Available online at www.ijapie.org

International Journal of Advanced Production and Industrial Engineering

IJAPIE-SI-MM 511 (2017) 71–80

Special Issue on

MATERIALS & MANUFACTURING

Characteristics and Properties of Different Reinforcements in Hybrid Aluminium Composites: A Review

Ravi Butola*, Ranganath M.Singari, Ashwani Bandhu, R S Walia

(Delhi Technological University, Delhi, India)

**Email: ravimed@dtu.ac.in*

Abstract : Aluminium composites have a wide range of applications and serve as an important tool in various industries. Different reinforcements have different effects on aluminium matrix composite. In this paper these different effects and properties are studied for reinforcing materials such as Silicon Carbide, Graphite, Fly ash, Rice husk ash and boron halide. Properties like hardness, corrosion behaviour, tensile strength, wear resistance etc have been studied rigorously and been summarised. It's been observed that there is an enhancement in the properties of hybrid composites so formed on addition of these reinforcing materials to aluminium composites.

Keywords: Al matrix Composites, Reinforcement, Corrosion behaviour, wear resistance

I. INTRODUCTION

The importance of metal matrix composites has gained a large importance in recent years. MMCS are fast replacing conventional metallic alloys in so many applications as their use have been extended from predominantly aerospace and automobile to defences, marine sports and recreation industries. The different reinforcing materials used in the development can be classified into three broad groups, which are synthetic ceramic particulates, industrial wastes and agro waste derivatives. The final properties of the hybrid reinforcement depend on individual properties of the reinforcement selected and the matrix alloy [1] the aluminium matrix composites (AMCS) represent a class of MMCS possessing properties like low density, high stiffness and strength, superior wear resistance, controlled co-efficient of thermal expansion, higher fatigue resistance and better stability at elevated temperature.[2]Aluminium is most widely used industrial metal and due to its wide applications ,this review emphasizes on studying the effects of different types of reinforcement on aluminium composites .

II. METHODOLOGY

This review revolves around the works of various people in the field of hybrid aluminium composites and studying the effects of different reinforcements used. Various research papers have been studied rigorously for this review considering the reinforcing materials like SiC, rice husk ash, fly ash, graphite and B_4C. All the research works that were used were mainly taken from Sciencedirect.com and have been cited in the work as well. Major properties like Corrosion behaviour, wear behaviour, tensile strength, hardness etc. were studied .Efforts have been made to ensure that similar properties were studied for every reinforcement.

III. DATA AND ANALYSIS

A. ALUMINUM WITH BORON

Tensile strength :

B. Vijaya Ramnath[4] investigated the properties of hybrid composite formed by using alumina and boron carbide as reinforcements to aluminium alloy matrix. Stir casting method was used for production. The tensile test was carried out using a universal testing machine. Three samples were studied are shown in table I

Table I [4]

Sample	Composition of composite specimen	Tensile strength (MPa	Elongation (%)
Sample 1	Aluminium alloy—95% Alumina—3%,Boron carbide—2%	54.60	4.00
Sample 2	Aluminium alloy-95% Alumina-2%,Boron carbide-3%	51.75	3.71
Sample 3	Aluminium alloy	68.24	4.00

It was observed that tensile strength of sample 3 is marginally higher than other two samples because of its aluminum content. But, the sample 1 has higher tensile strength (54.60 MPa) than sample 2 (51.75 MPa)[4]. A. Baradeswaran [5] investigated the Aluminum alloy (AA) 6061 and 7075 that were reinforced with 10 wt.% of boron carbide (B4C) and 5 wt.% of graphite. Liquid casting technique was used.

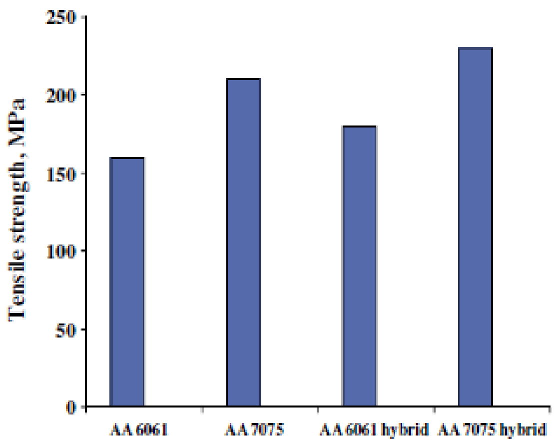


Fig 1.[5]

Thus tensile strength has been observed to increase with increasing B4C particle content and it is significantly higher than the strength of the matrix alloy.

K. Shirvanimoghaddam [6] investigated the effect of ceramic particles on aluminum He observed that the effect of B_4C was temperature dependent for example at 750^o Celsius, increase in amount of boron carbide content leads to decrease in tensile strength whereas at 850^o Celsius, increasing boron carbide increases the tensile strength.[6]

B. Ravi [10] used Stir casting process for fabrication of aluminum matrix composite and plotted the graph shown in fig 2.

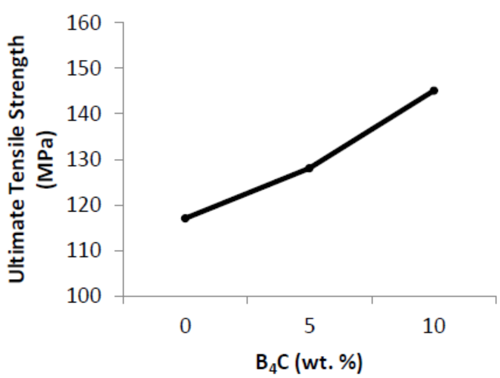


Fig 2[10]

Thus concluded that The B4C reinforcement has enhanced the tensile strength of Aluminum Matrix Composites.

Wear Resistance :

R. Palanivel synthesized and investigated /(TiB2 + BN) hybrid AMCs using Friction Stirring Process and studied the associated microstructure and dry sliding wear behavior. [3]. He observed the values shown in Table.II

Table II [3]

Material	Wear rate ($\times 10^{-5}$ mm3/Nm)
AA6082	23.75
AA6082/TiB2 AMC	15.50
AA6082/(TiB2 + BN) hybrid AMC	13.00
AA6082/BN AMC	14.25

Thus concluded that addition of BN particles enhanced the sliding wear resistance of the AMCs. A. Baradeswaran[5] studied the effect of 10 wt.% boron carbide(B_4C) and 5 wt % of graphite as reinforcement and plotted the below shown graphs shown in Fig 4 and Fig 5 . Also it was observed that there is an optimal condition at which the AA 7075/B4C/graphite hybrid composite exhibits higher wear resistance property compared to base alloys and AA 6061 hybrid composite.

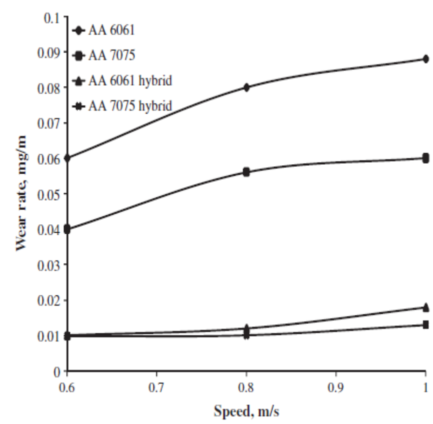
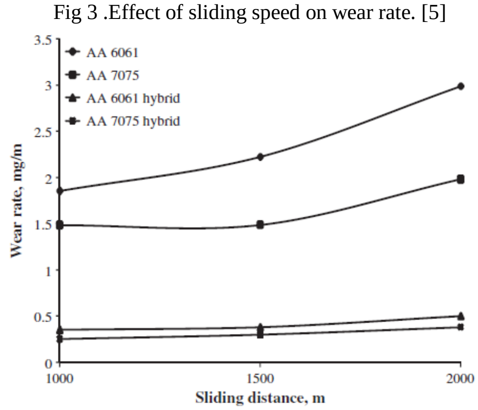


Fig 3 .Effect of sliding speed on wear rate. [5]



.

Fig 4.Effect of sliding distance on wear rate[5]

Siddhartha Prabhakar[9] also studied the wear behaviour under dry sliding motion of aluminum/B4C composite. Results revealed that wear rate and coefficient of friction has a direct relation with the load, whereas inverse with the sliding speed and distance.

Hardness :

B. Vijaya Ramnath[4] studied boron carbide metal matrix composite and measured hardness using Brinell's hardness test. The observation of the work is shown in Table III.

Table III [4]

Sample	Composition of composite specimen	Average hardness (BHN)
Sample 1	Aluminum alloy—95%Alumina—3%,Boron carbide—2%	48.53
Sample 2	Aluminum alloy 95% Alumina—2% Boron carbide—3%	52.80
Sample 3	Aluminum alloy	37.83

Thus hardness increases with increase in boron carbide wt %. K. Shirvanimoghaddam[7] investigated manufacturing of aluminum–boron carbide composites using the stir casting method and studied various properties like hardness and density. During his study about hardness of the hybrid composite so formed, the below shown diagrams were plotted.Thus stated that in general increasing the volume fraction of B4C enhances the and hardness of the composite.[7]

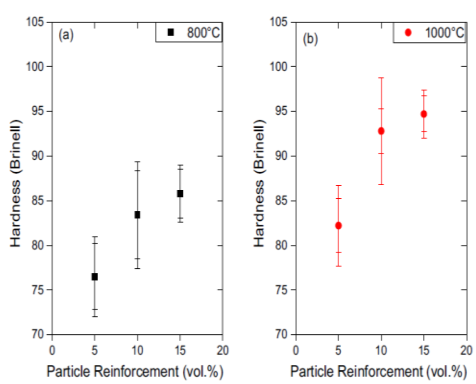


Fig 5[7]

Ehsan Ghasali [11] also studied the properties of B_4C-aluminum metal matrix composite and used the method of microwave sintering for the production. In her work ,she studied the property of microhardness, where it was stated that the average micro hardness of the microwave sintered composites was higher than the corresponding value for the reference 6061 Al alloy and the hardness increased with the increasing amount of B4C.[11]

Impact test :

R. Harichandran [8] used the process of ultrasonic cavitation-assisted solidification for fabrication in his work and studied effect of B_4C as reinforcement on aluminum metal matrix composite.He plotted the graph shown in Fig 6.

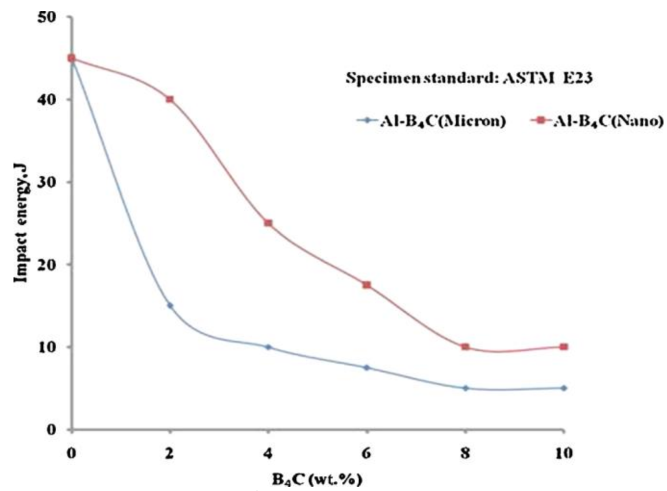


Fig 6.variation of impact energy with B_4C wt%[8]

Thus, the impact energy of the B4C nanoparticle-reinforced aluminum composites was higher than that of the micro B4C particle-reinforced aluminum composites. Similarly B. Vijaya Ramnath[4] used Charpy test to perform the impact test and got the following observations shown in Table IV

Table IV [4]

Sample	Composition of composite specimen	Energy absorbed (J)
Sample 1	Aluminum alloy—95% Alumina—3% Boron carbide—2%	2.18
Sample 2	Aluminum alloy—95% Alumina—2% Boron carbide—3%	2.42
Sample 3	Aluminum alloy	2

It can clearly be seen that the impact value of sample 1 (2.18 J) is lower than the impact value of sample 2 (2.42 J), but higher than that of sample 3 (2 J).[4]Thus addition of Boron Carbide contributes in making the hybrid composite stronger against impacts.

B. ALUMINUM WITH FLY ASH

Hardness :

Liang-Jing Fan[12] prepared Al–3Mg/5 wt.% fly ash composites through stir casting with reactions at 850 °C for various durations (0, 10, 20, 30, and 40 h).He used brinnels hardness tests to study the haedness of the so formed hybrid composite. The hardness fly ash composites increased with increasing reaction time.The plot for the same have plotted below.

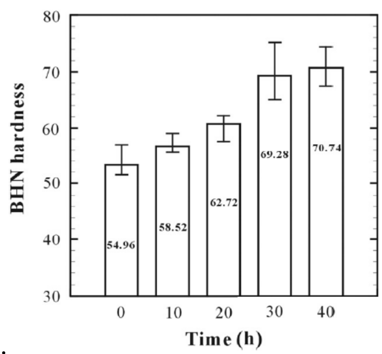


Fig 7 BHN hardness of specimens in different reaction time.[12]

G.Narasaraju [16] made rice husk ash and fly ash reinforced aluminum composite using liquid metal processing technique The hardness was measured using Brinell Hardness Tester at a load of 500 kg for a period of 15 sec in accordance with the ASTM E10.In his work he plotted the below shown diagram.

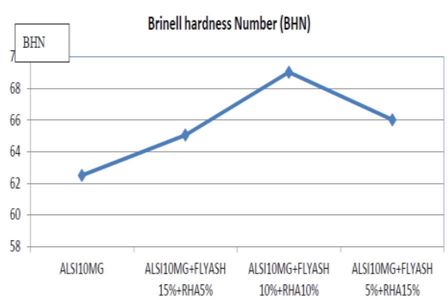


Fig 8[16]

Thus concluded , The hardness of the test specimens increased with increase in Rice Husk Ash and decrease in Fly ash weight proportions.[16]. I. Dinaharan[14] studied wear characteristics and other properties in his work.[14]He studied microhardness of fly ash reinforced aluminum ,plotting the below shown graph. Thus concluding that the use of fly ash as reinforcement greatly enhanced the microhardness of the composite.[14]

Density :

Liang-Jing Fan [12] in is work also studied the reaction of fly ash on density of aluminum hybrid composite so formed. The density was detected using the Archimedes method and plotted the below shown graph on the basis of his experimentation.

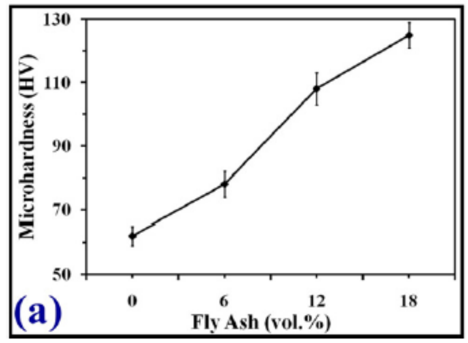


Fig 9 Variation of Micro hardness vs. fly ash wt %[14]

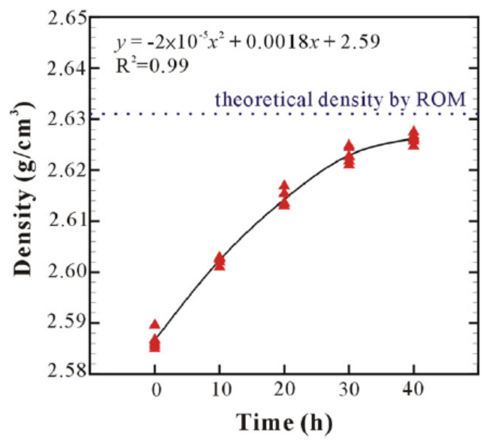


Fig 10 Measured densities of specimens in different reaction time, the dash line indicating the theoretical density.[12]

S.G.Kulkarni [15] during his work on reaction of fly ash hybrid reinforcement on aluminum 356 alloy also studied the density and mechanical properties of the hybrid .He plotted the below shown graph showing theoretical and actual density of various composites.

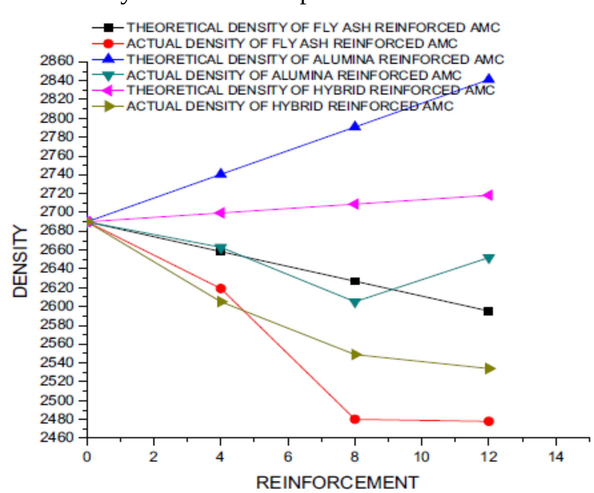


Fig 11 Variation of density with reinforcement %[15]

Thus ,addition of fly ash reinforcement reduces density of composite to much extent.[15]

Wear Resistance :

I. Dinaharan [14] investigated the wear properties of fly ash reinforced aluminum alloy using friction stirring process .He observed that The wear rate reduced as the volume fraction of FA particles was increased. The wear rate was found to be 411 x 10^{-5} mm3/m at 0 vol. % and 203 x 10^{-5} mm3/m at 18 vol. %.

Also FA particles affected the wear mode as well as the morphology of the wear debris. The increased volume fraction of FA particles altered the wear mode from adhesion to abrasive. The wear debris changed from thin plate at 0 vol. % to spherical shape at 18 vol. %. Thus FA particles improved the wear resistance of the composite.

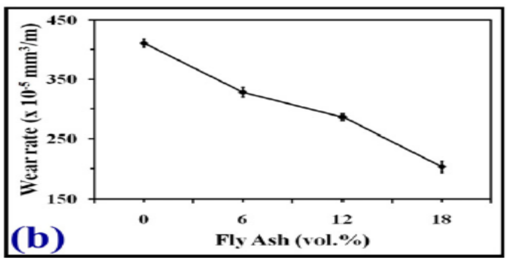


Fig 12 Wear rate vs. Fly ash vol % [14]

Percentage elongation and Tensile strength :

ShueiwanH.Juang [13] observed the the properties like tensile strength and elongation during his work. The tensile strength of the as-cast ALFA composite (ADC6 + 5 wt% fly ash) subjected to Multipath friction stir processing(MS-FSP), as determined from a specimen sampled parallel to the processing paths, increasedto227MPa.This represented significant improvement of the strength compared to the original as-cast ALFA composite. The elongation was 7.18 %, which was far better than that of the original as-cast ALFA composite. The tensile strength of the specimen sample perpendicular to the processing paths also increased to 226 MPa , but its elongation was only 3.12%.[13]. Also G.Narasaraju[16] also studied tensile strength and elongation in his investigation on Rice husk ash and fly ash reinforcement for aluminum alloy .He plotted the below shown diagram for Tensile strength.[16]

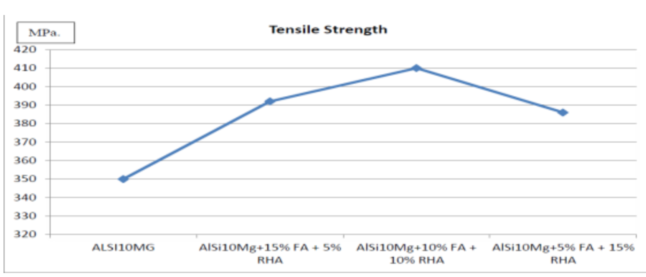


Fig 12 Tensile strength vs. different weight % of reinforcement[16]

Thus concluded That Tensile Strength of MMC increased with increase in Fly ash and percentage elongation is more with decrease in Fly ash by his observations.[16]

C. ALUMINUM WITH GRAPHITE

Hardness :

S. Mosleh-Shirazi [17]studied variation in the hardness of Al/2SiC/Gr hybrid nanocomposites with their Gr . shows that the increased volume fraction of graphite particles resulted in decreased hardness of Al/2SiC/Gr hybrid nano-composites. These results are attributed to the presence of soft graphite particles in the composites that contribute in lowering their hardness values.[17]. Syed Nasimul Alam studied Al-matrix composites reinforced with exfoliated graphite nano- platelets (xGnP) is developed in order to keep the desired properties of Al intact while improving the limiting factors .he gave the following conclusion.[18]

The hardness of the Al- xGnP composites increase up to the ad- dition of 1wt% of xGnP.However,the addition of xGnP beyond 3 wt% leads to a large decrease in the hardness of the Al-xGnP composites. The hardness of the composites possibly reduces due to the agglomeration of xGnP in the Al matrix which also leads to poor densification of the composites. [18]

L.A. Yolshina , R.V. Muradymov used the method for synthesizing aluminum-based metallic composite materials, containing up to 2 wt. % graphene sheets uniformly distributed in a metal matrix,.According to his work synthesis of aluminum-carbon metallic composites with improved structure and unique mechanical properties proceeds at relatively low temperatures without aluminum carbide formation; as a consequence, these composites have sufficiently high corrosion resistance. The hardness, strength, ductility and elasticity of aluminum-graphene composites are higher than the initial aluminum materials, corresponding to the concentration of graphene.[19]. Mohammed Imran [20] in his work made aluminum matrix hybrid composites have been fabricated by stir-casting method using Waste sugarcane bagasse-ash and graphite as reinforcements for aluminum alloy (Al-7075) based matrix.

Brinell hardness tests were carried out on samples of both unreinforced alloy and its composites.Thus concluded that increasing the graphite content and keeping the bagasse ash concentration constant contributes in increasing the hardness of composite.[20]

P. Ravindran [21] Studied the tribological behavior of Al 2024–5 wt.% SiC–X wt.% graphite (X = 5 and 10) hybrid nano-composites was produced using powder metallurgy (P/M) technique. The hardness of sintered compacts were performed in Brinell's scale. According to his study hardness of the composites was decreased with the increase in weight percent of Gr reinforcements. [21]

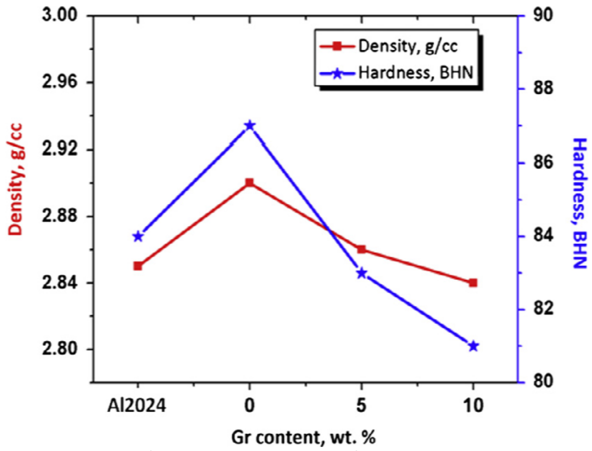


Fig 13 Variation of density and hardness of hybrid nano-composites with different weight percentage of Gr.[21]

Wear Characteristics :

P. Ravindran [21] investigated properties of aluminum hybrid nano-composites with the additions of solid lubricant. investigation, nano-sized SiC and Gr particles were used as a reinforcement for a nano-aluminum alloy matrix (Al 2024). Dry sliding wear tests were performed in pin-on-disc equipment. The following graphs (fig 14) were obtained showing variation of wear loss with respect to graphite wt % ,.

Thus his investigation gave the following conclusions:
Wear loss of the composite increases as the amount of graphite addition increases up to 5% Gr addition, then drops to a lower value for 10% Gr addition The wear resistance of hybrid nano-composites was higher than the matrix alloy. Amount of the graphite released on the wear surface increases as the percentage of graphite addition increases.[21]. S. Suresha[22] in his work studied wear characteristics using dry sliding wear behavior on aluminum matrix with graphite and SiC as reinforcements. Thus made the below shown graph on the basis of the investigation.

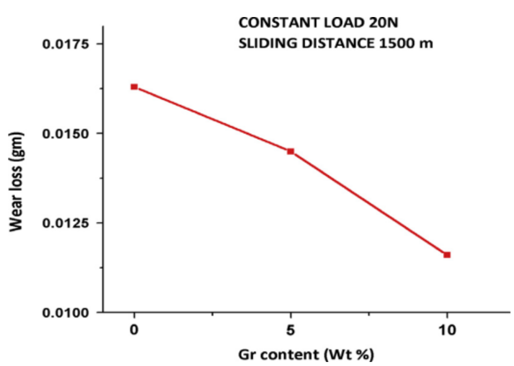


Fig 14 Variation of wear loss vs. Graphite wt %[21]

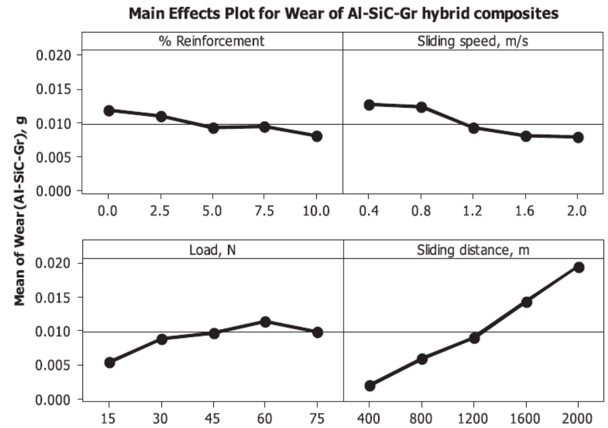


Fig 15 Variation of wear wrt. Various factors [22]

Kenneth Kanayo Alaneme [23]studied microstructural characteristics, mechanical and wear behaviour of Aluminum matrix hybrid composites reinforced with alumina, rice husk ash (RHA) and graphite. The wear characteristics of the composites were studied using a Taber abrasion wear testing machine He concluded that The composites without graphite exhibited greater wear susceptibility in comparison to the composite grades containing graphite. However the wear resistance decreased with increase in the graphite content from 0.5 to 1.5 wt%.[23]

S. Mosleh-Shirazi studied Effects of graphite (Gr) content on the dry sliding wear, solid-particle erosion and corrosive wear of Al6061based hybrid nano-composites fabricated via powder metallurgy route containing 2 vol% of SiC nano-particles and 0,2, 5 and 7vol%of micron-sized Gr particles and performed Dry sliding wear tests.From these tests concluded that TheAl/2SiC/2Grhybridnano-composite;as compared with Al/2SiC; possessed higher wear resistance and lower friction coefficient. However, when the volume percent of graphite exceeded 2%,both the volume wear loss and friction coefficient of nano-composites increased due to decreased toughness and reduced hardness caused by brittle graphite Particles.[17]

Corrosion Behaviour :

S. Mosleh-Shirazi corrosion, corrosive wear and abrasive wear, of Al/2SiC/Gr hybrid nano-composites to understand and optimize the materials for improved performance.
The corrosion rates of such nano-composites in that acidic solution as a function of their Gr content were studied. The SiC nano-particles addition increased the corrosion potential of the matrix alloy, due to non-reactivity of a part of the material (nano SiC particles)with the corrosive solution .

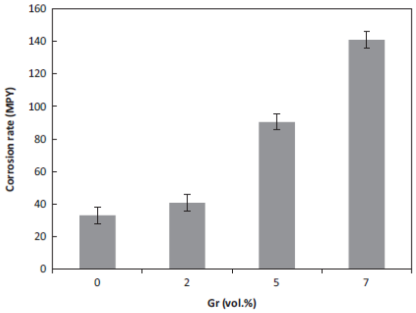


Fig 16 Corrosion rate vs. graphite weight %[17]

Thus concluding That the observed increase in the corrosion rate with Gr particles is attributed to the fact that the added conductive graphite particles may act as micro-cathodes, promoting the galvanic effect and thus increasing the corrosion rate. Both the high-angle solid-particle erosion and the corrosive wear of Al/2SiC/Gr hybrid nano-com- posites increased with their graphite content due to increased amount of the brittle phase (Gr) in the material that contributed in lowering the toughness and hardness of the material.[17]

Elongation and Ductility:

Kenneth Kanayo Alaneme studied effects of varied weight ratios of the three reinforcing materials namely, alumina, rice husk ash, and graphite on the microstructure, mechanical and wear behaviour of Al-Mg-Si alloy matrix. According to him The % Elongation for all composites produced was within the range of 10 to13% and the values were invariant to the RHA and graphite content.[23]

D. ALUMINUM WITH RICE HUSK ASH

Tensile strength and hardness :

S.D.Saravanan[27] studied Effect of Mechanical Properties on Rice Husk Ash Reinforced Aluminum alloy (AlSi10Mg) Matrix Composites. material. A rice husk ash particle of 3, 6, 9 & 12 % by weight were used to develop metal matrix composites using a liquid metallurgy route. The mechanical properties such as tensile strength, compressive strength, hardness and percentage elongations are studied for reinforced RHA composites.[27]

The tensile tests were conducted using a universal testing machine. The hardness was measured using Brinell's Hardness Test. The following graphs were plotted .

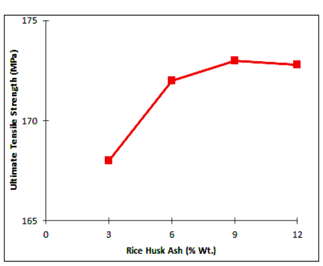


Fig 17 UTS vs. Rice husk ash wt. % [27]

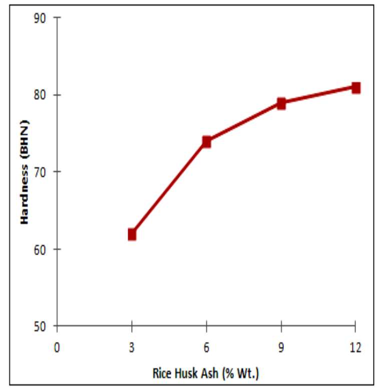


Fig 18 Hardness vs. Rice husk ash wt %[27]

Thus , The Tensile Strength and Hardness increases with the increase in the weight fraction.[27]

Elongation and Ductility :

G.Narasaraju studied Characterization of Hybrid Rice Husk and Fly ash-Reinforced Aluminum alloy (AlSi10Mg) Composites.the investigation on the property of ductility was done. The following results were obtained shown in table V.

Table V [28]

Sl. No	Sample Designation	Percentage elongation
1	AlSi10Mg	2.0
2	AlSi10Mg + 15% Fly Ash +5% Rice Husk Ash	2.9
3	AlSi10Mg + 10% Fly Ash +10% Rice Husk Ash	3.2
4	AlSi10Mg + 5% Fly Ash + 15% Rice Husk Ash	2.7

The percentage elongation is more with decrease in Fly ash and increase in Rice Husk Ash. This is due to decrease in hardness with increase in Rice Husk Ash and decrease in Fly Ash [28]

Damping Behaviour :

Dora Siva Prasad[24] studied the damping behaviour of hybrid composites has been investigated using dynamic mechanical analyzer (DMA). The composites were fabricated with 2, 4, 6, and 8% by weight of rice husk ash (RHA) and SiC in equal proportions using two stage stir casting process. The damping measurements were performed using a GABO Eplexor dynamic mechanical analyser at frequencies ranging from 1 Hz to 15 Hz at room temperature using three point bending mode. All the damping experiments are performed at a static load of 50 N, a dynamic load of 40 N, and at constant strain amplitude (ε) of 1 × 10−5.

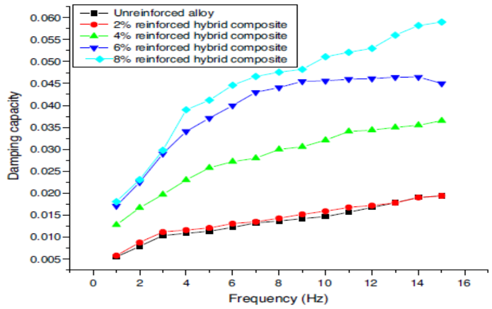


Fig 19 Variation of damping capacity with frequency for unreinforced alloy and hybrid composites.[24]

Wear Resistance :

Kazeem Oladiti Sanusi [26] It is also observed that the effect of RHA on wear susceptibility was not as consistent as the case of graphite but generally for the composites containing RHA there was on the average an increase in wear susceptibility with increase in RHA content. The wear resistance thus decreases with decrease in RHA.[26]

Corrosion:

Kenneth Kanayo Alaneme [25] in his work on corrosion behavior of hybrid composites using rice husk ash and silicon carbide as reinforcements stated that the hybrid composite grades with a higher RHA content generally exhibited a lower tendency to corrode compared to the other composite grades. He used thermally cycled aluminum composites for his study and also concluded that the composites are structurally stable and maintain their corrosion resistance levels even after exposure to thermal cycling.[25]

E. ALUMINUM WITH SiC

Aging behaviour :

Yan Cui [29] studied Aging behaviours of the high-volume-fraction SiCp/Al-Mg-Si composite fabricated by pressure less in filtration and its base alloy at 170° C. The aging behaviours of the base alloy and the composite were studied by Rockwell hardness measurement. Following results were obtained by Yan Cui :

(1) The hardness of the 55% SiCp/Al composite and the matrix alloy could be improved by age-hardening treatment. The maximum hardness increment of the matrix alloy is 242% after aging treatment for 3 h while that of the composite is 22%.(2) The aging kinetic of the 55% SiCp/Al composite is accelerated due to the high density of the dislocation, in comparison to the performance of the Al-Mg-Si alloy.(3) The mechanisms of the age-hardening treatment of the unreinforced Al-Mg-Si alloy and the high volume fraction SiCp/Al composite are quite different. For Al-Mg-Si alloy, double hardness peaks are observed. For 55% SiC/Al composite, only one visible peak is observed.[29]

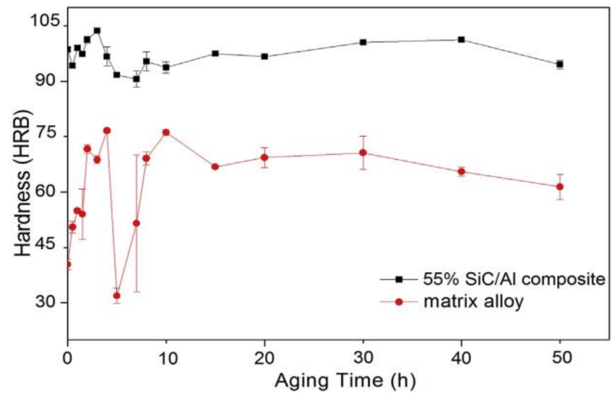


Fig 20 Aging curves at 170° C for solution-treated matrix alloy and solution-treated composite.[29]

Compression Behaviour :

Jufu Jiang studied[30] The compression mechanical behaviour of the fabricated composite in semisolid state .Consequently, they lead to a significant reduction of porosity and an improvement of mechanical properties of the final products.

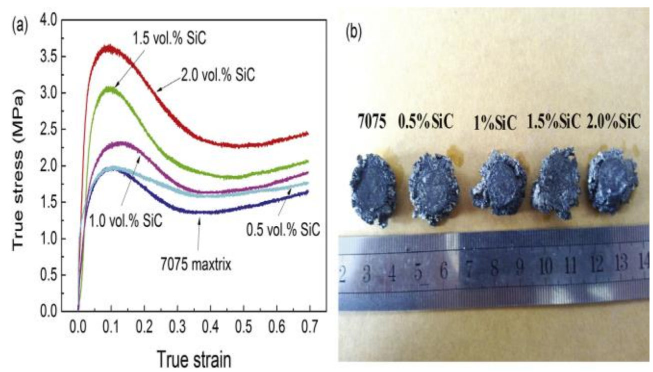


Fig 21 True stress–strain curves (a) and macrograph (b) of the samples with different volume fraction of SiC particles.[30]

Jufu Jiang observed that Peak stress and steady stress increase with increasing volume fraction of SiC particles and there was a significant improvement in properties.

Wear characteristics :

S. Suresha[31] studied the dry sliding wear behaviour of Al matrix composites reinforced with Gr and SiC particulate up to 10%, to study the effect of % reinforcement, load, sliding speed and sliding distance on stir cast Al–SiC–Gr hybrid composites, Al–Gr and Al–SiC composites. Addition of SiC particulates increases both mechanical strength and wear resistance of Al alloy. But the consequent increase in hardness makes the machining difficult . On the other hand, addition of Gr particulates facilitates easy

machining and results in reduced wear of Al–Gr composites compared to Al alloy.[31]
Thus addition of SiC particulates improve the wear characteristics effectively and upto a great extent.

Corrosion Behaviour :
H.M. Zakaria [32]studied the corrosive properties of Al/SiC metal matrix composites (MMCs). Following observations were made by Zakaria in his experiments.
1.) At room temperature, the Al/SiC composites exhibited better corrosion resistance than the pure Al matrix in
3.5 wt.% NaCl aqueous solution.
2.) Increasing the volume fraction of the SiC particulates increased the corrosion resistance of the Al/SiC composites. Moreover, reducing the SiC particles size
enhanced significantly the corrosion resistance of the SiC composites. Increasing the duration exposure reduces the corrosion rate.
3.) At elevated temperature, the Al/SiC composites exhibited lower corrosion resistance than the pure Al matrix in 3.5 wt.% NaCl aqueous solution. However, increasing the volume fraction and/or the SiC particles size reduce(s) the corrosion rates of the Al/SiC composites. The corrosion rates of the pure Al as well as the Al/SiC composites were found to increase linearly with the temperature.[32]

IV. Conclusions

The conclusion derived by this study about the effects of five different reinforcing materials on aluminium matrix composites is as follows.

- Addition of Boron carbide enhances the tensile strength, wear resistance, hardness. Also impact energy absorbed was higher for hybrid AMC with boron carbide.
- On Addition of Fly ash density and hardness decreases There was an improvement in wear resistance.Tensile Strength of MMC increased with increase in Fly ash and percentage elongation is more with decrease in Fly ash.
- Hardness increased up to a maximum value on addition of graphite and then decreased. Both Corrosion and wear resistance decreases on increasing graphite weight proportion. Elongation is generally invariant on addition of graphite.
- Tensile strength and hardness increases with increase in RHA concentration. Elongation, wear resistance, damping capacity and corrosion resistance showed significant improvement on addition of RHA.
- Aging kinetic of 55% SiCp/Al composite is accelerated due to the high density of the dislocation. Peak stress and steady stress increase with increasing volume fraction of SiC particles and there was a significant improvement in compressive properties. Also wear resistance and corrosion resistance improved on addition of SiC particles.

References

[1]. Michael Oluwatosin Bodunrin , Kenneth Kanayo Alaneme, Lesley Heath Chown; Aluminium matrix hybrid composites: a review of reinforcement philosophies; mechanical, corrosion and tribological characteristics. j mater r estec no l . 2015; 4(4):434–445
[2]. Jaswinder Singh, Amit Chauhan; Characterization of hybrid aluminium matrix composites for advanced applications – A review. j mater res tech no l . 2016;5(2):159–169
[3]. R. Palanivel , I. Dinaharan , R.F. Laubscher , J. Paulo Davim, Influence of boron nitride nanoparticles on microstructure and wear behavior of AA6082/TiB2 hybrid aluminium composites synthesized by friction stir processing.. Materials and Design 106 (2016) 195–204
[4]. B. Vijaya Ramnath , C. Elanchezhian , M. Jaivignesh , S. Rajesh , C. Parswajinan , A. Siddique Ahmed Ghias ,Evaluation of mechanical properties of aluminium alloy–alumina–boron carbide metal matrix composites. Materials and Design 58 (2014) 332–338
[5]. A. Baradeswaran , S.C. Vettivel , A. Elaya Perumal , N. Selvakumar , R. Franklin Issac,Experimental investigation on mechanical behaviour, modelling and optimization of wear parameters of B4C and graphite reinforced aluminium hybrid composites. Materials and Design 63 (2014) 620–632
[6]. K. Shirvanimoghaddam, H.Khayyam, H.Abdizadeh, M.KarbalaeiAkbari, A.H.Pakseresht, F. Abdi, A.Abbasi, M.Naebe,Effect of B4C, TiB2 and ZrSiO4 ceramic particles on mechanical properties of aluminium matrix composites Experimental investigation and predictive modelling. Ceramics International 42 (2016) 6206–6220
[7]. K. Shirvanimoghaddam , H.Khayyam, H.Abdizadeh , M.KarbalaeiAkbari , A.H.Pakseresht , E.Ghasali , M.Naebe ,Boron carbide reinforced aluminium matrix composite: Physical, mechanical characterization and mathematical modelling. Materials Science& EngineeringA658(2016)135–149
[8]. R. Harichandran , N. Selvakumar,Effect of nano/micro B4C particles on the mechanical properties of aluminium metal matrix composites fabricated by ultrasonic cavitation-assisted solidification process. archives of civil and m echanical engineering 16 (2016) 147 – 158
[9]. Siddhartha Prabhakar , Radhika , Raghu.R ,Analysis of tribological behavior of aluminium/ B4C composite under dry sliding motion. Procedia Engineering 97 (2014) 994 –1003
[10]. B. Ravi, B. Balu Naik , J. Udaya Prakash ,Characterization of Aluminium Matrix Composites (AA6061/B4C) Fabricated by Stir Casting Technique. Materials Today: Proceedings 2 (2015) 2984 – 2990
[11]. Ehsan Ghasali, Masoud Alizadeh, Touradj Ebadzadeh, Amir hossein Pakseresht, Ali Rahbari,Investigation on Microstructural and mechanical properties of B4C–aluminium matrix composites prepared by microwave sintering. j mater res tech no l . 2015; 4(4):411–415
[12]. Liang-Jing Fan, Shueiwan H. Juang, Reaction effect of fly ash with Al–3Mg melt on the microstructure and hardness of aluminium matrix composites. Materials and Design 89 (2016) 941–949
[13]. Shueiwan H. Juang , Cheng-ShuoXue, Investigation of mechanical properties and microstructures of aluminium-fly ash

composite processed by friction stirring. Materials Science Engineering A640(2015)314–319

[14]. I. Dinaharan , R. Nelson, S.J. Vijay , E.T. Akinlabi ,Microstructure and wear characterization of aluminium matrix composites reinforced with industrial waste fly ash particulates synthesized by friction stir processing. Materials Characterization 118(2016)149–158

[15]. S.G.Kulkarni, J.V.Meghnani, Achchhe Lal ,Effect of fly ash hybrid reinforcement on mechanical property and density of aluminium 356 alloy. Procedia Materials Science 5 (2014)746 – 754

[16]. G.Narasaraju, D. Linga Raju, Characterization of Hybrid Rice Husk and Fly ash-Reinforced Aluminium alloy (AlSi10Mg) CompositesMaterials Today: Proceedings 2 (2015) 3056 – 3064

[17]. S. Mosleh-Shirazi , F.Akhlaghi , D.Y.Li ,Effect of graphite content on the wear behavior of Al/2SiC/Gr hybrid nano-composites respectively in the ambient environment and an acidic solution. Tribology International 103(2016)620–628

[18]. Syed Nasimul Alam , Lailesh Kumar, Mechanical properties of aluminium based metal matrix composites reinforced with graphite nano platelets Materials Science Engineering A667(2016)16–32

[19]. L.A. Yolshina , R.V. Muradymov , I.V. Korsun , G.A. Yakovlev , S.V. Smirnov ,Novel aluminium-graphene and aluminium-graphite metallic composite materials: Synthesis and properties. Journal of Alloys and Compounds 663 (2016) 449e459

[20]. Mohammed Imran, A.R. Anwar Khan, Sadananda Megeri, Shoaib Sadik, Study of hardness and tensile strength of Aluminium-7075 percentage varying reinforced with graphite and bagasse-ash composites.Resource-Efficient Technologies 2(2016) 81–88

[21]. P. Ravindran, K. Manisekar, S. Vinoth Kumar, P. Rathika c, Investigation of microstructure and mechanical properties of aluminium hybrid nano-composites with the additions of solid lubricant. Materials and Design 51 (2013) 448–456

[22]. S. Suresha , B.K. Sridhara,Wear characteristics of hybrid aluminium matrix composites reinforced With graphite and silicon carbide Particulates.Composites Science and Technology 70(2010)1652–1659

[23].Kenneth Kanayo Alaneme, Kazeem Oladiti Sanusi ,Microstructural characteristics, mechanical and wear behaviour of aluminium matrix hybrid composites reinforced with alumina, rice husk ash and graphite. Engineering Science and Technology, an International Journal 18(2015) 416e422

[24]. Dora Siva Prasad , Chintada Shoba ,Experimental evaluation onto the damping behavior of Al/SiC/RHA hybrid composites. j mater res tech no l . 2016; 5(2):123–130

[25]. Kenneth Kanayo Alaneme , Joshua Ogheneakporobo Ekperusi, Samuel Ranti Oke,Corrosion behaviour of thermal cycled aluminium hybrid composites reinforced with rice husk ash and silicon carbide. Journal of King Saud University – Engineering Sciences (2016) xxx, xxx–xxx

[26]. Kenneth Kanayo Alaneme, Kazeem Oladiti Sanusi, Microstructural characteristics, mechanical and wear behaviour of aluminium matrix hybrid composites reinforced with alumina, rice husk ash and graphite. Engineering Science and Technology, an International Journal 18 (2015) 416e422

[27]. S.D.Saravanan, M.Senthil Kumar,Effect of Mechanical Properties on Rice Husk Ash Reinforced Aluminium alloy (AlSi10Mg) Matrix Composites. Procedia Engineering 64 (2013)1505 – 1513

[28]. G.Narasaraju1, D. Linga Raju , Characterization of Hybrid Rice Husk and Fly ash-Reinforced Aluminium alloy (AlSi10Mg) Composites. Materials Today: Proceedings 2 (2015) 3056 – 3064.

[29]. Yan Cui, Tingzhu Jin, Leigang Cao , Fengbin Liu, Aging behavior of high volume fraction SiCp/Al composites fabricated by pressureless infiltration. Journal of Alloys and Compounds 681 (2016) 233e239

[30]. Jufu Jiang ,Gang Chen ,Ying Wang , Compression Mechanical Behaviour of 7075 Aluminium Matrix Composite Reinforced with Nano-sized SiC Particles in Semisolid State. Journal of Materials Science & Technology (2016)

[31]. S. Suresha , B.K. Sridhara, Wear characteristics of hybrid aluminium matrix composites reinforced with graphite and silicon carbide particulates. Composites Science and Technology 70(2010)1652–1659

[32]. H.M. Zakaria, Microstructural and corrosion behavior of Al/SiC metal matrix composites. Ain Shams Engineering Journal (2014) 5, 831–838.