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## EFFECTS OF SPIN CASTING ON MICROSTRUCTURE AND MECHANICAL BEHAVIOUR OF AA6063/SiC COMPOSITE COLD ROLLED AND HEAT TREATED

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**Abstract:** This study investigated the effects of spin casting method on mechanical behavior of aluminum composite (Al6063/SiC). The composites were cold rolled to 10% deformation before solution heat treating at 520°C for 1 hour after which it was rapidly cooled in water. Experimental and theoretical density was used to evaluate the porosity of the composite. After cold rolling with 10% deformation and solution heat treating, it was discovered that silicon carbide were well dispersed in aluminum matrix better when compared with the as-cast of both spin and sand casting. The tensile strength and yield strength for spin casting were better when also compared with sand casting.

**Keywords:** aluminum, silicon carbide, composite, solution heat treating, spin casting

### INTRODUCTION

Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify, and upon solidification, the metal assumes the shape of the mould but experience some shrinkage [1]. The solidified part is also known as a casting. Casting is the most economical of all fabrication processes. There are different casting processes which include, sand, die, spin, continuous and investment casting. Sand casting is the most common employed of all the casting processes [2].

Different casting methods have different microstructure and different Properties when cold rolled but improper casting may give rise to defects such as pin hole, porosity, shrinkage cavity and which are largely responsible for poor mechanical properties of aluminum alloys produced. Aluminium alloys have great use potential in the structural components in the aerospace and automobile industries mainly because of their low density and high specific strength [3], also aluminium alloys have a wide diversity of industrial applications because of their high specific strength, light weight and corrosion resistance. Therefore these alloys motivate considerable interest to the aviation industries [4, 5].

AMCs have found wide applications in our daily life. There are some advantages in using particles reinforced AMCs materials than unreinforced materials such as- greater strength and high specific

modulus, improved stiffness, light weight, low thermal expansion coefficient, high thermal conductivity, tailored electrical properties, increased wear resistance and improved damping capabilities. Reinforcing constituents can be incorporated within the matrix in the form of particles, short fibers, continuous fibers or mono filaments. Now it is used in aerospace, thermal management areas, industrial products, automotive applications such as engine piston, brake disc [6]. The research work presented here is aimed at improving and also comparing the mechanical properties of AA 6063/SiC composites by adopting cold rolling and solution heat-treatment in combination as a secondary processing stage using spin and sand casting methods.

### MATERIAL

The AA6063 was utilised for this research with chemical composition shown in Table 1.

Table 1. Chemical Composition of AA6063

Element (%)	Si	Mg	Fe	Mn
	0.48	0.86	0.46	0.9
Element (%)	Cr	Zn	Ti	Al
	0.04	0.005	0.01	98.82

### METHODS

The two casting methods used were spin and sand casting

#### Mould Preparation

A woodworking lathe machine model MCF3020 was used to machine the wooden pattern materials obtained from hard wood that produced the pattern, sprue and risers with adequate taper. The

patterns were dimensioned 300 mm long and of different diameters; 15 mm, 20 mm, 30 mm, 35 mm. The size of the patterns was made 2% oversize than the specified dimension to compensate metal contraction during solidification. The down sprue of diameter 50 mm, was tapered to diameter 40 mm and 30 mm long was also made.

The mould is prepared with green sand being the main material used which comprises of the mixture of bentonite, recycled silica sand and water. The green sand has good permeability, good grain size, accurate moisture content and with a very good refractoriness which can withstand heat at very high temperature. Bentonite is added to the green sand to increase its bonding strength. Suitable moulding boxes is first selected, large enough to accommodate the pattern of its varying sizes and then rammed slowly but with good force. Facing sand was mixed into the drag and the content was well rammed. The drag was turned upside down on the mould board, the pattern as well as its accessories were placed on the board inside the flask in such a position that space is left for gate cutting. The excess sand will be cut off to bring it in line with the edge of the cope, a parting sand was properly applied for the easy removal of the mould from the pattern. The gating system was properly designed for smooth channeling of the molten metal into the mould cavities through the sprue, runner, in-gates and riser that were perfectly placed in position [2]. The cope was placed over the drag and top parts of the pattern assembled in position.

#### Melting and Charging

Charge calculation was worked out to determine the quantities of Aluminium (6063) and silicon carbide required to produce the composite. Prior to charging, the crucible furnace was checked to prevent leak of molten metal and also to guide against moisture, which can generate vapour during melting. The Aluminium (6063) ingot were charged into the crucible furnace and heated to 700°C with the introduction of silicon carbide. The molten composite was then cast into prepared spin casting mould and stationary sand moulds.

#### Cold Rolling and Heat Treatment

The products from spin and sand casting were subjected to cold deformation using a miniature cold rolling machine. The cold rolling operation was performed using a round orifice to 10% degree. The heat treatment procedure carried out on 10% cold rolled spin and sand samples involved heating the samples to a single-phase solid solution temperature of 520°C and held for 1hour at this temperature before cooling rapidly in water.

#### Density Measurement

The determination of the experimental densities of the various casting products were carried out

measuring the weight of the test samples using a high precision electronic weighing balance with a tolerance of 0.1mg. The weights of the measured samples were divided by their respective volume. The theoretical density was evaluated by using the rule of mixtures given by:

$$\rho_{AA6063/SiC} = \text{Vol. AA 6063} \times \rho_{AA6063} + \text{Vol. SiC} \times \rho_{SiC}$$

where,

$\rho_{AA6063}$  = Density of aluminium alloy, Vol. Al 6063 = Volume fraction of AA 6063, Vol. SiC = Volume fraction SiC, and  $\rho_{SiC}$  = Density of SiC,

$$\text{Experimental density} = \frac{\text{mass of the sample}}{\text{volume of the sample}} \quad (1)$$

The percentage porosity of the cast aluminium was determined by use of equation

$$\% \text{ Volume porosity} = \frac{\rho_{cal} - \rho_{exp}}{\rho_{cal}} \quad (2)$$

where  $\rho_{cal}$  = Theoretical Density ( $\text{g}/\text{cm}^3$ ),  $\rho_{exp}$  = Experimental Density ( $\text{g}/\text{cm}^3$ ) [7, 8]

#### Tensile Properties Determination

Universal testing machine was used to determine the tensile strength, uniaxial tension tests were performed on the samples after cold rolled and heat treated. The testing was performed using an instron universal testing machine for spin casting sample and stationary casting sample respectively. Four repeated tests were performed for each test condition to guarantee reliability of the data generated. The tensile properties evaluated from the stress-strain curves developed from the tension test were ultimate tensile strength ( $\sigma_u$ ), and yield strength ( $\sigma_y$ ).

#### Metallographic Examination Procedure

The microstructures for each cast products were investigated. The specimens were prepared for optical examination by polishing using series of emery papers of grit sizes ranging from 600 $\mu\text{m}$  – 60 $\mu\text{m}$ , while fine polishing was performed using polycrystalline diamond suspension of particle sizes ranging from 10 $\mu\text{m}$  – 0.5 $\mu\text{m}$  with ethanol. The samples were etched using 2% nital before the microstructure examination was performed, using optical metallurgical microscope of model AX10 (ZEISS).

#### RESULTS AND DISCUSSIONS

The effect of casting methods on the deformation of AA6063/SiC products with 10% cold rolled and solution heat treated were given in fig.1. The ultimate tensile strength (UTS) for spin casting is 51.42MPa and 22.38MPa for sand casting while the yield strength (YS) for spin casting is 47.01MPa and 22.93MPa for sand casting. The reasons for the low UTS and YS in sand casting is as a result of clustering of SiC in the aluminium matrix even after cold rolled and heat treated and while for spin casting there were even distribution and

homogenization of SiC and after cold rolled and heat treated, there were more distribution of SiC which enhance the yield strength and ultimate tensile strength.

Table 2. Tensile Strength Result

Casting methods	AA6063 alloy products, 10% cold-rolled + solution heat-treated	
	Yield strength (YS) (MPa)	Ultimate tensile strength (UTS) (MPa)
Spin casting	47.01	51.42
Sand casting	22.93	22.38

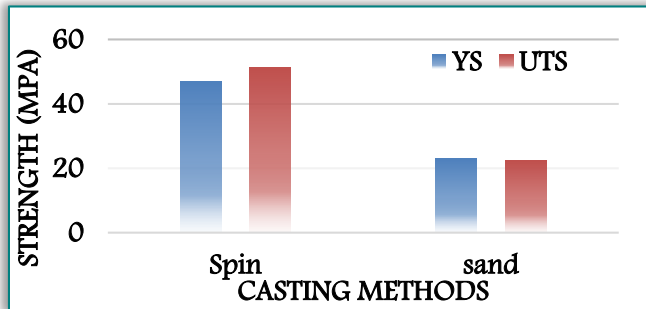


Figure 1. Tensile strength of cast AA6063/SiC, 10% cold-roll with solution heat-treated

#### Rockwell hardness test

The results obtained from hardness test conducted using the Rockwell hardness test method and four indentations are presented in table 3.

Table 3: Hardness test (HRA)

Casting methods	Cast AA6063/SiC products, 10% cold-roll + solution heat-treated				
	1st	2nd	3rd	4th	Average
Spin casting	43.4	50.7	57.6	57.2	52.7
Sand casting	53.0	49.7	54.3	50.0	49.5

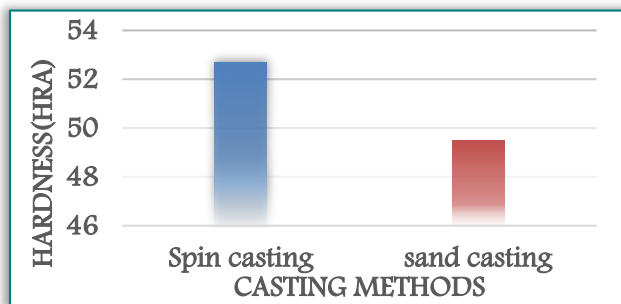


Figure 2. Hardness of cast AA6063/SiC, 10% cold-rolled and solution heat-treated

The hardness of the test samples varies with the methods used, from Figure 2 it was observed that spin casting had higher hardness than sand casting, this is as a result of crystal lattices of SiC precipitates in spin casting which show coherency with that of the aluminium phase, and these two elements (silicon and carbide) form the primary hardening phase (silicon carbide, SiC) in aluminium alloy 6063 [9]. Consequently, severe strain fields are created around these crystals which impede the motion of dislocations and thereby causing increased hardness of castings obtained in spin casting [10]. The variation found in hardness of the

two cast products may also be attributed to their porosity and density.

Table 4: Percentage Porosity

Types of casting	Theoretical density (g/cm <sup>3</sup> )	Experimental density (g/cm <sup>3</sup> )	Porosity (%)
Spin	2.75	2.73	0.74
Sand	2.75	2.66	1.48

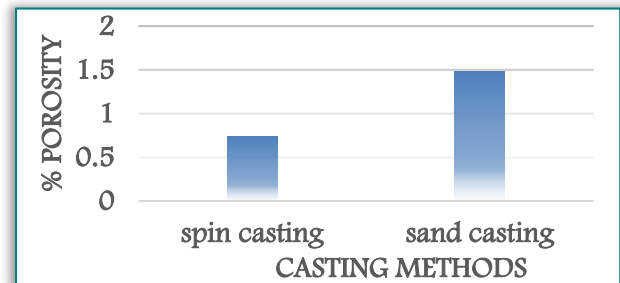


Figure 3: Percentage Porosity for cast AA6063/SiC, 10% cold rolled and solution heat treated

#### Percent Porosity

The percent porosity of the as-cast for spin casting and sand casting, also 10% cold rolled and solution heat treated AA6063/SiC for spin and sand casting were presented in figure 3. It was observed that as-cast sand casting has higher porosity percentage in comparison with as-cast spin casting, which can be attributed to the spin machine which compresses the alloys thereby aiding the collapse of voids, micro-cracks vacancies in the alloy making it more compacted. When the as-cast for spin and sand casting were 10% cold rolled and solution heat treated, there were reductions in percentage porosity with sand casting still having higher percentage porosity of 1.48 when compared with spin casting 0.74. It was cleared that cold rolling and solution heat-treating aids in reducing the percentage porosity, thereby improving the quality of the cast product, therefore it could be deduced that cold rolling and solution heat treating helps in collapse of voids, micro-cracks thereby making the cast products compact and denser.

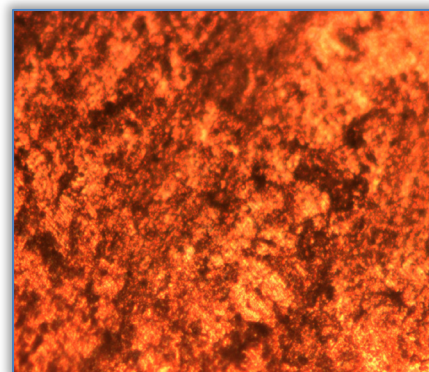


Plate (a) Micrograph of cold rolled and solution heat treated AA6063/SiC for spin casting (X200)



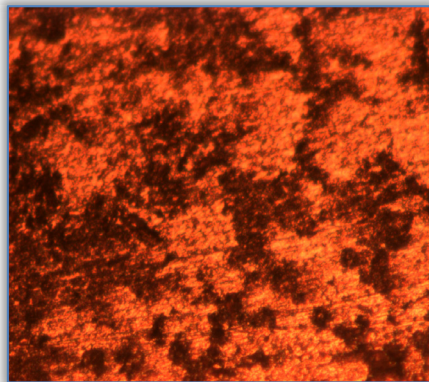


Plate (b) Micrograph of cold rolled and solution heat treated AA6063/SiC for sand casting (X200)

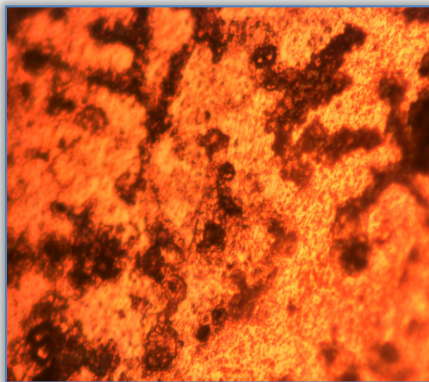


Plate (c) Micrograph of as-cast spin casting for AA6063/SiC (X200)

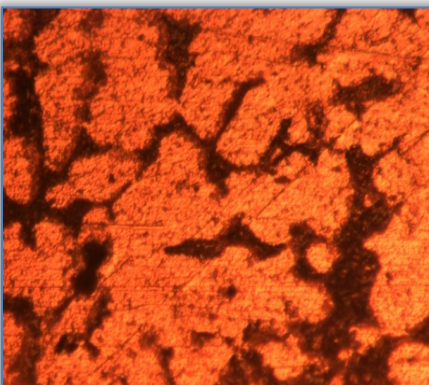


Plate (d) Micrograph of as-cast sand casting for AA6063/SiC (X200)

### Microstructure

Plate (a) and (b) shows optical photomicrographs for spin and sand casting of AA6063/SiC which were 10% cold rolled and solution heat-treated conditions. SiC particulates were observed to be well dispersed in the cold rolled and solution heat-treated in spin casting when compared to sand casting which was also cold rolled and solution heat treated. This is a clear indicator that the cold rolling and solution heat-treatment processes helped in achieving a homogenization of SiC particles in aluminium matrix and reduced particle clusters in the composites produced. In plate (c) and (d) which shows the as-cast for spin and sand casting, it was

observed non homogenization of SiC particles in aluminium matrix in sand casting whereas in spin casting the SiC were well dispersed aluminium matrix which may be attributed to shaking and movement of spin casting machine.

### CONCLUSIONS

In this experimental study, where SiC content were made constant for spin and sand casting and thereafter cold rolled and heat treated, the following conclusions can be expressed.

- (a) Clustering and non homogenization of SiC particles in aluminium matrix of as-cast sand casting was observed, while as-cast for spin casting, the SiC were dispersed.
- (b) When cold rolled and heat treated, both the spin and sand casting products show appreciable dispersion of SiC in aluminium matrix in which spin casting was better.
- (c) The hardness, ultimate tensile strength and yield strength in spin casting were better than sand casting.

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