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Investigation of Mechanical Properties of Al6061 with Reinforcement of SiC/B_4C Metal Matrix Composites

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Abstract. The advanced modern manufacturing of aeronautical, automobile, marine industries are required higher in strength, corrosion resistance, and good formability with lesser in weight; these requirements fulfilled by the Aluminium Metal Matrix Composites (AMMCs). In the aluminium alloys, Al6061 exhibits to meet the above requirements of its mechanical and other properties by adding the reinforcement particles to the AMMCs, which improves the mechanical properties. In this research, the article made an attempt to improve the mechanical properties of the Al6061 by adding the reinforcement particles of silicon carbide (SiC) and boron carbide (B_4C). The stir casting technique is used for manufacturing the AMMCs with various propositions and their mechanical properties were investigated. The microstructure of the composite was analyzed using Scanning Electron Microscopy techniques. During this investigation, it was found that the reinforcement particles of SiC, B_4C are improving the aluminium alloys of Al6061's mechanical properties in appreciable level.

INTRODUCTION

The invention of materials has pushed the human from stone age to the modern society man, without material the normal man's today's life is almost not possible. So the material is unavoidable one in day to day activities of modern life. The researches were invented new materials for the society and the industrial needs which make the world to be safe and comfortable day by day. The automobile, defense, marine, and aerospace industrial modern applications need higher resistance, higher strength, good weldability and lower in corrosion [1, 2]. Generally, these characteristics can be provided by the third generation of aluminium metal matrix composites (AMMCs) which possess the good strength to weight ratio, these composites have lightweight, low thermal expansion coefficient, and improved mechanical properties. AMMCs have increased hardness, increased tensile strengths and a very good heat treatable capability also [3, 4]. The aluminium composites were most widely used such as automobile, electronics components, defence, and aerospace components manufacturing [5]. To prepare the composite materials stir casting, compo casting, and powder metallurgy like many fabrication methods are available among them the stir casting is one of the low-priced composite manufacturing processes.

The hybrid composites were prepared with proper blending of the other reinforcement's materials this can be done in the friction stir casting work setup. The experimental setup of the stir casting composite fabrication process

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is flexible and simple when compared to all other composite manufacturing methods [6, 7]. It very easily fabricates a large quantity of composite material. In this stir casting process, there is no chemical reaction between matrix alloy and reinforcements; during the stir casting process, which causes a very low porosity can be achieved [8, 9]. The reinforcement particle uniform distribution in the composites materials can be achieved by the optimal process parameter condition of the metal matrix composites [10]. The stir casting process is one of the low-priced methods used to produce composite materials [11]. To improve the hardness and the strength of aluminum alloy the reinforce particles of SiC and B_4C particles were added through the stir casting process [12, 13]. The reinforcement of boron carbide particles and silicon carbide particles improved the composite materials' mechanical properties of the hardness and the tensile strengths to a large extent [14]. The aluminum alloy of 6061 composite materials chemical was confirmed by the chemical analysis test, by using an optical emission spectrometer. The aluminium 6061 materials weight in the percentage of the chemical composition is shown in table 1.

TABLE 1. Chemical composition of 6061 aluminum alloy

Element	**Al**	**Mg**	**Fe**	**Si**	**Cr**	**Cu**	**Zn**	**Mn**	**Ti**
Weight %	96.5	1	0.7	0.6	0.375	0.275	0.25	0.15	0.15

EXPERIMENTAL PROCEDURE

Material Composition

The aluminium alloy AA6061 is used as the base material for metal-matrix composite and Silicon Carbide (SiC) and Boron Carbide (B_4C) were used as the reinforcements. The various compositions of the metal matrix composites fabrication are shown in table 2. Sample A consists of 98 % weight of Al6061, 1% weight of SiC and 1% weight of B_4C, similarly Sample B, consists of 96 % weight of Al6061, 2% weight of SiC and 2% weight of B_4C, Sample C consists of 94 % weight of Al6061, 3% weight of SiC and 3% weight of B_4C and consists of 92 % weight of Al6061, 4% weight of SiC and 4% weight of B_4C.

TABLE 2. Composition of composites

Samples	**AL6061 (%)**	**SiC (%)**	**B_4C (%)**
Sample A	98	1	1
Sample B	96	2	2
Sample C	94	3	3
Sample D	92	4	4

Fabrication of Composites

The stir casting technique is a primary process of fabrication of composite, this fabrication of the casting process Al6061, SiC and B_4C aluminum metal matrix composite fabrication process flow chart shown in figure 1. The aluminium alloy 6061 and the coverall were placed into a stir casting crucible and then up to 800^0C temperature the furnace is heated and it was retained till the end of the aluminium metal matrix preparation. The reinforcement particles of boron carbide and silicon carbides were preheated by a separate electric muffle furnace that was used to heat the particles to the temperature of 1000^0C [15, 16]. The reinforcement material is incorporated into the molten matrix metal by stirring. The continuous stirring of the molten aluminum matrix is followed by the addition of reinforcements. The resulting mixture of matrix and reinforcement is then poured into the mould and allowed to solidify. In stir-casting, the reinforcement used to form agglomeration/clustering which can be prevented by vigorous stirring at high temperature to get a uniform distribution of reinforcement in the matrix and to get a uniform or homogenous microstructure such that a composite with better mechanical properties can be obtained.

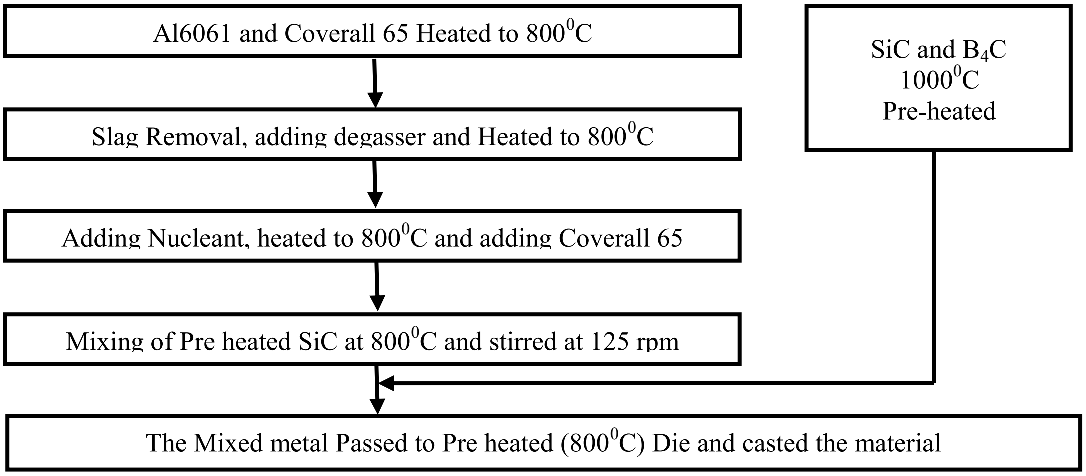

FIGURE 1. Stir Casting process flow chart

The degasser powder was added to the molten metal when it reaches a temperature of 800^0C. The recommended amount to be added is 250gm for a melt of 50Kg [17]. Degasser powders are essential in reducing blowholes that are formed during the casting process. The casting die was first heated to a temperature of 973^0C before pouring the metal. The molten metal properly stirred and it was passed gently pass through the die, then the die was permitted to cool around one hour after that the job was removed appropriately.

RESULT AND DISCUSSION

Theoretical and Actual Densities of AA-B_4C-SiC Composites

The rule of mixtures equation states that the increase of reinforcement improves the increased density of the composite, so the actual densities of the composites are lesser than their theoretical counterparts. The proper blending of the reinforcement particles leads to the porosity and the settle down of reinforcement's particles arises due to the density difference and formation of intermediate compounds.

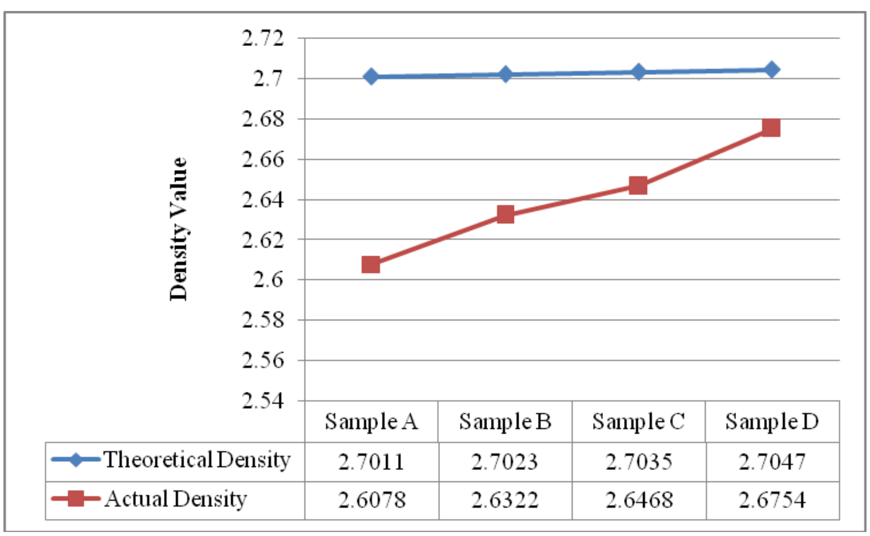

FIGURE 2. Comparison of Theoretical and actual densities of the Composites

Tensile Test

TABLE 3. Tensile test values of the composites

Name of Sample	Break load (kN)	Maximum displacement (mm)	Tensile strength (MPa)	Elongation (%)
Sample A	6.85	10.12	127.54	7.12
Sample B	6.72	11.38	127.28	7.12
Sample C	7.35	12.12	127.50	6.15
Sample D	8.25	8.50	118.20	6.45

The tensile test composite material proves its ability to withstand the static load under the tension or compression load, which is carried out in the Universal Testing Machine (UTM). The samples of the test specimens were made by as per ASTM B: 557 standard and results are tabulated in table 3. In the tensile test, it was observed that sample A is superior to all the other samples and sample D is a lesser tensile value than other samples. The sample A also had a higher value in the percentage of elongation.

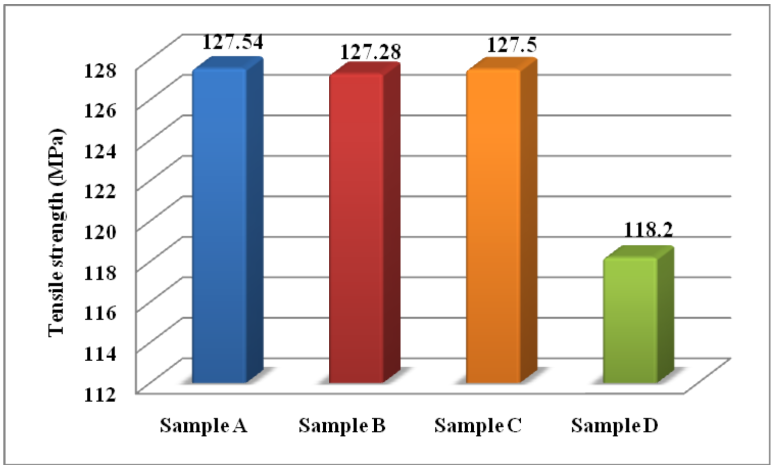

FIGURE 3. Tensile test values of the composites

Flexural Test

In the flexural test, the material (composite) is subjected to a simple bending load and the behavior of the material is observed. The samples of the metal matrix composites test specimens were more as per ASTM A: 370 standards and the flexural test values of the samples were tabulated in table 4. In the flexural test, it was observed that sample D is superior to all the other samples and sample A is the lesser value of other samples.

TABLE 4. Flexural strength of the composites

Name of Sample	Flexural Break Load (kN)	Maximum Deflection (mm)	Flexural Strength (MPa)
Sample A	1.74	9.5	111.02
Sample B	3.42	8.42	147.45
Sample C	3.54	8.32	159.42
Sample D	4.64	8.2	224.25

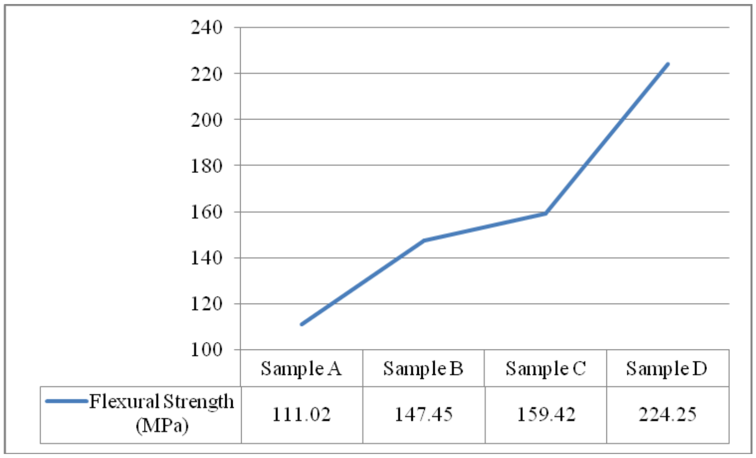

FIGURE 4. Flexural strength of the composites

Impact Test

In the impact test, the behavior of the material studied for the sudden dynamic load applied to the material and the response amount of energy absorbed by the specimen is recorded. The composite materials test specimens were prepared as per IS: 1757standards, the test was conducted in the Charpy impact test and the absorbed values were tabulated in table 5. In the impact test, it was observed that sample D is superior than all other samples.

TABLE 5. Result of Impact Test of the composites

Name of Sample	Sample A	Sample B	Sample C	Sample D
Energy absorbed (J)	8.11	8.15	7.2	8.45

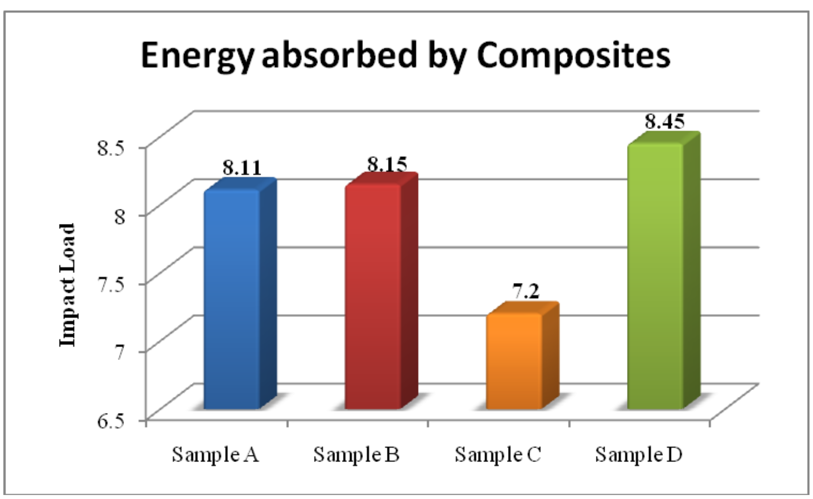

FIGURE 5. Result of Impact Test of the composites

Hardness Test

Finding of the hardness value in one of the important aspects of any mechanical characterization of the new metal matrix composites, this can be improved the resistance power during the deformation under load. The Hardness test was carried outof for all the samples of A, B, C and D by the Brinell hardness test, and the appropriate value of the samples is listed in table 6. Among the four samples, The test specimen sample of D's hardness value is higher than other samples due to the presence of the high amount of silicon carbide and boron carbide.

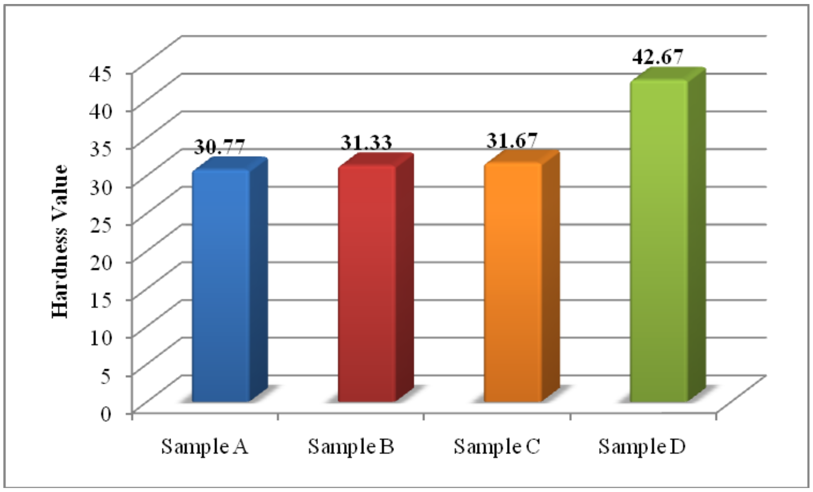

FIGURE 6. The average hardness value of the composites

TABLE 6. The average hardness value of the composites

Name of Sample	Trial 1	Trial 2	Trial 3	Average Hardness
Sample A	31.2	30.9	30.2	30.77
Sample B	31.4	31.2	31.4	31.33
Sample C	31	33	31	31.67
Sample D	42	44	42	42.67

Microstructure Analysis of Samples

The microstructure of the composite material 92% of Al6061, 4% of SiC and B_4C of 4% Particles (specimen of sample D) 50µm magnification Scanning Electron Microscopy (SEM) image is shown in figure 6. In the specimen of sample D's Scanning Electron Microscopy (SEM) image, it is seemed to be that boron carbide (B_4C) particles are slightly clustered of some area over the aluminum matrix surfaces.

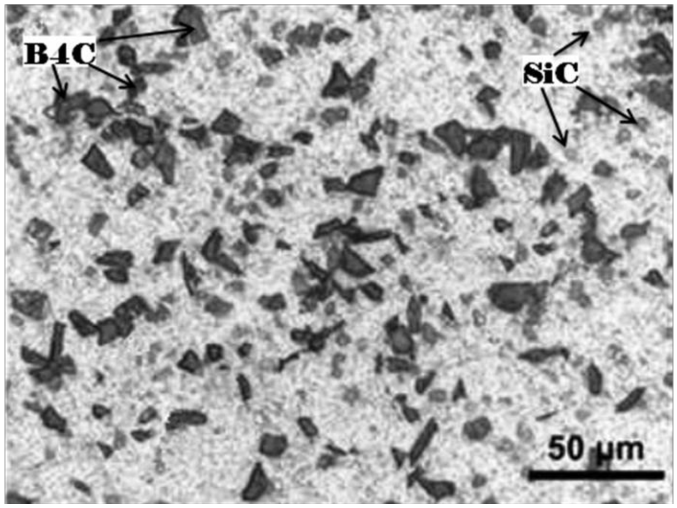

FIGURE 7. SEM image of Al6061 with reinforcement of 4% of SiC and B_4C

CONCLUSION

In this investigation of the aluminium metal matrix composites (AMMCs) study, the Al6061 aluminium alloy is taken as a base metal and reinforcement of Silicon carbide (SiC), Boron carbide (B_4C) are used to improve the mechanical properties of the material. The material composite is prepared by various compositions in the stir casting process and their mechanical properties were investigated. The density analyses were made in which it was found that the lightweight material achieved a better wear resistance. The aluminium metal matrix composites (AMMCs) of Al6061 with 4% of SiC and 4% of B_4C is comparatively given better results in high flexural strength and a better bending properties material than the other composition of the materials with high impact load carries the material.

REFERENCE

1. Virinchy, Chintala Sai, V. Jayakumar, Abdul Hafeez Asif, and R. Pugazhenthi. "Experimental Investigation of Al-Mg-SiC-Fly Ash Composites for Automotive Alloy Wheel Rims", International Journal of Vehicle Structures & Systems (IJVSS), 11, 2 (2019).
2. Yang, J. B., C. B. Lin, T. C. Wang, and H. Y. Chu, "The tribological characteristics of A356. 2Al alloy/Gr (p) composites", Wear, 257 (9-10), 941-952, (2004).
3. Rajasekaran, A., and R. Pugazhenthi, "Study of mechanical properties of stir casted Al7075/SiCp composites after thermomechanical treatment", Materials Today: Proceedings, (2019).
4. Sun Y, Lyu Y, Jiang A, “Fabrication and characterization of aluminum matrix fly ash cenosphere composites using different stir casting routes”, Jr Materi Res., 29:260–266, (2014).
5. Parthiban, A., R. Pugazhenthi, R. Ravikumar, and P. Vivek. "Experimental Investigation of Turning Parameters on AA 6061-T6 Material", In IOP Conference Series: Materials Science and Engineering, vol. 183, no. 1, p. 012013. IOP Publishing, 2017.
6. Baradeswaran, A., A. Elayaperumal, and R. Franklin Issac, "A statistical analysis of optimization of wear behaviour of Al-Al2O3 composites using Taguchi technique", Procedia Engineering, 64, 973-982, (2013).
7. Pugazhenthi, R., D. Sreeram, SS Vijay Ananth, and A. Devaraju, "Surface fracture analysis of stir casted AA 6063/TiC/Gr hybrid composites under different solidification rate", Materials Today: Proceedings (2019).
8. Chen P, “High- performance machining of SiC Whisker Reinforced Aluminium Composite by Self Propelled Rotary Tools”, CIRP Ann, 41:59–62, (1992).
9. NHarishGarg K, KetanVerma AM, Kumar R, “Hybrid metal matrix composites and further improvement in their machinability”, Int J Latest Res Sci. Technol, 36:2278–5299, (2012).

10. Pugazhenthi, R., S. Sivaganesan, C. Dhansekaran, and A. Parthiban, "Morphological and Mechanical Characteristics of Hybrid Aluminium Matrix Composites", International Journal of Vehicle Structures & Systems (IJVSS) 11(2), (2019).
11. Caracostas, Constantinos A., W. A. Chiou, M. E. Fine, and H. S. Cheng, "Tribological properties of aluminum alloy matrix TiB2 composite prepared by in situ processing", Metallurgical and Materials Transactions A, 28 (2), 491-502, (1997).
12. Baradeswaran A, Elayaperumal A, "Influence of B4C on the tribological and mechanical properties of Al 7075-B 4C Composites", Composites Part B, 54:146–15210, (2013).
13. Jino, R., R. Pugazhenthi, K. G. Ashok, T. Ilango, and P. R. Chakravarthy, "Enhancement of Mechanical Properties of Luffa Fiber/Epoxy Composite Using B4C", Journal of Advanced Microscopy Research, 12 (2), 89-91,(2017).
14. N. L. Han, Z. G. Wang, and L. Z. Sun, "Low Cycle Fatigue Behaviour of SiCp Reinforced Aluminium Matrix Composite at Ambient and Elevated Temperature", Scr. Metall. Mater., 32 (11), 1739–1745, (1995).
15. Hashim, J., L. Looney, and M. S. J. Hashmi, "Metal matrix composites: production by the stir casting method", Journal of materials processing technology, 92, 1-7, (1999).
16. V. Jayaseelana, S. Vijayananth, J. Francis Xavierc, S. Ajith Arul Daniel, Nallapaneni Manoj Kumard, X.X. Jiange, "Experimental investigation on bi-axial superplastic forming characteristics of AA6063/SiCp with various percentages of SiCp under various temperatures and pressures", Results in Physics, 15, 1-4, (2019).
17. Vijayananth S, Jayaseelan, Ajith Arul Daniel S, Nallapaneni Manoj Kumar, "High temperature superplasticity and its deformation mechanism of AA6063/SiCp", Case Studies in Thermal Engineering, 14, 1-6, (2019).