

# Fabrication and Friction Stir Welding of Aluminium SiC metal matrix composites

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**ABSTRACT:** This paper is exclusively focused on the preparation procedure of Al-SiC composite and testing the prepared sample composite for various mechanical properties like tensile strength, hardness, impact strength along with the micro structure evaluation of the composite at the welded portion. The sample composites prepared is of two different compositions, one made with pure aluminium and 10% SiC base and the other with 15% SiC base. Also the properties are checked on a welded and non-welded samples of each type.

**KEYWORDS:** Friction Stir Welding, Aluminium, SiC, microstructure

## I. INTRODUCTION

Friction stir welding is widely used in welding heat treatable aluminium alloys and it is a new technology in the high performance aerospace automotive industries and marine applications. The process is used for the joining of two similar and dissimilar metal pieces at molecular level without melting [1]. Joining of materials is one of the key aspects of production departments. Every material is different to one another and hence possess distinct features and characteristics. While arc welding is still widely preferred technique, many other type of welding techniques proved to be more effective considering the requirements in production sector. The need arises to develop new technique to join different metals together and to attain desired properties. Such a technique developed is Friction Stir Welding process by The Welding Institute (TWI). This technique is however not widely used because of the certain disadvantages it has. But it has proved to be most efficient and effective welding technique till date and aerospace has been benefitted by the invention of this Friction stir welding process. FSW tool is used to perform friction stir welding process and on simultaneous performance of rotating and sliding in the direction of laying weld [2]. They did the experiment on butt joining of AA6061 aluminium alloy and concluded that, the Square tool pin profile followed by Triangular pin profile gives better result compared to other tool profiles [3]. Many researchers are interested in many topics like variation of microhardness, material flow, material location, temperature distribution, residual stresses, and so forth, across the interface of the abutting materials and their consequent effect on the mechanical properties [4–6]

## II. REQUIRED MATERIALS

This work mainly concentrated on Aerospace application, it is advisable to consider properties of the materials in such applications. The most common and important property is to be considered for selection of material is weight. A lighter aircraft requires less energy and, hence, less fuel to operate. The materials selected are Aluminium and Silicon Carbide.

Aluminium(Metal matrix): It is a cheap and widely used metal in production sector for both industrial and domestic purposes. So developing a proper welding process will only benefit production departments worldwide.

Silicon Carbide (SiC)-(Reinforcement) : This material is long known to be a good structural material used in cutting and abrasive materials. It is known to enhance thermal resistivity of the material to which it is added and also improves other mechanical properties as well.

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The compositions of Al and Silicon Carbide are

For sample of composites ;

Al - 98% pure

SiC- Silicon- 70%,Carbon- 29.94% ,Trace Elements- 0.06%

i) For sample with 10% SiC base ;

Al- 90% in total

SiC-10% in total

ii) For sample with 15% SiC base ;

Al- 85% in total

SiC-15% in total

### III.EXPERIMENTAL SETUP

The method that has been selected for composite making is stir casting method. Stir casting equipment consist of cylindrical shaped graphite crucible which is used for fabrication of AMCs, as it withstands high temperature often more than required temperature [680°C]. This crucible is placed in muffle which is made up of high ceramic alumina. Aluminium, at liquid stage is very reactive with atmospheric oxygen and results in oxide formation when it comes in contact with the open air. Therefore, the process of stirring is carried out in closed chamber with nitrogen gas as inert gas in order to avoid oxidation. A K-type temperature thermocouple whose working range is 200°C to 1250°C is used to record the temperature of the liquid. Due to corrosion resistance to atmosphere en 24 is selected as stirrer shaft material. One end of shaft is connected to 0.5 hp PMDC motor with flange coupling. While at the other 4 blades are welded to the shaft at 45°. A constant feeding rate of reinforcement particles is required to avoid coagulation and segregation of the particles and for this a hopper is used. Aluminium alloy matrix will be formed in the crucible by heating aluminium alloy ingots in furnace. A stirring action is started at slow rate of 30 rpm and increases slowly in between 300 to 600 rpm with speed controller. The reinforcement (SiC) is to be added in the metal matrix slowly. After that slurry is reheated to a temperature above melting point and then it is poured into mould.

### IV.PROCEDURE

The materials which are needed in specimen preparation are to be kept nearby in advance. Before starting the process the reinforcement material (SiC base) is preheated for 20 minutes at 500°C separately. Once it is done the equipment is turned on and heating temperature is set at 500°C and then it is slowly increased to 900°C. While the crucible is getting heated up pure aluminium ingots are placed in it. As the temperature rises the ingots start to melt and finally it is converted into liquid form. Once aluminium ingots are liquified ,SiC base can be added into it slowly. For both of them to get mixed properly stirring is to be done continuously.The stirring speed is maintained between 300-600 rpm, most preferably at 450 rpm. After some time because of temperature rise and stirring action the base totally melts and tries to blend in with aluminium matrix. The heating is continued for some time and then the final molten mix is transferred to moulds. In our experiment, the composites of two different compositions are made as mentioned earlier. One with 10% SiC base and the other with 15% SiC base is prepared separately and specimens of both combinations are prepared. The specimens are initially made into plates and later cut into dog-bone shaped ones.

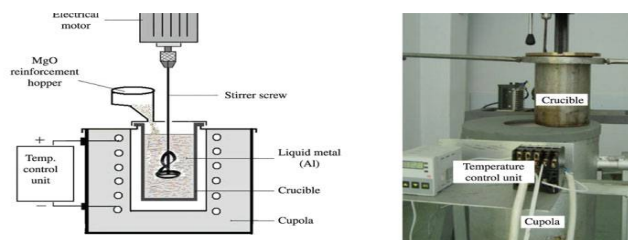


Figure 1. Melt stirring test apparatus (For the production of composite specimens).

Fig. 1 Melt Stirring test apparatus, for production of composites

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The specimens hence prepared are taken and few of them are selected and cut into two halves and then they are welded back together using friction stir welding process. Therefore two sets of specimen are made, one which has welded pieces of both the 10% SiC base composite and 15% SiC base composite and the other which has non welded pieces of two combinations.

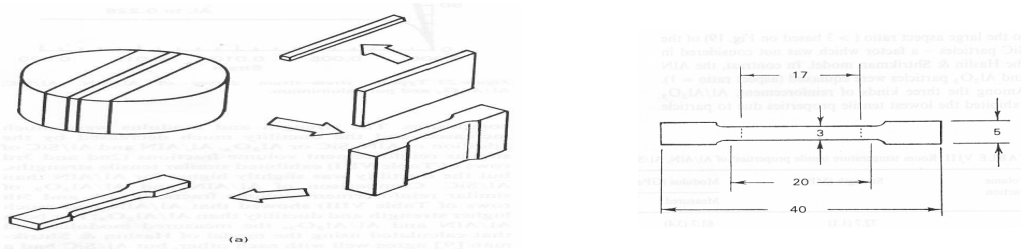


Fig. 2 Test specimen preparation and required specimen

## 1. Impact test (performed on specimens with 10% SiC base and 15% SiC base) :

### i) Impact test on Pure Al + 10% SiC base

Equipment used : KRYSTAL ELMEC  
Test Procedure : IS 1757-1988  
Impact type : Charpy V  
Notch Depth : 2mm  
Notch angle : 45°  
Specimen size : 10x5x55 mm  
Impact test temperature : At room temperature

On trial 1 : The impact strength obtained is 20 Joules

On trial 2 : The impact strength obtained is 20.12 Joules

On trial 3 : The impact strength obtained is 20.09 Joules

Average Impact Strength = 20.07 Joules

### ii) Impact test on Pure Al + 15% SiC base

Equipment used : KRYSTAL ELMEC  
Test Procedure : IS 1757-1988  
Impact type : Charpy V  
Notch Depth : 2mm  
Notch angle : 45°  
Specimen size : 10x6.7x55 mm  
Impact test temperature : At room temperature

On trial 1 : The impact strength obtained is 16.22 Joules

On trial 2 : The impact strength obtained is 16.45 Joules

On trial 3 : The impact strength obtained is 16.39 Joules

Average Impact Strength = 16.35 Joules

## 2. Tensile Test:

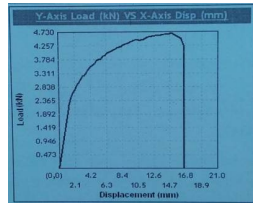
### i) Tensile test on Pure Al + 10% SiC base with Friction Stir Weld

Test procedure : ASTM B 557:2006

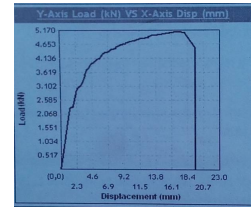
Input data :

Specimen Type : Flat  
Specimen Width : 12.67mm  
Specimen Thickness : 5.2mm  
C/S Area : 65.884 mm<sup>2</sup>  
Original Gauge Length : 50 mm  
Final Gauge Length : 58.01 mm

Results:



**Fig.3 Al&10% SiC with FSW**



**Fig.4 Al&10% SiC without FSW**

Fig 3: Graph between temp Vs displacement with FSW

Fig 4: Graph between temp Vs displacement without FSW

Ultimate Load	: 4.680 kN
Ultimate Tensile Strength	: 71.038 N/mm <sup>2</sup>
Elongation	: 16.020%
Yield Load	: 2.400kN
Yield Stress	: 36.430 N/mm <sup>2</sup>

ii) Tensile test on Pure Al + 10% SiC base without Friction Stir Weld

Test procedure : ASTM B 557:2006

Input data :

Specimen Type	: Flat
Specimen Width	: 10.6 mm
Specimen Thickness	: 5.7 mm
C/S Area	: 60.42 mm <sup>2</sup>
Original Gauge Length	: 50 mm
Final Gauge Length	: 63.6 mm

Results:

Ultimate Load	: 5.120 kN
Ultimate Tensile Strength	: 84.740 N/mm <sup>2</sup>
Elongation	: 27.200 %
Yield Load	: 3.600 kN
Yield Stress	: 59.583 N/mm <sup>2</sup>

iii) Tensile test on Pure Al + 15% SiC base with Friction Stir Weld

Test procedure : ASTM B 557:2006

Input data :

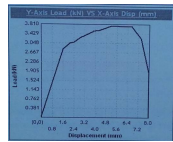
Specimen Type	: Flat
Specimen Width	: 10.72 mm
Specimen Thickness	: 5.03 mm
C/S Area	: 53.922 mm <sup>2</sup>
Original Gauge Length	: 50 mm
Final Gauge Length	: 55.03 mm

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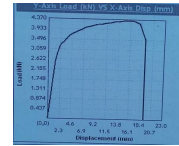
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Results:



**Fig 5. Al&15%SiC with FSW**



**Fig 6. Al&15%SiC without FSW**

Fig 5: Graph between temp Vs displacement with FSW

Fig 6: Graph between temp Vs displacement without FSW

Ultimate Load : 3.760 kN  
Ultimate Tensile Strength : 69.733 N/mm<sup>2</sup>  
Elongation : 10.060 %  
Yield Load : 2.640 kN  
Yield Stress : 48.961 N/mm<sup>2</sup>

iv) Tensile test on Pure Al + 15% SiC base without Friction Stir Weld

Test procedure : ASTM B 557:2006

Input data :

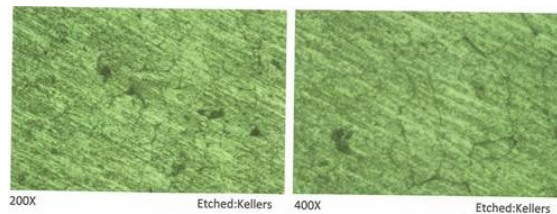
Specimen Type : Flat  
Specimen Width : 10.75 mm  
Specimen Thickness : 5 mm  
C/S Area : 53.75 mm<sup>2</sup>  
Original Gauge Length : 50 mm  
Final Gauge Length : 64.5 mm

Results:

Ultimate Load : 4.320 kN  
Ultimate Tensile Strength : 80.372 N/mm<sup>2</sup>  
Elongation : 29.00%  
Yield Load : 2.480 kN  
Yield Stress : 46.140 N/mm<sup>2</sup>

### 3. Microstructure Evaluation:

i) Microstructure of Pure Al + 10% SiC base without Friction Stir Weld



**Fig.7 Microstructure with FSW**

The Microstructure consists of non-uniform grains of silicon carbide with inter metallic compounds in aluminium matrix and free from eutectic melting. No micro porosity, stringers and segregations are seen Fig.7.

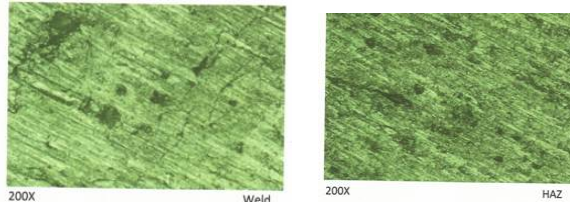
ii) Microstructure of Pure Al + 10% SiC base with Friction Stir Weld

The Microstructure consists of fine inter metallic compounds in aluminium matrix. SiC particles are seen in weld portion. No cracks and blow holes are observed at welded part is observed in Fig.9.

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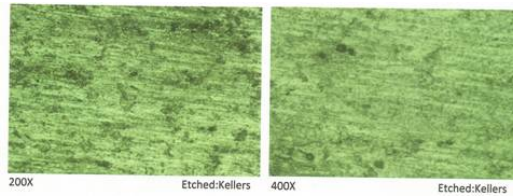
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**Fig.9 Microstructure with FSW(Al&10%SiC)**

Heat affected zone shows fine intermetallic compounds and uniform distribute silicon carbides in weld to Al solid solution. No cracks and blow holes are observed

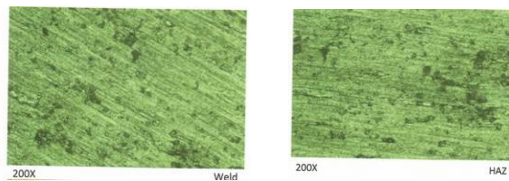
iii) Microstructure of Pure Al + 15% SiC base without Friction Stir Weld



**Fig 10 Microstructure with FSW**

Microstructure consists of non-uniform grains of silicon carbide with inter metallic compounds in aluminium matrix and free from eutectic melting. No micro porosity, stringers and segregations are seen Fig.10.

iv) Microstructure of Pure Al + 15% SiC base with Friction Stir Weld



**Fig 11 Microstructure with FSW (Al&15%SiC)**

Microstructure consists of fine inter metallic compounds in aluminium matrix. SiC particles are seen in weld portion. No cracks and blow holes are observed at welded part.

Heat affected zone shows fine intermetallic compounds and uniform distribute silicon carbides in weld to Al solid solution. No cracks and blow holes are observed in Fig.11

## V. CONCLUSION

It can be concluded that Friction stir welding is indeed possible on Al-SiC composite for less base percentages and the mechanical properties and microstructure of the composite does not vary much even after friction stir processing and the test results significantly supports this fact.

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