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EXPERIMENTAL INVESTIGATION ON SIC AND AL2O3 REINFORCED FRICTION STIR WELDED JOINT OF ALUMINIUM ALLOY 6061

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ABSTRACT

In this work the Mechanical behavior of reinforced welded butt joints of AA6061 aluminium alloy fabricated by friction stir welding process has been investigated. 10%, 15%, 25%, 30% volume fraction of Aluminium Oxide (Al2O3) powder and Silicon carbide (SiC) particulates of 400 mesh were added at weld interface to enhance the mechanical properties at weld zone. This work has been focused to study the effect of Al2O3 and SiC as reinforcing material along with different volume proportions on the mechanical properties of friction stir welded joint of AA6061.The experimental results indicated that the reinforcing material and percentage of reinforcing material has a major effect on the mechanical properties of friction stir welded joint. The results of reinforced friction stir welded joints were correlated with mechanical properties of parent material and without reinforced friction stir welded joint. The best results have been obtained at 25% and 30% volume fraction reinforced particulates of Silicon Carbide and Aluminium Oxide respectively. But at the same time percentage of elongation decreases and the behavior of material changes from ductile to brittle.

Key Words: *Friction Stir Welding, Reinforcing material, Silicon Carbide of 400mesh, Aluminium oxide powder, Aluminium Alloy AA6061, Mechanical properties.*

1. INTRODUCTION

Aluminum alloys are more attractive for a wide variety of aerospace, automotive, marine and defense applications. But due to porosity and poor solidification microstructure, these alloys are considered as non weldable by different fusion or conventional welding processes. Some of the aluminium alloys can be resistance weldable but surface preparation is more expensive **[1].** Due to these reasons in 1991 the welding institute was developed a solid state friction stir welding process. Initially it was implemented to aluminium alloys **[5].** But after friction stir welding, welded joints loses its mechanical properties at weld portion compare to parent or base material. To overcome these problems, reinforcing materials such as silicon carbide (SiC) and aluminium oxide (Al_2O_3) were added at butting edges of the plates or weld interface to enhance the mechanical behavior of the friction stir welded joint**[2].** The experiments were performed with different volume proportions of silicon carbide and aluminum oxide individually as reinforcing materials by keeping all other parameters constant. The reinforcement particles which are consist of 10, 15, 25 and 30 percentage of volume. In this research it includes, the effect of reinforcement, type of reinforcement and volume percentage of reinforcement which is adding at weld interface on mechanical behavior and metallurgical behavior of friction stir welded joint. Four friction stir welds were produced with four different volume percentage of Sic such as 10, 15, 25 and 30%. Four friction stir welds were produced with four different volume percentage of Al_2O_3 such as 10, 15, 25 and 30%. This paper has been explained the enhancement of mechanical properties of friction stir welded joint by adding different reinforce particulates at weld interface. It consists of comparison between reinforced and unreinforced friction stir welded joint **[2-4].**

2. Experimental procedure

2.1 Materials and Welding Parameters

Friction stir welding technique by applying automatic CNC machine was used to produce butt welds. The parent alloy used was AA6061 aluminum plates with thickness of 4 mm. The nominal compositions (in wt %) is displayed in Table 2. The butt joint configuration was prepared to add the reinforcement particles and to produce the joints. The

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direction of welding was normal to the rolling direction of Aluminium plates. A non-consumable welding tool made of high carbon steel (H13) was applied to fabricate the joints. The composition is displayed in table 1. The welding conditions and the chosen tool parameters used for welding in this work used to produce the joints in this investigation are listed in Table 3. To improve the mechanical properties at weld joining, the Aluminium Oxide (Al2O3) reinforcement particles were added at weld interface with different proportions such as 10%, 15%, 25%, and 30% by creating separate geometries at weld interface. After inserting reinforcement particulates in separate geometry which was created to add the reinforced particles, geometry has been closed by processing the tool of diameter 24 mm at 560 R.P.M without pin. The friction stir welding was produced.

Table 1. Chemical composition of H13 Tool

Element	C	Mn	Cr	Mo	V	Si	Fe
Weight (%)	0.40	0.35	5.20	1.30	0.95	1.0	Reminder

Table 2. Chemical composition of AA6061

Element	Mg	Si	Fe	Cu	Cr	Mn	Zn	Ti	Al
Weight (%)	0.9	0.62	0.33	0.28	0.17	0.06	0.02	0.02	Bal.

2.2 Tool and Reinforcement material

Fig.1 FSW Tool

Fig.2 Al_2O_3 powder

Fig.3 SiC Powder

Table 3. Welding conditions and process Parameters used in this work

PARAMETER	VALUE
Rotation speed (RPM)	1120
Welding speed (mm/min)	40
Tool shoulder diameter	18 mm
Pin diameter (mm)	7
Pin length (mm)	3.5
Tilt angle (◦)	0
Pin profile	Conical

2.3 Friction Stir Welded specimens with SiC as Reinforcement:

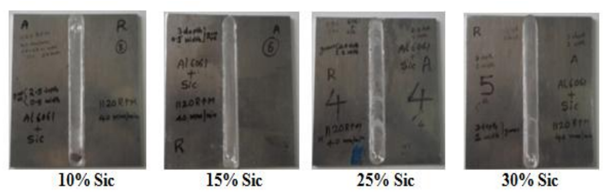

Fig. 4 Friction Stir Welded Joints with 4 volume praportions of SiC as Reinforcement

2.4 Friction Stir Welded specimens with Al2O3 as Reinforcement

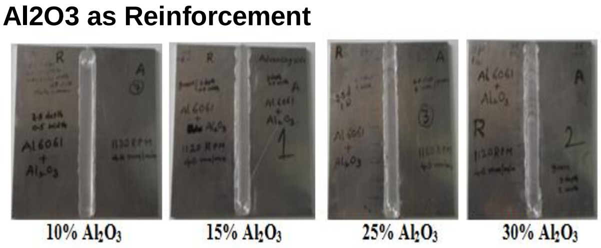

Fig.5 Friction Stir Welded Joints with 4 volume praportions of Al_2O_3 as Reinforcement.

2.5 Tensile Test Specimens

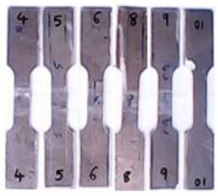

Fig.6 Tensile Test Specimens with SiC

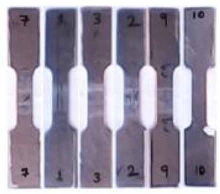

Fig.7 Tensile Test Specimens with Al_2O_3

3. Results and discussion

3.1 Mechanical properties of base metal and FSW without reinforcement

Table 4. Mechanical properties of base metal and FSW without reinforcement

Mechanical properties	Base Metal AA6061 (without weld)	FSW Joint Without reinforcement
Ultimate Tensile strength (MPA)	315.269	163.815
Yield Strength (MPA)	265.260	138.157
% Of Elongation (%)	17.240	9.00
Impact Strength (Charpy) (J)	9	12
Hardness (BHN)	55	68
Bend	180^0	180^0

Table4 reveals that the mechanical properties of friction stir welded joint of aluminium Alloy 6061. From the results it was concluded that after friction stir welding of aluminium alloy 6061, the mechanical properties such as ultimate tensile strength, yield strength and percentage of elongation were decreased. Impact strength was increased.

Table 5. Mechanical properties of FSW with Sic as reinforcement at weld interface

Sl. No	% of Silicon carbide (by Volume)	Ultimate Tensile strength (MPA)	Yield Strength (MPA)	% Of Elongation (%)
1	10	221.15	191.18	7.47
2	15	252.00	217.42	7.02
3	25	303.05	263.68	6.09
4	30	263.28	261.03	3.80

Table 6. Mechanical properties of FSW with Sic as reinforcement at weld interface

Sl. No	% of Silicon carbide	Impact Strength (J)	Hardness (BHN)	Bend
1	10	8	93	
2	15	8	96	
3	25	6	104	Not bending to 180^0
4	30	6	101	

Table 7. Mechanical properties of FSW with Al_2O_3 as reinforcement at weld interface

Sl.No	% of Al_2O_3 (by Volume)	Ultimate Tensile Load(KN)	Ultimate Tensile strength (MPA)	Yield Load (KN)	Yield Strength (MPA)	Final Gauge Length (mm)	% Of Elongation (%)
1	10	14.287	187.98	13.51	177.79	54.03	8.07
2	15	15	197.36	13.90	182.89	54.13	8.27
3	25	17.44	225.57	15.71	206.71	54.30	8.6
4	30	18	236.85	16	210.52	54.50	9

Table 8. Mechanical properties of FSW with Al_2O_3as reinforcement at weld interface

S.NO	% Al_2O_3 (By Volume)	Impact Strength (Charpy) (J)	Hardness (BHN)	Bend
1	10	8.8	80	
2	15	8.6	84	Not bending to 180^0
3	25	8.2	88	
4	30	8.0	91	

3.2 Ultimate Tensile and Yield Strength

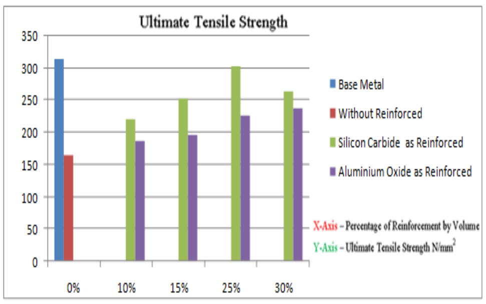

Fig.8 Comparison of Tensile strength

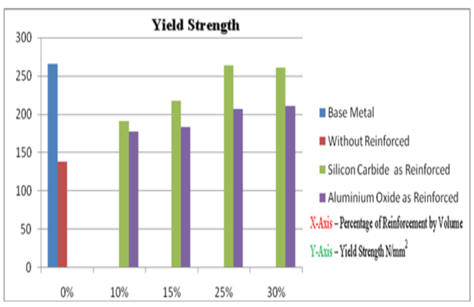

Fig.9 Comparison of Yield strength

The Fig. (8 & 9) reveals that the ultimate tensile strength and yield strength of unreinforced friction stir welded joint decreases about 48% than parent metal.

Ultimate tensile strength and yield strength of friction stir welded joint was 51.96% and 52.08% of parent metal respectively. But when the 10% by volume

of silicon carbide particulates were added at weld interface, the ultimate tensile strength and yield strength were 70.15% and 72.07% of parent metal. When 15% by volume of silicon carbide particles were added as reinforcement at weld interface, the ultimate tensile strength and yield strength were 79.93% and 81.96% of

parent metal. When 25% by volume of silicon carbide particles were added as reinforcement at weld interface, the ultimate tensile strength and yield strength were 96.12% and 99.40% of parent metal. When 30% by volume of silicon carbide particles were added as reinforcement at weld interface, the ultimate tensile strength and yield strength were 83.51% and 98.41% of parent metal. In all conditions, by adding the reinforcement at weld interface ultimate tensile and yield strengths were increased.

But when the 10% by volume of aluminium oxide particulates were added at weld interface, the ultimate tensile strength and yield strength were 59.63% and 67.02% of parent metal. When 15% by volume of aluminium oxide particles were added as reinforcement at weld interface, the ultimate tensile strength and yield strength were 62.60% and 68.95% of parent metal. When 25% by volume of aluminium oxide particles were added as reinforcement at weld interface, the ultimate tensile strength and yield strength were 71.55% and 77.93% of parent metal. When 30% by volume of aluminium oxide particles were added as reinforcement at weld interface, the ultimate tensile strength and yield strength were 75.13% and 79.36% of parent metal.

3.3 Hardness

Fig.10 reveals that the Hardness of friction stir welded joint was 23.64% more than the hardness of parent metal. But when the reinforced particulates were added at weld interface, increasing percentage of hardness increased more.

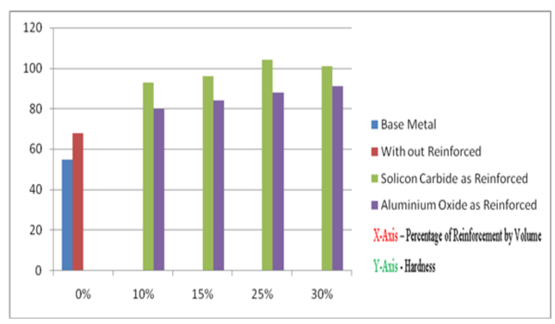

Fig.10 Comparison of Hardness

When the 10% by volume of silicon carbide particulates were added at weld interface, the hardness was increased by 69.09% than parent metal. When the 15% by volume of silicon carbide particulates were added at weld interface, the hardness was increased by 74.55% than parent metal. When the 25% by volume of silicon carbide particulates were added at weld interface, the hardness was increased by 89.09% than parent metal. When the 30% by volume of silicon carbide particulates were added at weld interface, the hardness was increased by 83.64% than parent metal.

When the 10% by volume of Aluminium oxide particulates were added at weld interface, the hardness was increased by 45.45% than parent metal. When the 15% by volume of Aluminium oxide particulates were added at weld interface, the hardness was increased by 52.73% than parent metal. When the 25% by volume of Aluminium oxide particulates were added at weld interface, the hardness was increased by 60% than parent metal. When the 30% by volume of Aluminium oxide particulates were added at weld interface, the hardness was increased by 65.45% than parent metal.

3.4 Impact Energy

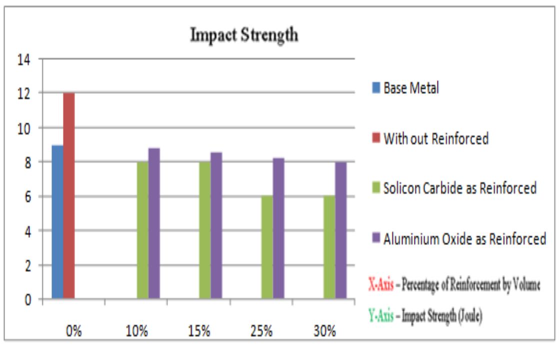

Fig.11 Comparison in Impact strength

Fig.11 is a graph showing the effect of reinforcement content on the impact energy of Friction stir welded Joint of AA6061.

Impact strength of friction stir welded joint without reinforcement was more than parent material and reinforced friction stir welded joint. Impact strength of friction stir welded joint was 33.33% more than the parent metal. When the reinforcing materials were added at weld interface the impact strength was decreased than parent metal also. When the 10% and 15% volume of silicon carbide was added, impact strength of weld was decreased by 11.11% than parent metal and 33.33% than unreinforced friction stir welded joint. When the 25% and 30% volume of silicon carbide was added, impact strength of weld was decreased by 33.33% than parent metal and 50% than unreinforced friction stir welded joint.

When the aluminium oxide was added as reinforcement at weld interface, when the 10% and 15% volume of aluminium oxide was added, impact strength of weld was decreased by 2.22% and 4.44% respectively than parent metal and 26.66% and28.33% respectively than unreinforced friction stir welded joint. When the 25% and 30% volume of aluminium oxide was added, impact strength of weld was decreased by 8.89% and 11.11% respectively than parent metal and 31.66% and 33.33% respectively than unreinforced friction stir welded joint.

When the silicon carbide was added at weld interface, impact strength was decreased more than the aluminium oxide used as reinforcement. Friction stir welded joint without reinforcement has good impact strength than parent metal.

3.5 Percentage of Elongation

Fig.12 is a graph showing the effect of reinforcement content on the percentage of elongation of Friction stir welded Joint of AA6061. Percentage of elongation of friction stir welded was decreased by 47.80% than the parent metal. When the silicon carbide was added in 10%, 15%, 25%, and 30% by volume, percentage of elongation was decreased by 56.67%, 59.28%, 64.68% and 77.96% respectively than parent metal.

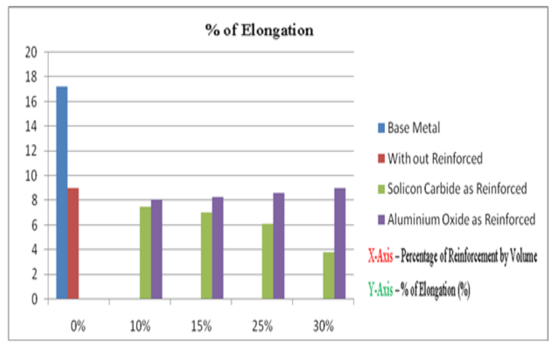

Fig.12 Comparison of % of Elongation

When the aluminium oxide was used as reinforcement in 10%, 15%, 25%, and 30% by volume, percentage of elongation was decreased by 53.19%, 52.03%, 50.12% and 47.80% respectively than parent metal.

From the above results it can be say that by increasing the percentage of reinforcing material, the value of decreasing percentage of elongation was increases.

When the aluminium oxide was used, percentage of elongation was more than silicon carbide used as reinforcement. By this it can be say that when the silicon carbide was used, friction stir welded joint was become more brittle

4. CONCLUSION

Mechanical properties of friction stir welded joint were enhanced by adding reinforcing materials such as silicon carbide and aluminium oxide at weld interface.

i. At 25% by volume of silicon carbide, mechanical properties were enhanced in large percentage compare to other percentage.
ii. At 30% by volume of aluminium oxide, mechanical properties were enhanced in large percentage compare to other percentage.
iii. Mechanical properties of a friction stir welded joint of Aluminium alloy 6061 was enhanced by addition of silicon carbide and Aluminium oxide particulates

at weld interface with volume proportions 10% to 30%. In all volume proportions percentage of elongation was decreased.

iv. Friction Stir welded joint without reinforcement having less mechanical properties than base metal and friction stir welded joint with reinforcement

v. Due to reinforcing materials which are added at weld interface the material behavior changes from ductile to brittle.

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