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Dwivedi, Prakash, Shashi

Department of Mechanical Engineering, G.L. Bajaj Institute of Technology and Management

Maurya, Manish

Department of Mechanical Engineering, Accurate Institute of Management and Technology

Maurya, Kumar, Nagendra

Department of Mechanical Engineering, G.L. Bajaj Institute of Technology and Management

Srivastava, Kumar, Ashish

Department of Mechanical Engineering, G.L. Bajaj Institute of Technology and Management

他

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

Shashi Prakash Dwivedi¹, Manish Maurya², Nagendra Kumar Maurya^{1*}, Ashish Kumar Srivastava¹, Satpal Sharma³, Ambuj Saxena¹

¹Department of Mechanical Engineering, G.L. Bajaj Institute of Technology and Management, Greater Noida -201308, India

²Department of Mechanical Engineering, Accurate Institute of Management and Technology, Greater Noida - 201308, India

³Department of Mechanical Engineering, Gautam Budha University, Gautam Budha Nagar -201310, India

*Author to whom correspondence should be addressed:

E-mail:nagendramnrit@gmail.com

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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 design¹). 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 temperature²). 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 conductivity³). In comparison to polymer matrix composite, metal matrix composites have some drawbacks such as higher processing temperature and higher densities⁴).

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 design⁵). 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 problems⁶). The effective utilization of groundnut shell in development of aluminium based composite is strongly encouraged in our society for environmental and economic reasons⁷).

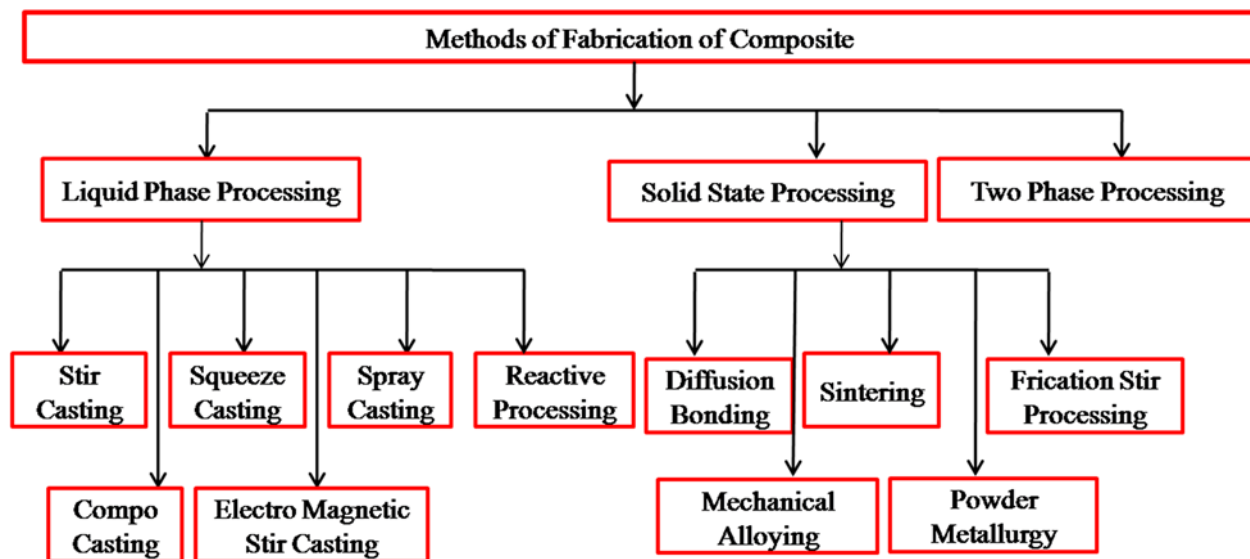


Fig. 1: Classification of Fabrication techniques for Metal Matrix Composite



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 (SiO_2) such as hematite (Fe_2O_3) and Alumina (Al_2O_3). It also contains small amount of alkalis and other trace elements⁸⁾. The chemical composition of GSA varies, depending on the geographic location, variety, and climate⁹⁻¹⁰⁾. 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 ₂ | Tensile Strength of Al 2024/4% MoS ₂ was maximum. Hardness was obtained to be maximum for Al 2024/4% MoS ₂ 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 ₄ C | Tensile strength and hardness was obtained to be maximum for Al 2024/5% B ₄ 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 ² as compared to 25 KJ/m ² 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 ₄ C/Gr | The observed microstructure test revealed that alloying elements are distributed homogeneously in aluminium matrix. B ₄ 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 ₄ C | Wear in height loss was lower in case of AA2024-B ₄ 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 ₂ O ₃ nano composite | Al 2024/Al ₂ O ₃ nanoparticles was positively made by compo casting method followed by FSP. | 35) |
| 30 | Al 2024 alloy | B ₄ C | UTS and YS of Al 2024/ B ₄ 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) |
|----|---------|----------------|---|-----|

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 ₂ O ₃ particles | Al 6061/ Al ₂ O ₃ composite was prepared by ultrasonic assisted squeeze casting method with avoiding the accumulation of Al ₂ O ₃ particulates. | 40) |
| 35 | Pure Al | TiO ₂ nanoparticles | Al/ TiO ₂ nano composite specimen was manufactured via powered stir casting technique with avoiding agglomeration of TiO ₂ nanoparticles. | 41) |
| 36 | Al 6061 | Nano ZrO ₂ content | Aluminium-ZrO ₂ 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 ₂ | The powder metallurgy method was used to prepare Al/ TiO ₂ composite successfully. Uniform distribution of 40reinforcement was observed. | 45) |
| 40 | Al-SiC alloy | Al ₂ O ₃ -WS ₂ | Increased Wt. % of WS ₂ solid lubricant had increased the hardness of the hybrid composite. The % of WS ₂ had increased the density of the composite by filling the gap of the composite. Composites with about 5 percent of WS ₂ have less pits and worn out surface as compare to composite without WS ₂ | 46) |
| 41 | AZ91E | Al ₂ O ₃ | AZ91E/ Al ₂ O ₃ composite was prepared by Semi Solid stir casting method with varied weight percentages. AZ91E/ 2 Wt.% Al ₂ O ₃ 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 ₂ O ₃ 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 ₂ O ₃ | 148.7 BHN | 148.7 N/mm ² | 50) |
| 45 | A 356 | 7.5 Wt.% Al ₂ O ₃ | 78BHN | 164 MPa | 51) |
| 46 | A 356 | 5 Wt.% SiC | 104.66 BHN | 309.83 MPa | 52) |
| 47 | Aluminium | 7 Wt.% Al ₂ O ₃ | 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 ₂ O ₃ | 185BHN | 195 MPa | 62) |
| 57 | Al 6061 | NiP coated 10 Wt.% Si ₃ N ₄ | 86.6BHN | 306 MPa | 63) |
| 58 | AA 6061 | 10Wt.% B ₄ C | 68HV | 145 MPa | 64) |
| 59 | AA 6061 | 15Wt.% TiC | | 230 MPa | 65) |
| 60 | AA 6063 | 12% Al ₂ O ₃ & 1%Gr | | 351.6 MPa | 66) |
| 61 | Al 6082 | 12Wt.% Si ₃ N ₄ | 93.5VHN | 201 MPa | 67) |
| 62 | AA 6082 | 10%Wt. WC | 83BHN | 190 N/mm ² | 68) |
| 63 | LM 25 | 2wt% Al ₂ O ₃ , 3wt% B ₄ 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 ² | 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 MOS₂ 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-glass⁷²⁾, SiC⁷³⁻⁷⁴⁾ and uncarbonized egg shell⁷⁵⁾ particles were successfully used to develop composite through stir casting techniques.

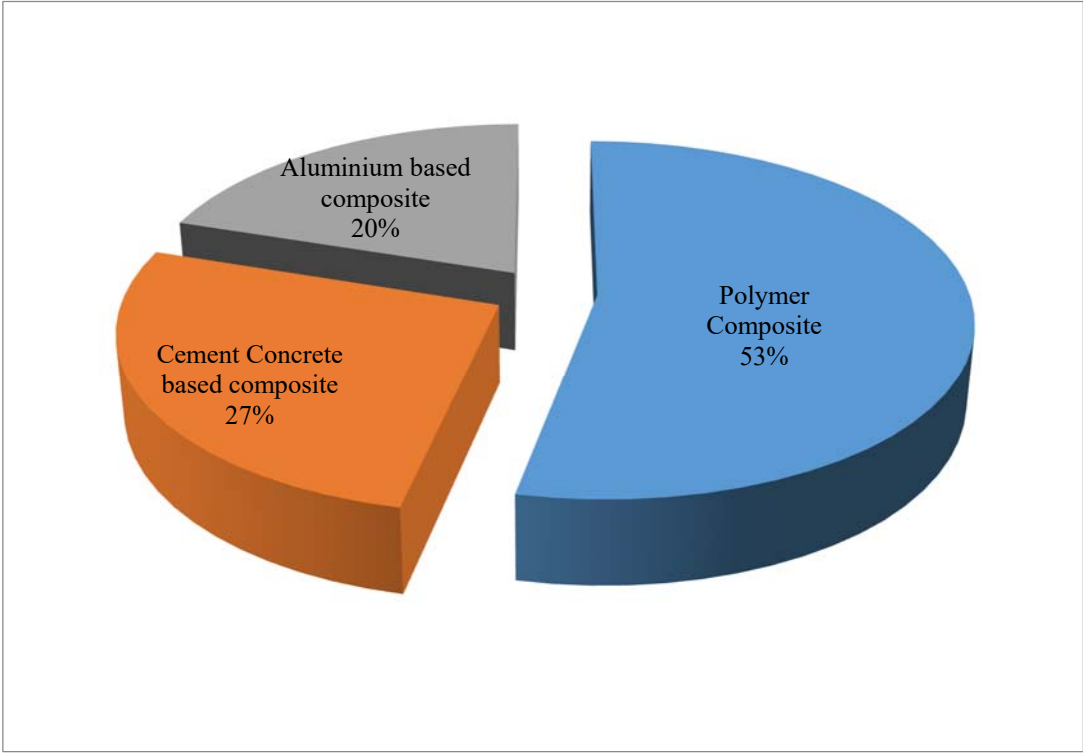


Fig 3: Summary of reported work GSA as reinforcement for the development of different types of composite

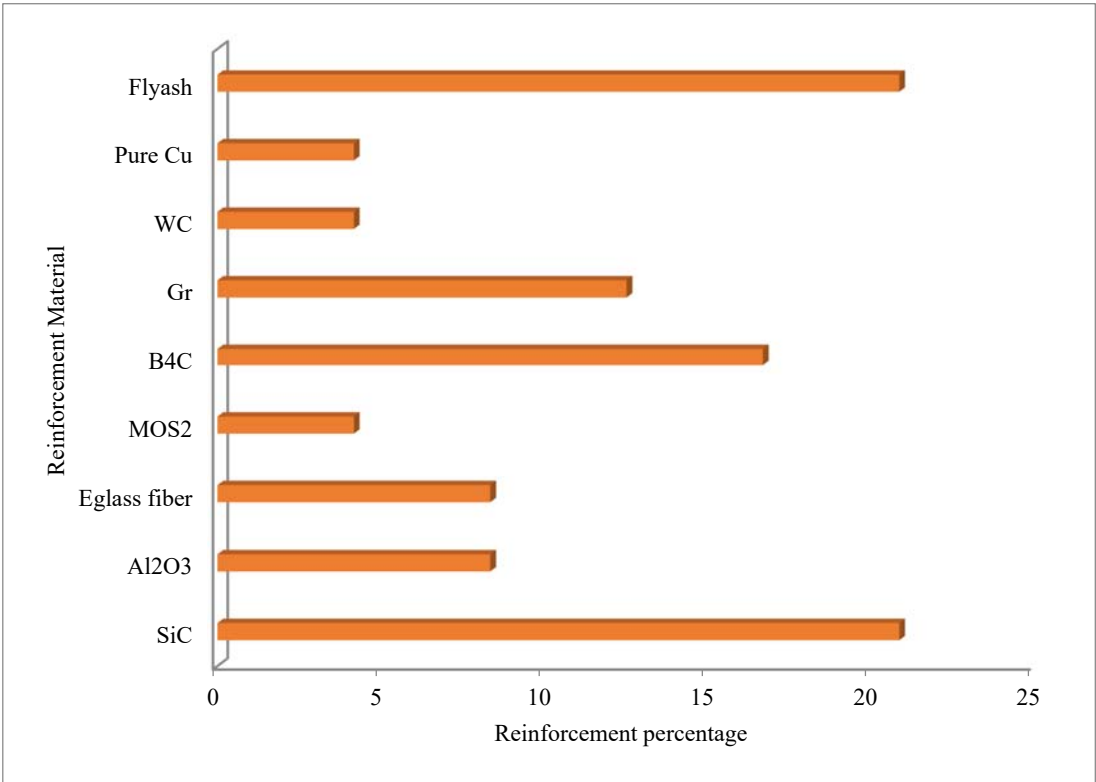


Fig 4: Summary of reinforcement material used for AA 2024 based metal matrix composite

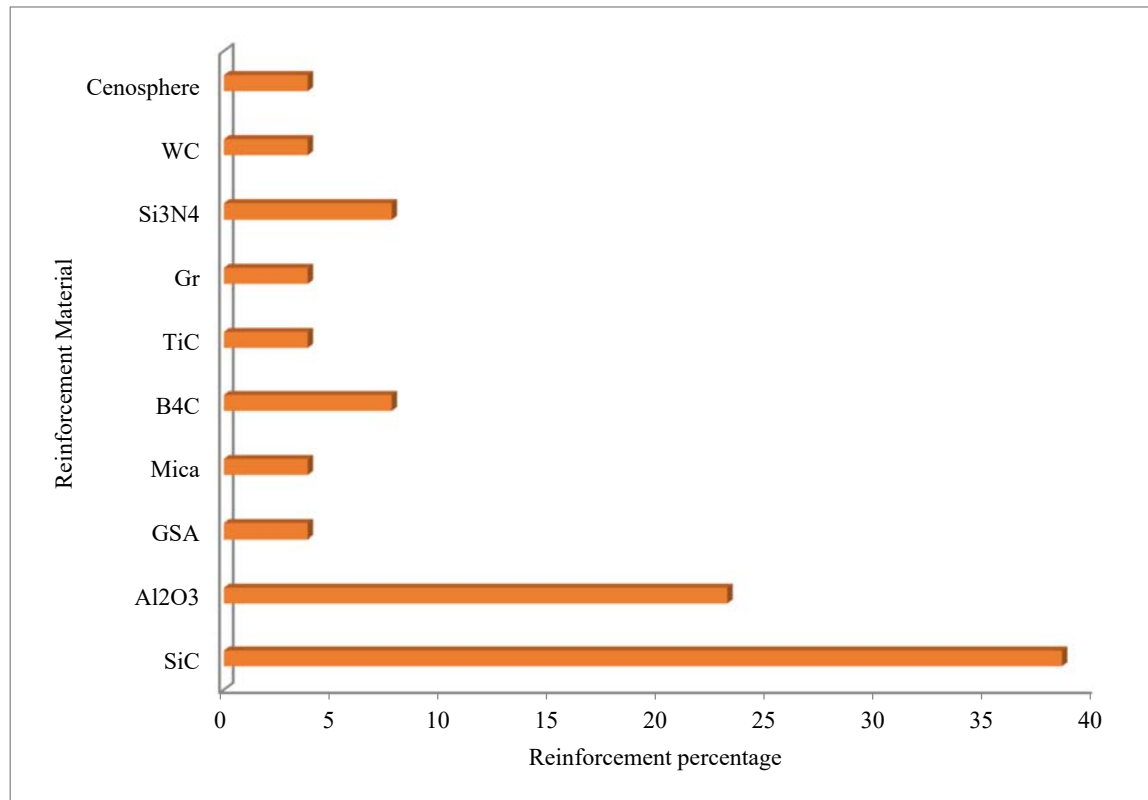


Fig 5: Summary of percentage of reinforcement material used for the development of metal matrix composite

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, Al₂O₃, B₄C, 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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