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バージョン：

Fabrication of a Hybrid Metal Matrix Composite of Al 6082, SiC, Graphite and Mg

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Abstract: Hybrid composites of Aluminum are emerging composites and have shown to yield great strength to weight ratio which is majorly one of the key features for being implied in the field of aerospace, parts of vehicles and other engineering applications. Test results showed a respectively lower tensile strength as compared to the parent metal (Al-6082), but higher hardness. The Optical Microstructure showed uniform distribution of the reinforcements with proper wetting and fine grains having size 9 µm – 18 µm.

Keywords: Hybrid composites, Stir Casting Process, Strength to weight ratio, Al 6082.

1. Introduction

When more than one reinforcing materials are embedded in a composite material, it's known as a hybrid composite. Hybrid composites can be effortlessly fabricated using Stir casting process. Such a hybrid composite is expected to exhibit better performance and enhanced set of properties.

2. Material preparation

The materials used were Al-6082, Silicon Carbide, Graphite and Magnesium. Other materials were green molding sand, water, saw dust and Bentonite clay which were used for preparing casting mold. A brief description of the materials used along with some of their noteworthy properties is given below:

Table 1. Properties of Al-6082

Properties	**Value**
Hardness	40-95 HB
Tensile Strength	140Mpa to 330 MPa
Young's Modulus	69 Gpa
Shear Strength	84 Mpa to 220 Mpa
Melting Temperature	580 º C – 650 º C
Density	2.7 g·cm^{-3}

2.1. Matrix Metal

I have used Al-6082 as my matrix material. Its properties are depicted below in the tables

Table 2: Chemical Composition of Al-6082

Element	**Percentage**
Al	95%-98%
Si	0.7%-1.3%
Mg	0.6%-1.2%
Mn	0.4%-1%
Fe	0%-0.5%
Cr	0%-0.25%
Zn	0%-0.2%
Ti	0%-0.1%
Cu	0%-0.1%
Others	0%-0.15%

2.2. Reinforcement materials

I have used Silicon Carbide, Graphite and Magnesium as reinforcement materials. Following are some of the reasons to use above materials as reinforcements for my Al-6082 metal.

- Silicon Carbide addition yields a composite with high hardness, brittleness and increased wear resistance, but due to its high hardness and abrasive nature it in turns makes the material prone to produce higher friction between contacting surfaces. About 6% of Silicon Carbide was mixed with the matrix material.

- Graphite has great lubricating properties which helps in reduction of brittleness and friction produced due to silicon carbide particles, but these particles have a poor wettability. About 4% of graphite was mixed the matrix material.
- An insignificant amount of Magnesium element is added to this composite which reacts with the oxygen present in the atmosphere rapidly so that aluminum is not able to get oxidize and hence helps in providing better wettability to the reinforcements with the aluminum alloy. About 1% of magnesium was mixed. Some of the key properties of the reinforcing materials are jotted below

Table 3: Properties of reinforcing materials

Reinforcement	Property	Value
Silicon Carbide	Melting point	2,830 °C
	Particle size	500 Mesh
	Density	3.16 g·cm^{-3}
Graphite	Melting point	3600°C
	Particle size	600 Mesh
	Density	2.23 g·cm^{-3}
Magnesium	Melting point	650 °C
	Particle size	36 Mesh
	Density	1.738 g·cm^{-3}

Below are the images of reinforcing materials**:**

Figure 1. Silicon Carbide, Graphite, Magnesium

3. Preparation of mold:

Sand casting process was used for preparation of the casts. The pattern used was of cuboid shape and had a dimension of. The material of the pattern used was also Al 6082. Several allowances like shrinkage allowance (6%), machining allowance (1%), draft allowance (1˚-2˚).

Green sand was prepared for the casting process by mixing silica sand, with 20% Bentonite clay and 6% to 8% of water and about 4% of coal dust. Single piece pattern was used and two patterns were placed in the molding flask at once. A metallic molding flask was used which had a dimension of.

Gates were build according to the requirement for consistent flow of metal in the mold cavity. A riser and a sprue with tapered surfaces was used for filling the mold cavity properly and for avoiding defects.

Collapsibility, strength and hardness of the molding sand was tested while preparing the mold using various instruments like mold hardness tester, universal sand strength machine, compactability tester. Following is a table showing properties of the molding sand prepared:

Table 4: Properties of the molding sand

PROPERTY	VALUE
Hardness	6
Compressive strength	11.05 kN/m^2
Permeability number	200

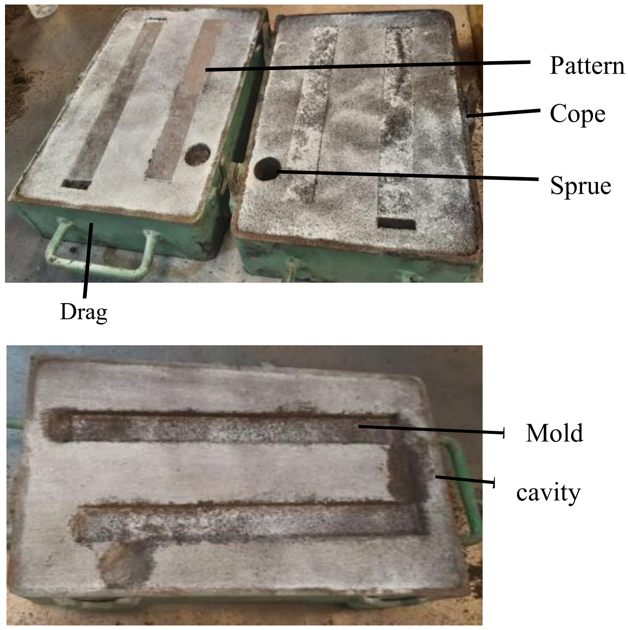

Figure 2 Images of Molding box

4. The Stir casting process:

The stir casting process was used to prepare the composite material. It is the best suited method to produce such a hybrid composite in bulk with simplicity and lower production cost. Figures 3(a) & 3(b) show the stir casting setup used for the process. Steps involved in the casting process are as follows:

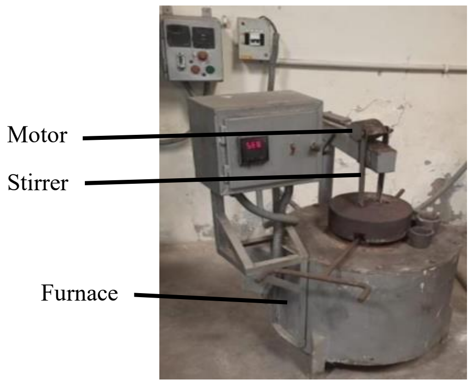

Figure 3(a): Stir Casting Setup

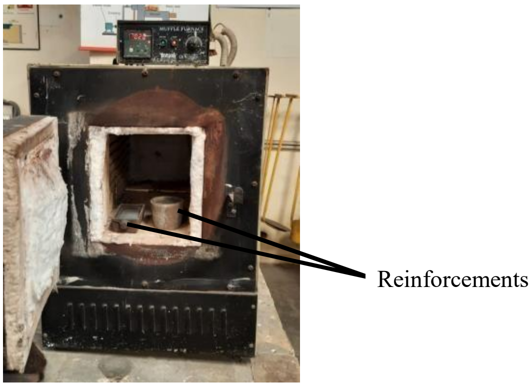

Figure 3(b): Muffle Furnace

Step 1*:* First the stir casting furnace was preheated to about 300˚C and the muffle furnace was also preheated. The Al was divided into smaller sized pieces and weighed along with the reinforcements, 89% by weight Al was taken, 6% by weight SiC, 4% by weight Graphite and 1% by weight Mg.

Step 2: The crucible had a capacity to hold about 2 kg of metal mixture. The Al was then transferred to the Stir casting furnace in a cast iron crucible for melting while the SiC and the Graphite were also kept in the Muffle furnace for preheating in order to remove any extra moisture present in them.

Step 3*:* After the metal has been melted, the reinforcements viz; SiC, Graphite and Mg, which was wrapped in an Al foil to avoid any accidents, were then gradually added to the molten metal while a consistent stirring speed was maintained.

Step 4: Some of main parameters in this process are stirring speed and stirring time. The stirring speed was then maintained of 600 rpm and the stirring was carried out for about 6 minutes consistently. Proper safety measures were taken into account in order to avoid accidents because as the speed is increased, chances of spatter increase.

Step 5*:* After 6 minutes of continuous stirring the molten mixture was then poured into the molding box and after the metal has cooled the casts were taken out.

Following figures show glances of the process throughout:

Figure 4(a): Weighing of the materials (Al, SiC, Graphite, Mg)

Figure 4(b): Stirring and addition of the reinforcements

Figure 4(c): Pouring of the prepared mixture

Figure 4(d): Prepared casts

5. Results and conclusions:

The cast was successfully prepared using this stir casting process. The cast thus obtained was having following properties:

- The tensile strength of the cast was found to 118 Mpa, this predicts that the material has somewhat turned brittle.
- The yield stress obtained from the UTM is 64 Mpa, hence the ductility of the material has decreased to a large extent.
- The melting temperature range of this material was found out to be 720˚C 800˚C.
- The material thus obtained is difficult to machine using conventional machining processes, nontraditional machining processes must be preferred for the machining of the material.

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