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Report on Joining of Al- Alloy Reinforced with Al_2O_3 by Friction Stir Welding

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***Abstract* – The friction stir welding process is a method of joining metals in the plastic condition. Metal doesn't reach to its melting temperature. It enhances the mechanical properties of the base metal. Some of the leading companies adopt the process for the manufacturing of aeroplanes, fuselages and cryogenic tanks for SLV's (Space launch vehicles).**

***Keywords*– friction welding, Stir Welding, Alloy Reinforced welding, Tension test.**

I. INTRODUCTION

Al-alloys composites have good mechanical properties but if we join them by fusion welding the properties achieved are very low as compared to the base metal. To achieve the properties of joint equivalent to or more than the base metal we use Friction Stir Welding.

Aluminium is light in weight which is suitable for the applications where weight is taken into design consideration. .Al2O3 has good hardness and strength that's why composite of aluminium and Al2O3 increases tensile strength, toughness and hardness of alloy. While using friction welding significant grain reduction is induced and better distribution of grains is seen in the matrix.

Friction-stir welding (FSW) is a solid-state joining process and is used for applications where mechanical properties of metal must remain unchanged. This process is used on the high melting point temperature metals like Aluminum, and Tungsten, which can't be easily heat treated post weld to recover characteristics.

Metal and reinforced particle selection
Al6061

Al6061 is a precipitation hardening aluminium alloy. It contains magnesium and silicon as major alloying elements. Silica increases hardness and it is corrosion resistant material with weldability characteristic.
Mechanical properties of Al6061

Ductility	Yield Strength	Ultimate Tensile Strength
15%	160MPa	221MPa

Chemical composition of Al6061/Al2O3

Alloy	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Reinforce-ment
6061	6	7	28	.15	2	25	2	1 5	20% Al2O3

Selected reinforced particle
Aluminium oxide
Chemical formulae - Al2O3
Appearance - white in colour
Size of particles used - 600 mesh
Melting point - 2072ºC
Boiling point - 2977 ºC
Solubility in water - insoluble
Density - 4.1 g/cm3
Thermal conductivity - 30 W-1K-1

1. Stir casting of Al6061 and Al2o3

The steps involved in the process of stir casting of Al6061 and Al2O3-

- Taking suitable composition of Al6061 and Al2O3.
- Preparation of sterling rod and blade
- Preparation of mould
- Pre heating of Al2O3
- Mixing of Al2O3 with Al6061 through sterling rod
- pouring and solidification of molten metal
- Cutting of metal in strip form
- preparation of tool for friction stir welding

Taking suitable composition of Al6061 and Al2O3
we have taken two different composition
1. Al6061 reinforced with 5% Al2O3(by weight)
2. Al6061 reinforced with 15% Al2O3(by weight)
Preparation of stirrer rod and blade
Stirrer rod is used to stir the molten metal and to mix the reinforced particles in the metal properly.the melting point of the stirrer rod and blade must be as high as it resist at the temperature of molten metal otherwise it will

melt in the molten metal and can increase the impurity level.for this,High speed steel strips are used to prepare stirrer wings and high speed steel rod is used to attach with wings. Nut of stainless steel is used to tightened the strip with the rod.Drilling the hole in the middle of strip to enter the high speed steel rod is required.This rod is clamped with the motor to work as the stirrer.

Fig. 1.Stirrer.

Preparation of mould

Following are the main parts are required to make mould.

1. Cope and drag
2. Pattern
3. Runner
4. Riser
5. Moulding sand
6. Reamer
7. Water (to provide moisture for binding)

Pattern of dimension 105mm x 105mm x 55mm is made.pattern used is of wood.depending on the requirement it can be made of the different material.allowance like-srinkage and taper are prvided in the pattern.after preparing the pattern Cope and drag are put together to get the proper height.Water is mixed in the clay to get proper binding property.pattern is than put into the cope and drag.before putting the clay inside the cope and drag system,runner in also connected with the pattern.Now clay is put into the cope and drag system.reaming in than done to get mould.pattern and runner is than retrieved from the cavity.

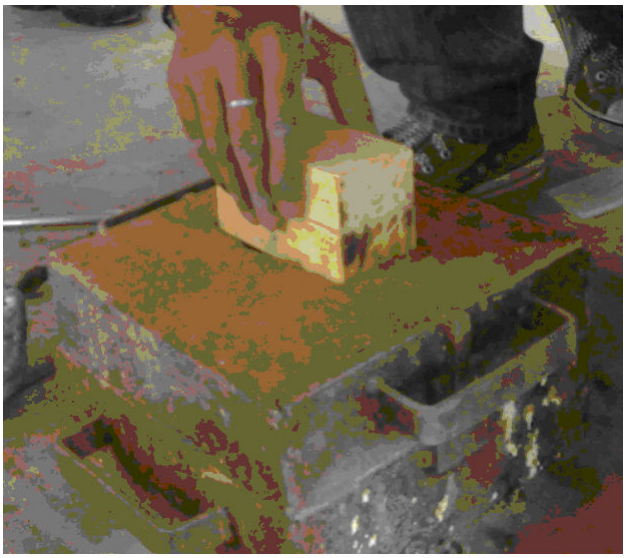

Fig .2. Prepared Mould.

- **Mixing of Al2O3 with Al6061 through stirrer rod**

Melting point of Al6061 is 680°C.at this temperature of furnace Al6061 is converted into molten state. Slag from the surface of molten metal is removed mechanically.arrangement of sterring is than installed on the furnace.pre heated Al2O3 particals are than poured into the crucible,which is in the furnace.the speed of pouring the Al2O3 in the crucible is slow so that it can be mixed properly and cluster will not formed in casting.Mixing of Al and reinforced particle can be done by stirrer rod which is connected through motor.Speed of stirrer rod is varied from lowest to the maximum speed of 600 rpm.up and down motion is provided for the better mixing of Al2O3.

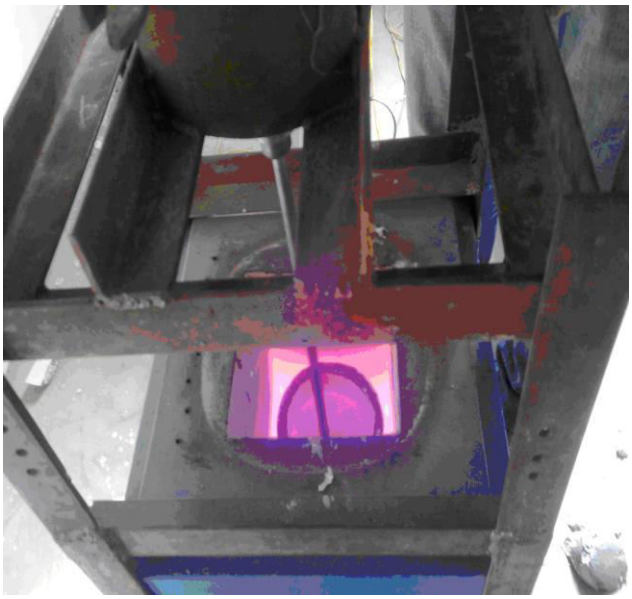

Fig. 3. Mixing of Reinforcement

- **Pouring and solidification of molten metal**

Arrangement for sterring is removed from the crucible after switch off the switch. Crucible of molten Al6061composite with Al2O3 is took out from the furnace through tongs safely. Molten composite is than poured into the runner which goes into the mould cavity through gate.before pouring the molten composite in runner we have to remove the impurities from the surface.Now left the casting at room temperature for 30 minutes to solidify.after solidification we have to break the sand to get solid cast metal.

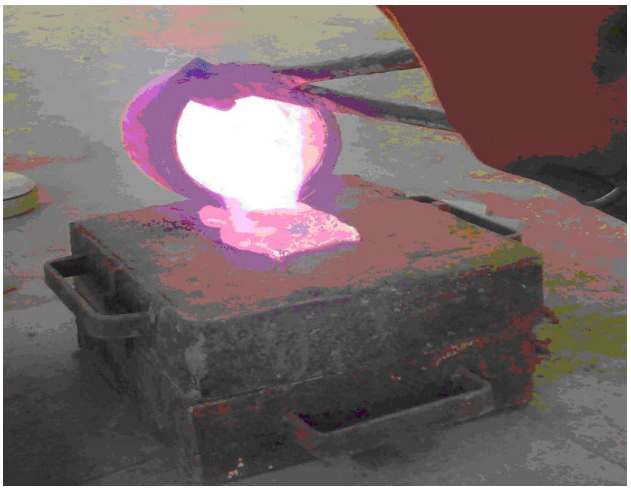

Fig. 4. Casting Process.

- **Preparation of Metal Strip and Tool**

Cutting of metal in strip form

Solid cuboids of composite metal is cut through the electric saw machine into the plates form.these metal plates are of dimension 105mm x 55mm x 7mm.we required the dimension of plates are 100mm x 50mm x 6mm,which can be achieved through the finishing process.this finishing can be done on the vertical milling machine.

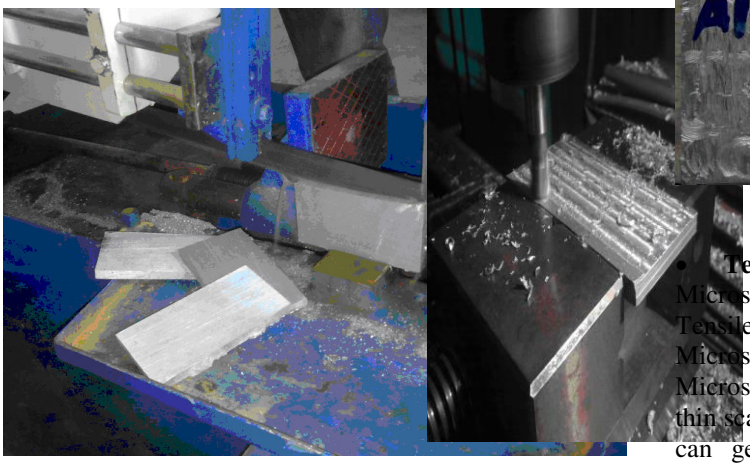

Fig.5(a): Metal Strip Fig.5(b): Milling Too

Fig. 6.Milling Tool.

Tool material	high speed steel
Radius of tool grip	8 mm
Major radius of pin	3.5 mm
Face design of tool	octagonal
Pin height	5.8 mm
Machine used	vertical milling machine.
Rotational speed of tool	1100 rpm
Tilt angle	2°
Traverse speed	40 mm/min

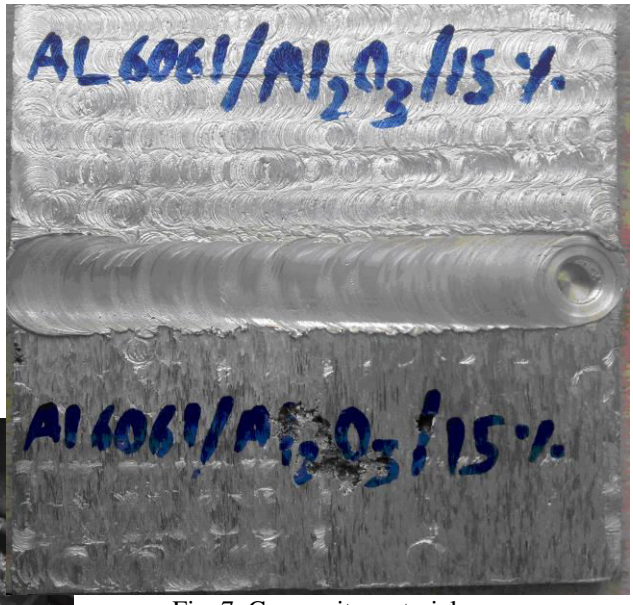

Fig .7. Composite material.

- **Testing of Properties**

Microstructure study

Tensile test

Microstructure study

Microstructure of any material is seen by magnifying its thin scale by 25 times. With the help of microstructure we can get the knowledge of physical and mechanical properties like toughness, hardness, ductility, corrosion resistivity, behavior of material with temperature change

and with the help of these properties its industrial applications are also increased.

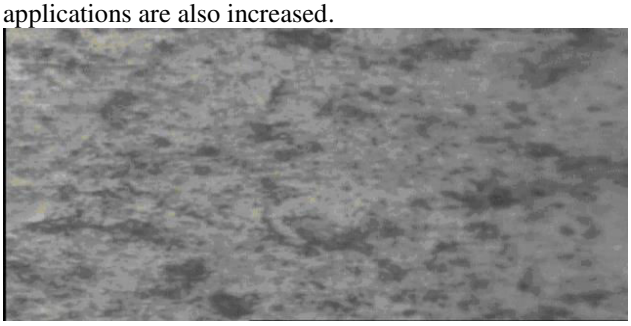

Fig.9. microphotographs of friction welded zone of cast Al6061- Al2O3 (15% by weight) and Al6061- Al2O3 (5% by weight).

- **Tensile test**

This test is performed to find out the behavior of material at different phases under tensile load. It is performed in a machine called Universal Testing Machine. A graph between stress and strain is automatically plotted for its different limits like elastic limit, pastic limit, yield limit, necking and breaking point. Results obtained during this test are used in industrial applications and for design considerations.

Specimen data
Total length - 100mm
Length of grip section- 28mm
Grip section Width - 10mm
Thickness of grip section- 6mm
Gage length - 25mm
Width of gage section- 6mm
Reduced section - 32mm
Corner radius - 6mm

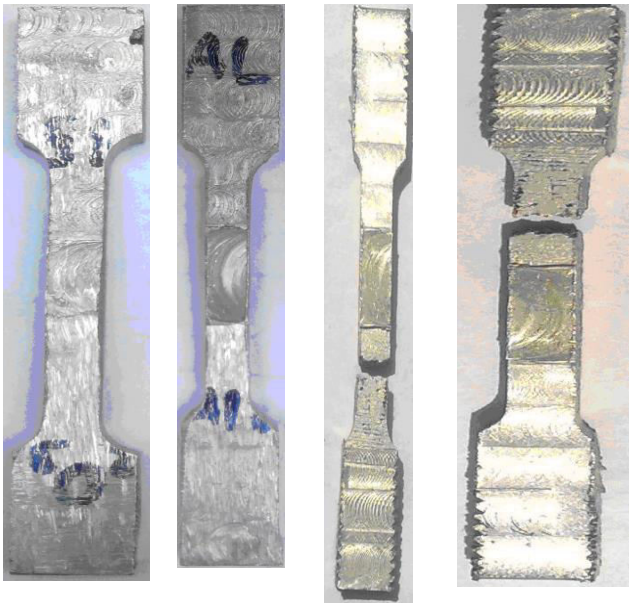

Fig.10. Specimen after tension test.

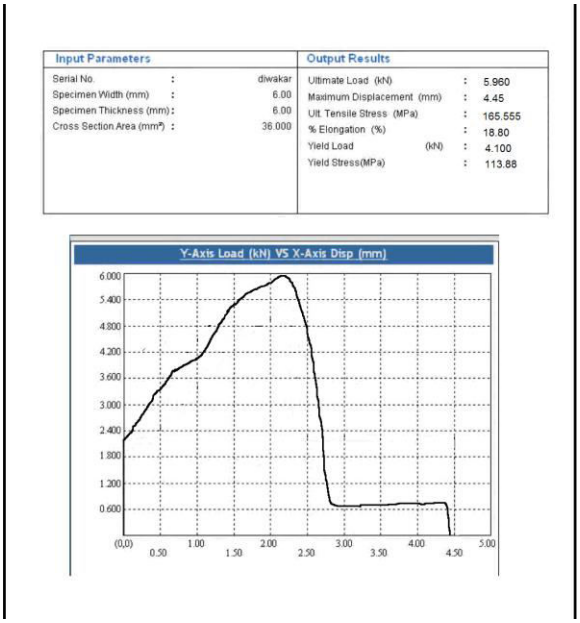

Fig .11. Stress-Strain Curve.

After this test it is clearly predictable that the strength of this joint is more than its base material and if amount of alloy in the base metal then tensile strength also increases.

II. CONCLUSION

It is not possible to detect defects like porosity generated during casting of any material. Friction stir welding (FSW) only provides homogeneous structure of grains in heat affected zone (HAZ).

FSW can provide very strong joint in terms of hardness and toughness that is shown by the tensile test performed on the alloy.

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