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Processing and Mechanical Characterization of ADC12 alloy-B_4C-RHA Hybrid Composites

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Abstract*: The effects of dual particulates addition on the mechanical behaviour of ADC12 alloy composites were studied. Boron carbide (B_4C) and rice husk ash (RHA) particulates were used as the reinforcements in the ADC12 alloy base matrix. Hybrid composites were prepared by using liquid melt method, keeping 5 wt. % of B_4C reinforcement constant and varying rice husk ash particles in steps of 3 and 6 wt. % in the ADC12 alloy. Samples were tested for microstructural characterization by using SEM and EDS. Mechanical behaviour like hardness, ultimate tensile strength; yield strength, percentage elongation and compression strength were evaluated as per ASTM standards. SEM photographs revealed the uniform distribution of B_4C and RHA particulates in the ADC12 alloy and these particles were confirmed by EDS analysis. Further, hardness, tensile and compression properties of base matrix ADC12 alloy was enhanced with the addition of B_4C and RHA particulates. Ductility of ADC12 alloy decreased after the incorporation of B_4C and RHA particles.

Keywords: ADC12 Alloy, Boron Carbide, Rice Husk Ash, Stir Casting, Microstructure, Mechanical Properties

I. INTRODUCTION

Composites are characterized as materials having two or more diverse materials, which when combined are stronger than the individual materials utilized. The wide definition of composite is "two or more diverse materials which when combined together is stronger than the conventional materials used" [1]. The persistent stage is called the network or matrix and the discrete constituent is called the fortification. Composite are classified based on the chemical nature of the matrix stage as ceramic matrix composites (CMC), polymer matrix (PMC), and metal matrix composites (MMC). Properties of the constituent stages, scattered stage geometry counting shape, introduction within the network, molecule measure choose the properties of the composites. MMCs are the matter of choice for analysts nowadays, due to its capacity to change their physical properties like density, thermal extension, thermal diffusivity and mechanical properties like strength and compressive characteristics, creep and triboogical behavior. Also the increasing need for advanced materials in the areas of automotive industries and aerospace has resulted in rapid development of MMCs [2].

Because of their attractive properties, ceramic reinforced composites have gained popularity in recent years. Silicon carbide, alumina, titanium carbide, boron carbide, and graphite particles are the popular reinforcement materials for these composites while the most common matrix materials are titanium, aluminum, and magnesium. In the past three decades, aluminum matrix composites (AMMCs) have received particular attention amongst MMCs due to their stiffness, high specific strength and superior wear resistance [3].

Combination of matrix and reinforcement (hard particles or ceramics) in MMCs in different ratios and proportions gives optimum tailored properties. Increase in demand of properties such as high strength, good capacity to withstand high temperature as well as wear and fatigue resistance, in industrial applications has led to great technologic interest in MMC Field. The paradigm shift in research and development in the (MMC) field towards low-cost and discontinuously reinforced composites has been a boon to automotive industry and aerospace applications. In the past three decades, aluminium metal matrix composites (AMMC) amongst MMCs have received particular attention due to their superior wear resistance, stiffness, and high specific strength. In the present scenario, one of the most popular materials for the composites is aluminum. Among MMCs, AMCs are high performance aluminum centric material systems and very light weight and are widely used in aerospace, automobile, marine etc.

A few analysts assessed the different properties of aluminum metal network composites to know the impact of fortification on base matrix. A few investigates are being made on mechanical properties like yield quality, UTS, hardness, fatigue, ductility, and behaviour of creep. Numerous components are subjected to sliding or rolling contacts amid working. To get it the conduct of MMC advance it is fundamental to ponder the mechanical and properties of AMCs. Sefiu et al. [4] studied the tensile properties of 1xxx series aluminium alloys and coconut shell ash particles reinforced composites.

In the present work, MMCs have been prepared by using ADC12 aluminium alloy reinforced with ceramic B_4C particles and rice husk ash particles. The work was aimed at investigating the effect of 5 wt. % of boron carbide and varying weight percentage of rice husk ash in steps of 3 and 6 wt. % on the hardness, tensile and compression behaviour of ADC12 alloy.

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II. EXPERIMENTAL DETAILS

A. Materials Used

In the present work silicon based aluminium alloy ADC12 is used as the matrix material. ADC12 aluminium alloy contains silicon as the major alloying element in the aluminium along with iron and copper. Table 1 is showing the chemical composition of the ADC12 alloy used in the present study.

Table I: Chemical composition of ADC12 Alloy

Elements	Content wt. %
Si	12.0
Fe	1.3
Cu	2.5
Mg	0.3
Mn	0.5
Ni	0.3
Zn	0.8
Pb	0.3
Ti	0.2
Al	Bal

In the present work, micro B_4C particulates are used as the reinforcement materials, 40 micron size particulates were used, which were procured from Speed Fam Ltd., Chennai. The density of boron carbide is lesser than the matrix material, which are 2.52 g/cm^3. The chemical composition of boron carbide particulates is shown in the Table 2. The average particle size of used B_4C is 40 µm.

Table II: Chemical composition of Boron Carbide particles

Elements	B	C
Wt. (%)	63.68	36.32

Table III: Chemical composition of Rice Husk Ash

Elements	Content wt. %
SiO_2	93.1
K_2O	1.28
CaO	1.10
MgO	0.56
Fe_2O_3	0.49
Al_2O_3	0.47
C	0.33
Na_2O	0.60
LOI*	2.61

*Loss of Ignition

Rice husk ash (RHA) is one of agricultural waste material and is natural reinforcement material. Huge amount of rice husk is generated across the world every year. This generated amount of waste is an environment nuisance. The current research focussed to convert the RH waste into useful reinforcement material by obtaining Si through rice husk ash. The chemical composition of prepared RHA is shown in the Table 3. The average particle size of used RHA is 30 µm.

B. Preparation of Composites

ADC12 alloy, ADC12-5 wt. % B_4C-3 wt. % RHA and ADC12-5 wt. % B_4C-6 wt. % RHA hybrid composites were synthesized by liquid phase melt stir casting method. The aluminium alloy ADC12 was melted in graphite crucible using electric resistance furnace. The temperature of the furnace was maintained at 750˚C. Before adding the reinforcements particles into the ADC12 alloy the preheating of reinforcement was done in the preheater at a temperature of 300˚C. This preheating of B_4C and RHA particles enhances the wettability of particles and also helps to remove the moisture content. Since, RHA contents Silica which is the combination of Silicon and Oxygen. The improvement in the wettability is very important to have the strong interface bonding between the ADC12 alloy and reinforcements. Before adding the B_4C and RHA particles in the melt, the vortex was created in the ADC12 alloy melt by mechanical stirring at 500 rpm. After the addition of preheated particles stirring was done 5 min continuously for proper mixing of boron carbide and RHA particles in the ADC12 alloy. The molten ADC12 alloy and reinforcement mixture was poured into permanent mould of cast iron having circular cavities of 15 mm diameter and 120 mm in length. The samples were removed from the cast iron mould after gradual cooling. The casted sample of ADC12 alloy-B_4C-RHA composites are shown in Fig. 1.

Fig. 1: Casted sample

C. Testing

The SEM and EDS characterization of ADC12 alloy and its B4C and Rice Husk Ash composites were examined by SEM with EDS attachment at BMS College of Engineering, Bangalore using Vegas made scanning electron microscope. The ADC12 alloy surface morphology and proper dispersion of reinforcement material in composites was observed by SEM analysis. EDS analysis was used to know the elemental analysis of casted ADC12 alloy, ADC12-5 wt. % B_4C- 3 wt. % RHA composites and ADC12-5 wt. % B_4C- 6 wt. % RHA composites. Mechanical behaviour of as cast ADC12 alloy, ADC12-5 wt. % B_4C- 3 wt. % RHA composites and ADC12-5 wt. % B_4C- 6 wt. % RHA composites were evaluated. Hardness test is conducted by using Brinell hardness tester as per ASTM E10 standard [5]. Load of 250Kgf for 30 sec was applied. The 5mm ball indenter was used to the indentation on each specimen. Each ADC12 alloy and its composites were tested for hardness.

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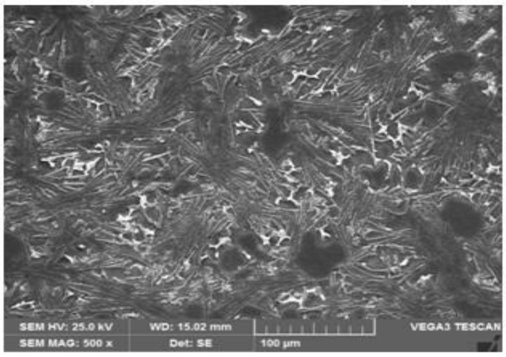
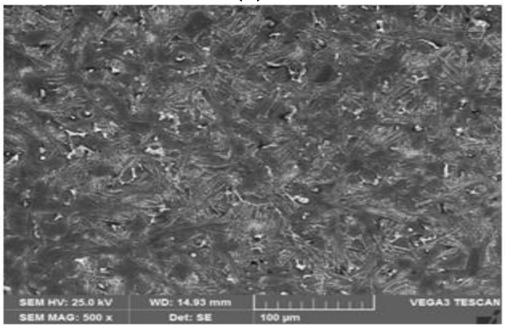
The tensile behaviour of ADC12 alloy and its B_4C and RHA reinforced hybrid composites were evaluated by conducting tensile test. The tensile test is used to determine yield point, ultimate strength and elongation of material. The tensile test was done using Instron made universal testing machine as per ASTM E8 standard [6]. Similarly, the compression test was done according to ASTM E9-09 standard. The cylindrical specimen with 15 mm in diameter and 30 mm in length were used.

III. RESULTS AND DISCUSSION

A. Microstructural Analysis



(a)



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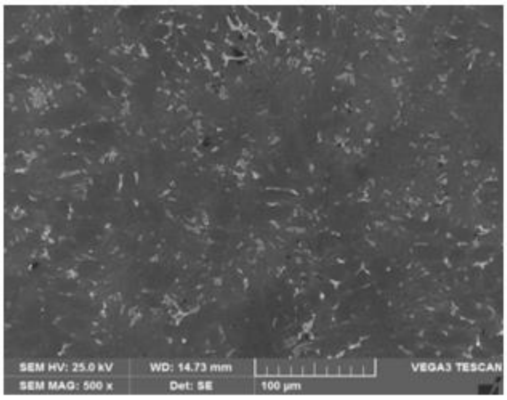

(c)

Fig. 1: Scanning electron micrographs of (a) as cast ADC12 alloy (b) ADC12-5 wt. % B_4C-3 wt. % RHC (c) ADC12-5 wt. % B_4C-6 wt. % RHA composites

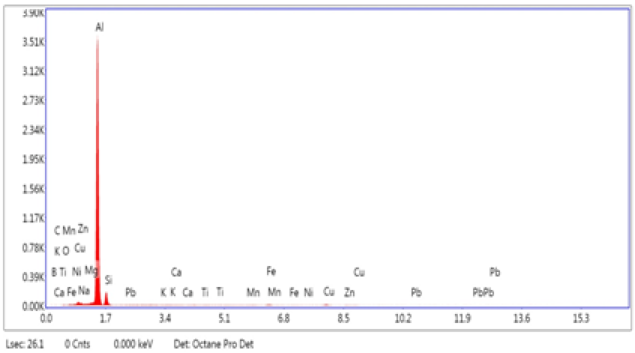

Fig. 2 indicates the scanning electron micrographs of as cast

ADC12 alloy (Fig.2a), ADC12 alloy-5 wt. % B_4C-3 wt. % RHA composites (Fig.2b) and ADC12 alloy-5 wt. % B_4C-6 wt. % RHA composites. Fig. 2a represents the SEM micrograph of the unreinforced ADC12 alloy sample. The microstructure of ADC12 alloy contains flakes kind structure. Since ADC12 is the one type of silicon based alloy, these flakes represents the presence of silicon content in the alloy. Also, it is visible in the micrograph tiny dark patches, which shows the high weight percentage of Si content in the ADC12 alloy. Further, Fig. 2b and 2c are the SEM micrographs of ADC12 alloy with dual particles reinforced composites. Fig. 2b-c displays fine microstructures with strong interfacial bonding between the ADC12 alloy with B_4C and rice husk ash particles. In the hybrid composites B_4C and RHA particles are well and evenly distributed and there is no segregation. Fig. 2b indicates B_4C and 3 wt. % of RHA particles in the ADC12 alloy along with the Si content. As the weight percentage of RHA increases from 3 to 6 wt. % in the ADC12 alloy along with 5 wt. % of B_4C, only RHA and B_4C particles are visible in the microstructure as in Fig. 2c.

Fig. 3: Energy dispersive spectrum of ADC12-5 wt. % B_4C-6 wt. % RHA composites Fig. 3 is showing the energy dispersive spectrum of ADC12 alloy reinforced with 5 wt. % of B_4C and 6 wt. % of rice husk ash reinforced composites. From the spectrum it is evident that Si content is more in the spectrum next to Al, which confirms the presence of more Silicon content in the ADC12 alloy. Further, from the spectrum the presence of B_4C particles confirmed in the form of B and C elements.

B. HardnessMeasurements

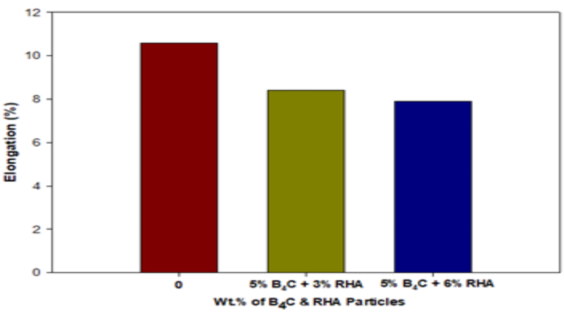

Fig3:

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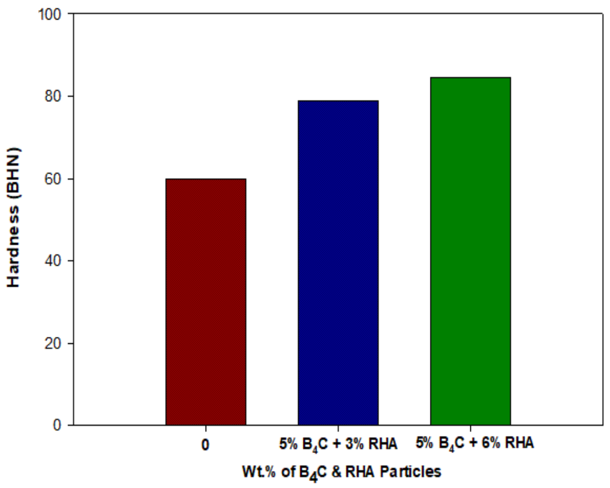


Fig. 4: Hardness of ADC12 alloy and its B_4C and Rice Husk Ash Reinforced Composites

Fig. 4 shows the variation in hardness of aluminium-silicon alloy ADC12 reinforced with the 5 wt. % of B_4C and 3 wt. % of rice husk ash and 5 wt. % of B_4C and 6 wt. % of rice husk ash hybrid composites. The hardness of ADC12 alloy is 59.8 BHN. Further, the hardness of ADC12 alloy is enhanced with the addition of 5 wt. % of boron carbide particles and 3 wt. % of rice husk ash particulates. Similar trend is observed in the case of ADC12-5 wt. % B_4C -6 wt. % rice husk ash reinforced composites. The hardness of ADC12-5% B_4C-3% RHA and ADC12-5% B_4C-6% RHA composites are 78.9 BHN and 84.6 BHN respectively. The improvements obtained in the hardness of ADC12 alloy after the addition of dual reinforcements are 31.9% and 41.4% respectively. This enhanced hardness is due to the combined effect of B_4C and rice husk particles presence in the ADC12 alloy matrix, which was revealed in the microstructural study. The enhancement in hardness can be attributed to refining the grain and raise the level of mismatch between the reinforcement particles and the ADC12 alloy matrix [7]. The improvement in BHN hardness of composites could be coming from the high hardness properties of B_4C+ RHA themselves. Due to the true of that aluminum is a soft metal and the B_4C-RHA particles are ceramics materials very hard. This property contributes positively to raise the hardness of ADC12 alloy composites.

C. Tensile Properties

Ultimate Tensile and Yield Strength

Fig. 5 shows the UTS of ADC12 alloy, ADC12-5 wt. % B_4C-3 wt. % RHA and ADC12-5 wt. % B_4C-6 wt. % RHA composites. From the graph it is indicated that B_4C and rice husk ash reinforced hybrid composites exhibited the superior strength as compared to the ADC12 alloy. The ultimate tensile strength of as cast ADC12 alloy is 165.1 MPa, ADC12-5 wt. % B_4C-3 wt. % RHA hybrid composites have UTS of 197.5 MPa. Further, the ultimate tensile strength of ADC12 alloy increased when RHA particles weight percentage is increased to 6 wt. % along with 5 wt. % of B_4C particles. The UTS of ADC12-5 wt. % B4C-6 wt. % RHA hybrid composite is 215.6 MPa. The increased UTS is mainly due to the combined effect of B_4C and rice husk ash particles in the ADC12 alloy. The addition of 5 wt. % of B_4C particles and varying weight percentages of RHA particles i.e. 3 and 6 wt. % in the matrix increases the surface area of the reinforcement and the matrix grain sizes are reduced, which was seen in the microstructural studies [8].

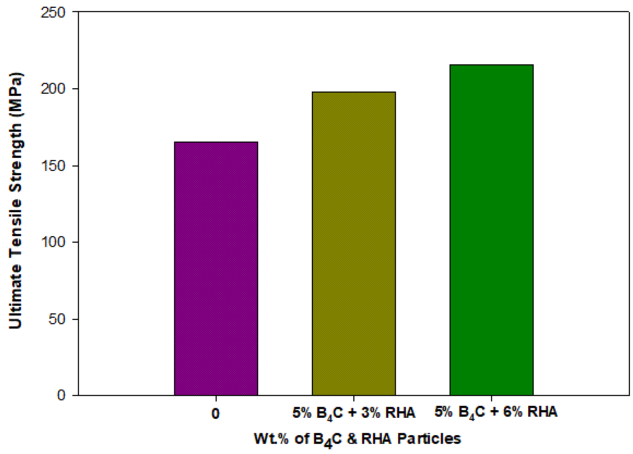
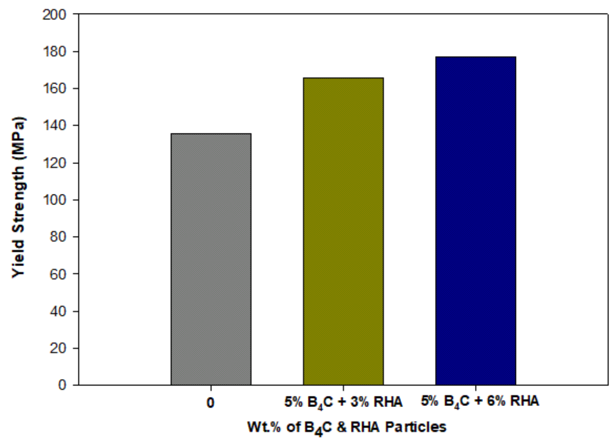


Fig. 5: Ultimate tensile strength of ADC12 alloy and its B_4C and Rice Husk Ash Reinforced Composites

Fig. 6 shows the relation between the yield strength of the ADC12-B_4C-RHA composites based on the weight percentage of B_4C and RHA particles in the ADC12 alloy matrix. It can be inferred that rice husk ash and B_4C particles are more effective in enhancing the yield strength of ADC12



alloy from 135.4 MPa to 176.8 MPa. Further, the thermal mismatch between the ADC12 alloy and B_4C-RHA reinforcement causes higher density dislocations in the base and load bearing capacity of the ceramic particles which frequently enhances the composite specimen's properties.

Fig. 6: Yield strength of ADC12 alloy and its B_4C and Rice Husk Ash Reinforced Composites

Percentage Elongation

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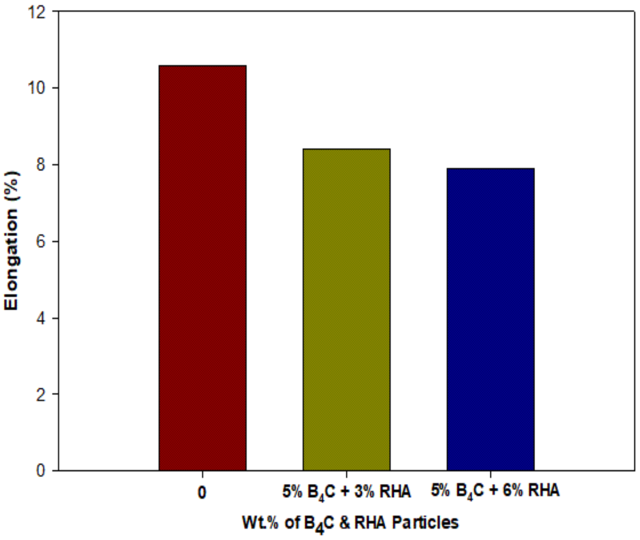

Fig. 7: Percentage elongation of ADC12 alloy and its B_4C and Rice Husk Ash Reinforced Composites

The percentage elongation of ADC12 alloy reinforced with B_4C and rice husk ash dual reinforcements composites is reported in the Fig. 7. It is observed that the ductility of the ADC12 alloy decreases with the addition of 5 wt. % of B_4C, 3 and 6 wt. % of RHA particles. This reduction in the elongation of ADC12 alloy composites is due to increase in the hardness. It is concluded from the Fig. 7 that the percentage elongation of the hybrid composites reduced as the weight percentage of RHA increases from 3 to 6 weight % in 5 wt. % of B_4C constant reinforcement. An amount of 25% decrease in the elongation is noticed with respect to the ADC12 alloy – 5 wt. % B_4C and 6 wt. 5% RHA reinforced hybrid composites. These results are similar to many researches who studied the mechanical behavior of MMCs.

D. Compression Strength

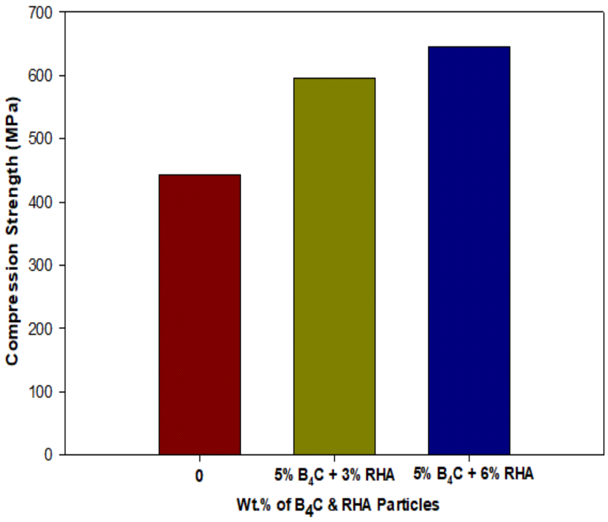

Fig. 8: Compression strength of ADC12 alloy and its B_4C and Rice Husk Ash Reinforced Composites

Fig. 8 is represented the variation in compression strength of ADC12 alloy and its constant weight percentage of B_4C and varying weight percentages of rice husk ash particles reinforced composites. Results of the compression test stated that the compression strength of ADC12 alloy increased with the addition of 5 wt. % of B_4C and 3 weight % of RHA particles, further this strength is increased more in 5 wt. % of B_4C and 6 weight % of RHA reinforced composites. The compression strength of ADC12 alloy is 443.6 MPa. The improvement obtained with the incorporation of 5 wt. % of B_4C and 6 wt. % of RHA in ADC12 alloy is 45.3%. This enhanced strength is high hardness of boron carbide particles especially, also the combined effect of rice husk ash particles. As it was observed in the several investigators research, hard ceramic particles strength is always indicated by compressive strength. This high compression strength particle improves the hardness of soft matrix, further helps in enhancing the compression strength of ADC12 alloy.

IV. CONCLUSIONS

The liquid stir casting techniques was successfully used to fabricate the ADC12 alloy with B_4C and rice husk ash particles reinforced composites. The microstructural studies identified the uniform distribution of 5 wt. % of B_4C and varying weight percentages of (3 and 6 wt. %) rice husk ash particles in the ADC12 alloy base matrix. Hardness of the ADC12 alloy increased with the addition of B_4C and RHA particles. This hardness further enhanced with the increased content of RHA. The tensile strength of the hybrid composites were found to increase than that of ADC12 alloy. The ductility of the ADC12-B_4C-RHA hybrid composites decreased as compared to the base alloy. Additionally, the B4C and rice husk ash particles contributed in enhancing the compression strength of ADC12 alloy. It can be detrained that ADC12-5 wt. % of B_4C and 6 wt. % of RHA hybrid composites exhibits superior mechanical properties.

REFERENCES

1. Madeva Nagaral et al., "Nano Al_2O_3 particulates reinforced AA7475 alloy composites", *Journal of Mechanical Engineering and Sciences*, 13, 1, pp. 4623-4635, 2019.
2. Prasad H Nayak, et al., "Characterization of tensile fractography of nano ZrO_2 reinforced copper-zinc alloy composites", *Frattura ed Integrity Strutturale (Fracture and Structural Integrity*), 48, pp. 370-376, 2019.
3. Madeva Nagaral et al., "Influence of two stage stir casting process on mechanical characetization of AA2014-ZrO_2 nano composites", *Transactions of the Indian Institute of Metals*, 2018.
4. Sefiu Adekunle Bello et al., "Study of tensile properties, fractography and morphology of aluminium coconut shell micro particle composites", *Journal of King Saud University Engineering Sciences*, 29, pp. 269-277, 2017.
5. T. Hariprasad et al., "Fly ash-B_4C reinforced Al5083 composites", *International Journal of Applied Engineering Research*, 10, 9, pp. 7834-7837, 2015.
6. J. David Raja Selvam et al., "In situ synthesized AA6061-TiB_2+Al_2O_3 hybrid aluminium matrix composites", *Journal of Alloys and Compounds*, 2018, 10.1016/j.jallcom.2018.01.016.
7. H. M. Kim et al., "Fabrication of A356 aluminium alloy matrix composite with CNTs-Al_2O_3 hybrid reinforcements", *Materials Science and Engineering A*, 573, pp. 92-99, 2013.
8. Hamid Khosravi et al., "Tensile properties of A356-SiCp composites", *Transactions of Nonferrous Metals Society of China*, 24, 2014, pp. 2482-2488.

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27 guest talks were delivered as a key note resource speaker in various engineering colleges of India. He has chaired as a Guest and Session Judge for National and International Conferences held at various Engineering Colleges.