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A Study On Mechanical And Machinability Characteristics Of Hybrid Metal Matrix Composite

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ABSTRACT
Aluminum based matrix composites remain the most explored metal matrix material for the development of MMCs. In the present study, the effect of Silicon carbide, Boron carbide on Stir cast Aluminum Metal Matrix Composites is discussed. Graphite is used as a lubricant. Aluminum Metal Matrix Composites with Silicon carbide and Boron carbide particle reinforcements are finding increased applications in aerospace, automobile, space, underwater, and transportation applications. The hybrid metal matrix composite which consists of aluminum and other constituents such as graphite, silicon carbide and boron carbide are to be casted and are further employed to different testing such as hardness test, compression test, tensile test, impact test, micro hardness and micro structural analysis. Further it is machined to know its characteristics. Conventional stir casting process has been employed for producing discontinuous particle reinforced metal matrix composites.
Keywords: Metal Matrix Composites, Aluminum, Silicon Carbide, Boron Carbide, Stir casting.

I. INTRODUCTION

Many of our modern technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics, and polymeric materials.
This is especially true for materials that are needed for aerospace, underwater, and transportation applications. Aluminum based matrix composites remain the most explored metal matrix material for the development of MMCs (Surappa *et al*, 2003). In AMCs one of the constituent is aluminum alloy, is termed as matrix phase. The other constituent is embedded in this aluminum/aluminum alloy matrix and serves as reinforcement, which is usually non-metallic and commonly ceramic such as silicon carbide and boron carbide. When these composites reinforced with silicon carbide particles there is an improvement in yield strength, lower coefficient of thermal expansion, higher modulus of elasticity and more wear resistance than the corresponding non-reinforced matrix alloy systems, Boron Carbide particulate reinforced aluminum composites possess a unique combination of high specific strength. Hence here the two ceramics namely boron carbide and silicon carbide both are reinforced as a particulate in aluminum matrix.

II. SELECTION OF MATERIALS

3.1 ALUMINUM

Aluminum is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. It is a good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical, while having only 30% of copper's density. Structural components made from aluminum and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The aluminum which was selected is 99.8% pure.

3.2 SILICON CARBIDE

Silicon carbide can be used as reinforcement in the form of particulates, whiskers or fibers to improve the properties of the composite. They possess extremely high thermal, chemical, and mechanical stability. Silicon carbide ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600°C with no strength loss. When embedded in metal matrix composites SiC certainly improves the overall strength of the composite along with corrosion and wear resistance. Aluminum MMCs reinforced with SiC particles have up to 20% improvement in yield strength, lower coefficient of thermal expansion, higher modulus of elasticity and more wear resistance than the corresponding un-reinforced matrix alloy systems. For these reasons silicon carbide particulate reinforced aluminum composites have found many applications such as brake discs, bicycle frames, aerospace and automotive industry (A.K. Vasudevan *et al* 1995 and B. Roebuck 1987).

3.3 BORON CARBIDE

Boron Carbide particulate reinforced aluminum composites possess a unique combination of high specific strength, high elastic modulus, good wear resistance and good thermal stability than the corresponding non-reinforced matrix alloy system. A limited research work has been reported on AMCs reinforced with B4C due to higher raw material cost and poor wetting. B4C is a robust material having excellent chemical
and thermal stability, high hardness (HV = 30 GPa), and low density (2.52 g/cm^3) and it is used for manufacturing bullet proof vests, armor tank, etc. Hence, B4C reinforced aluminum matrix composite has gained more attraction with low cost casting route (Kerti and Toptan, 2008; and Toptan *et al.*, 2010).

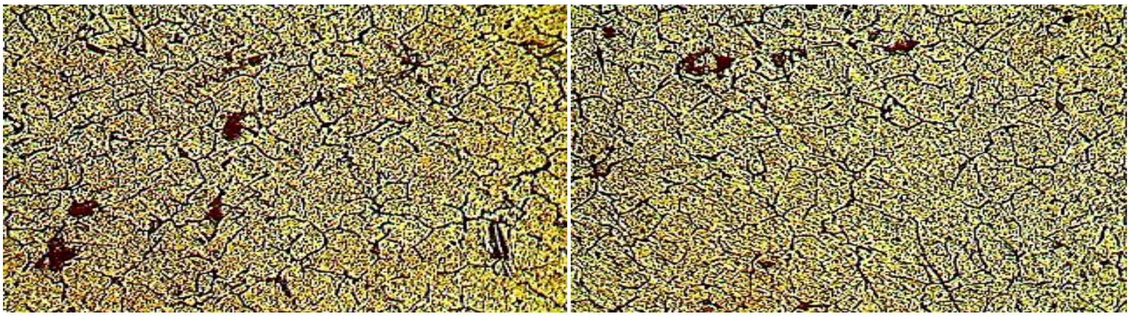
The composition of hybrid metal matrix composite is given below.

Table 1.1 Composition of hybrid composite

SI .N O	ALUMINUM	GRAPHITE	SILICON CARBIDE	BORON CARBIDE
1	**90%**	**2%**	**2%**	**6%**

4.2 CASTING PROCESS

According to the type of reinforcement, the fabrication techniques can vary considerably. From the contributions of several researchers, some of the techniques for the development of these composites are stir casting/ Compocasting (Y.H. Seo et al 1999), powder metallurgy (X. Yunsheng et al 1998), spray atomization and co- deposition (C.G. Kang et al 1997), plasma spraying (Y.H. Seo et al 1995) and



Magnification: 150X Etchant: Kellar's Reagent soln.

Figure 1.2 Micro structure of hybrid composite

squeeze-casting (S. Zhang et al 1998). The above processes are most important of which, liquid metallurgy technique has been explored much in these days. This involves incorporation of ceramic particulate into liquid aluminum melt and allowing the mixture to solidify. Here, the crucial thing is to create good wetting between the particulate reinforcement and the liquid aluminum alloy melt. The simplest and most commercially used technique is known as vortex technique or stir-casting technique. The vortex technique involves the introduction of pre-treated ceramic particles into the vortex of molten alloy created by the rotating impeller.

Ceramic particles and ingot-grade aluminum are mixed and melted. The melt is stirred slightly above the liquidus temperature (600−700°C). Stir casting offers better matrix-particle bonding due to stirring action of particles into the melts.

3.4 GRAPHITE

Natural graphite is an excellent conductor of heat and electricity. It has a good lubricating property. It is stable over a wide range of temperatures. Graphite is a highly refractory material with a high melting point (3650 ^{o}C). It is used as a lubricant.

Figure 1.1Stir Casting method of casting

III. METHODOLOGY

4.1 COMPOSITION

IV. RESULTS AND DISSCUSSION

5.1 MICRO STRUCTURAL ANALYSIS

Using Optical Metallurgical microscope, the distribution of silicon carbide and boron carbide inside the aluminum matrix for is investigated.

It is identified that the distribution of ceramic particles inside the matrix of aluminum is uniform over the matrix, which is maintained by stirring it for a period of 10 min and the uniformity is verified in the microstructure. The ceramic particles appear black against a bright background. The microstructures of the composites for various proportions are shown in Figure 1.4. It is observed that, the distribution of aluminum particles is more even. The average size of the aluminum particles visualized is 100 µm.

5.2 MICRO HARDNESS TEST

Micro Hardness Testing of metals, composites and ceramics are employed where a 'macro' hardness test is not usable. Micro hardness tests can be used to provide necessary data when measuring individual microstructures within a larger matrix, or testing very thin foil like materials, or when determining the hardness gradient of a specimen along a cross section. Here Vickers hardness test is carried out for the hybrid composite material. The Vickers hardness test uses a square-based pyramid diamond indenter with an angle of 136º between the opposite faces at the vertex, which is pressed into the surface of the test piece using a prescribed force, *F*. The time for the initial application of the force is 2 s to 8 s, and the test force is maintained for 10 s to 15 s. After the force has been removed, the diagonal lengths of the indentation are measured and the arithmetic mean, *d*, is calculated. The Vickers hardness number, *HV*, is given by:

HV = Constant × Test force / Surface area of indentation

$$= 0{\cdot}102 \times 2F\left(sin\frac{136^\circ}{2}\right)\Big/d^2$$

At 0.5 Kg load the hybrid composite is tested, the Vickers Hardness (H.V) obtained was 49.3 H.V, 47 H.V and 50.0 H.V.

5.3 TENSILE TEST

The basic idea of a tensile test is to place a sample of a material between two fixtures called “grips” which clamp the material. The material has known dimensions, like length and cross-sectional area. We then begin to apply weight to the material gripped at one end while the other end is fixed. We keep increasing the stress while at the same time measuring the change in length (strain) of the sample.

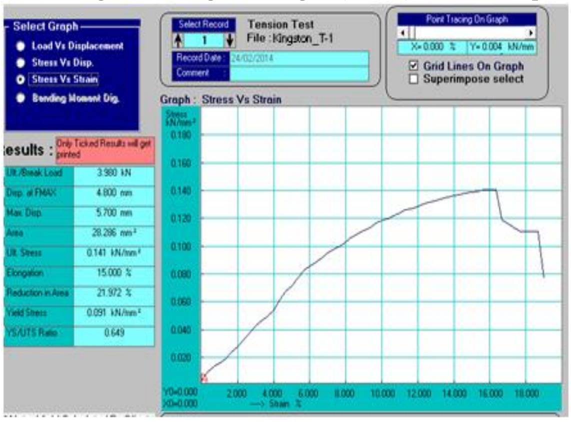


Figure 1.3 Tensile test

It is found that the strain value increases proportionally as the stress value increases for a maximum limit and further as the stress increases the strain drops.

5.3 COMPRESSIVE TEST

A Compressive test is a mechanical test measuring the maximum amount of compressive load a material can bear before fracturing.

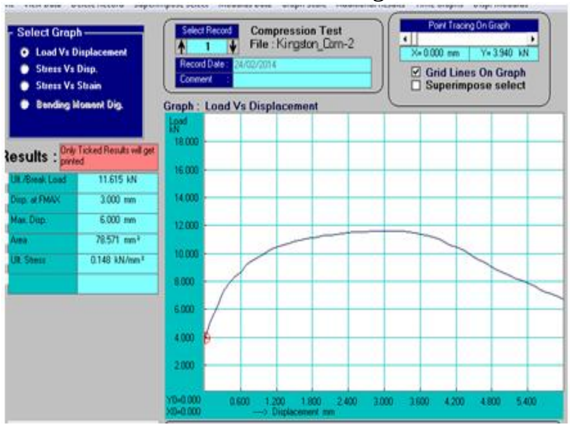


Figure 1.4 Compressive testing

The test piece, in the form of a cylinder, is compressed between the platens of a compression-testing machine by a gradually applied load. The specimen is compressed and deformation at various loads is recorded and the corresponding displacement is noted. The ultimate load is 12.010 KN. It is found that at maximum load 12.010 KN the displacement is 2.300 mm.

V. CONCLUSION

Various proportions of silicon carbide and boron carbide particles are mixed with aluminum matrix were casted by stir casting method and they are employed for testing. The mechanical strength of the composite is characterized by compression test, tensile test, micro hardness, and the machinability characteristics were also determined and optical metallurgical microscope is employed to investigate distribution of ceramic particles inside the composite.

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