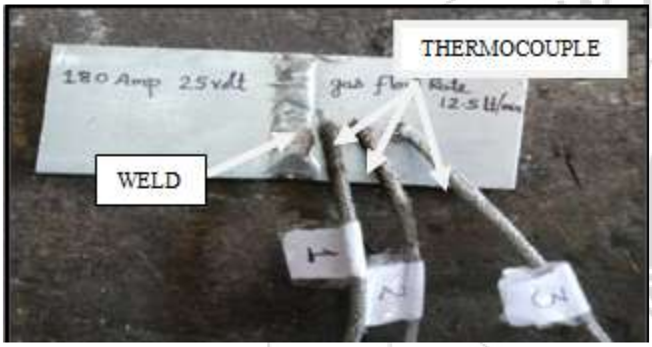

**Figure 1:** Temperature distribution in welding plate by experiment

### 2.2 Temperature distribution in welding plate By ANSYS

The temperature dependant thermal materials properties for the plates, the filler weld material and heat affected zone (HAZ) were assumed to be the same. The 3D model of a butt-weld joint of two plates shown in Fig.2 was simulated. The Thermal analysis of the temperature distribution in butt welding plate is carried out in the ANSYS Workbench software

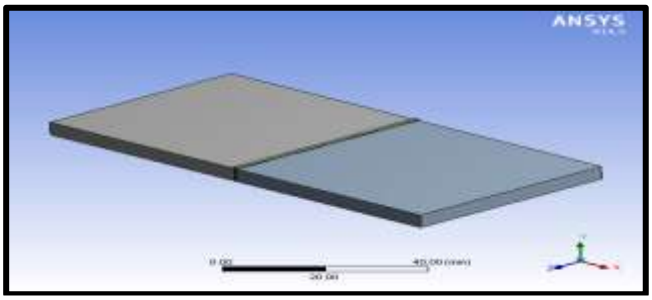

**Figure 2:** 3D model of Butt-weld joint

The triangular surface meshing is given to model to obtain better result as shown fig.3

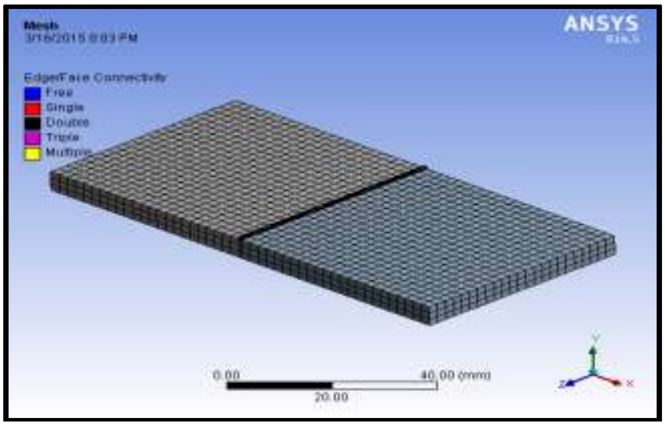

**Figure 3:** Triangular Surface Meshing

The temperature of 580 $^{o}$C (melting point temperature of filler material ER 4043) is given at the welded joint that is between the plates along the centre line. Environment temperature of 23$^{0}$C is given at the end of the plates. The model with thermal boundary conditions has been shown in fig. 4

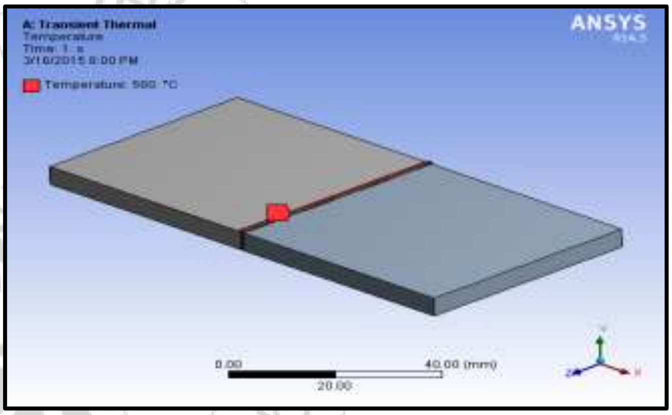

**Figure 4:** Thermal Boundary Conditions

The simulation has been carried out for transient thermal analysis as shown fig 5.

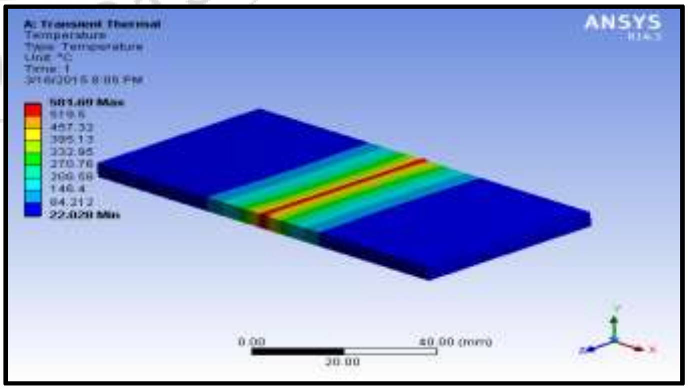

**Figure 5:** Temperature Distribution

### 2.3 Comparison of Temperature distribution by Experiment and FEM

Validating the temperature profile between the experiment and the FEM analysis is shown by graph. The temperature distribution of the welding plate in experimental is nearly equal to the temperature distribution by Workbench. From these results it is conclude that the input conditions used in experiment are also nearly same as finite element analysis.

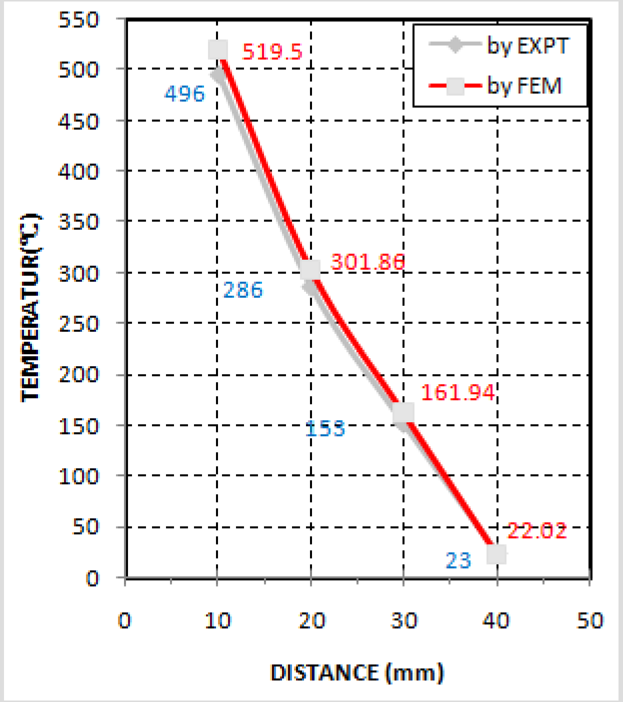

**Figure 6:** Comparison of simulation and experimental thermal profiles

## 3. Coupled Field Analysis

The welding is simulated by the FEM. The welding process computation can be split into two solution steps mechanical and thermal and analyses. To simplify the weld simulation, it is computationally efficient to perform thermal and mechanical analyses separately. It is assumed that changes in the mechanical state do not cause a change in the thermal state. But a change in the thermal state causes a change in the mechanical state.

Firstly, the computation of the temperature history during welding is completed and this temperature field is applied to the mechanical model as a body force to perform the residual stress analysis. This work includes FE models for the thermal and mechanical welding simulation. To develop suitable welding numerical models it necessary to consider the process parameter such as welding speed, filling material etc. Since the thermal field has a strong influence on the stress and deformation field with little inverse influence, a sequentially coupled analysis works very well. Moreover, a 3-D FE analysis is the optimum method of as pertaining the thermal cycle of welding. Therefore, in this paper, the welding process is simulated using a sequentially coupled 3-D thermo-mechanical FE formulation based on the ANSYS code. For both the thermal and mechanical analyses, temperature dependent thermo-physical and mechanical properties of the materials are incorporated.

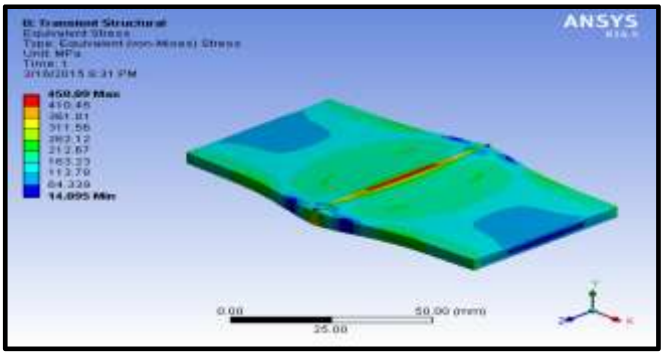

**Figure 7:** Residual stresses in welding plate

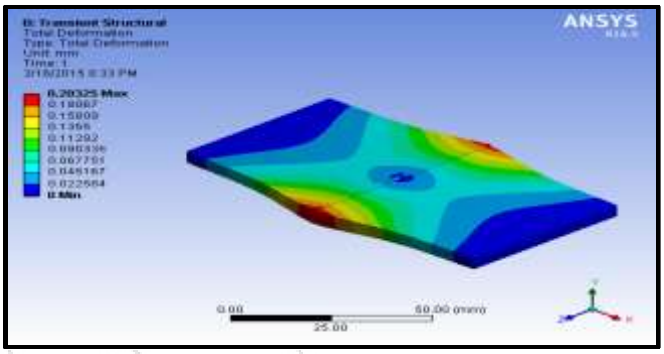

**Figure 8:** Total Deformation

## 4. Results

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

**Table 1:** Temperature Distribution by experiment and FEM

| *Sr No.* | *Distance (mm)* | *Temp. by Expt ($^{O}$c )* | *Temp. by FEM ( $^{O}$c )* | *Percentage difference* |
|---|---|---|---|---|
| 1 | 10 | 496 | 519.50 | 4.73 |
| 2 | 20 | 286 | 301.86 | 5.67 |
| 3 | 30 | 153 | 161.94 | 7.58 |
| 4 | 40 | 23 | 22.02 | 4.45 |

### A. Residual Stresss

The maximum residual stress is formed at centre of weld i.e 459.06 mpa and minimum at extreme point of plates 14.09 mpa this shows that as the temperature is increased residual stress also goes on increased or else vice-versa.

### B. Total Deformation

Total deformation is maximum at the tip of weld portion with 0.20 mm. and minimum at extreme point of plates with zero deformation.

## 5. 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, it can be predict that stress profiles and deformation got by simulation must match with experimental profile.
2) There are various experimental methods for measuring residual stresses 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.

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## Author Profile

**Swapnil Ingle** received the B.E degrees in mechanical Engineering from R.T.M.N University in 2012. During 2013-2015, he is pursuing his M.Tech in Production from Government College of engineering Amravati an Autonomous Institute of Maharashtra. My area of research work is “Analysis of Temperature Distribution of Aluminum Alloy 6082”.

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