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# Utilization of Groundnut Shell as Reinforcement in Development of Aluminum Based Composite to Reduce Environment Pollution: a review

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**Abstract:** There are various types of reinforcements used in the development of aluminium based metal matrix composites. It was observed that by the use of ceramic particles, mechanical characteristics such as hardness and tensile strength were enhanced. However, density and cost was also increased. Groundnut shell is waste product that produces lots of soil pollution. By utilizing ground nut shell ash as reinforcement material with aluminium, mechanical properties can be improved. Further, density and cost of composite can be reduced. The aim of this review article is to study the influence of various types of reinforcements in the fabrication of composites with enhanced mechanical properties.

**Keywords:** Waste products, groundnut shell ash, tensile strength, hardness, density.

## 1. Introduction

As the name tells us that, in metal matrix composites, the matrix phase should be in the form of metal like aluminium, magnesium, titanium. Metals are mainly reinforced to increase or decrease the properties according to the requirement of needed design<sup>1</sup>. Metal matrix composites provide following advantages- it includes modulus and higher specific strength by reinforcing low density metals like aluminium and titanium; Lower coefficients of thermal expansion by reinforcing with fibers of low coefficient of thermal expansions such as graphite; and maintaining properties such as strength at high temperature<sup>2</sup>. Metal matrix composites provide several advantages as compared to polymer matrix composites that include higher service temperature, higher elastic properties, better wear, fatigue and flaw resistance and higher electric and thermal conductivity<sup>3</sup>. In comparison to polymer matrix composite, metal matrix composites have some drawbacks such as higher processing temperature and higher densities<sup>4</sup>.

When two or more than two reinforcements are added to the matrix then the resulting composite is called hybrid composite. Addition of reinforcement materials had

increased the mechanical characteristics like hardness and tensile strength of composite. The reinforcement for a matrix alloy is selected based on the property requirement for the composite, wettability of the reinforcement and the matrix compatibility. Hybrid metal matrix composites imparts the expected properties by bringing the combined advantages of both matrix and reinforcement into full play, which gives us a rather high degree of freedom in material design<sup>5</sup>. Various techniques present to present composites are shown in Fig 1. In this review article, focus is presented on the composites prepared through stir casting technique.

### 1.1 Green Metal Matrix Composites

Green manufacturing is a business technique that focuses on profitability through environmentally friendly operating processes. Groundnut shell is an aviculture by product that has been listed worldwide as one of the worst environmental problems<sup>6</sup>. The effective utilization of groundnut shell in development of aluminium based composite is strongly encouraged in our society for environmental and economic reasons<sup>7</sup>.

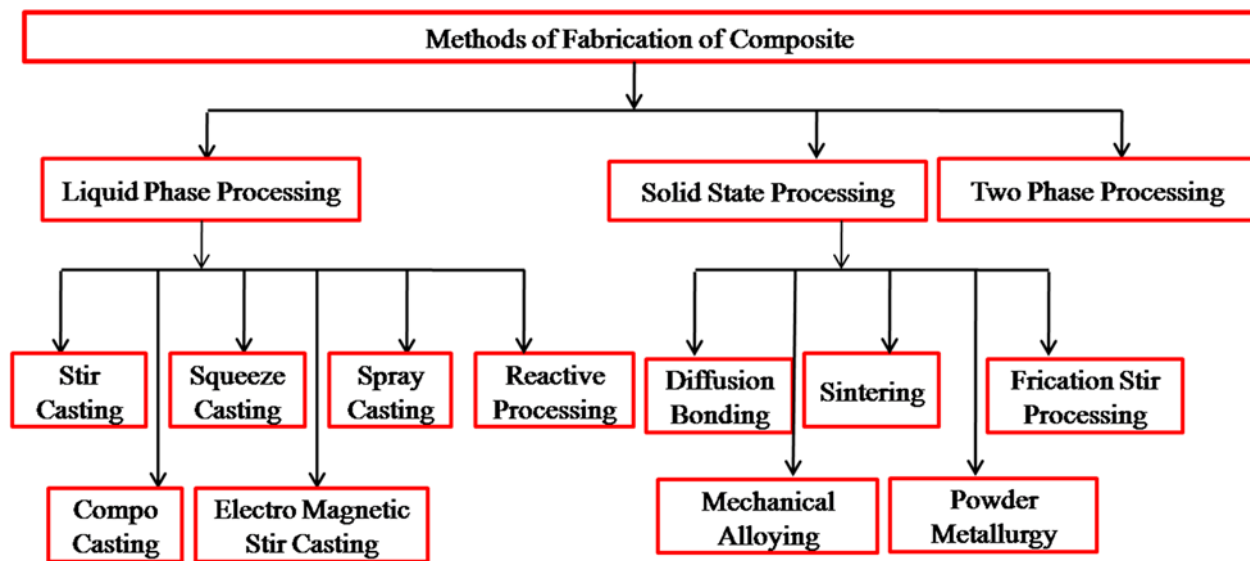


Fig. 1: Classification of Fabrication techniques for Metal Matrix Composite



Fig. 2: Some photographs of Groundnut shell

Groundnut shell ash (GSA) is a product obtained from burning groundnut shells. GSA consists of considerable amount of refractory oxides and active silica ( $\text{SiO}_2$ ) such as hematite ( $\text{Fe}_2\text{O}_3$ ) and Alumina ( $\text{Al}_2\text{O}_3$ ). It also contains small amount of alkalis and other trace elements<sup>8)</sup>. The chemical composition of GSA varies, depending on the geographic location, variety, and climate<sup>9-10)</sup>. Photographs of Groundnut shell waste (source from ADA BIO ENERGY) is shown in Fig. 2.

## 1.2 Nano Reinforced Composites

There is a growing body of evidence that composite materials containing a nano scale constituent have the potential to serve as a new generation of high performance and robust engineering materials. There is also a strong supposition that the thermal and electrical properties of some nano scale constituents could confirm these composite materials with secondary characteristics that will make them very attractive for a wide range of

structures and platforms. Such materials could be fabricated either through incorporation of a nano-scale constituent as the reinforcing phase in a polymer matrix, or as an additional constituent to a continuous fiber/polymer matrix composite (i.e. a hierarchical composites). These nano-constituents can take a range of forms, but the research we have pursued here has been on using carbon nanotubes (CNTs) as a reinforcing phase. Research is underway worldwide to develop nanostructured and hierarchical composite materials. Over the last decade a number of researchers have attempted to incorporate nano constituents into bulk polymers using fairly direct approaches (such as simple mixing), with disappointing results. A particular hurdle has been the limited nano constituent loading fractions which can be achieved (under 1% by weight) before the composite becomes unprocessable. This has highlighted the need to consider the composite architecture in the material development process. However, over the last few years, considerable advances have been made in the material characterization methods to allow researchers to understand the interactions between the parent and nano scale constituents. Furthermore, advances in material modelling have provided the research community an insight into how to optimize the formulation of these materials. Presently there is a growing understanding of the issues which need to be addressed in order to bring these materials to a technical readiness level at which they can then be exploited and utilized by industry [11]. The next sub section will provide the detailed literature review.

## 2. Development of Composite Material

In this study, electromagnetic or mechanical stir casting technique is studied to fabricate the composites by various reinforcements. Traditional electromagnetic or mechanical stir casting technique is still preferred nowadays due to its simplicity, easiness and effective cost.

## 3. Literature Review

Large volume of work was earlier carried on development of metal matrix composites, hybrid metal matrix composite and nano-reinforced composite using various reinforcements via different casting technique. Keeping these facts in the mind, exhaustive literature review has been carried in the present work and it has mainly been divided into four categories. Some of the important literature outcomes are summarized below for the development of GSA based reinforcement material with aluminium.

1. Literature Review of GSA as reinforcement
2. Literature Review of AA 2024 aluminium as a matrix material
3. Literature Review of Aluminium based Nano reinforced Composites
4. Literature review of Hybrid metal matrix composites
5. Literature review of various reinforcements in aluminium metal matrix composites

Table 1: Literature Review of GSA as reinforcement

S.No.	Materials Used	Reinforcements	Conclusion and Results	Ref. No.
1	Polymer composites	GSA	Mixing of the reinforced content had increased the mechanical properties up to some weight % and with further increase of reinforced particles, the reduction of characteristics was observed.	7)
2	(OPC) concrete	GSA	Compressive strength of the GSA/OPC concrete was increased from 29% to 40% by the addition of GSA.	8)
3	Groundnut Shell Fiber	Epoxy resins	Groundnut fiber, used as the matrix material had enhanced the physical and mechanical properties.	9)
4	Polymer Composite	GSA and CSP	Maximum tensile strength was obtained for the composite fabricated by reinforcing 40% vol. fraction CSP & GSP volume fraction. Maximum flexural strength was obtained for composite manufactured with 50% CSP&GSP filled.	10)
5	Zn –Al hybrid composite	GSA	The fracture toughness has been increased with the increase of GSA content in the hybrid composite.	11)
6	Aluminium 6063	GSA	Tensile strength increases up to 9% of reinforcement and then started decreasing.	12)
7	Polyester resin matrix	GSA	This investigation has found that the 15 Wt.% groundnut shell reinforced polyester composite exhibited the highest tensile strength.	13)
8	Cement Concrete Cubes	Cement/GSA	Experiment is evolved to determine optimum percentage of cement can be replaced with ground nut shell ash pozzolona without sacrificing the strength mortar cubes.	14)
9	CBRPC and	GSA/Cow Bone	Mechanical properties of epoxy can be significantly enhanced by these reinforcements	15)

	GSRPC epoxy			
10	Polymer composites	Al-Mg-Si alloy	The corrosion behavior of GSA reinforced composite was investigated.	16)
11	Recycled polyethylene composite	GSA	Alkaline treated GS powder had better-quality of mechanical properties for GSP-recycled polyethylene composites, by mixing 20% weight fraction.	17)
12	Aluminium alloy	GSA/SiC	Mechanical properties was improved by for the 6 Wt.. % Al-Mg-Si/SiC-GSA grades. An improvement of 15.7% was attained, as compared to 7.33% accomplished by 10 Wt.. % composite grades.	18)
13	Eichhornia charcoal (EC)	Groundnut shells	In this medical research paper, the adsorption of dye Basic Blue 9 (BB9) was considered using groundnut shells charcoal and Eichhornia charcoal as adsorbents.	19)
14	Concrete	GSA	The compressive strength of 10% replacement of GSA shows an increase of 2.95% and 1.21% for 7 and 28 days respectively when compared to the conventional concrete.	20)
15	Epoxy Composites	GSA /RHA	Samples consisting of GSA and RHA epoxy composites having 2.5%, 5%, 7.5%, 10%, 12.5% and 15% content of GSA and RHA were fabricated. Outcomes of this research work showed that the GSA reinforced epoxy composites had better mechanical properties in comparison to the RHA epoxy composites.	21)

Table 2: Literature Review of AA 2024 aluminium as a matrix material

S. No.	Materials Used	Reinforcements	Conclusion and Results	Ref. No.
16	Al 2024	SiC/Fly Ash	Al/SiC, Al/fly ash, Al/SiC/fly ash composites were positively manufactured by the two step stir casting method.	22)
17	Al 2024	Fly ash and E glass fiber	E-glass fiber & fly ash had reduced the corrosion level from 17 mpy to 7 mpy for a period of 2 days.	23)
18	Al 2024	MOS <sub>2</sub>	Tensile Strength of Al 2024/4% MoS <sub>2</sub> was maximum. Hardness was obtained to be maximum for Al 2024/4% MoS <sub>2</sub> composite	24)
19	AA 2024	SiC/Gr	AA 2024 10%SiC+5%Gr composite consist of better hardness value as compare to base metal.	25)
20	Al 2024	B <sub>4</sub> C	Tensile strength and hardness was obtained to be maximum for Al 2024/5% B <sub>4</sub> C composite.	26)
21	AA 2024	Fly ash	Fracture toughness of AA2024 was in the range of 17-18 MPa as compared to 21 MP for re-melted alloy AA2024. The JIC fracture toughness of composites was 6-15 KJ/m <sup>2</sup> as compared to 25 KJ/m <sup>2</sup> for the re-melted AA 2024.	27)
22	AA 2024	Fly ash/ E-Glass	UTS was improved with increase in reinforce content. E-glass fibre and fly ash resists deforming stresses and improves the compressive strength of AA 2024/.Fly ash/ E-Glass composite.	28)
23	AA 2024	B <sub>4</sub> C/Gr	The observed microstructure test revealed that alloying elements are distributed homogeneously in aluminium matrix. B <sub>4</sub> C and Gr had enhanced the strength of the AA 2024.	29)
24	AA 2024	SiC	Mechanical characterization had proved that there is enhancement in the mechanical properties.	30)
25	AA 2024	B <sub>4</sub> C	Wear in height loss was lower in case of AA2024-B <sub>4</sub> C composites as compared to base AA2024.	31)
26	AA 2024	Tungsten Carbide	The reinforcement had improved the micro hardness and wear characteristics of fabricated composite.	32)
27	AA 2024	pure Cu	Microstructural examination of a dissimilar AA2024 to pure Cu joint made by linear friction welding was observed.	33)
28	Al 2024 alloy	SiC+ Gr	The tensile strength and yield stress was increased. Elongation was reduced as the volume fraction of SiC content was reduced. Interfacial bonding of Gr/matrix and SiC/matrix had enhanced the relative homogeneity in the fabricated composite.	34)
29	Al 2024 alloy	Al <sub>2</sub> O <sub>3</sub> nano composite	Al 2024/Al <sub>2</sub> O <sub>3</sub> nanoparticles was positively made by compo casting method followed by FSP.	35)
30	Al 2024 alloy	B <sub>4</sub> C	UTS and YS of Al 2024/ B <sub>4</sub> C composite was improved whereas percentage elongation of the composites was decreased by the increase of the order of boron carbide.	36)

31	Al 2024	SiC – Graphene	Al2024-SiC-Graphene hybrid nano composite was developed by ultrasonic liquid processing (ULP) technique .	37)
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Table 3: Literature Review of Aluminium based Nano reinforced Composites

S. No	Alloy	Reinforcement	Result	Ref.
32	Al 356	Nano-SiC particles	A356 /nano-SiC composite was fabricated by stir casting method. SiC content was distributed uniformly within the matrix. Mixing of 4.5 vol. % of SiC had improved the UTS from 145 to 240 MPa.	38)
33	AA 7075	Nano SiC particles	AA 7075/SiC nano composites were manufactured by mechanical stirring and ultrasonic cavitation process. Hardness and impact strength of AA 7075/10%SiC nano composite was improved by 10% and 75 % respectively.	39)
34	Al 6061	Nano Al <sub>2</sub> O <sub>3</sub> particles	Al 6061/ Al <sub>2</sub> O <sub>3</sub> composite was prepared by ultrasonic assisted squeeze casting method with avoiding the accumulation of Al <sub>2</sub> O <sub>3</sub> particulates.	40)
35	Pure Al	TiO <sub>2</sub> nanoparticles	Al/ TiO <sub>2</sub> nano composite specimen was manufactured via powered stir casting technique with avoiding agglomeration of TiO <sub>2</sub> nanoparticles.	41)
36	Al 6061	Nano ZrO <sub>2</sub> content	Aluminium-ZrO <sub>2</sub> nano composites 7.5% successfully produced by stir casting method.	42)
37	Al 2219	Nano silicon carbide (SiC) particles	AA 2219/SiC nano composite was prepared via ultrasonic assisted stir casting method.	43)
38	AZ31	Graphene nano platelets (GNP)	The AZ31-GNPs composite was fabricated by using stir-casting method followed by hot extrusion. The mechanical testing at room temperature had depicted the enhancement in mechanical properties.	44)
39	Pure aluminum	Nano TiO <sub>2</sub>	The powder metallurgy method was used to prepare Al/ TiO <sub>2</sub> composite successfully. Uniform distribution of 40reinforcement was observed.	45)
40	Al-SiC alloy	Al <sub>2</sub> O <sub>3</sub> -WS <sub>2</sub>	Increased Wt. % of WS <sub>2</sub> solid lubricant had increased the hardness of the hybrid composite. The % of WS <sub>2</sub> had increased the density of the composite by filling the gap of the composite. Composites with about 5 percent of WS <sub>2</sub> have less pits and worn out surface as compare to composite without WS <sub>2</sub>	46)
41	AZ91E	Al <sub>2</sub> O <sub>3</sub>	AZ91E/ Al <sub>2</sub> O <sub>3</sub> composite was prepared by Semi Solid stir casting method with varied weight percentages. AZ91E/ 2 Wt.% Al <sub>2</sub> O <sub>3</sub> composite had improved mechanical properties than other varied reinforcements. Macro hardness and tensile strength was enhanced by 22.5% and 26.54%.	47)
42	AA 7075	SiC+ Al <sub>2</sub> O <sub>3</sub> Nano composites	Single and hybrid reinforced nano composites was manufactured via stir and squeeze cast process. Hardness was enhanced by 63.7% and 81.1% for single and hybrid reinforced nano composite.	48)

Table 4: Literature review of various reinforcements in aluminium metal matrix composites

S. No.	Materials Used	Percent Reinforcements	Hardness	Tensile Strength	Ref. No
43	Al 6061	8 Wt.% SiC	51 HRB	298 MPa	49)
44	A 359	8Wt.% Al <sub>2</sub> O <sub>3</sub>	148.7 BHN	148.7 N/mm <sup>2</sup>	50)
45	A 356	7.5 Wt.% Al <sub>2</sub> O <sub>3</sub>	78BHN	164 MPa	51)
46	A 356	5 Wt.% SiC	104.66 BHN	309.83 MPa	52)
47	Aluminium	7 Wt.% Al <sub>2</sub> O <sub>3</sub>	63BHN	120 MPa	53)
48	Aluminium	15 Wt.%SiC	52BHN	145 MPa	54)
49	Aluminium	6 & 10 Wt.% GSA, SiC	63HRV	166 MPa	55)
50	Aluminium	10 Wt.%SiC	147.2VHN	163	56)

51	Aluminium	6 Wt.% SiC	88HV	130 MPa	57)
52	Aluminium	20 Wt.% SiC	45.40 BHN	77.56 MPa	58)
53	AA 5083	10 Wt.% SiC	76 BHN	253 MPa	59)
54	LM 25	10% mica & 10% activated Carbon	89.5 BHN		60)
55	LM 6	10 Wt.% SiC	78BHN		61)
56	Al 6061	12 Wt.% Al <sub>2</sub> O <sub>3</sub>	185BHN	195 MPa	62)
57	Al 6061	NiP coated 10 Wt.% Si <sub>3</sub> N <sub>4</sub>	86.6BHN	306 MPa	63)
58	AA 6061	10Wt.% B <sub>4</sub> C	68HV	145 MPa	64)
59	AA 6061	15Wt.% TiC		230 MPa	65)
60	AA 6063	12% Al <sub>2</sub> O <sub>3</sub> & 1%Gr		351.6 MPa	66)
61	Al 6082	12Wt.% Si <sub>3</sub> N <sub>4</sub>	93.5VHN	201 MPa	67)
62	AA 6082	10%Wt. WC	83BHN	190 N/mm <sup>2</sup>	68)
63	LM 25	2wt% Al <sub>2</sub> O <sub>3</sub> , 3wt% B <sub>4</sub> C	52.8BHN	54.6 MPa	69)
64	Al 7075	10Wt.% SiC	229.9 MPa	110 BHN	70)
65	AA 6061	5Wt. % Cenosphere	57VHN	0.075 KN/mm <sup>2</sup>	71)

#### 4. Summary and discussion

Utilization of groundnut shell as reinforcement is an interesting research area in the development of various composite materials. However, utilization of GSA as reinforcement in the development of concrete based composite material has been carried out by various researchers is shown in Table 1. Very few researchers have tried to utilize GSA with aluminum alloy.

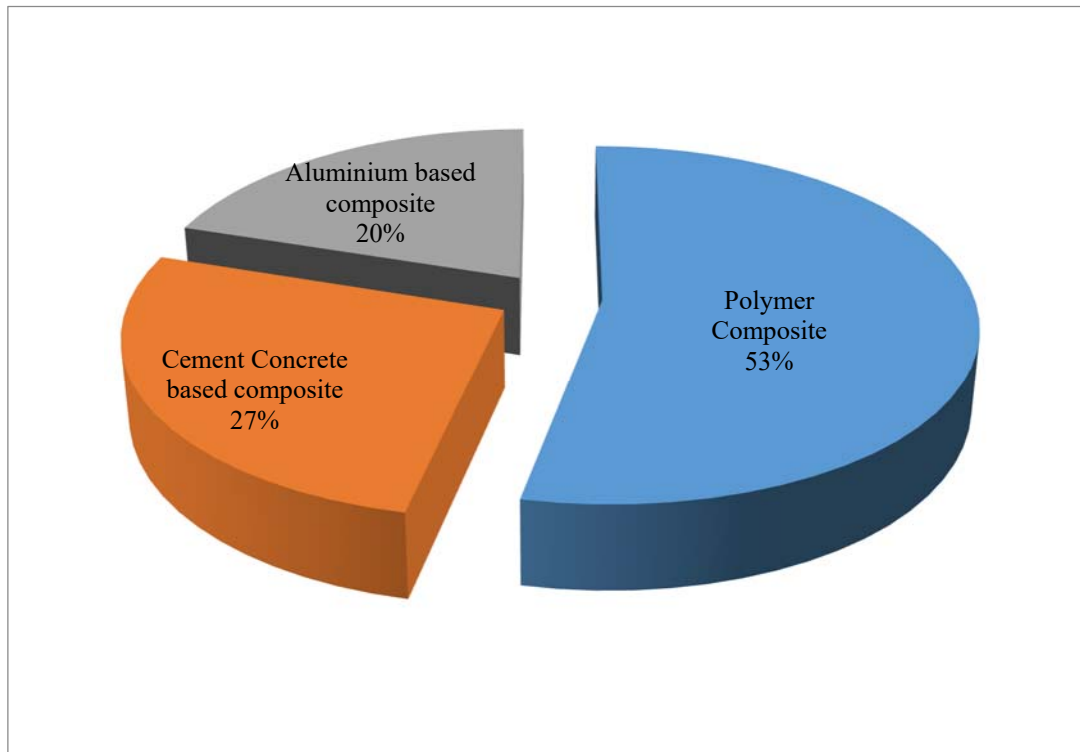
Fig. 3 shows the summary of reported work GSA as reinforcement for the development of different types of composite. It can be observed that GSA was utilized as reinforcement for the development of polymer based composite about 53%. In the development of cement concrete based composite GSA was used about 27%. However, only about 20% GSA was used as reinforcement material for the development of metal matrix composite.

Nowadays, aluminum copper based alloy AA 2024 based composite is highly demanding material in the automotive industries due to high strength to weight ratio. Fig.4 shows the summary of reinforcement material used

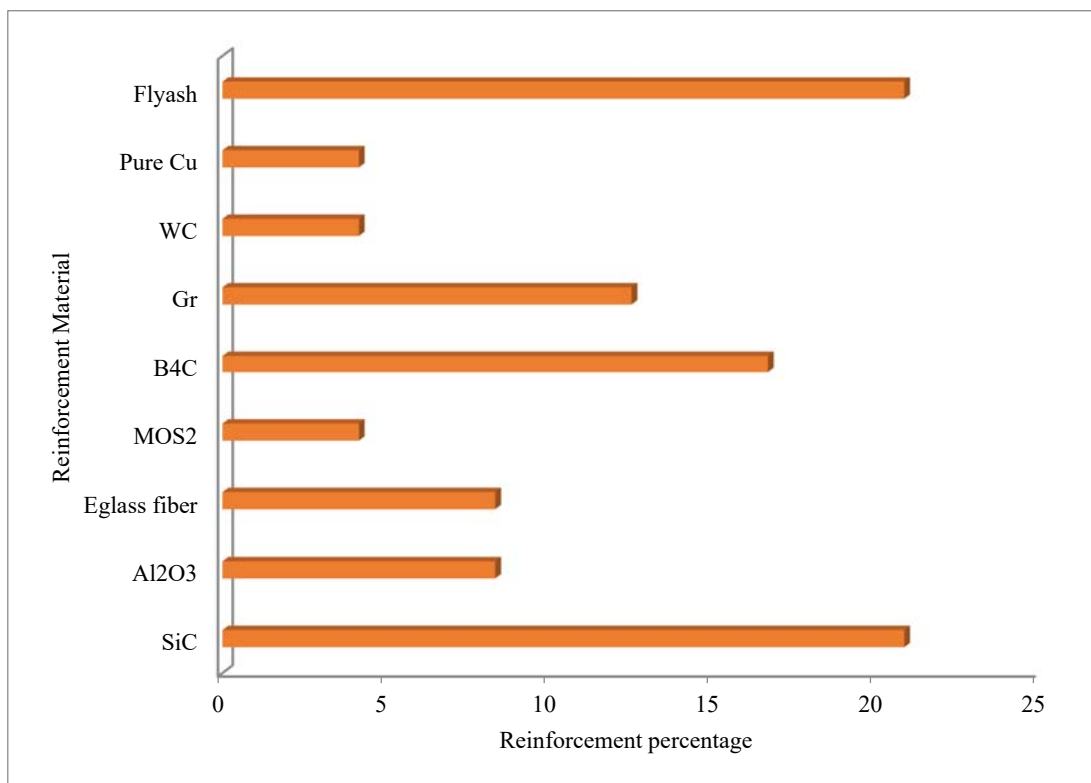
for development of AA 2024 based metal matrix composite. It can be observed that most of the researchers have used flash and SiC as a reinforcement to enhance mechanical properties of AA 2024 alloy. However, very fewer efforts have been made to understand the effect of pure Cu, WC and MOS<sub>2</sub> on mechanical behavior of AA 2024 based composite. Table 2 shows the summary of reported work of various reinforcement materials for the development of AA 2024 based composite material.

Fig.5 shows the summary of percentage contribution of various reinforcement material used for the development of metal matrix composite. The details of reported work related to various reinforcement material presented by various researchers is provided in Table 4.

Furthermore, through literature survey it was found that Kenaf/E-glass<sup>72)</sup>, SiC<sup>73-74)</sup> and uncarbonized egg shell<sup>75)</sup> particles were successfully used to develop composite through stir casting techniques.

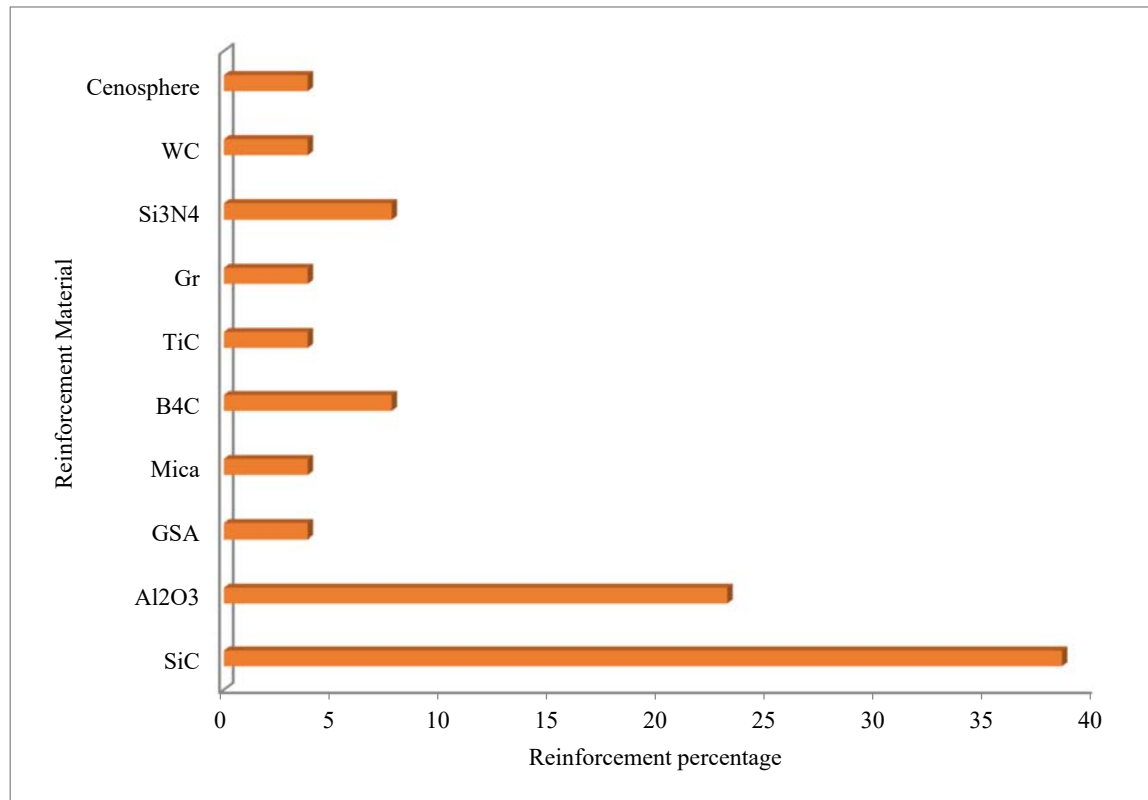


**Fig 3:** Summary of reported work GSA as reinforcement for the development of different types of composite



**Fig 4:** Summary of reinforcement material used for AA 2024 based metal matrix composite





**Fig 5:** Summary of percentage of reinforcement material used for the development of metal matrix composite

## 5. Conclusions

After the exhaustive review of literature it was observed that waste groundnut shell (agricultural residues) is inexpensive and valuable biopolymers, which can be used as reinforcement for the development of the metal matrix composite. The following observations of this research work can be concluded as follows.

- It was observed that GSA was successfully used as a reinforcement for the development of various composite like metal matrix composite, cement concrete based composite and polymer composite.
- AA 2024 alloy with various combinations of reinforcements developed by various stir casting method to find out its mechanical and tribological characteristics. Though in all cases tensile strength, hardness, fatigue strength improved, but toughness is reduced. Decrement of toughness cannot be ignored.
- From the literature, it can be observed that by using GSA as a reinforcement material, overall toughness can be improved. But very few researchers used GSA as reinforcement material in the development of aluminium base composite.
- A lot of work has been carried out for AA 2024 aluminium alloy using various reinforcement such as SiC, Al<sub>2</sub>O<sub>3</sub>, B<sub>4</sub>C, fly-ash, Rice Husk Ash, graphite. But very few works has been carried out for AA 2024 aluminium alloy using GSA as reinforcement.

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