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Mechanical Characterization and Corrosion Behaviour of Magnesium and Boron Carbide Composites

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Abstract
Magnesium is a light metal used as a source of construction compounds. Today magnesium-based metal matrix alloys are widely used in aerospace, structural, marine, and automobile applications for their light weight, low density (two-thirds that of aluminum), high-temperature mechanical properties, and excellent corrosion resistance. This project comprehensively determines the effect of boron carbide (B4C) on mechanical and reinforcement in magnesium metal matrix composite for corrosion behavior has been studied. Fabrication of Mg-MMC was done by stir casting process. Mechanical properties such as tensile strength, impact strength and hardness of composites were analyzed. Corrosion behavior of magnesium composites was studied by salt spray test and laboratory immersion test with different corrosion media. investigated by the method. The result of the experimental investigation, the proposed composite exhibits higher hardness, higher yield strength and lower wear rate, but no significant improvement. Also salt spray res. A higher corrosion resistance occurs in the base material area.

1. Introduction

Magnesium is the eighth most abundant element and makes up 2% of the Earth's crust. It is the third most abundant element dissolved in seawater, with an average concentration of 0.13%. Although magnesium occurs in more than 60 minerals, dolomite, magnetite, rhizite, carnelite, and olivine are of commercial importance. Magnesium and magnesium compounds are produced from sea water, well water and lake brines and brines, as well as from the minerals mentioned above. Magnesium is the lightest of the structural metals with a density of 1.74 g/cm3. However, magnesium is used as a structural metal in alloy form and most magnesium alloys have a slightly higher density than pure magnesium. Magnesium is a reactive metal and is usually found in nature in oxide, carbonate or silicate form, often combined with calcium. This reactivity is one of the reasons why magnesium metal production requires large amounts of energy. Lighter weight translates into higher fuel efficiency, making magnesium metal parts more attractive to the automotive industry. These lightweight components come with good ductility and elongation properties, which give the material good and impact resistance, as well as fatigue resistance. Magnesium exhibits good high-speed mechanical properties and good thermal and electrical conductivity.

2. Magnesium Alloys

Magnesium alloys are combinations of magnesium with aluminum, zinc, manganese, silicon, copper, rare earths and zirconium. Magnesium alloys have a hexagonal lattice structure, which affects the basic properties of these alloys. The plastic deformation of hexagonal lattice is more complex than that of cubic lattice metals such as aluminum, copper and steel. Therefore, magnesium alloys are commonly used as cast irons, but research on these alloys since 2003 is more extensive. Cast magnesium alloys are used for many parts of modern cars, and magnesium block engines are used in some high-performance vehicles. -Cast magnesium is also used for parts in camera bodies and lenses. As a pure metal, magnesium is very weak due to its poor mechanical strength. Pure magnesium must be mixed with other elements to provide enhanced properties. Mg-Al-Zn alloys contain aluminium, manganese and zinc. These are the most common alloying elements for room temperature applications. Thorium, cerium and zirconium (without aluminum) are used for elevated temperatures and form the Mg-Zn-Zr group. Thorium or cerium is added to improve strength at 260°C to 370°C. Aluminum is the most effective ingredient in improving results. 2% to 10% aluminum with minor additions of zinc and manganese increase strength and toughness. Magnesium alloys containing more than 1.5% aluminum are susceptible to stress corrosion cracking and must be stress relieved after welding. Iron, copper, and nickel are considered limited impurities because they reduce the corrosion resistance of magnesium alloys. Zinc combined with aluminum counteracts the harmful corrosive effects of iron and nickel impurities that may be present in magnesium alloys.

3. Materials & Manufacturing Methods

Selection of raw materials: AZ91 magnesium alloy was selected as the matrix material for the present investigation. Offering a good combination of castability, corrosion resistance and mechanical properties, die-cast magnesium alloys are widely used for structural applications including automotive, industrial, materials-handling, commercial and aerospace equipment. Disadvantages of these materials include poor workability, limited ductility, and low stiffness due to their hexagonal

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structure and deterioration of mechanical properties at elevated temperatures. As a common means of manufacturing products, welding can be used to improve product design and reduce manufacturing costs. Published information on welding of magnesium alloys was still limited. The high strength weight ratio of Mg AZ91 and its alloys is based on the Al-Zn-Mg system.

TABLE 1. Composition of AZ91 magnesium alloy

Material	Mg	Al	Zn	Si	Mn	Cu	Fe	Be
Composition (%)	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 (^0C)	533
Coefficient of thermal expansion at20^{0}C (m/m^{0}C)	25.2
Specific heat (kJ/kg K)	1.02
Thermal conductivity (W/m K)	72.3

4. Reinforcement – Boron Carbide (B_4C)

Boron Carbide, (B4C) A crystalline compound of boron and carbon. It is a very hard, synthetic material that is used in abrasive and wear-resistant materials, lightweight composite materials, and control rods for nuclear power generation. As an abrasive, it is used in powder form in the lapping (fine abrasive) of metal and ceramic materials, although its low oxidation temperature makes it unable to withstand grinding heat of 400–500 °C (750–930 °F). Hard tool steels. Because of its hardness, with very low density, it has found use as a reinforcing agent for aluminum in military armor and high-performance bicycles. A neutron absorber, boron carbide is used in powder or solidified form to control the fission rate in nuclear reactors

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FIGURE 1. Boron Carbide

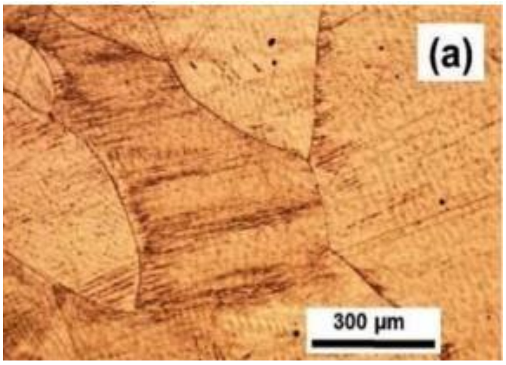

FIGURE 2. (a) Pure Mg

5. Fabrication of the Composites - Stir Casting Process

Stir casting method is used for composite development. The process involves mixing the particles with the aid of a stirrer to melt the magnesium, then allowing the material to solidify in the mold under normal environmental conditions. In this technique, required amount of AZ91 alloy is taken in graphite crucible and melted in electric furnace at 800oC. Three blades with graphite stirrups inclined at an angle of 45o were used for stirring. During melting, the stirrer is placed at a distance of 2/3 of the melt, so that while stirring the melt is not thrown upwards, this will increase the porosity of the mixture. Redyl pellets were preheated at 300oC to remove moisture. These powders were charged to the melt from the side of the swirl created during rotation with the aid of a funnel at a rate of 12-15 gm/min. Melting temperature and stirring speed are maintained continuously during charging of redial particles. Stirring was continued for 5 min after particle addition to ensure uniform distribution of the molten particles.

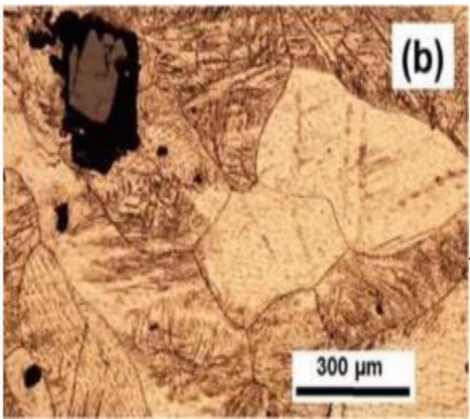

FIGURE 3. (b) Mg+ B_4C Composite **FIGURE 4.** (c) Raw Magnesium

FIGURE 5. (d) Mould Cavity

6. Mechanical Testing & Evaluation

Tensile Test: Tensile tests were conducted as per ASTM standard E8M- 08. Tensile test specimens with gauge length of 96mm and 9mm diameter were machined from cast iron and age hardened specimens. Room temperature tensile tests were carried out for the polished sample on a computerized universal testing machine. The cast iron and age-hardened sample were polished to different levels to eliminate the effects of surface roughness on the tensile test. Four tests are conducted for each sample and the average value is taken. The ability of any material to withstand a static loading condition can be determined by testing it in the direction of tension or compression. Determining the mechanical behavior of any material is important from a research and application point of view. Testing of these materials helps in assessing the quality of the material and understanding its basic nature. It is very important to know how much load a material can withstand under service conditions. It should be strong and tough enough to withstand different loading conditions at different temperatures. The most common test to evaluate the tensile behavior of any material is the tensile test. The stress-strain curve obtained in this test gives Ultimate Tensile Strength (UTS), Modulus of Elasticity (E), Percentage Elongation and Reduction in Area (A%). Additional information such as ratio of poisons (u), elasticity etc. can be deduced from tensile test. The tensile test specimen is prepared such that the ends of the specimen are held in the jaws of the testing machine. Tensile testing is done using a standard Universal Testing Machine (UTM). The pattern can be rectangular or cylindrical. But it should be machined as per test standards. A rectangular or square cross-sectional material is generally preferred for composites. A load in a tensile direction is applied until the test specimen fractures. The load required to produce some elongation in the specimen is recorded. The tensile behavior of the material is obtained by plotting a load-extension curve.

TABLE 3. Results of Tensile Test

Sample	Composition	Tensile strength (N/mm2)	Elongation (%)
Sample 1	AZ91+ 5% B4C	175.74	7
Sample 2	AZ91+ 10% B4C	182.64	5
Sample 3	AZ91+ 15% B4C	238.26	4

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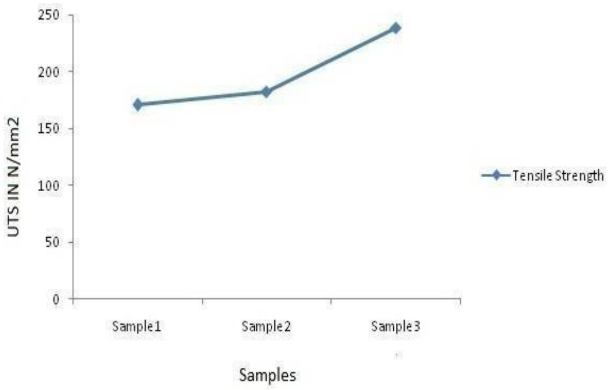

FIGURE 6. The effect of the weight fraction on the UTM

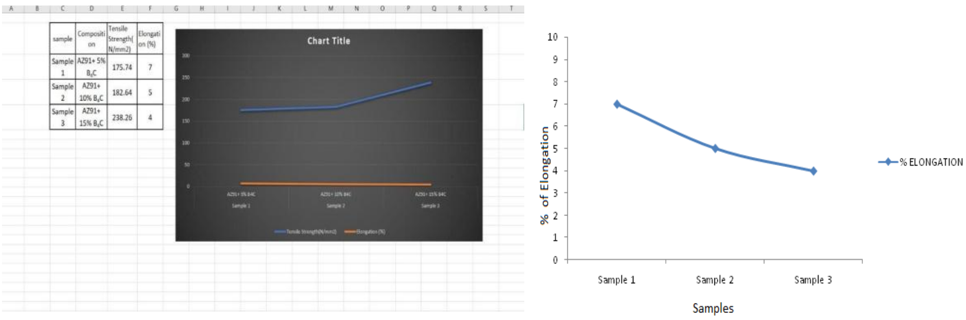

FIGURE 7. The effect of the weight fraction on the % of Elongation

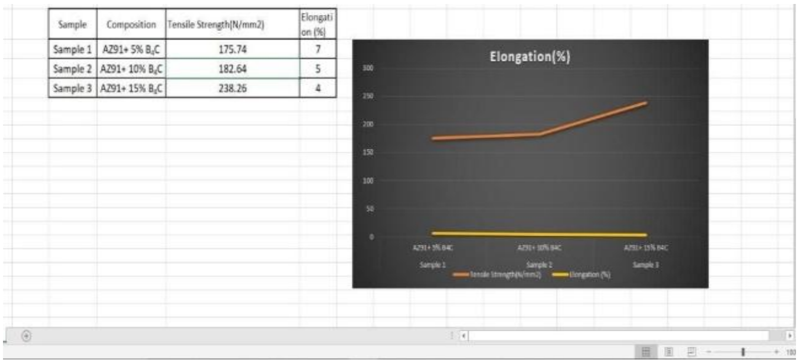

FIGURE 8. The effect of the weight fraction on the % of Elongation

Impact Test: The Charpy impact test, also known as the Charpy v-notch test, is a standardized high strain- rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness. The results of impact test.

TABLE 4. Results of Impact test

Sample	Composition	Energy Absorbed (Kg-m)
Sample 1	AZ91+ 5% B4C	6.8
Sample 2	AZ91+ 10% B4C	7.5
Sample 3	AZ91+ 15% B4C	8.5

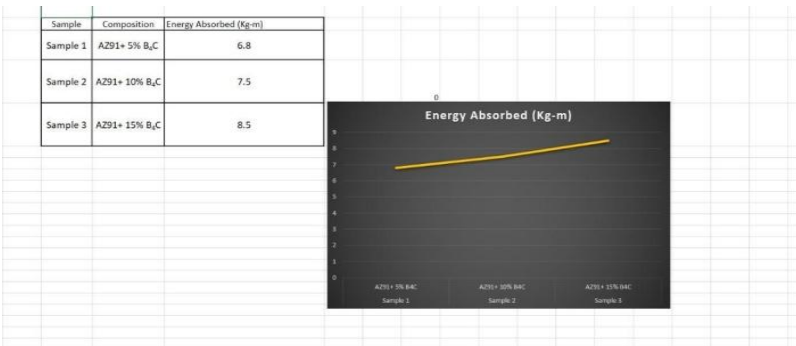

FIGURE 9. The effect of Energy Adsorbed

Hardness Test: The hardness analyzer used in this test was Vickers Micro Hardness Analyzer, Materials Testing Lab, Faculty of Mechanical and Manufacturing, University Tun Hussain An (UTHM). The applied test load for CFRP, GFRP and all types of hybrid composite was 2.942 N (HV 0.3). The motivation behind why these piles are used depends on the impact of the space provided for each case and the initial effects accomplished after the load is attached. This program undertakes the significant task of determining the hardness value after completion of the hardness test. The microhardness test of ASTM E-384 refers to the objective of light loads using a jewel indenter to create a space where a space is calculated and converted to 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

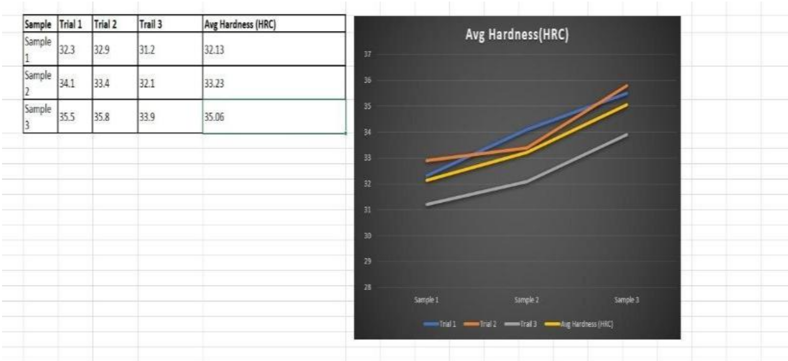

FIGURE 10. The effect of hardness

WEAR: Dry sliding wear test was performed according to ASTM: G99-05 test standards for pin-on-disc wear testers. Counter disc material is made of EN31 steel. The three biological performances of the hybrid composites were studied as a function of reinforcement content (wt.%), applied load (N), sliding distance (m) and sliding speed (m/s). Before and after each test, the sample and counterface disk were cleaned with acetone to remove traces. The pin was weighed before and after the test to an accuracy of 0.001 g to determine the amount of wear loss. The experiment was repeated three times and the average results were taken. The friction force was recorded during the test. The coefficient of friction was calculated by dividing the frictional force by the normal load. Garment debris particles were collected during each test.

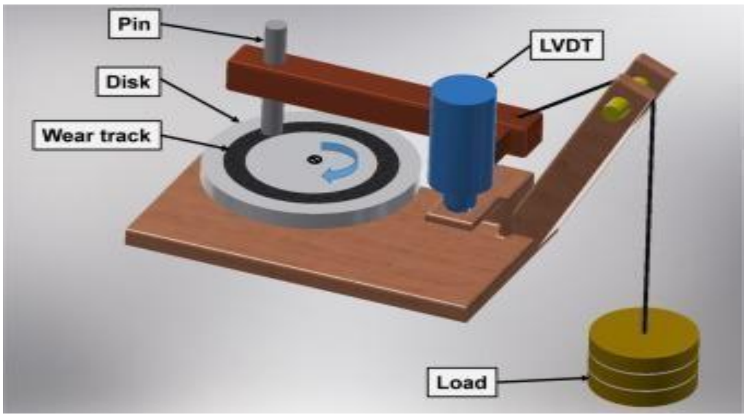

FIGURE 11. Pin-on-Disc

TABLE 6. Results of Wear using Pin-on-Disc

Sample	Composition	Wear in µm	Wear rate in mm3/m	Wear resistance in m/mm3
Sample 1	AZ91+ 5% B4C	162	0.024	41.66
Sample 2	AZ91+ 10% B4C	110	0.016	62.5
Sample 3	AZ91+ 15% B4C	82	0.012	83.33

Corrosion Analysis Test: Corrosion test is conducted to evaluate the ability of material resistance to corrosion in atmospheric condition, salt water and acidic nature solution environment. Corrosion testing mainly focuses on industrial materials and construction materials for its failure analysis. There are several types of corrosion such as atmospheric corrosion test, uniform corrosion, pitting corrosion, corrosion corrosion, pressure corrosion, galvanic corrosion, corrosion corrosion, fatigue corrosion and intergranular corrosion. Salt spray test: Salt spray corrosion test is one of the traditional methods for analyzing

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the corrosion resistance of materials. From the salt spray test, a rapid corrosive attack is induced on the samples within a short period of time and is a simple method to estimate the corrosion rate. This method typically accurately estimates the difference between predicted and actual corrosion resistance. In the salt spray test, high corrosive attack can be achieved by applying a solid solution such as 5% NaCl-sodium chloride with a predetermined time. These tests are carried out in a closed test chamber. The salt water solution is forced and continuously supplied to a sample through a spray nozzle. After some time, samples are taken and analyzed by the appearance of oxides in the samples and weight loss is measured. High corrosion resistant material took longer time to see oxides. Testing time varies based on materials and typically it can take anywhere from 24 hours to 1000 hours. Laboratory Immersion Test: In laboratory immersion tests mainly test specimens are prepared in small portions and cut into corrosion test solution (sea water) in beakers. Immersion testing is carried out cyclically, where a test specimen is immersed in a test solution such as seawater for a specified period of time. After immersion, samples are taken from the beakers and thoroughly dried. Before re-immersion, the weight of the samples is measured and the weight losses are calculated to continue the sequence of the test.

FIGURE12 . Immersed Specimen in Beakers

7. Merits & Applications

Merits of Magnesium Composites:

1. High specific strength,
2. High limit of elasticity, stiffness, fatigue strength
3. Superior wear and corrosion resistance,
4. Improved of damping
5. High strength-weight ratio
6. Thermal expansion decrease

Applications of Magnesium Composites:

1. Magnesium matrix composites are potential materials for variousapplications of aerospace and defense organizations due to their lowdensity, good mechanical and physical properties.
2. In the field of construction, the Mg MMC has a part in Concrete structure.
3. Since the explosive nature of Mg, it is used in explosive regions for thesafety.

FIGURE 13. Final Photographs

8. Conclusion

In this study, tensile strength increases with increasing weight percentage of B4C. It was found that elongation decreases with increasing particle weight percentage, confirming that boron carbide increases brittleness. Impact strength of hybrid composite increases with increase in weight percentage of B4C. It was found that the addition of boron carbide to the hybrid mixture increases the wear test. Mg-B4C composites are one of the new materials that have come to occupy important fields such as aerospace, defense, automobile, biomaterials, and sports and leisure. The results of the salt spray test and immersion test provided evidence to indicate that the weight loss in the weld area was much lower than that of the magnesium MMC sample.

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