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Experimental investigation of mechanical and tribological properties of AA7065- B_4C nano-composite

A.B Madan[1*], *A.*Parthiban[2]
[1]Research Scholar, Mechanical Engineering, Vels Institute of Science, Technology & Advanced Studies, Chennai
[2]Mechanical Engineering, Vels Institute of Science, Technology & Advanced Studies, Chennai.

Abstract. The present study used the stir casting technique to create hybrid composites employing aluminium AA 7065 alloy for the matrix and boron carbide reinforcements. In order to study the high-temperature tribological behaviour of aluminium boron carbide composites, the pin-on-disc method with pin heating setup was adopted. As a supplemental reinforcing material, fly ash particles were used due to their exceptional mechanical, metallurgical, and tribological properties. Microhardness testing, microstructure analysis, and tensile testing were all carried out. The wear rate of hybrid composites was studied on load, sliding velocity, and temperature. Mechanical properties and particle distribution were vastly improved during the testing phase. Although the ductility of hybrid composites was down, their tensile and compression strengths increased dramatically. The surface morphology of the pin was analyzed using a high-resolution scanning electron microscope. The impact of wear parameters on wear rate was analyzed using analysis of variance.

1 Introduction

Traditionally, researchers worldwide in materials have mostly concentrated on producing lightweight, high-performance, cost-effective, and energy-efficient materials for industrial usage. In order to achieve this goal, material scientists have endeavoured to create an Aluminum Matrix Composite (AMC) material that exhibits an outstanding blend of physical, mechanical, electrochemical, and tribological characteristics. Hence, this material possesses a diverse range of applications in the fields of aerospace engineering, defence engineering, car engineering, and general engineering. AMCs are individualized materials that can be created and manufactured according to the requirements of a particular application.

In most cases, particle fillers are used in metal moulds for a variety of reasons, including but not limited to the following: cost reduction, improved dispensing, thermal conductivity, density control, control of thermal extension, magnetic properties, electrical properties, improved hardness, and superior wear resistance [1]. Currently, there is

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* Corresponding author: abmadan23@gmail.com

widespread use of rigid particulate fillers composed of ceramic or metal particles, such as SiC, Al2O3, graphite, aluminium diboride, cemented carbide, tungsten carbide, boron carbide (B4C), NiAl, TiC, Si3N4, MoSi2, Mg, and TiB2, in order to significantly enhance the performance of metal-based composites [2]. Some researchers are exploring the possibility of using industrial waste products such as fly ash [3, red mud [4, and copper slag] as reinforcement in metal matrix composites to enhance the particular features of these materials. Particulate and metal matrix composites have mechanical properties strongly dependent on the constituent part size, particle-matrix crossing point adhesion, and particle load. Efforts have been made towards increasing the raised temperature property of alloy structures by alloying elements with a high melting point, such as manganese, nickel, and silicon, or by utilizing resources of distributed hard next-phase particles [5]. This study investigated the influence of nanoparticles based on aluminium and magnesium on improving mechanical properties [6]. According to the findings of this study, the proof stress of 0.2%, tensile strength, and ductility all decrease with increasing particle size [7]. Typically, the stress transfer between the particles and the matrix significantly contributes to the composite's strength [8]. When it comes to particles with fine bonds, the useful stress can be transferred to the particles from the matrix effectively, increasing potency.

On the other hand, it was discovered that a drop in efficacy had occurred for only weakly linked micro-particles [9]. Research on porosity nucleation in metal composites has shown that reinforcement coatings, such as Cu on SiC, decrease the contact angle and enhance the wettability of the interface. The present finite element analysis investigated the macroscopic and microscopic interactions of particulate-reinforced metal matrix composites (MMCs). Metal matrix composites incorporating metal particles find wide-ranging applications in various fields, such as automotive, optomechanical, and aerospace industries. They are utilized in thermal management systems, gas turbine mechanisms (specifically fan exit lead vanes), ventral fins, fuel access cover doors in military aircraft, helicopter turning blade sleeves, and other similar applications [10].

The current research focuses on the synthesis as well as the evaluation of the mechanical and tribological behaviour of the AA7065 alloy base composite with the reinforced B_4C particles. The purpose of this research is to create a composite that may be used in various automotive applications, such as for pistons and piston rings, as well as cylinder blocks, and so on.

2 Experimental Methodology

2.1 Materials Selection

2.1.1 AA7065 alloy

Alloy 7065 can be utilized in key intermediate thickness applications instead of alloys 7010, 7050, 7075, and 7475 due to its high strength, fracture toughness, and corrosion resistance. It made possible by alloy 7065's excellent combination of these characteristics. This is because the material possesses both high strength and fracture toughness, which makes it possible for this to happen. These include, but are not limited to, structural parts that have been integrally machined, such as spars and ribs, and they are suitable for use in brand-new aircraft, aircraft that have been modified, or aircraft that have been retrofitted. Al 6065 solid cube is shown in Figure 1.

Table 1. Chemical composition of the 7065 alloys (wt.%)

Zn	Cu	Mg	Ti	Zr	Al
7.6	2.1	1.7	0.02	0.1	Balance

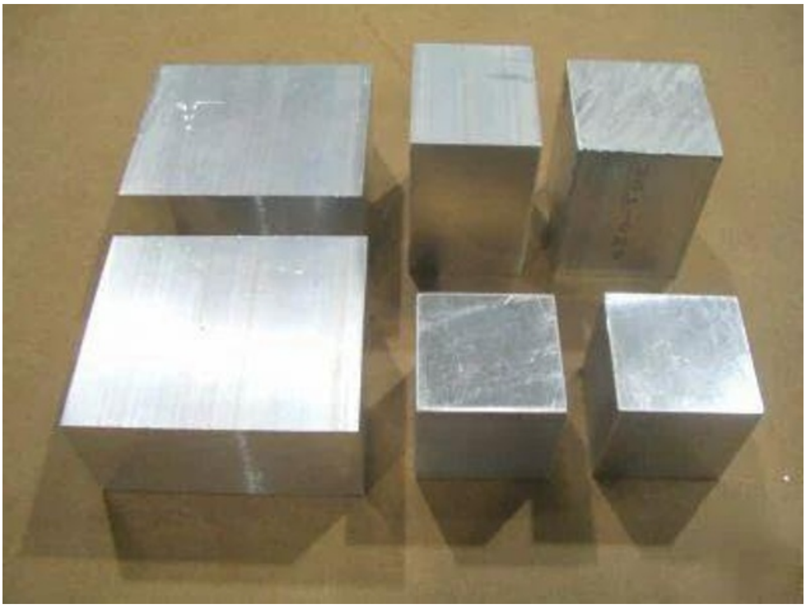

Fig. 1. AA 7065

2.1.2 Boron Carbide

Boron carbides are the third hardest known substance, following diamond and cubic boron nitride. As a result, they have been given the nickname "black diamond." Boron carbide has the formula "B_4C" in the chemistry world. Boron carbon ceramic is known for its exceptional hardness and is utilized in various engineering applications, as shown in Figure 2. These uses include tank armour, bulletproof vests, and engine sabotage powder.

Fig. 2. Nano B_4C Powder

2.2 Fabrication Process

Figure 3 depicts the stir-casting arrangement that was employed. It includes a resistance-type muffle furnace, an assembly stirrer, and a probe assembly to produce composites. The stirrer assembly comprises one stirrer attached to a variable speediness vertical type drilling machine with a steel shaft on the end where the stirrer blade was attached. The use of a muffle furnace, seen in Figure 3, is required to bring the Boron Carbide reinforcement temperature up to 350 degrees Celsius for preheating. The equipment was used for at least one hour to remove moisture and gas from the surface of these particles and prevent a substantial decrease in temperature following their insertion.

The stirrer is started to control the temperature, and once that has been accomplished, the reinforcement B_4C is added to the molten alloy. The mechanical stirrer is turned off for fifteen minutes during each stage of the process, both before and after the introduction of the reinforcement. Since the bottom is also running at a speediness of 250 rpm, the stirrer is positioned so that it is just about to the depth of about 2/3 of the height of the molten metal. The speed of the stirrer is gradually increased until it reaches 800 revolutions per minute. After that, the reinforcement B_4C particles were stirred into the melt using a spoon of 15-20 grammes per minute. The speed control ensured that the stirrer operated consistently; however, the speed of the stirrer decreased to somewhere between 55 and 60 revolutions per minute (rpm) due to the increased viscosity of the melt caused by the addition of particles. After the reinforcement had been added, the stirrer continued for twenty to twenty-five minutes in order to ensure an accurate mixing of the prepared particles into the matrix.

Fig. 3. Stir Casting Machine Setup

The AMC was made using three distinct compositions, which were AA7065 plus 3% B_4C, AA7065 plus 5% B_4C, and AA7065 plus 7% B_4C, respectively.

3 Result and Discussion

3.1 Hardness

It was discovered that raising the weight percent of boron carbide (B_4C) increased the hardness of amorphous metal composites (AMCs). The hardness of a composite is contingent upon both the weight percentage of the reinforcement and the matrix. Figure 4 displays the outcomes of the comprehensive tests conducted on the object's hardness. The results show that boron carbide influences the hardness range of the AMMC composite. The maximum hardness value is 62HB in 93%-AA7075 7%-B_4C.

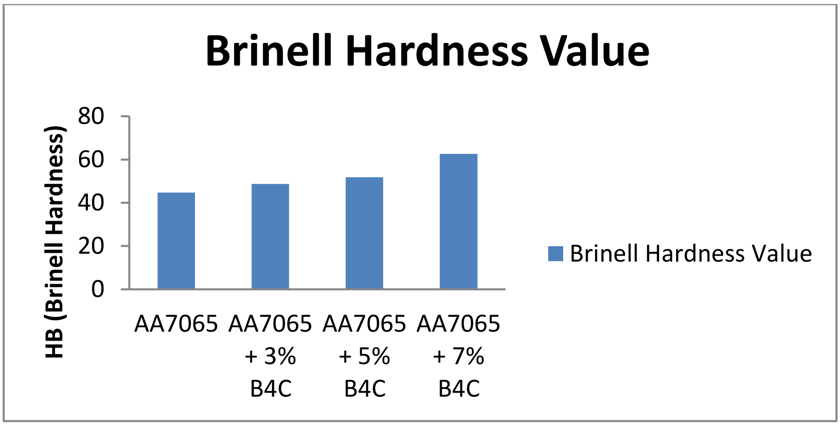

Fig. 4. Brinell Hardness values

3.2 Tensile Stress

Figure 5 shows how the composite's tensile strength increases as more B_4C reinforcement is included in the material. The rise in Ultimate Tensile Stress may be traced back to the matrix alloy's improved strength thanks to the incorporation of hard Boron Carbide particles, which also boost the alloy's resistance to tensile stresses. The Value of tensile stress is indicated in megapascal. The presence of these particles in the matrix alloy explains the observed behaviour. The space between the tough Boron carbide particles shrinks as the concentration of particles rises. As a result, the backlog of relocations grows even larger. Since the particles are dispersed randomly throughout the matrix, this causes a restriction in the plastic flow. The composites' tensile strength improves as a result. The result shows the maximum Tensile stress 269MPa archived in 93%-AA7075 7%-B4C.

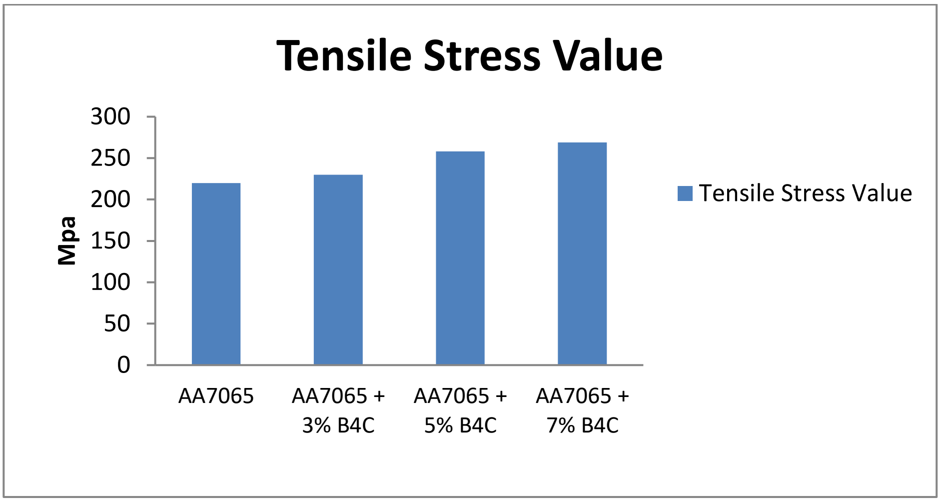

Fig. 5. Ultimate Tensile Stress values

3.3 Wear Test

The findings of the wear tests conducted on the AA7065 composites and the unreinforced specimens while they were subjected to a dry sliding condition have been displayed in Figure 6. The weight loss of the test specimens during sliding was used to compute the wear rate of the specimens, and the result was expressed in millimetres per metre (mm3/m). The wear test was carried out with three different loading circumstances: a sliding velocity of 10 Newton metres per second, a speed of 1.57 metres per second, and a sliding distance of 1600 metres. The examination was conducted on three combinations of the composite's components: AA7065 plus 3%, 5%, and 7% by weight of B4C, respectively. The higher wear rate percentage occurs in 97%-AA7075 3%-B4C composite.

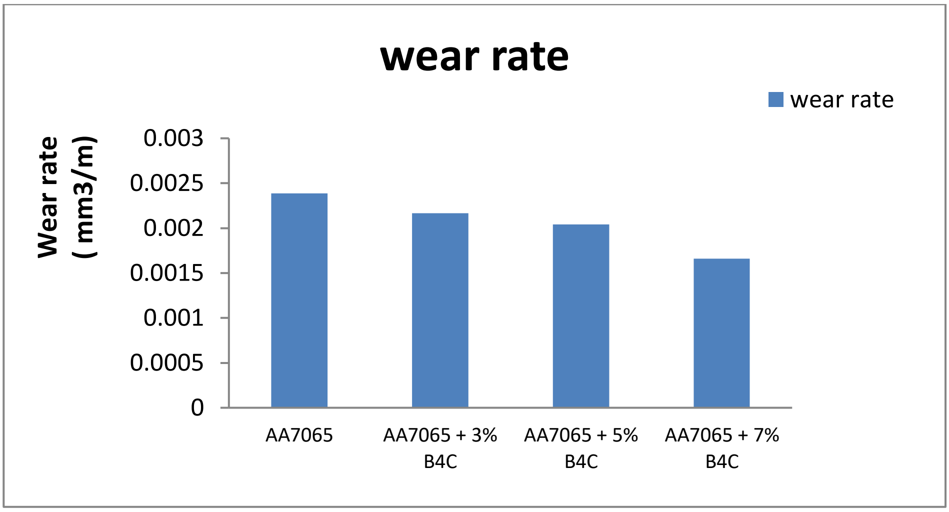

Fig. 6. Wear rate

4 Conclusion

The test specimens for these three different compositions, in addition to pure AA7065, were constructed in order to compare the change in characteristics and get a deeper comprehension of the impact that reinforcement has on matrix alloys.

1. The stir casting method produced a B4C-reinforced aluminium matrix composite (AA7075 + B_4C) with 3%, 5%, and 7% B_4C by weight. This goal has been reached.
2. The hardness of the composites is higher than that of the unreinforced alloy, and it keeps going up as the percentage of B4C particles in the composites grows.
3. Three, the ultimate tensile strength of composites can be increased by increasing the weight percent of B4C particles up to 7%, where it then plateaus.
4. When the sliding distance is held constant, it has been demonstrated that an increase in sliding velocity reduces the wear rates of all the composites. Both its maximum and minimum load capacities are 10 N.

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