Journal on Materials and its Characterization
Vol: 2(1), 2023
REST Publisher; ISSN: 2583-6412
Website: https://restpublisher.com/journals/jmc/
DOI: https://doi.org/10.46632/jmc/2/1/7

Mechanical Characterization and Corrosion Behavior of Magnesium/Boron Carbide Composites

A. Kristhoperraj, M. Srinivasan, Abilavan P, Arsath Ahamed A, Lokesh S, Mohanraj J
Arasu Polytechnic College, Kumbakonam, Tamil Nadu, India.
*Corresponding Author Email: arasupolytechnic@gmail.com

ABSTRACT: The lightest metal used as a base for construction alloys is magnesium. Due to their light weight, low density (about one-third that of aluminum), high temperature mechanical capabilities, and superior corrosion resistance, magnesium-based metal matrix composites are now widely employed in aircraft, structural, oceanographic, and car applications. In-depth analysis of the mechanical and corrosion behavior of magnesium metal matrix composites is done in this study to identify the impact of boron carbide (B4C) reinforcement. The Mg-MMC was produced using the stir casting process. We looked at the mechanical properties of the composites, such as their tensile strength, impact strength, and hardness. Salt spray testing and lab immerse testing using various corrosion media were used to analyze the corrosion behavior of magnesium composites. The experimental examination's findings demonstrated the proposed composite's low rate of wear. high yield strength, and high hardness, but no appreciable improvement in impact strength. Additionally, the salt spray causes the region of the base material to exhibit increased corrosion resistance.

INTRODUCTION

Magnesium makes up around 2% of the Earth's crust, making it the eighth most abundant element on the planet. It has an average concentration of roughly 0.13% and is the third most common element in seawater. While magnesium can be found in more than 60 minerals, only a few, including dolomite, magnetite, brucite, carnallite, and olivine, hold commercial significance. Production of magnesium and its compounds is achieved through various methods, such as extracting it from seawater, well water, lake brines, and bitterns, as well as refining it from the aforementioned minerals. With a density of 1.74 g/cm3, magnesium stands as the lightest among the structural metals. Magnesium is, nevertheless, employed as a structural metal in alloy form, and the majority of magnesium alloys have a density that is a little bit higher than pure magnesium. Being a reactive metal, magnesium is usually found alongside calcium and appears in nature as oxide, carbonate, or silicate. The high energy needs for producing magnesium metal are caused in part by the metal's reactivity. Because lighter weight increases fuel efficiency, the car industry finds magnesium metal parts to be particularly appealing. Due to the high ductility and elongation characteristics of these lightweight sections, the materials have good impact and fatigue resistance. Additionally, magnesium exhibits good thermal and electrical conductivity as well as good high-speed machinability.

Hexagonal lattices are more difficult to plastically distort than cubic lattices found in metals like steel, copper 3, and aluminum. As a result, magnesium alloys are primarily employed as cast alloys; nevertheless, since 2003, wrought alloy research has increased significantly. Additionally, lens components and camera bodies are made of die-cast magnesium. Many parts of modern automobiles are made of cast magnesium alloys, and some high-performance vehicles feature magnesium block engines. Due to its weak mechanical strength, magnesium is exceedingly weak when it is pure. Magnesium needs to be alloyed with other elements to gain better characteristics. Alloys in the Mg-Al-Zn group are composed of zinc, manganese, and aluminum. For room temperature applications, these alloying elements are most typical. The Mg-Zn-Zr group is composed of thorium, cerium, and zirconium (without aluminum) and is utilized for high temperatures. The addition of thorium or cerium increases strength at temperatures between 260°C and 370°C. The most successful element for enhancing outcomes is aluminum. Strength and hardness are increased with as little as 2% to 10% aluminum and small amounts of zinc and manganese, without affecting weldability or the alloy's capacity to respond to heat treatment, at the penalty of less ductility. Magnesium alloys that include more than 1.5% aluminum must be stress-relieved after welding because they are prone to stress corrosion. Iron, copper, and nickel are viewed as impurities that should be kept to a minimum since they decrease the corrosion resistance of magnesium alloys. Impurities such as iron and nickel that may be present in magnesium alloys have deleterious corrosive effects that are countered by the combination of zinc and aluminum. Magnesium alloys' benefits The following is a list of the benefits of magnesium and its alloys: high damping capacity due to vibration absorption, good creep resistance to reduce vibration and noise in a variety of applications, Lowest density of all metallic construction materials, good machinability, high specific strength, and high thermal conductivity allow for quick heat dissipation.

Applications of Magnesium Alloys: Applications for magnesium and magnesium alloys include both structural and non-structural ones. Automotive, industrial, materials-handling, truck components, and aerospace equipment are all structural uses. Steering column lock housings, housings for manual transmissions, and brackets to hold the clutch and brake pedals are all automotive applications. For sections that must function at high speeds and be lightweight to reduce inertial forces, magnesium alloys are utilized in industrial machinery like textile and printing machines. Gravity conveyors, dock boards, and grain shovels are a few examples of materials-handling machinery. Examples of commercial use include portable tools, travel items, computer housings, and ladders. Magnesium alloys are important for aeronautical applications because they are lightweight and exhibit good strength and stiffness at both normal and high temperatures.

LITERATURE REVIEW

K. Ravikumar and others (2017) The study demonstrates that titanium belt articles and force them in Aluminum Alloy (A 6063) Successfully Manufactured with Titanium Carbide Additions at 2%, 4%, 6%, 8%, and 10% by Weight: Effects on Composite Density, Hardness, and Tensile Strength. According to Mohammad Javad Nasr Isfahani et al. (2019), The density of (Al-B4C) nanocomposite was calculated using the mixture law and found to be in good agreement with the measured density of the (Al-B4C) nanocomposite. The preparation of the aluminum boron carbide nanocomposite involved using a ball milling process.K. Kalaiselvan et al. in 2011, the researchers investigated the fabrication of an aluminum (6061-T6) matrix composite reinforced with varying weight percentages of boron carbide (B4C) particles using a modified stir casting process. Their focus was on evaluating the mechanical properties, specifically hardness and tensile strength.as these properties are critical indicators of a material's performance. Vasuddevan N. et al. demonstrated the successful preparation of an AA5083 aluminum alloy composite reinforced with boron carbide (B4C) particles. The incorporation of B4C particles led to improved mechanical properties of the composite, but it also resulted in reduced corrosion resistance. This research contributes to the understanding of how different reinforcement compositions can impact the properties of aluminum-based composites and can guide material selection based on specific application requirements.Shashi Prakash Dwivedi, et al, (2020), From this paper the present investigation can attempt was made to develop and aluminium base metal matrix composite within lightweight and a good Mechanical properties were studied roughness ductility and intensity reduced by increasing the boron carbide percentage in the matrix material. Ravikumar Saranu, et al, (2020), in this case, magnesium metal matrix hybrid composites are applied in various industries, including vehicle manufacturing, industrial applications, and aerospace. The present work reviews the research conducted by Nahin et al., which examines the corrosion and tribological properties of hybrid composites like Az91E, poly ash, and silicon carbide. The composite material exhibits high corrosion resistance and high wear resistance. Palanikumar and Karthikeyan, et al, (2006the optimal machining conditions for turning particulate metal matrix composites were investigated. Carbide tools were used for the turning process instead of using PCD tools to reduce production costs. The study evaluated the effects of various machining parameters on surface roughness and metal removal rate. The goal was to determine the optimum machining conditions that would maximize metal removal rate while minimizing surface roughness. Dalmia mandir magnesium metal composites are created mostly by the resting method because of their excellent buildability and dispersion of reinforcement in the matrix phase, according to Nanjappa Natrajan et al.The molten matrix alloy with the train forcement at a specific temperature and speed has been mounted in the permanent dies or sand casting, followed by the application of brake gram, which was significantly a composite study on the MMC. This process has been less expensive, but you can use a wide range of reinforcement, and the process conditions can be slim controllable.

MATERIALS & MANUFACTURING METHODS

Raw-Materials Selection: AZ91 Magnesium alloy is chosen as the matrix material for the present investigation. Die-cast magnesium alloys are frequently used for structural applications, such as automotive, industrial, materials-handling, commercial, and aerospace equipment because they provide a good mix of castability, corrosion resistance, and mechanical qualities. Due to their hexagonal structure, these materials have poor workability, limited ductility, and low stiffness. They also degrade mechanical qualities at high temperatures. Although welding can be employed as a general method of material production to enhance product design and lower production costs, there is still a dearth of published information on the welding of magnesium alloys. The Al-Zn-Mg system provides the foundation for the excellent strength-to-weight ratio of Mg AZ91 and related alloys.

TABLE 1. Makeup of the magnesium alloy AZ91

Material	Mg	Al	Zn	Si	Mn	Cu	Fe	Be
Compositio n (%)	90.8	8.25	0.63	0.035	0.22	.003	0.014	.002

TABLE 2. Physical properties of AZ91 Magnesium alloy

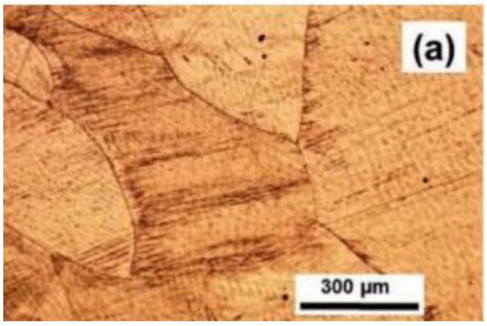
Density (g/cm^3)	1.81
Melting point (^{0}C)	533
Coefficient of thermal expansion at 20^{0}C (m/m^{0}C)	25.2
Specific heat (kJ/kg K)	1.02
Thermal conductivity (W/m K)	72.3

Reinforcement – Boron Carbide(B4C): A crystalline form of boron and carbon is called boron carbide (B4C). It is a very tough synthetic material used to make control rods for nuclear power plants, lightweight composite materials, and items that are abrasive and wear-resistant. It works as a fine abrasive for products made of metal and ceramic in its powdered state. It cannot, however, survive the heat produced when grinding hardened tool steels because to its low oxidation temperature of

400–500°C (750–930°F). Boron carbide has been used to reinforce aluminum in high-performance bicycles and military armor because of its hardness and extremely low density. Due to its wear resistance, it is also used in pump seals and sandblasting nozzles. In addition, boron carbide is employed in solidified or powdered form as a neutron absorber to regulate the pace of fission in nuclear reactors.

FIGURE 1. Boron Carbide

Fabrication of the Composites - Stir Casting Process: The composite is developed using the stir casting method. With the aid of a stirrer, the particles are first incorporated into the magnesium melt, after which the material is allowed to solidify in the mold under usual climatic conditions. The needed amount of AZ91 alloy was placed in the graphite crucible for this process and melted at 800°C in an electric furnace. For stirring, a graphite impeller with three blades was angled at a 45-degree angle. To avoid the melt being flung upward, which would enhance the porosity of the composite, the impeller was maintained at a distance of 2/3 into the melt. To get rid of any moisture, the retile particles were warmed at a temperature of 300°C. Using a funnel, these powders were then charged into the melt at a rate of 12–15 gm/min from the side of the rotating vortex. The charging of retile particles was done while maintaining a consistent melt temperature and impeller speed. To achieve a uniform dispersion of the particulate in the melt, stirring was kept up for an additional five minutes following the addition of the particles.



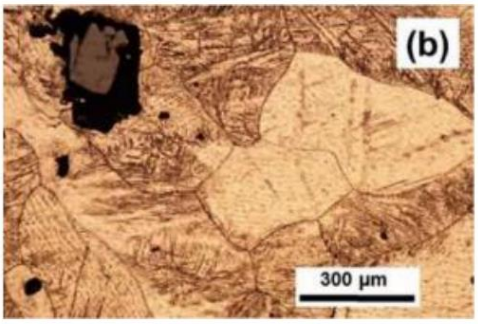


FIGURE 2. Pure Mg; **FIGURE 3.** Mg+ B4C Composite

FIGURE 4. Raw Magnesium; **Figure 5**. Mould Cavity

Tensile Test: The ASTM standard E8M08 was used to conduct the tension testing. The cast, forged, and age-hardened specimens were machined into tensile test specimens with gauge lengths of 96mm and 9mm. using a computerized universal testing machine, the polished specimens underwent room temperature tensile tests. The cast, forged, and age-hardened specimens were polished at different stages to eliminate the effects of surface roughness on the tensile test. Four tests were conducted for each sample, and the average value was taken. Any material can be tested in tension or compression to see if it can handle a static loading condition. The determination of the mechanical behavior of any material is important from both research and usage points of view. Testing these materials helps us to evaluate their quality and understand their fundamental nature. It is crucial to know how much load a material can withstand when subjected to service conditions. It should be strong and rigid enough to withstand different loading conditions at various temperatures. The most common test to evaluate the tensile behavior of any material is the Tensile Test. The Ultimate Tensile Strength (UTS), Modulus of Elasticity (E), percentage elongation, and decrease in area (A %) are all information that may be gleaned from the stress-strain curve that was produced during this test. Additional information such as Poisson's ratio (ν), resilience, etc., can be inferred through the Tensile Test. The Tensile Test specimen is prepared in a way that the ends of the specimen are gripped into the jaws of the testing machine.

The Tensile Test is performed using a standard Universal Testing Machine (UTM). The specimen may be rectangular or cylindrical, but it should be machined according to test standards. For composites, a rectangular or square cross-sectional shape is usually preferred. A load is applied in the tensile direction to the test specimen until it fractures. The load required to achieve a certain elongation on the specimen is recorded. The tensile behavior of the material is then obtained by plotting a load-elongation curve.

TABLE 3. Results of tensile test

Sample	Composition	Tensile Strength(N/mm2)	Elongation (%)
Sample 1	AZ91+ 5% B_4C	175.74	7
Sample 2	AZ91+ 10% B_4C	182.64	5
Sample 3	AZ91+ 15% B_4C	238.26	4

Impact Test: A standardized high strain-rate test that measures the amount of energy absorbed by a material during fracture is the Charpy impact test, sometimes referred to as the Charpy v-notch test. This absorbed energy serves as a gauge for the toughness of a particular material.

TABLE 4. results of Impact test

Sample	Composition	Energy Absorbed (Kg-m)
Sample 1	AZ91+ 5% B_4C	6.8
Sample 2	AZ91+ 10% B_4C	7.5
Sample 3	AZ91+ 15% B_4C	8.5

Hardness Test: The hardness analyzer used in this examination was the Vickers Micro Hardness analyzer at the Materials Testing Lab, Faculty of Mechanical and Manufacturing, University Tun Hussein Onn Malaysia (UTHM). The test load utilized for CFRP, GFRP, and all kinds of Hybrid Composites was 2.942 N (HV 0.3). The selection of this load was based on the space effect produced for each case and was determined from preliminary results achieved after applying the load. This project plays a significant role in calculating the hardness value during the hardness test. A diamond indenter is used to make an indentation during the Micro hardness trial of ASTM E-384, which is subsequently measured and transformed into a hardness value.

TABLE 5. Results of Hardness test

Sample	Trial 1	Trial 2	Trail 3	Avg Hardness (HRC)
Sample 1	32.3	32.9	31.2	32.13
Sample 2	34.1	33.4	32.1	33.23
Sample 3	35.5	35.8	33.9	35.06

Corrosion Analysis Test: The corrosion test was conducted to assess the ability of material resistance to corrosion in the atmospheric condition, salt water and acidic nature solution environment. The corrosion test mainly concentrates on the industrial materials and construction materials for its failure analysis.

Salt Spray Test: The salt spray corrosion test is one of the traditional methods used to analyze the corrosion resistance of materials. This test induces accelerated corrosive attack on the samples within a short time period, making it a simple method to estimate the corrosion rate. The salt spray test accurately contrasts the predictable and actual corrosion resistance. In the test, a high corrosive attack is achieved by using a steadfast solution, such as 5% NaCl (Sodium chloride), within a predetermined time frame. These tests are carried out in a closed testing chamber where the salt water solution is continuously supplied to a sample through a spray nozzle. After a specific time, the samples are taken out and analyzed for the appearance of oxides and the weight loss is measured. Materials with high corrosion resistance take longer for the oxides to become visible. The testing time varies depending on the materials, and it normally ranges from 24 hours to 1000 hours.

Laboratory Immersion Test: In laboratory immersion tests, the testing samples are typically prepared in small sections and exposed to the corrosion test solution (sea water) in beakers. The immersion test is carried out in a cyclic manner, where test samples are immersed for a specific period of time in the test solution, such as sea water. After the immersion period, the samples are taken out from the beakers and dried thoroughly. Before re-immersion, the weight of the samples is measured to calculate the weight loss, continuing the sequence of tests.

CONCLUSION

In this study, it was found that as B4C's weight percentage rises, so does the tensile strength. It was also found that elongation tends to decrease with increasing particle weight percentage, confirming that the addition of boron carbide increases brittleness.

As the weight % of B4C rises, the hybrid composite's impact strength rises as well. It was discovered that the wear test tends to get worse as more boron carbide is added to the hybrid composite. Mg-B4C composites are among the new materials that have gained importance in various fields, including aerospace, defense, automobile, biomaterials, sports, and leisure. The results of the salt spray test and immersion test provided evidence indicating that the weight loss at the weld region is significantly less than in the Magnesium MMC specimen

Reference

1. K. Ravikumar, K. Kiran, V.S. Sreebalaji, "Micro structural characteristics and mechanical behaviour of aluminium matrix composites reinforced with titanium carbide", 2017, Vol. 723, pp. 795-801. Journal of Alloys and Compounds.
2. Mohammad Javad Nasr Isfahani, Fereidoun Payami, Mohsen Asadi Arababad, Ali Asghar Shokri, "Investigation of the effect of boron carbide nanoparticles on the structural, electrical and mechanical properties of Al-B4C nano composites", 2019, Vol. 797, pp. 1348-1358. Journal of Alloys and Compounds.
3. K. Kalaiselvan, N. Murugan, Siva Parameswaran, " Production and characterization of AA6061–B4C stir cast composite", 2011, Vol. 32, pp. 4004-4009, Materials and Design.
4. Vasudevan N , Bhaskar G.B, Rajendra Prasad A , Suresh S.M, "Corrosion study on AA5083 aluminum alloy - boron carbide composite", 2019, Vol. 16, pp. 1124-1129. Materials Today: Proceedings.
5. Shashi Prakash Dwivedi, "Microstructure and mechanical behaviour of Al/B4C metal matrix composite", 2020, Vol.25, No.4, pp. 751-754. Materials Today: Proceedings
6. Ravikumar Saranu, Ratnam Chanamala & Srinivasa Rao Putti, "Corrosion and tribological behavior of magnesium metal matrix hybrid composites-A review", 2020, Vol. 2259, No.1, pp. 612-620. AIP Conference Proceedings.
7. Palanikumar K. and Karthikeyan R. (2006), 'Optimal machining conditions for turning of particulate metal matrix composites using Taguchi and response surface methodologies', Machining Science and Technology, Vol. 10, pp. 417-433.
8. Ramulu M., Rao P.N. and Kao H. (2002), 'Drilling of (Al2O3)p/6061 metal matrix composites', Journal of Materials Processing Technology, Vol. 124, pp. 244-254.
9. Manna A. and Bhattacharyya B. (2003a), 'A study of machinability of Al-SiC Metal Matrix Composites', Journal of Materials Processing Technology, Vol. 140, pp. 711-716.
10. Hashim J., Looney L. and Hashmi M.S.J. (1999), 'Metal matrix composites: production by the stir casting method', Journal Materials Processing Technology, Vol. 92/93, pp. 1-7.
11. Nanjappan Natrajan, Vijayan Krishnaraj & Paulo David J, 2015, 'Metal Matrix Composites, Synthesis, Wear Characteristics, Machinability Study of MMC Brake Drum', Springer, London.
12. Kishor, DSC, Rao, KP & Mahamani, A 2014, 'Investigation of cutting force, surface roughness and flank wear in turning of In-situ Al6061- Tic metal matrix composite', Procedia Material Science, vol. 6, pp. 1040– 1050.
13. Umanath, K, Palanikumar, K & Selvamani, ST 2013, 'Analysis of dry sliding wear behaviour of Al6061/Sic/Al2O3 hybrid metal matrix composites', Compos Part B: Eng., vol. 53, pp. 159–168.
14. Outeiro, JC, Rossi, F, Fromentin, G, Poulachon, G, Germaine, G & Batista, AC 2013, 'Process mechanics and surface integrity induced by dry and cryogenic machining of AZ31B-O magnesium alloy', Procedia CIRP, Vol. 8, pp. 487–492.
15. Baradeswaran, A & Elayaperumal, A 2011, 'Effect of graphite content on tribological behavior of aluminium alloy–graphite composite', European Journal of Scientific Reseaserch, vol. 53, no. 2, pp. 163– 170.
16. Lloyd, DJ 1994, 'Particle reinforced aluminium and magnesium matrix composites produced by molten mixing', Int. Mater. Rev., vol. 39, no. 1, pp. 1-23.
17. Mordike, BL & Ebert, T 2001, Magnesium Properties applications and potential, Material Science Engineering, vol. 302, pp. 37-45.
18. Di Ilio, A & Paoletti, A 2012, 'Machinability aspects of metal matrix composites in Machining of Metal Matrix Composites ', Springer, pp. 63-77.