Evaluation of Mechanical Properties of Boron Carbide and Short E-Glass Fiber Reinforced with Aluminium 2014 for Aircraft Application

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Abstract*— Now a days the aluminium metal matrix composites are enormously used in application of aircraft wheel rim material, aerospace, transport application. In this present work to study the effort is made to enhance the tensile strength of AMCs by reinforcing, AA 2014 matrix with both B_4C(2%,4%,6%,8%) and short E-glass fiber (2%,4%,6%,8%) of varying Proportion by stir casting technique and hybrid composites are fabricated. The microstructure, hardness and ultimate tensile strength of the fabricated AMCs were analyzed. The SEM was studied to know the homogeneous dispersion of B_4C particles and Short E-glass fiber in the composite. In this present investigated has been done to study the effect of each process parameter such as composition (2%, 4%, 6%, 8%), stirring speed (300, 320, 340, and 360 rpm) and stirring temperature (700, 750, 800 and 850°C). Fabricated the different specimens of hybrid composite material using stir casting technique and each parameter has four levels, L16 orthogonal array used to made different specimen. The effect of this input response or input parameter on the output response or output parameters has been analyzed by using design of experiment by taguchi technique (MINITAB17). Based on the results obtained from tensile and hardness test of the hybrid composites it is observed that, the ultimate tensile increases as the increase in the amount of both $B_4C$and short E-glass fibers up to(4%) after that the addition of both B_4C and short E-glass fiber is not much changes in UTS. If the addition of both B_4C and short E-glass fiber increases thus hardness also gradually increases. The results are reveal that the composition, stirring speed, stirring temperature of hybrid composite material have a significantly effect on the ultimate tensile strength, hardness and ductility.

***Keywords*— AA-2014, E-GLASS FIBER, BORON CARBIDE, STIR CASTING, MINITAB**

I. INTRODUCTION

A composite is a heterogeneous material having two or more distinct phases which combined at a macroscopic level to obtain improved performances such as high strength, high stiffness and low density [15].

II. LITERATURE SURVEY

G.Kosec in this study the generally failure of different aircraft components and parts are revealed and examined by the use of non-destructive examination methods. Further detailed explanation and interpretation of failure optical and scanning electron microscopy are used. In this work problem of a crack on the aircraft wheel rim made from aluminium alloy 2014-T6. the crack was observed during regular control by the maintenance unit non-destructive examination of the Slovenian air carrier Adrian airways. The crack on the rim of an aircraft wheel investigated was a typical fatigue crack. It was ramified. Its size was lower than the critical size which at sufficient load could cause immediate collapse. Numerous pits found on the rim surface, and the crack propagated over them. Therefore, it can be concluded that pits served as the stress concentrators on the rim surface until one of them finally initiated the fatigue crack [1].

Chia-lung chang, sha-huei yang in this work investigated to achieve better quality, design and safety of wheel. The number of trials is to carry out to meet safety of the wheel rim. The impact test is to conduct on the tire wheel assembly. In this work, dynamic finite element analysis is used to simulate the SAE wheel assembly impact test. The finite element analysis is verified by comparing the tabulated values with measure values. The total wheel assembly material which can obtain from tensile test, which utilized as a ductile fracture criterion. The result is show that the effectively employed as a fracture criterion to predict the wheel fracture [2].

R.Sadeler and M.Ocal this paper has investigated the effect of relative slip on fretting fatigue behavior of aluminium2014 alloy with the age-hardened condition T4 and T6 in contact with a dissimilar mating material AISI 1045 STEEL, using a plane-on-plane configuration. In this work experiment is conducted for the as cast 2014 and heat treated AL2014-T4 and T6 condition, which AL2014-T4 are heated to 520°C for 2 hours by water For 5 days at room temperature. The authors had conducted the hardness test for both as cast and heat treated specimens using Vickers hardness machine and taken an eight trial in each surface of specimen and taken average values. The fretting fatigue test is conducted in Schenk type testing machine which has capacity is 30N-m. In this study concluded that the hardness values are increasing as age-hardened is also increases for both T4 and T6 condition. The stress amplitude also increases if the age hardened is increases, the maximum stress 300mpa obtain for T6 condition and fatigue life cycle also increases [3].

III. ALUMINIUM2014

Aluminum alloy 2014 is a copper based alloy having 4 to 5% of copper in AA2014 with strength are very high together with machining characteristics are very good. Figure 1 shows the Aluminium alloy 2014 samples and table 1 shows typical properties for AA2014[12]. Due to its high strength it is commonly used in many applications

Figure 1: Aluminium201Ignots

PROPERTIES	VALUE	UNIT
UTS	186	Mpa
Modulus of elasticity	72.4	Gpa
Tensile yield strength	96.5	Mpa
Melting point	507-638	°C
Density	2.8	g/cm^3
Thermal expansion	23	µm/m-k

Table 1: Typical properties for AA2014 [12] Boron carbide

In this work boron carbide (200 to 250µm) is selected as a reinforced material because the boron carbide is third hardest material in ceramics matrix material as shown figure 2. The name as boron originates from a combination of carbon and the Arabic word buragu meaning borax. The boron carbide is a high melting point and thermal stability and low density and it is commonly used in nuclear applications. The table 2 shows the typical properties for boron carbide.

Figure 2: Boron carbide particle

PROPERTIES	VALUES	UNITS
Density	2.52	g/cm^3
Melting point	2445	°C
Hardness	2900	-
Young's modulus	450	Gpa
Electrical conductivity	140	-

Table 2: Properties for boron carbide

IV. SHORT E-GLASS FIBER

Short electrical glass fiber also used as the reinforced material in this work. In E-glass fiber E stands the electrical grade glass, if the fiber as quite low in density is and strength is high, however young's modulus is not high. The E-glass fiber is cost is very low compare to other glass fiber and it is also easily available in market. The table 3 shows the chemical composition for short E-glass fiber. The typical properties of E-glass fiber as shown in table 3.4 [13] and figure 3 shows the short E-glass fiber.

Figure 3: Short E-glass fiber

PROPERTIES	VALUES	UNITS
Density	2.6	g/cm3
Hardness	5.6	—
Tensile strength	200	Mpa
Tensile modulus	73	Gpa
Elongation at break	2.2-2.5	%

Table 3: Mechanical properties for short E-glass fiber [13]

V. STIR CASTING PROCESS

Stir casting is a simple casting process and in this work stir casting process is employed to fabricate the hybrid composites, in which a reinforcement particulates and molten metal is mixed with by means of stirring. The fabrication of hybrid composites by stir casting process(AA2014, B_4C, short E-Glass fiber) and casting process setup as shown in figure 3.5 below. In this work the casting is done in four stages as constant boron carbide (2% 4% 6% 8%) and varying the short e-glass fiber as (2% 4% 6% 8%) the table 3.5 shows composition of various percentages of boron carbide and short E-glass fiber. Aluminium alloy 2014 ignots were taken in to graphite crucible and melted in an electrical furnace to 750°C after that fixing the % of boron carbide particulate to 2% and varying the short E-glass fiber (2% 4% 6% 8%) were added and mixed with mechanical stirring at 300 rpm for 5minutes. After stirring the molten metal is poured in to cast steel mould of 14mm diameter dies as shown in figure 4 and is allowed to cool to obtain cast rods. Figure 5 shows the cast components.

Figure 4: Pouring of molten metal in to dies

Figure 5: Cast components

Specimen preparation

After the completion of casting process the cast components obtained were machined on the lathe according to ASTM E-8 standards for tensile tests, hardness. The figure 6 shows the sum of casting which were machined tensile test

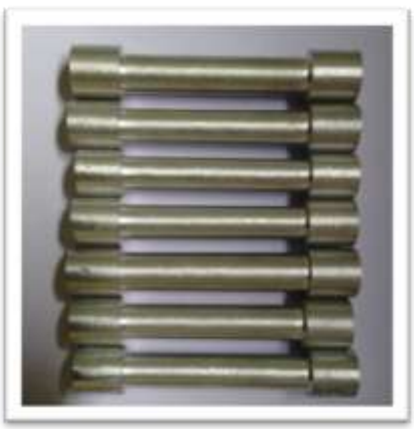

Figure 6: Tensile test specimens

VI. RESULTS AND DISCUSSION

1) Tensile test

After successful completion of tensile test in computerized tensometer which is evaluated the ultimate tensile strength for each composition of the specimen. In this present work is made to study the effect of each reinforcement material with base material aluminium alloy 2014. The results for each composition are shown in table 4

COMPOSITION PERCENTAGES	ENGG UTS N/mm^2	TRUE UTS N/mm^2
AL+2B4C+2E	172.4	179.8
AL+2B4C+4E	173.1	178.9
AL+2B4C+6E	178.6	184.5
AL+2B4C+8E	181.6	188.5
AL+4B4C+2E	204	208
AL+4B4C+4E	205.2	208.4
AL+4B4C+6E	232	234.4
AL+4B4C+8E	255	260
AL+6B4C+2E	185.3	189.6
AL+6B4C+4E	178.6	183.2
AL+6B4C+6E	172.4	175.4
AL+6B4C+8E	170.2	175.2
AL+8B4C+2E	154.2	159.1
AL+8B4C+4E	142.6	146.9
AL+8B4C+6E	141.4	145.7
AL+8B4C+8E	138.1	142.6

Table 4: Results for UTS

The both Eng and True UTS of the hybrid composite material specimens are observed from the table 5.1. As the ultimate tensile strength increases addition of constant boron carbide upto 4% in the composite. The 4% is shows the best result in its properties.

2) Effect of boron carbide and short E-glass fiber on ultimate tensile strength

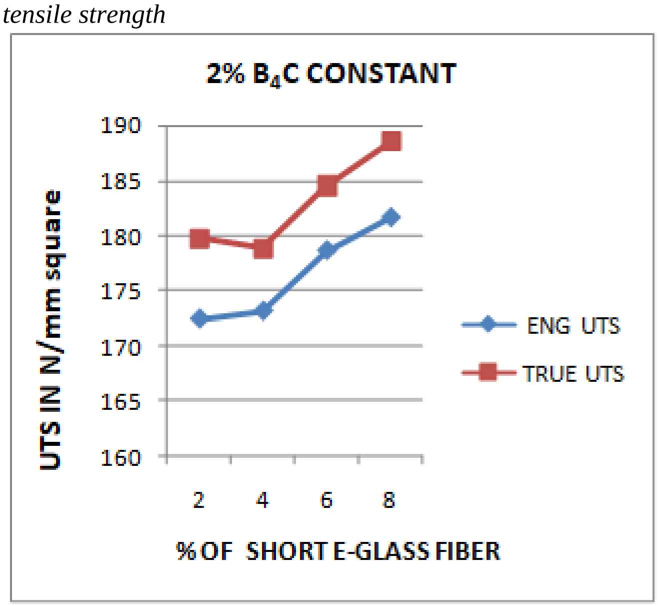

Figure 7: UTS (Mpa) v/s varying % of short E-glass fiber B4C constant)

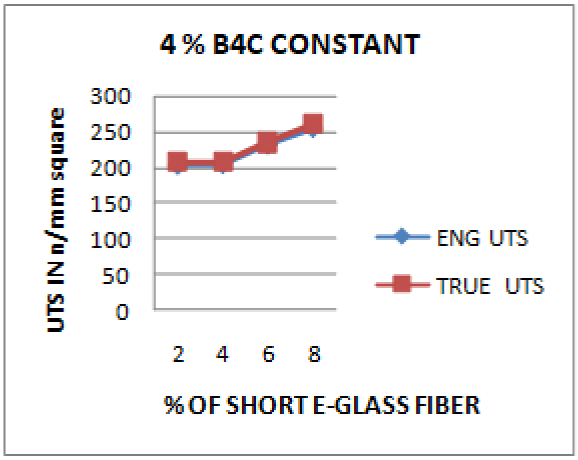

Figure 8: UTS (Mpa) v/s varying % of short E-glass fiber (4% B4C constant)

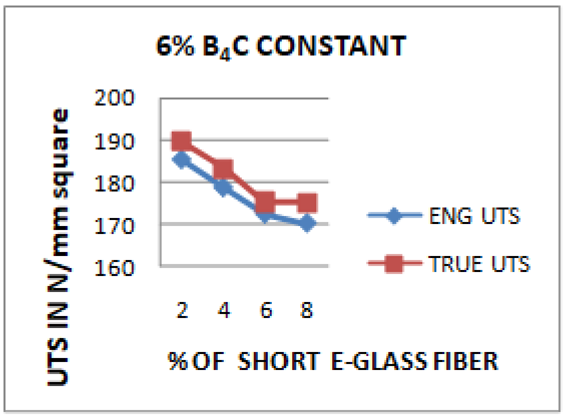

Figure 9: UTS (Mpa) v/s varying % of E-glass fiber (6% B4C constant)

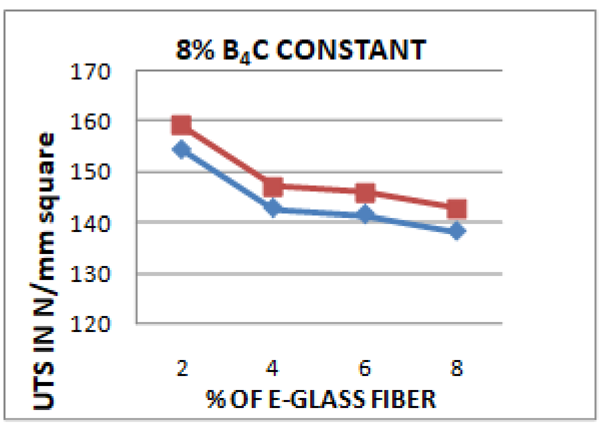

Figure 10: UTS (Mpa) v/s varying % of E-glass fiber (8% B4C constant)

The figure 7, 8, 9,10 shows the results for the each composition of specimen. The test revealed that, if % of the reinforcement material is added to aluminium2014, thus the UTS gradually increased by the increase in % of weight. The maximum ultimate tensile strength was observed at 4% constant boron carbide with varying the 2%, 4%, 6%, 8% of short E-glass fiber which is shown in figure 7. If the more reinforcements are added with aluminium2014 which is increases the strength up to 4%B4C after that the material behaviors the brittle in nature because there is a reduction in the interspatial distant between particulates, which cause an increase in the dislocation in reinforcement and number of grain formation. At higher percentage of reinforcement the strength may be reduces as due to poor bonding of both fiber and boron carbide particulates

3) Hardness test

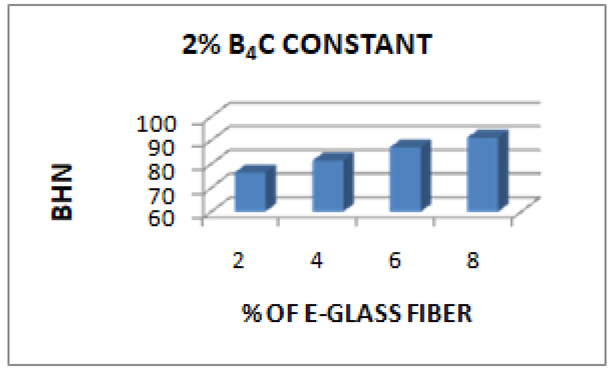

Figure 11: Hardness v/s varying % of short E-glass fiber (2% B4C constant)

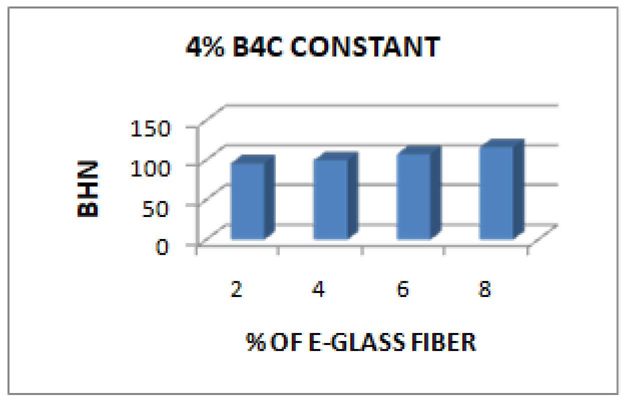

Figure 12: Hardness v/s varying % of short E-glass fiber (4% B4C constant)

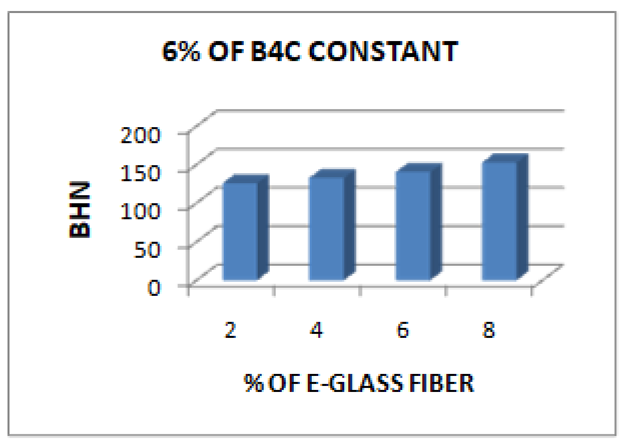

Figure 13: Hardness v/s varying % of short E-glass fiber (6% B4C constant)

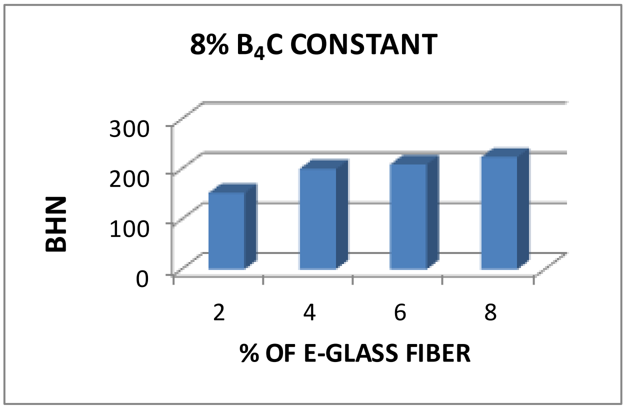

Figure 14: Hardness v/s varying % of short E-glass fiber (8% B4C constant

VII. CONCLUSION

Aluminum alloy 2014 metal matrix composites with varying weight percentage of 2, 4, 6 and 8 of Boron carbide and short E-glass fiber are successfully fabricated using stir casting process. The specimens prepared were subjected to tensile and hardness testing and the effect of reinforcement on the strength of the alloy were studied. Based on the study conducted on the Boron carbide, E-glass containing AA2014 composite material, the following conclusions can be made

- Using stir casting technique uniform distribution of reinforcement material can be obtained.
- It has been notable improvement in the ultimate tensile strength have increased significantly with addition of short E-glass fiber (8%) and boron carbide (4% constant) with AA2014 after that we observed that there is no increasing in strength. Because the boron carbide particle and short electrical grade glass fiber prevents the movement of dislocation in the aluminium2014 alloy matrix through dispersion strengthening mechanism. Moreover the addition of boron carbide particles and short E-glass fiber into the aluminium2014 alloy matrix increases thus strength should be decreases is behaviors the brittle in nature.
- If the percentage of boron carbide and short E-glass fiber increases gradually thus the hardness of the hybrid composite material increases from 76.3 BHN TO 223.9 BHN.

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