Mechanical Characterization of Aluminium Alloys for TIG Welding-Experimental and Modeling Studies

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Abstract - In the past, researchers did not consider welded joints in their finite element models. This could give large discrepancies to the mechanical characteristics of the structure and consequently would lead to inaccuracies in their predicted results. This paper attempts to present an appropriate way to model welded joints in a structure using the finite element method. Initially, two single-plates were developed in 3-dimensional finite element model and then welded. Later all three parts are assembled in CREO software. The two plates were joined together to form a single butt-joint of simple structure that involved gas tungsten arc welded (GTAW) joint. Mechanical characteristics of the butt-joint structure were determined experimentally and by finite element analysis and the predicted results were then compared with each other. FEA analysis is carried out in ANSYS 14.0 V software.

Key Words: Aluminium alloy, Specimen, Tungsten Inert Gas (TIG) welding, GTAW joint, Filler rod

1. INTRODUCTION

Aluminium alloys are widely used to produce aerospace components with high specific strength. High strength precipitation hardening 7xxx series aluminium alloys, such as 7075 are used extensively in aerospace industry [1]. 7xxx series alloys are heat treatable with ultimate tensile strength of 520 MPa. The commonly welded alloys in this series such as 7075 are predominantly welded with the 5xxx series filler alloys. Today's aluminium alloys together with their various tempers, comprise a wide welding procedure development. It is important to understand the differences between the many alloys available and their various performances and weld ability characteristics. When developing arc weld procedures for these alloys, consideration must be given to the specific alloy being welded [1]. It is often said that arc welding of aluminium is not difficult; it is just different it is believed that an important part of understanding in differences is to become familiar with the various alloys

2. ANALYTICAL WORK

In the present work, tensile test analysis of a V-butt jointed specimen is conducted in a virtual environment. The material used for the analysis is AA7075-T6 aluminium alloy, whose composition is listed in Table 1.

Table -1: Chemical composition of AA7075-T6

Material type	Composition in %
Silicon	0.067
Iron	0.0236
Copper	1.640
Manganese	0.041
Magnesium	2.670
Nickel	0.004
Zinc	6.070
Titanium	0.054
Lead	0.002
Tin	0.001
Aluminium	89.00

1.1 TIG welding

In TIG welding processes, the arc is struck from a consumable electrode to the work piece and metal has been melted from electrode, transferred across the arc and finally incorporated into the molten pool. TIG process employs an electrode, made from high melting point metal, usually a type of tungsten, which is not melted. The electrode and the molten pool are shielded from the atmosphere by a stream of inert gas which flows around the electrode and is directed onto the workpiece by a nozzle which surrounds the electrode. In TIG welding, the primary functions of the arc are to supply heat to melt the workpiece and any filler metal which may be necessary.

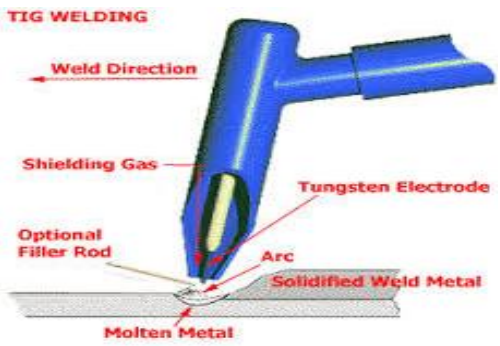

Fig -1: working of TIG welding

3. EXPERIMENTAL WORK

Material is welded at specific conditions. Specimen identification is done, and is marked as G8, G9, G13 and G14. Following are the specimens welded at different conditions i.e. G8 with ER5356, G9 with ER5356+Sc 0.5%, G14 with ER5356 + Sc 0.5% at T6 (hardening temperature), G13 with ER5356 at T6. Two specimen of aluminium alloy AA7075 T6 of 150 mm each is polished and chamfered at one of edge by 45^0. Filler rod ER5356 of 3mm is placed at the groove and welded under TIG welding machine.

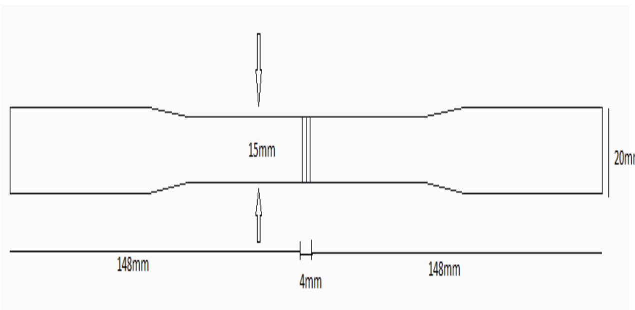

Fig-2: Specimen geometry and dimensions

Tensile test is carried out on each specimen with gauge length of 80mm. Testing is being carried out at Karnataka Material Testing and Research Centre, Hubli.Testing of specimens

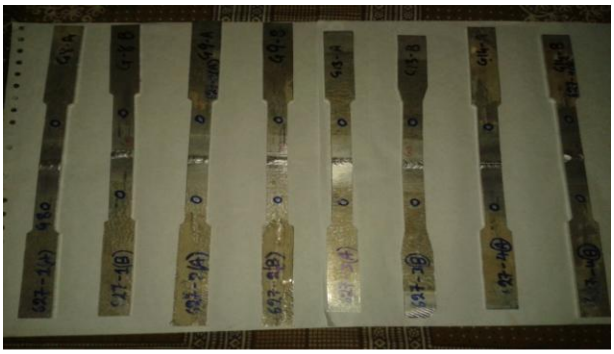

Fig -3: Specimens before tensile test

Fig- 4: Specimens after tensile test

4. FINITE ELEMENT ANALYSIS

Using dimensions from Fig 2, the geometry is developed in ANSYS as shown below.

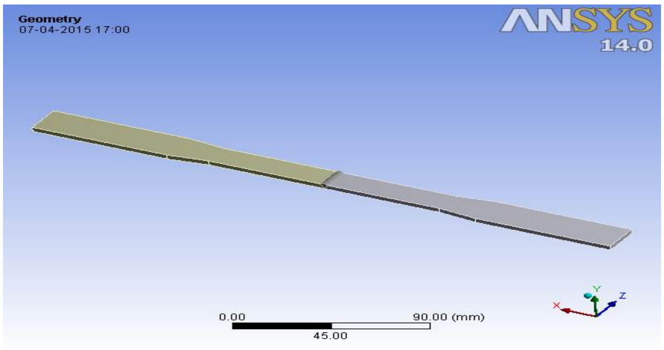

Fig 5 Specimen geometry in ANSYS

Analysis is carried out in ANSYS 14.0 V software. Specimen is considered here to be a solid model, which is referred as plate henceforth. Later weld pool is generated on the plate. The mesh used for this plate is solid mesh (standard mesh).

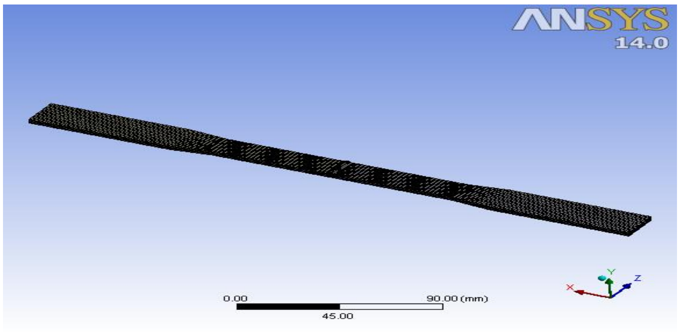

Fig- 6: Meshed model of specimen

The weld joint considered for analysis is a single V-butt joint. The joint is modeled using CREO modeling software. The analysis of welded specimen of thickness 3.48 mm, width 15mm and length of each plate is 150mm, total length of specimen after assembling all three parts is 300 mm and area of specimen is 52.2 mm^2.

4.1 Boundary Conditions

Properties are applied to the plate material with young's modulus as 72GPa, young's modulus of weld pool as 68GPa and Poisson ratio for plate and weld pool as 0.33. Tensile load on each side of surface specimen is applied. Different results are generated by varying the load conditions. Deformations of mechanical properties are obtained, which are explained later.

5. OBSERVATION

From above TIG welding of aluminium alloy AA7075-T6, it is observed that, G8 welded joint have higher ductility due to usage of low strength filler wire ER5356 [2]. G9 welded joint ductility decreases due to usage of additional Sc 0.5% with ER5356 filler wire. This may be due to formation of precipitate [3]. G14 welded joint ductility decreases due to usage of ER5356 with additional Sc 0.5% at T6. This may be due to the formation of precipitate in the weld zone [3]. G13 welded joint further decreases. This may be due to precipitate formation [2].

6. RESULTS AND DISCUSSIONS

The test result includes the behavior of the base material and the weld pool. As material AA7075-T6 aluminium alloy is ductile in nature, its mechanical properties of 7xxx series such as ultimate tensile strength (UTS) ranges between 221-720 MPa, and for AA7075-T6 is 520 MPa and yield tensile strength (YTS) ranges from 20-320 MPa. Table 2 and Table 3 provide values for ultimate tensile strength and yield strength for welded specimen.

Table- 2: Experimental results

Sl.no	Specimen	UTS (MPa)	YTS (MPa)
1	G8	196.62	25.58
2	G9	88.90	32.05
3	G13	205.3	76.76
4	G14	130	52.89

Table-3: FEA results

Sl. No	Specimen	UTS (MPa)	YS (MPa)
1	G8	259.15	34.10
2	G9	115	41.52
3	G13	267.68	100
4	G14	170.18	69.29

Fig 7 and Fig 8 shows graphical representation of ultimate tensile strength and yield strength curves for experimental and FEA result respectively.

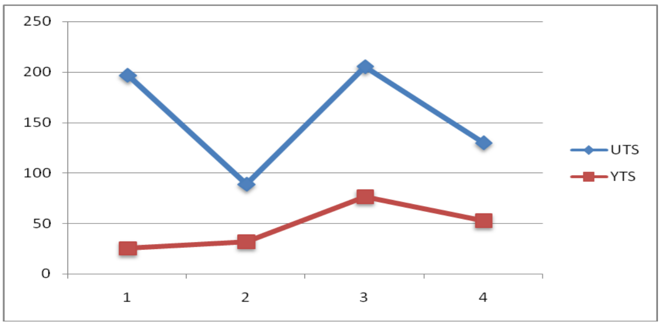

Fig- 7: Experimental results

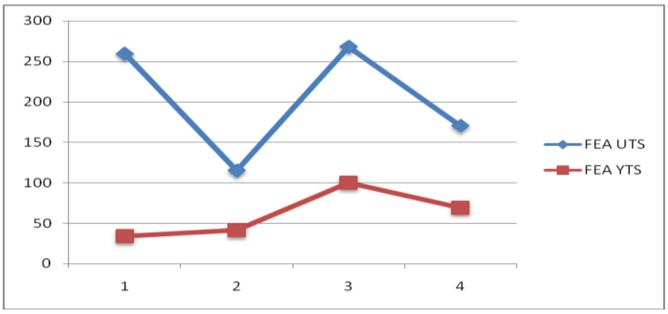

Fig -8: FEA results

The result obtained for tensile test carried out at different load condition

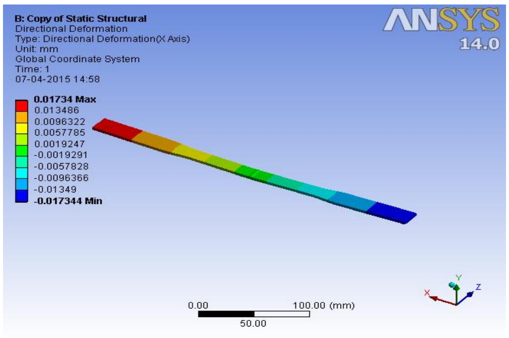

Fig- 9: Analysis of welded specimen for tensile test

Fig 9 shows the result plot of welded specimen for tensile test. The result shows a clear picture of the deformation distribution of the specimen.

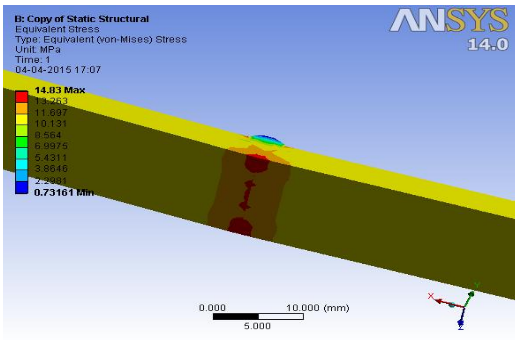

Fig-10: Equivalent von-mises stress analysis of welded specimen

Fig 10 shows the stresses at the weld pool and maximum stress at center of weld pool. During analysis it was observed that specimen does not elongate in axial direction; but instead, it tends to bend at center of weld pool. This nature is due to brittleness of the welded joint as compared to aluminium alloy plates before welding.

6. CONCLUSION

In this paper, the effect of GTAW of AA7075 T6 aluminium alloy has been analyzed by experimental and FEA approach. From the above observations and study of four specimens G8, G9, G13, G14 at their weld pool, following conclusions are the drawn:

1. After welding with ER5356 filler rod, the ductility of weld zone is higher due to low strength filler wire. So the ultimate tensile strength and yield strength of specimen G8 and G13 are higher.
2. By adding Sc 0.5% with ER5356 filler rod to G9 and G14, its tensile properties of joints appreciably improved, which may be due to the grain refinement. Its ductility reduces compared to G8 and G13 and its ultimate tensile strength and yield strength of specimen are found to be reduced as shown in the graphs.

ACKNOWLEDGEMENT

I take this opportunity to thank my project guide Prof. Vivek V. Kulkarni of KLS Gogte Institute of Technology, Belgaum for his expert and timely guidance that I could direct my efforts in covering the manifold features of the project.

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