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MICROSTRUCTURE AND MECHANICAL PROPERTIES OF B_4C AND ZrO_2 REINFORCED AZ91D MAGNESIUM MATRIX HYBRID COMPOSITE IN FRICTION STIR PROCESSING (FSP)

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Abstract—Metal matrix composites are typically used for applications that need increased specific strength, high temperature tolerance, and wear resistance.

Friction Stir Casting is used to create a magnesium (AZ91D) hybrid composite reinforced with Boron Carbide and Zirconia in this work. The influence of FSP on the surficial characteristics of AZ91-based hybrid composites was investigated using FSP on the surface. FSP process parameters were used to investigate grain size refinement, as well as mechanical and metallurgical properties. Based on revisions in the level of grain sizes, improvements in mechanical qualities such as tensile properties, and micro hardness improvement features of the Friction Stir Processed composites, process parameters for the FSP of AZ91 hybrid composites are found. The addition of Boron Carbide and Zirconia enhanced the composite's hardness, as evidenced by a micro-hardness test. The objective of this article is to use the stir casting technique to efficiently fabricate non-reinforced (AZ91D alloy) and reinforced (AZ91D+B_4C+ZrO_2) hybrid Magnesium matrix composite materials, as well as to perform FSP and prepare test specimens. In addition, investigate the impact of B_4C and ZrO_2 weight percentage variations on mechanical properties. The microstructure of the AZ91D/ZrO_2/B_4C composite was also studied using an optical microscope.

Keywords—AZ91D/B_4C composites, Zirconia, Friction Stir Casting (FSC), Friction Stir Processing (FSP), ultimate tensile strength, microhardness.

INTRODUCTION

Magnesium (Mg), Aluminum (Al), and Titanium (Ti) are commonly referred to as "light metals" because of their potential to reduce the weight of components that are typically composed of iron. When compared to Al and Titanium, magnesium-based components are the rising focus of study because they successfully reduce the weight of the material by 35 percent compared to Al and 75 percent compared to iron. With a density of 1.74 g/cm3, magnesium is one of the lightest structural metals. magnesium alloys are denser than pure aluminium. Magnesium is a reactive metal that occurs naturally as oxides, carbonates, and silicates, and is commonly found in conjunction with calcium. The reactivity of magnesium metal is one of the reasons behind its high energy consumption.

Composite materials are materials that are created by mixing two or more materials to get the desired qualities. At the macro level, the constituent materials that are not soluble with each other are combined. Magnesium and its alloys have desired qualities such as high strength-to-weight ratio, stiffness, superior castability, machinability, and electrical conductivity, in addition to their high strength-to-weight ratio. As a result, they're widely employed in the aerospace, automotive, and medical industries. When appropriate reinforcements are applied to the magnesium MMC, the mechanical, fatigue, and tribological properties are improved even more. classification of composite materials based on matrix (Polymer, metal matrix, ceramic matrix) and its reinforcements (article, Fiber).

EXPERIMENTAL DETAILS:

Stir casting was used to create Mg-based hybrid composite materials. In order to improve the surface qualities of the hybrid composites, friction stir processing was used to further process the composite castings. The method of experimentation used in this study. The most extensively used magnesium die cast alloy, AZ91D

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Alloy, provides a great mix of mechanical characteristics, corrosion resistance, and castability. AZ91D magnesium alloy was selected as the starting point for this project. The chemical composition of the AZ91D alloy are shown in Table 1

TABLE 1. Chemical composition of the AZ91D matrix alloy

%	Al	Mn	Zn	Si	Fe	Cu	Ni	Mg
AZ91D	9.16	0.27	0.88	0.12	0.004	0.08	0.002	89.43

- Mechanical qualities such as strength and hardness are usually used as one of the key criteria for selecting reinforcing particles. Based on the literature, it was chosen to employ B_4C and ZrO_2 as reinforcements.
- Boron carbide (B_4C) is the third hardest substance after diamond and cubic boron nitride. Extreme hardness, strong chemical resistance, good nuclear properties, and low density are all characteristics of B_4C.
- Zirconium dioxide (ZrO_2) is a chemically inert material known as zirconia. Zirconia is mostly used to make hard ceramics, but it can also be used as a protective coating, a refractory material, insulation, and abrasives.

In a steel crucible held in a furnace, magnesium ingot pieces are mixed with 2wt% ZrO_2 and (3,5,7) wt% B_4C. In a mild steel crucible, a comprising a mixture of magnesium and ZrO_2 with flux is heated to 400ºC in a furnace. B_4C particles were added to the charge after being warmed to 300ºC. The temperature of the furnace was increased to 500°C, and the melt was homogenised for one hour. The temperature was raised to 730°C before being lowered to 700º. The composite melts were stirred using a stainless-steel impeller. For 20 minutes, the stirring was done at a speed of 120 rpm. After stirring, the composite melt was quickly heated to around 730º C and poured into a mould to make rectangular plates with dimensions of 200 mm x 100 mm x 12mm)

Friction stir process test was carried out for a variety of control factors, including speed, sliding velocity, and tool penetration depth, where friction and recrystallization occur in the contact area of tool and the work piece. A specifically customised vertical milling machine was used for the FSP. Using suitable clamps, the cast rectangular hybrid composite plates were fixed on the milling machine. no of Composition is 3 (AZ91D + 3,5,7% Weight of B_4C +2% Weight of ZrO_2) with Sample Size of $100 \times 20 \times 12$mm no of Samples is 4. Square tools with varying pin diameter=5mm (3.54×3.54mm^2), pin length=2.5mm, shoulder diameter=15mm are used for doing FSP. FSP characteristics such tool rotating speed 1000 rpm and linear speed 14mm/min are taken into account. FSP was carried out using a 3^0tilt angle, 0.3 mm penetration depth, and a single pass condition.

Fig 1. Vertical Lathe Machine During FSP

EXPERIMENTAL RESULTS

A. EFFECT OF REINFORCEMENT ON MICROHARDNESS IN FSP:

Microhardness measurements were performed under a Vickers hardness tester with a force of 10 N for a dwell length of 10s to investigate the effect of the Friction stir technique on the Mg metal matrix composites.

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The Vickers Hardness has a Vernier calliper least count of 0.01mm. Before and after the FSP, the composite specimens' micro hardness must be evaluated. Individual specimen readings collected by Vickers micro hardness testing facility's average results. before FSP is tested, the hardness of a pure magnesium-based hybrid composite. When the composite is FSP using the following process settings, i.e., high tool speed 1000rpm and low tool feed 14mm/min, this value reaches its maximum. This is due to mechanical recrystallization, which causes the grain size to shrink.

Micro hardness investigations on pure Magnesium based hybrid composites found that friction stir processing improved the material's hardness. According to the findings, the hardness of Mg alloy (AZ91D) increases as the amount of boron carbide increases. This enhancement is due to the high hardness of boron carbide, the homogenous dispersion of reinforcement particles, and the superior wettability of boron carbide with the matrix. The addition of 7% B_4C and 2% ZrO_2 to a magnesium alloy increases its hardness (AZ91D). The hardness of the prepared hybrid magnesium matrix composite improved as the weight % of B_4C was increased, and the hardest composite was AZ91D/7%B_4C/2%ZrO_2, which had an average hardness value of 81.5BHN. On the other side, the AZ91D cast without reinforcement had the highest hardness value, with an average hardness value of 118BHN. As a conclusion, the hardness of AZ91D was decreased by about 30.9%.

TABLE 2. Results of microhardness with different reinforcement in Friction Stir Process

Sample Code	Composition	Rotating Speed	Linear Speed	Micro Hardness
		Rpm	mm/min	BHN
F1	AZ91D	1000	14	118
F2	AZ91D+3%B_4C+2%ZrO_2	1000	14	69.8
F3	AZ91D+5%B_4C+2%ZrO_2	1000	14	75
F4	AZ91D+7%B_4C+2%ZrO_2	1000	14	81.5

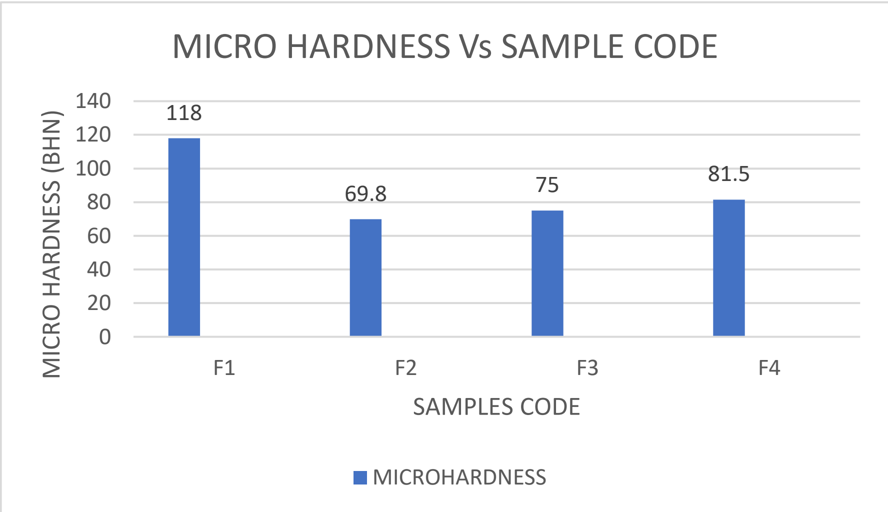

Fig 2. Variation of Microhardness of samples in FSP

B. EFFECT OF REINFORCEMENT ON TENSILE STRENGTH IN FSP:

The tensile strength of the FS treated composites is tested at the METMECH Engineers Research Lab. As For the tensile testing of Mg hybrid composite specimen is prepared as per the per ASTM standard (E8).

Ceramic powders such as boron carbide, Zirconia and others can improve the mechanical properties of Mg alloys. With the addition of particle reinforcements, the ductility of Mg alloy (AZ91D) is more in brittle nature and increases the strength with % wt. of B_4C increases. AZ91D/7% B_4C/2% ZrO_2 has the lowest percentage elongation, which reduces the ductility of the base matrix. The highest value of UTS was obtained at AZ91D/7% B_4C/2% ZrO_2 hybrid composite with a value of 181MPa.

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Fig 3. After tensile test specimens a) AZ91D b) AZ91D +2%ZrO_2+3%B_4C c) AZ91D + 2%ZrO_2+5%B_4C d) AZ91D + 2%ZrO_2+7%B_4C

TABLE 3. Results of tensile strength with different reinforcement in Friction Stir Process

Sample	Composition	Rotating Speed	Linear Speed	Tensile Strength
		Rpm	mm/min	MPa
1	AZ91D	1000	14	131.48
2	AZ91D+3%B_4C+2%ZrO_2	1000	14	157
3	AZ91D+5%B_4C+2%ZrO_2	1000	14	170
4	AZ91D+7%B_4C+2%ZrO_2	1000	14	181

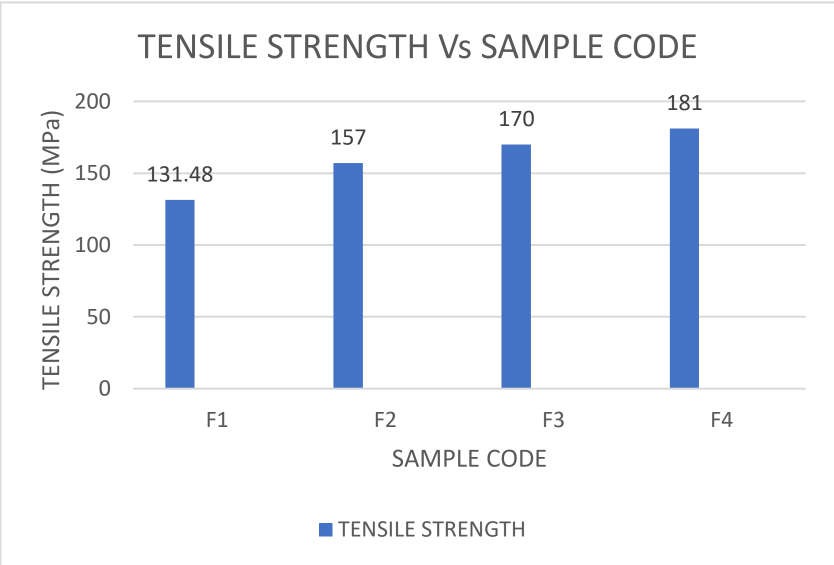

Fig 4. Variation of tensile strength of samples in FSP

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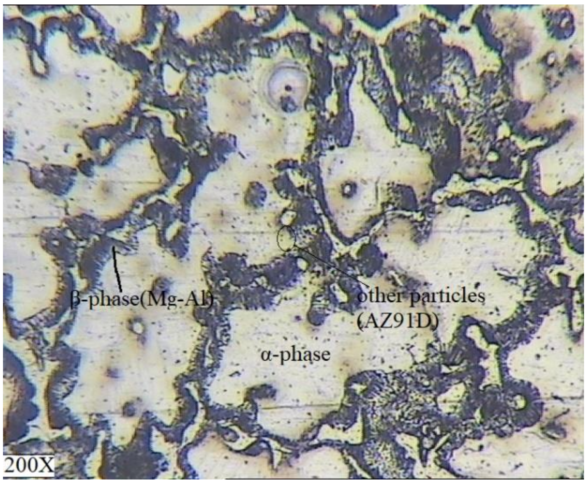
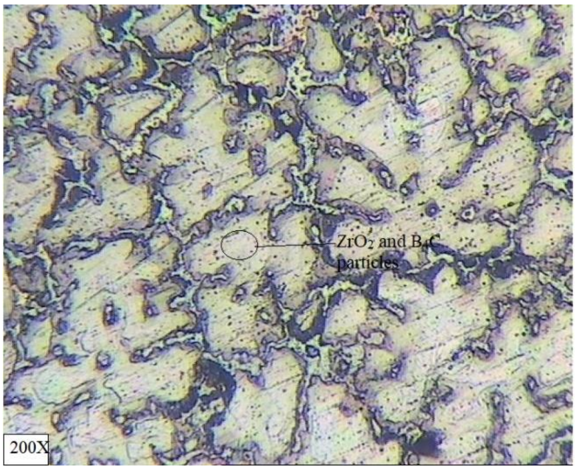
C. EFFECT ON REINFORCEMENT ON MICROSTRUCTURE IN FSP:

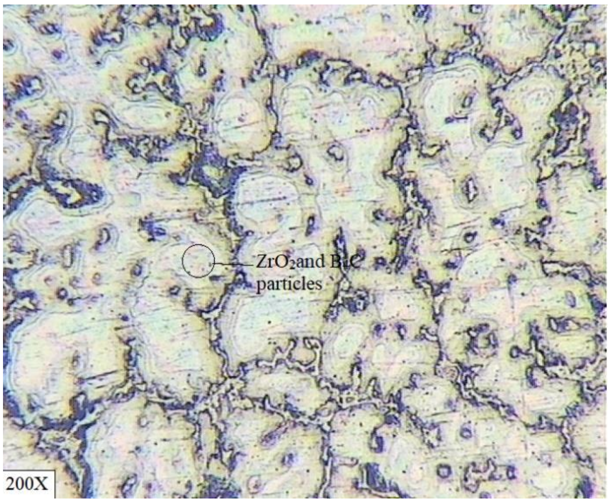
The distribution of reinforcements in the Magnesium metal matrix was studied using a Optical microscopes (OM). The shape and distribution of reinforcement particles in the AZ91D matrix were studied at 20x magnifications in this study. The overall the following procedures are used while preparing specimens for metallographic analysis are the specimens were processed using sandpapers of 220, 400, 800, 1200, and 2000 grits, respectively, after being cut to a 6*7 area cross section. Polishing was done with an RT-2002 Model Double Disc Polishing Machine. Standard etching, which involved etching the specimens using Nital chemical etchants, followed by a microstructure analysis using an optical microscope.



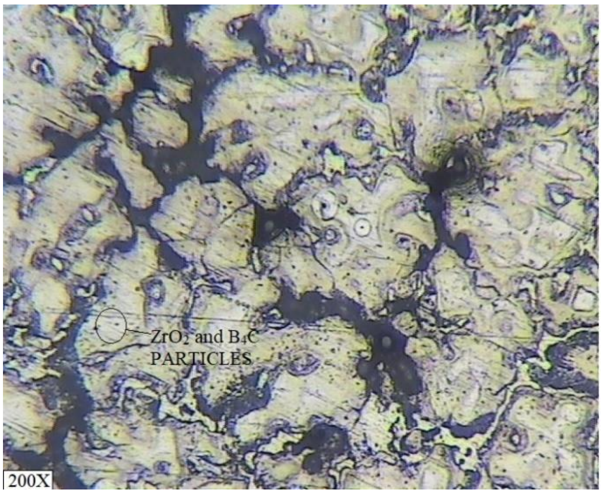
5a) AZ91D



5b) AZ91D +2%ZrO2+3%B4C



5c) AZ91D + 2%ZrO2+5%B4C.



5d) AZ91D + 2%ZrO2+7%B4C

Fig 5. Optical microscope image of the produced composites: in 5a, 5b, 5c, 5d.

These microstructure studies reveal that B_4C and ZrO_2 are present in hybrid composites. The microstructure of pure AZ91D matrix alloy formed by stir casting and under goes to FSP is shown in Fig. 5a. The microstructure of the AZ91D–3 percent B_4C-2 percent ZrO_2 composite is shown in Figure 5b. The microstructure of the AZ91D–5% B_4C–2% ZrO_2 hybrid composite is shown in Figure 5c. The microstructure of the AZ91D–7% B_4C–2% ZrO_2 hybrid composite is shown in Fig. 5d. The B_4C and ZrO_2 particles are distributed uniformly throughout the matrix phase of the AZ91D. The absence of cracks can also be seen under a microscope. The increases in % of B_4C reinforcement in AZ91D the particles increases than the base metal can be seen in fig 5.

CONCLUSION:

The microstructure, tensile strength and hardness of a hybrid magnesium alloy (AZ91D) metal matrix composite with different weight percentages (3,5,7) of B_4C and constant 2 percent ZrO_2 were evaluated in this study. The following are the conclusions:

Stir cast process and FSP were used to successfully generate hybrid AZ91D matrix composites. The reinforcement particles were uniformly distributed throughout the magnesium alloy (AZ91D) matrix, according to optical microscope pictures of the composite.

The hardness of the prepared hybrid magnesium matrix composite improved as the weight % of B_4C was increased, and the hardest composite was AZ91D/7B_4C/2ZrO_2, which had an average hardness value of 81.5BHN. On the other side, the AZ91D cast without reinforcement had the highest hardness value, with an average hardness value of 118BHN. As a conclusion, the hardness of AZ91D was decreased by about 30.9%.

The addition of B_4C and ZrO_2 improved the hybrid AZ91D composites' ultimate tensile strength. The ultimate tensile strength of the material was increased by 27.6 percent by adding 7% B_4C and 2% ZrO_2.

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