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Comparative Study of Different Filler Materials on Aluminium Alloys using TIG Welding

*Mangalagiri Rakesh
*M Tech Scholar,
Dept. of Mechanical Engineering,
DMSSVH College of Engineering, Machilipatnam,
Andhra Pradesh, India

**T Ravi Kumar
**Associate Professor of Mechanical Engineering,
DMSSVH College of Engineering, Machilipatnam,
Andhra Pradesh, India

***Abstract*:- The present paper is focused on the investigation of the effect of Aluminium filler materials, 4043 and 5356 on the mechanical properties, namely tensile strength, percentage elongation, bending strength and permissible bending angles on different Aluminium alloys welded using Tungsten Inert Gas (TIG) welding process. Double V butt welded joint is considered for preparing the welding joints. The sizes of the samples are prepared in compliance with the ASME specifications for tensile and bending tests. Three varieties of Aluminium, namely 6061, 6063 and 6082 grades are considered as the base metals for welding. Argon inert gas environment is used during TIG welding process.**

INTRODUCTION

Aluminium alloys find wide applications in aerospace, automobile industries, railway vehicles, bridges, offshore structure topsides and high speed ships due to its light weight and higher strength to weight ratio.

Tungsten Inert Gas (TIG) Welding

TIG welding works on same principle of arc welding. Aluminium alloys are welded effectively using TIG welding process. In a TIG welding process, a high intense arc is produced between Tungsten electrode and work piece. In this welding mostly work piece is connected to the positive terminal and electrode is connected to negative terminal. This arc produces heat energy which is further used to join metal plate by fusion welding. Argon shielding gas is also used to protect the weld surface from oxidization.

METHODOLOGY

a) Selection of Base Materials

Aluminium is remarkable for its low density and its ability to resist corrosion . Aluminium and its alloys are vital to the aerospace industry and important in transportation and building industries, such as building facades and window frames. The oxides and sulfates are the most useful compounds of Aluminium. Three varieties of Aluminium, namely 6061, 6063 and 6082 grades are considered as the base metals for welding

Aluminium 6061

Silicon as its major alloying elements. Originally called "Alloy 61S. It has good mechanical properties, exhibits good weld ability, and is very commonly extruded (second in popularity only to 6063). It is one of the most common alloys of Aluminium for general-purpose use.

6061 has an ultimate tensile strength of more than 200 MPa (42,000 psi) and yield strength above 150 MPa (35,000 psi).

Aluminium 6063

6063 is an Aluminium alloy, with Magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The Aluminium Association. It has generally good mechanical properties and is heat treatable and weld able. It is similar to the British Aluminium alloy HE9.

The yield strength and tensile strength of base metal are 73 N/mm² and 131 N/mm² respectively.

Aluminium 6082

6082 Aluminium alloy is an alloy in the wrought Aluminium-Magnesium-silicon family . It is one of the more popular alloys in its series although it is not strongly featured in ASTM (North American) standards. It is typically formed by extrusion and rolling, but as a wrought alloy it is not used in casting. It can also be forged and clad, but that is not common practice with this alloy. It cannot be work hardened, but is commonly heat treated to produce tempers with a higher strength but lower ductility.

b) Selection of Filler materials

In selection of the filler, one may wish to consider the following facts about each of these filler 4043 and 5356 Al alloys.

4043 should not be used if you are considering the best colour match after post weld anodizing, as this filler alloy will

typically turn dark gray in colour after the anodizing process. 5356 will provide a much closer colour match after anodizing.

4043 is suitable for service temperatures above 150^0 F. However 5356, because of its 5% Magnesium content is not suitable for these elevated temperature applications.

4043 has lower ductility than that of 5356. This may be of some consideration if forming, after welding is to be carried out.

4043 has lower shear strength than that of 5356. This may be of consideration when calculating the size of fillet welds.

4043 is a softer alloy in the form of spooled wire, when compared to 5356. Typically when Gas Metal Arc Welding (GMAW), feedbility will become a less critical issue when feeding the more rigid 5356 alloy.

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4043 will typically provide a higher rating for weld ability and provide slightly lower crack sensitivity. 4043 will generally tend to produce welds with improved cosmetic appearance, smoother surfaces, less spatter and less smut. For this reason, it is sometimes more appealing to the welder.

4043 is an Aluminium/silicon filler metal designed for welding heat treatable base metals and is a common choice for welding 6061.

4043 offers good fluidity and less crack sensitivity than 5356 when welding 6000 series base metals. It is often used to for repair welding Aluminium/silicon cast alloys.

Post weld cracking, corrosion resistance and behaviour under elevated temperature also need to be taken into consideration. Cracking usually can be minimized by choosing a filler metal alloy of higher alloy content than the base metal.

c) Weld Samples Preparation

The double-V butt joint is an excellent joint for all load conditions. Its primary use is on metals thicker than 3/4 inch but can be used on thinner plate where strength is critical. Both sides of the weld joint are beveled. In thick metals, when welding can be performed from both sides of the work piece, a double-V joint is used. Because of the heat produced by welding, you should alter weld deposits, welding first on one side and then on the other side. This practice produces a more symmetrical weld and minimizes war page

The three Aluminium alloys 6061, 6063, 6082 are brought in the large sheets of thickness 12 mm. These sheets are cut into smaller work pieces with the dimensions of 200mm length 50mm width and 12 mm thickness. The welded pieces are ground in to the “ v” shape for the welding of the TIG welding the joint are made by the double v joint .

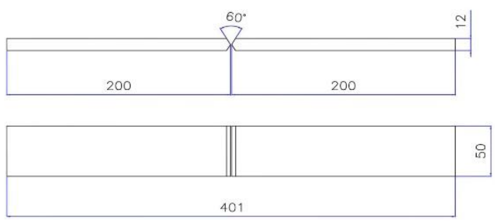

Figure 1: dimensional details of the weld sample

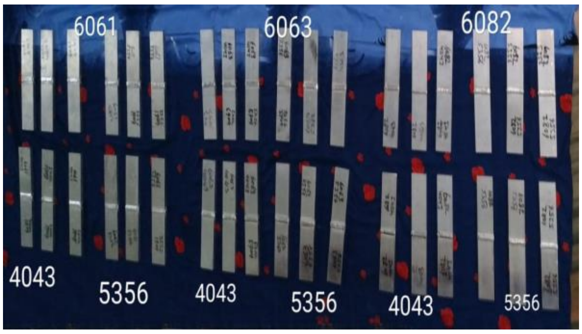

Figure 2: Weld samples prepared using TIG welding

PERFORMANCE TESTS

The weld samples are initially tested using a Non-destructive testing (X- ray diffraction test) to detect any errors in the quality of the weld. The accepted samples are then tested for Mechanical properties using a standard procedure prescribed in the ASTM standards. A 300kN SHIMADZU Ultimate Tensile Machine is used for the tensile testing.

a) Tensile Test

Tensile tests are performed for several reasons. The results of tensile tests are used in selecting materials for engineering applications. Tensile properties frequently are included in material specifications to ensure quality. Tensile properties often are measured during development of new materials and processes, so that different materials and processes can be compared. Finally, tensile properties often are used to predict the behaviour of a material under forms of loading other than uniaxial tension.

Preparation of work piece for Tensile Test

Consider the typical tensile specimen. It has enlarged ends or shoulders for gripping. The important part of the specimen is the gage section. The cross-sectional area of the gage section is reduced relative to that of the remainder of the specimen so that deformation and failure will be localized in this region. The gage length is the region over which measurements are made and is centered within the reduced section. The distances between the ends of the gage section and the shoulders should be great enough so that the larger ends do not constrain deformation within the gage section, and the gage length should be great relative to its diameter. Otherwise, the stress state will be more complex than simple tension.

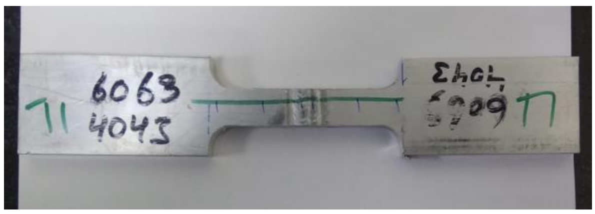

Figure 3: Weld sample prepared for tensile test

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Tensile Test Results Analysis

The tensile tests are carried out on the samples after preparing the welded samples into dumbbell shape as per the ASTM testing procedure for tensile tests. Out of the 18 samples tested, a few of them have not yielded the results as per the ASTM standards. The main reason for the inferior and incompliant results was identified as the errors or defects in the weldments.

It is also observed that among all the samples tested Aluminium 6061 with 5356 filler has higher tensile strength.

The Aluminium 6063 with 4043 has the least strength and high elongation.

S.No	Sample details	Tensile Strength (MPa)	Elongation (%)
1	6061-4043-T1	152.51	20.46
2	6061-4043-T2	151.51	20.05
3	6061-5356-T1	156.07	19.22
4	6061-5356-T2	156.51	19.01
5	6082-4043-T1	150.87	20.26
6	6082-4043-T2	152.31	20.46
7	6082-5356-T1	148.19	21.03
8	6082-5356-T2	146.27	20.56
9	6063-4043-T1	119.39	26.9
10	6063-4043-T2	117.39	26.5
11	6063-5356-T1	126	24.3
12	6063-5356-T2	125	22.6

Table 1: tensile strength and elongation test results

Note: The location of fracture in all the above tensile tests are in the HAZ area, outside the weld metal.

TENSILE STRENGTH

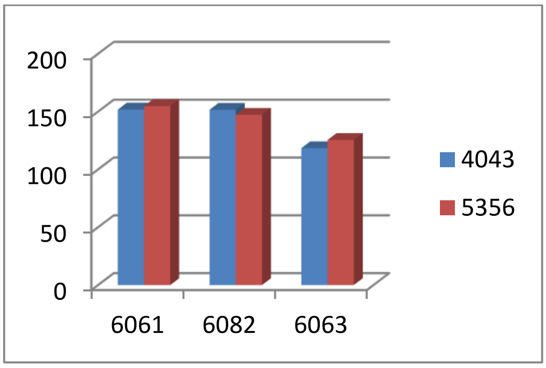

Figure 4: comparison of maximum values of tensile strength:

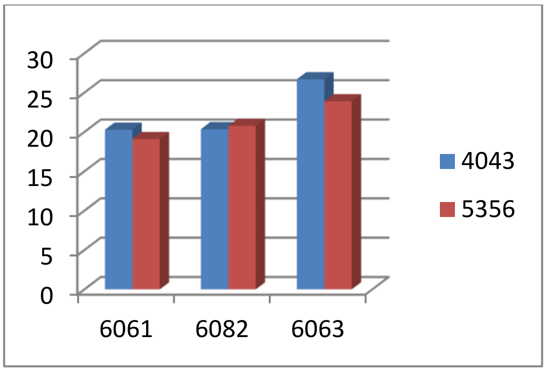

Figure 5: Comparison of maximum values of % elongation

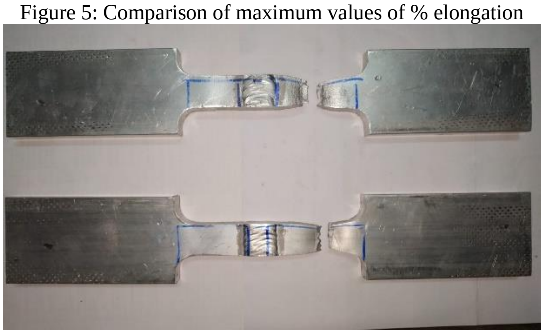

Figure 6: samples in Tensile testing showing fracture in HAZ area

Figure 7: 300kN capacity SHIMADZU UTM

b) Bend Test

Bend testing is a procedure to determine the relative ductility of metal that is to be formed (usually sheet, strip, plate or wire) or to determine soundness and toughness of metal (after welding, etc.)

Preparation of work piece for Bend Test

The bend zone is to be worked flat (excess weld metal, excess penetration removed) and be free from scratches or instructions across the test piece. Undercuts shall not be removed. Processing may be done by machining or grinding, with appropriate precautions being taken to avoid superficial hardness increase

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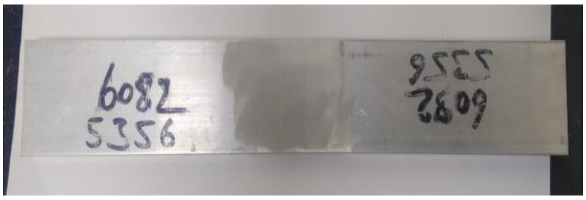

Figure 8: sample preparation for bend tests

Bend Test Results

The following table provides load application and corresponding bend angle for various samples under bend test.

SNo.	Sample Details	Load (N)	Bend Angle	Observations on bent surface
1	6061-4043-B1	**1.3**	**10^0**	No Cracks Observed
2	6061-4043-B2	**12**	**40^0**	Cracks Observed
3	6061-5356-B1	**1.32**	**8^0**	No Cracks Observed
4	6061-5356-B2	**14**	**40^0**	Cracks Observed
5	6082-4043-B1	**1.3**	**15^0**	No Cracks Observed
6	6082-4043-B2	**16**	**45^0**	Cracks Observed
7	6082-5356-B1	**1.2**	**11^0**	Cracks Observed
8	6082-5356-B2	**10**	**50^0**	Cracks Observed
9	6063-4043-B1	**1.1**	**7^0**	No Cracks Observed
10	6063-4043-B2	**12**	**70^0**	Cracks Observed
11	6063-5356-B1	**1.6**	**15^0**	No Cracks Observed
12	6063-5356-B2	**9**	**45^0**	Cracks Observed

Table 2: Observations from bend tests

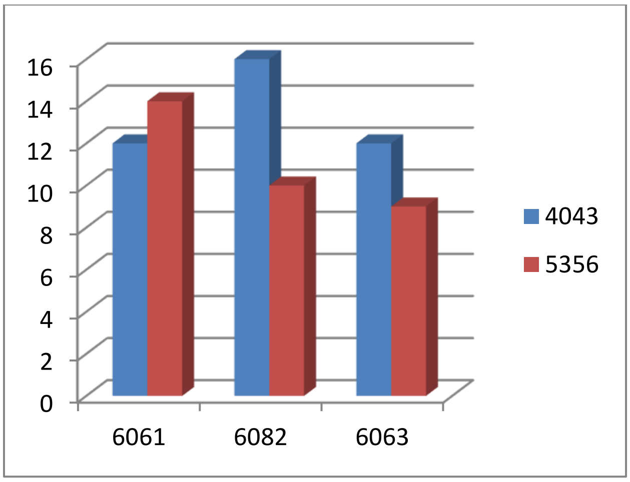

Figure 9: Comparison of maximum load (N) in bending

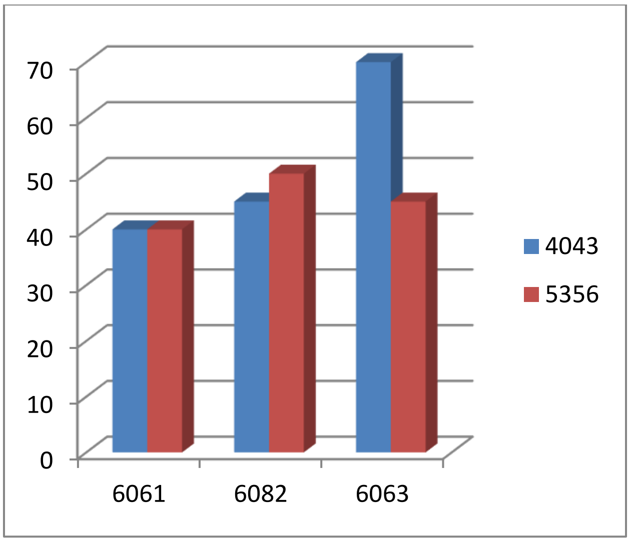

Figure 10: Comparison of maximum bend angle (degrees)

Figure 11: sample weldments after bend test

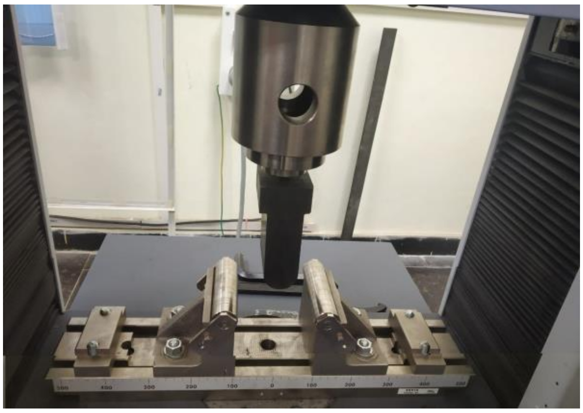

Figure 12: Bend test set up

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Bend Test Results Analysis

In the bend test initially a less loading condition is applied on the samples and then
the load has been increased gradually to a maximum until the failure (observation of the cracks on the surface) occurred.

The 6082 with 4043 is having the highest load bearing capacity.

The 6063 with 4043 is having the best elongation with maximum bend angle of 70^0.

The 6061 having the least bending angle and the average load bearing capacity. In it, both 4043 and the 5356 showed the similar bend
angle.

CONCLUSIONS

In this paper, using TIG welding process we have welded Aluminium alloys of 6061, 6063, 6082 grades with 4043 and 5356 as the filler materials. These weld samples are tested for tensile strength and bending. A total of 36 samples were tested for assessing the tensile strength, elongation and bending properties.

In the tensile test we have observed 6061-5356 samples have the higher Tensile strength and the 6063 got the low tensile strength but higher elongation. In the bend test 6063-4043 got the highest bending angle, the load bearing capacity was highest for 6082-4043.

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