Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 1, No. 3, January : 2024

MECHANICAL CHARACTERIZATION, PHYSICAL AND EXPERIMENTAL ANALYSIS OF GRAPHITE, SILICON CARBIDE, MARBLE DUST FILLER OF ALUMINIUM ALLOY ZA-27 HYBRID COMPOSITE FOR BEARING APPLICATION

Mr. Dheeraj Kumar Lecturer, Department of Mechanical Engineering (Production), IIMT College of Polytechnic, Greater Noida, India Email Id: dkumargautam2016@gmail.com
Mr. Prabhash Chandra Katiyar Lecturer, Department of Mechanical Engineering, Feroz Gandhi Polytechnic *Raebareli*, India
Mr. Sachin Kumar Lecturer, Department of Mechanical Engineering (Production), IIMT College of Polytechnic, Greater Noida, India.
Mr. Pawan Kumar Head of Department Mechanical Engineering (Production), IIMT College of Polytechnic, Greater Noida, India

ABSTRACT
Due to its light weight nature, high strength to weight ratio, corrosion resistance, and high thermal conductivity, aluminium metal matrix composites have become one of the most important advancements in the area of composites in recent years. These composites are utilised extensively in the aerospace, automotive, and aircraft sectors. In this study, stir casting is used to create an aluminium alloy (ZA-27) hybrid composite with three reinforced materials: graphite (Gr)which ranges in weight from 0 to 6 weight percent, silicon carbide (SiC)which weighs 2 weight percent, and marble dust (MD), which weighs 2 weight percent. By conducting studies to assess the density, hardness, compressive strength, and impact strength values for the manufactured hybrid composite, the physical and mechanical characteristics of the material are determined. As the weight percentage of reinforcement rises, so do the composite's density and void content. The rise in the hybrid composite's weight percentage of filler component causes increases in The experimental hardness value, flexural strength, and impact strength of the manufactured hybrid composite are decreases as the reinforced weight percentage in the composite rises. Only compressive Strength is increases as the reinforced weight percentage of the composite rises

Keywords: Stir casting Technique, ZA-27alloy, Physical & Mechanical properties.

1. Introduction
The aluminium metal matrix composites are widely used for aircraft, automotive and aerospace industries because they are lightweight, high strength to weight ratio, corrosion Resistance and workability. To day advance bearing materials are demands are more because during movements of the shafts minimum friction and multiple demands are fulfilled by advanced bearing materials. The Al based bearing materials are more because The fatigue Strength of Al-based bearing materials are more than the white material and the thermal conductivity aluminium alloy is higher so that Aluminium alloy have low cost, aluminium alloys are high corrosive resistance, Aluminium alloys have good fatigue Strength, aluminium alloys are lighter and workability. Aluminium alloys used for bearing application for many years. [1]Zhen gang Liu *et al.*[2] have used natural crystalline flake Graphite particles as reinforcement along with pure Al and Mg as a matrix. The nominal diameter of the mesh is 82 m. Mg's weight percentages are 0, 0.2, 0.4, 0.6, 0.8, and 1.0. The composite Specimen that Stir Casting created. Vickers hardness improves by 13% hardness value 67 as Mg concentration rises, with 0.6 wt% Mg having the highest tensile strength of 185 M Pa. Kart hick E and others [3] manufactured a composite metal of AZ 31 with 95 -87 wt .% take as base metal matrix. Al_2O_3 and SiC particles take a reinforcements .The alumina (Al_2O_3) take 5wt.% and SiC varied from0-8wt. % The samples prepare with the help of PM. the hardness increase with increase the wt. %of filler content. The hardness 16.47 % at 8 wt. % SiC filled AZ-31 alloy composite. Fei CHEN and colleagues'[4] creation of ZA 27 the

chemical composition as take as matrix and TiB_2 take as reinforcement the wt.% of TiB2(1%, 3%, and 5%).the stir casting technique used to create the sample. The outcome demonstrated that hardness and tensile strength increased significantly with an increase in the weight percentage of TiB_2. The maximum Brinell hardness at 5 % TiB_2 is up to 128 and the UTS of alloy composites including ZA-27 TiB2 at 5% is 434 M Pa, respectively. Barad eswaran, A., et al. [5] Aluminium alloy Al 7075 is used as the base metal matrix and B4C powder is used as the reinforcement in composite materials. The filler content of Boron carbide B_4C as 5, 10, 15 & 20 vol. the particle size 16µm to 20 µm the specimen prepare with the help of stir casting .The result showed that, The Hardness, The ultimate tensile, wear resistance, The Flexural and compressive Strength are increase with increasing the B_4C filler content. [6]Fabricated done an experiment in which a composite metal of Aluminium alloy (AA6063) as base matrix and clay take reinforcement. The clay 5–30 wt. % of clay particles with Grain size 250 micron and specimen with the help of liquid stir casting route. The specimen prepared for the tensile, Vickers hardness and wear test. The Clay particles added in base metal which is improved the mechanical & wear performance of clay particles filled
Aluminium alloy composite. P.B.Pawar *etal.*[7]perform an experiment and shows that pure Aluminium is taken as matrix and Silicon Carbide particulate taken as reinforcement. Metal matrix is prepared by stir casting. The wt. % of SiC were 0, 2.5, 5, 7.5, and 10 in wt. %.Different mechanical tests are done and result shows that there is enhancement in Hardness, material toughness. The maximum enhancement is shown in 10% of SiC particulate sample.

2. Material and methods of fabrication

2.1MatrixMaterial

The aluminium alloy (ZA-27) has a good thermal conductivity and a high strength to weight ratio. The aluminium alloy ZA-27 is frequently used for bearing and structural applications. The ZA-27 alloy composite's chemical makeup is (Al 25%, Cu 2%, Mg 0.01, and the remaining Zn % of the alloy).

2.2 Reinforcement Material

Enhancing the mechanical property is one of the key functions of reinforcement applied to the matrix material to create a composite material. The price of the finely filled SiC, graphite, and marble dust composites are less expensive than fiber-reinforced composites because the cost of the components is lower.

Silicon Carbide (SiC)

SIC is a low density, very hard ceramic particle. The Sic powder was included into the matrix material to improve the composite's overall mechanical characteristics. SiC particles are 25 µm in size. The picture of SiC Micro powder is depicted in Figure 1 (a).

Graphite particle (Gr)

A kind of solid lubrication is graphite. To improve the manufactured composite's wear resistance, Gr particle was added to the matrix material. Gr particles are 25 µm in size. The Gr Micro powder picture is shown in Figure 1(b).

2.2.3Marble dust (MD)

MD is a very hard particle.MD added in to matrix material to enhance the overall mechanical and wear properties of fabricated alloy composite. The size MD particle is 25 µm. Figure 1 (C) shows the image of Marble Dust Micro powder.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 1, No. 3, January : 2024

(a) (b) (c)

Figure 1 (a) SiC particle (b) Gr particle (c) MD Particle

Composition of Samples

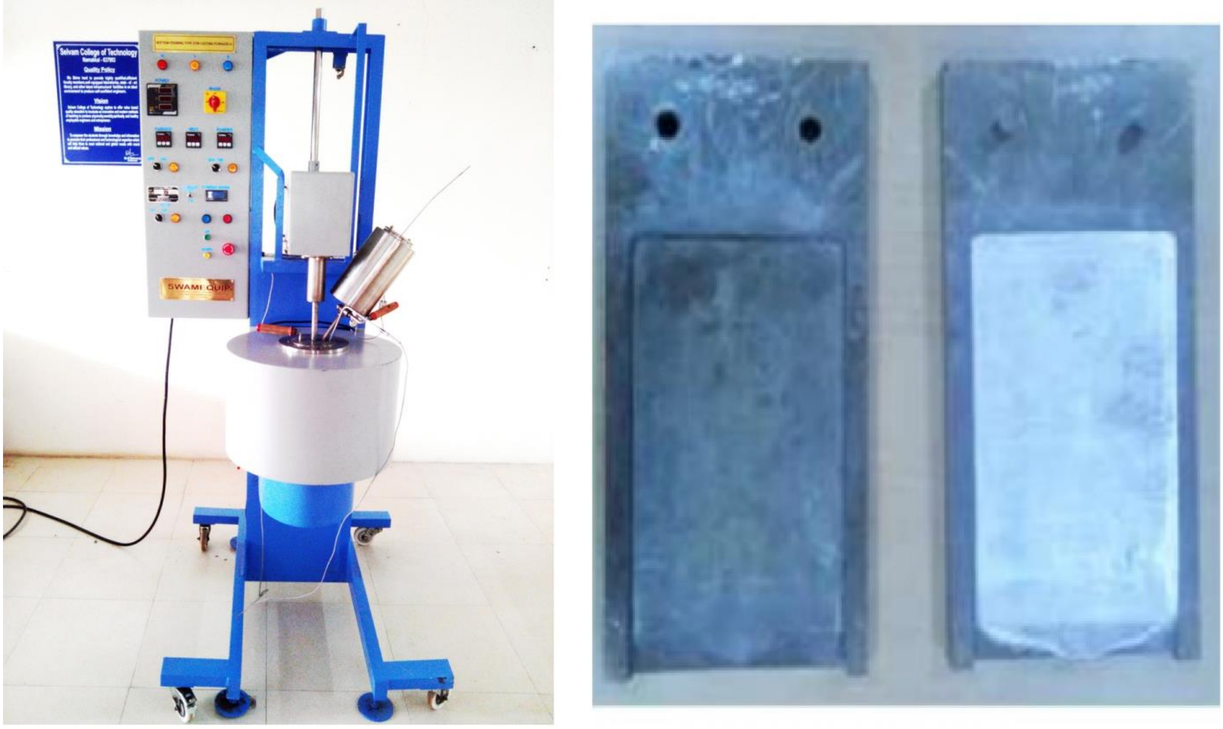
The fabrication will be carried out using the stir casting method, using the ZA-27 alloy as the fabrication matrix material and silicon carbide (SiC), graphite, and alumina (SiC) as the reinforcing materials. The many compositions in which these elements are used are mentioned below.

Table1 Chemical composition of ZA-27 metal alloy hybrid composite

Designation of Sample	**Chemical Composition**
ZA-27-0% Gr.	ZA-27 +2 wt. % Gr +2 wt. % SiC +2 wt. % MD
ZA-27-2% Gr	ZA-27 +4 wt. % Gr +2 wt. % SiC +2 wt. % MD
ZA-27-4% Gr	ZA-27 +4 wt. % Gr +2 wt. % SiC +2 wt. % MD
ZA-27-6% Gr	ZA-27 +6 wt. % Gr +2 wt. % SiC +2 wt. % MD

Prior to combining the warmed powders with the melted ZA-27 alloy, the crucible containing the ZA-27 alloy base metal is heated to 800°C. In an electric furnace, the matrix material (ZA-27) is heated to a temperature that is higher than its liquid temperature of roughly 500°C.A furnace with electricity is shown in Figure 2(a). The reinforcement in the melt base matrix is blended more thoroughly using a ZA-27 alloy stirring mechanism. A motor and a mechanical graphite stirrer that is heated again in a furnace make up the stirring apparatus. After that, the crucible is removed from the furnace, agitated for a second time for 6 to 8 minutes, and then poured into the Hardened steel die. The dimensions of the hardened steel die are 145 x 90 x 10 mm ^{3} In Figure 2(b), the solidified plate is depicted. After allowing the fluid to set for two to three minutes, the plate was removed from the metallic die. A plate of composite that had just formed was abruptly submerged in cold water

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 1, No. 3, January : 2024



(a) (b)

Figure 2 (a) Stir Casting Machine (b) Solidified composite plate

3. RESULT AND DISCUSSION

3.1 Influence of voids content on Gr. filled ZA-27 alloy composites

The theoretical density of the Gr mixed ZA-27 metal alloy composites is decide with the help of rule Of-mixture by Equation (1), while experimental density is evaluated using water immersion Technique based on Archimedes' principle. Thereafter, void content's computed as per Equation (2).

$$\rho_{th} = \frac{1}{\frac{W_m}{\rho_m}+\frac{W_{Gr}}{\rho_{Gr}}+\frac{W_{Sic}}{\rho_{Sic}}+\frac{W_{MD}}{\rho_{MD}}} \qquad (1)$$

$$\text{Void contents} = \frac{\text{Theortcal density } (\rho_{th}) - \text{Experimental density } (\rho_{th})}{\text{Theortcal density } (\rho_{th})} \qquad (2)$$

The variation in void content in the metal fabricated alloy composites may be due to the presence of air bubble during mechanical mixing of filler materials in the alloy composites during fabrication.

Table 2 Void fraction of Gr Mixed ZA-27 alloy Composite

Composites System	Theoretical Density (gm./cc)	Experimental Density (gm./cc)	Void fraction (%)
27-Gr. 0 %	4.67	4.55	2.53
ZA-27-Gr. 2 %	4.57	4.42	3.26
ZA-27-Gr. 4 %	4.50	4.30	4.34
ZA-27-Gr. 6 %	4.42	4.36	4.38
27-Gr. 0 %	4.67	4.55	4.59

3.2 EFFECT OF HARDNESS ON Gr. METAL POWDER-FILLED ZA-27 ALLOY COMPOSITES

Figure 3.1Indicates the Rockwell hardness values of the ZA-27 alloy composites metal filled with various weight percentage of Graphite metal powder filler content. It is revealed that the addition Graphite powder filler Decrease the hardness significantly Hardness (Rock well Hardness tester with 10 Kgf. Minor Load on 'B' scale) of the specimen samples prepared 10*10*30 mm3. The neat alloy shows 42 HV and the addition of 2 wt.-% Graphite powder filler content leads to a reduce in hardness by 4.76 % to 40 HV. Furthermore, increment of 4 wt.-% Graphite powder filler content over neat alloy composite leads to a reduce in hardness by 11.90 % to 37 HV. Furthermore, addition of 6 wt. % Graphite particulate filler content Leads to a reduce in hardness by 23.8 % to 32 HV. The similar result's also reported by R. Dali's et al., fabricated Graphite particulate filled ZA-27 alloy composite, the increase the wt. % of Graphite filler content in ZA-27 alloy composite effects decrease the hardness the reason behind this due to agglomeration behaviour of Nano-sized particles we get excessive porosity at high graphite additive. This has led to a further decrease in hardness [8].

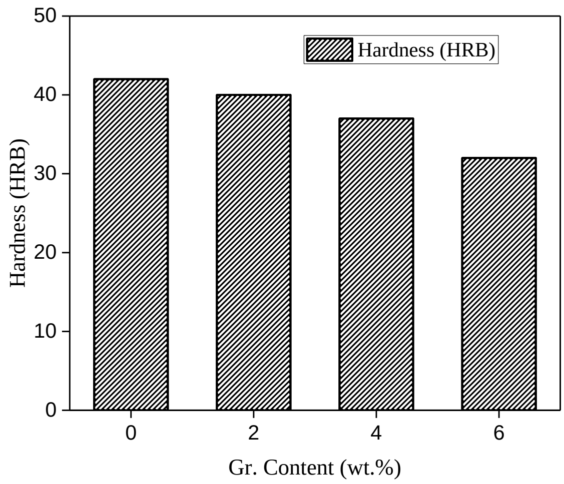


Figure 3.1Variation of composite hardness (HRB) with Graphite content

3.3 EFFECT OF COMPRESSIVE STRENGTH ON Gr. METAL POWDER-FILLED ZA-27 ALLOY COMPOSITE.

The impact of Graphite particulate filled ZA-27 alloy composite on compressive strength, the compressive strength of composite varies 406 MPa-496MPa is shown in figure 3.2 that the weight percentage of graphite particulate increases the result that compressive Strength is increases.

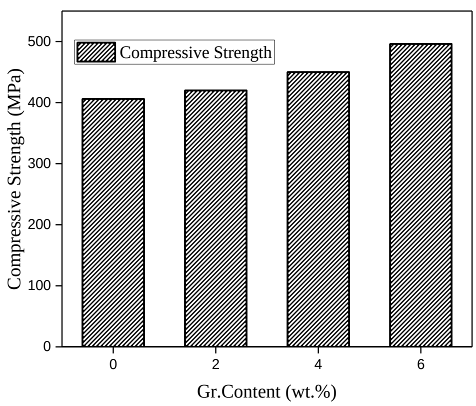


Figure 3.2 Variation of composite compressive strength with Graphite content.

The highest compressive strength is 6 wt. % Gr filled ZA-27 alloy composite that is 496 MPa. The unfilled particulate alloy composite has compressive strength 406 M Pa , And the addition of 2 wt. -% filler content Graphite particle leads to an increase in compressive strength by 3.44 % to 420 M Pa. Furthermore, increment of 4 wt.-% filler content Graphite particle over unfilled reinforced alloy composite leads to an increase in compressive strength by 10.83 % to 450 M Pa. Furthermore, addition of 6 wt.-% particulate contents an increase in compressive strength 22.16 % to 496 M Pa. The similar result is also found by K.H.W Seah et al. fabricated a composite Graphite particulate filled ZA-27 alloy composite, the increase the wt. % of Graphite content in ZA-27 alloy composite consequences increases the compressive strength.[9]

3.4 EFFECT OF FLEXTURAL STRENGTH ON Gr. METAL POWDER-FILLED ZA-27 ALLOY COMPOSITES.

The impact on flexural strength of Graphite particle filled ZA-27 alloy composite, the Increase in filler content the flexural strengths gradually decreases as observed in Fig.3.3 the Highest flexural strength is 0 wt. % Graphite ZA-27 alloy composite 552 MPa and the minimum Flexural strength 6 wt.

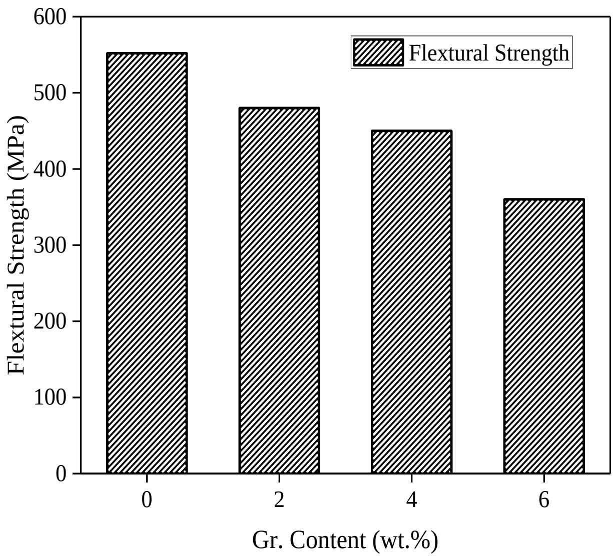


Figure 3.3 Variation of Flexural strength with Graphite filled content.

Graphite two % ZA-27 alloy composite is 360 MPa. The neat alloy shows flexural strength of 552 M Pa without the addition of filler material. On addition of 2 wt-% Graphite particle content in the base alloy, the flexural strength is decreased by 13% (i.e. from 552 M Pa to 480 M Pa).

Furthermore, increment of 4 wt-% Graphite over neat alloy composites leads to a decrease in flexural strength by 18.47 % to 450 M Pa. Furthermore, addition of 6 wt.-% Graphite particulate content leads to a reduce in flexural strength by 34.78 % to 360 M Pa. The decrease Rate of flexural strength is 360 M Pa over neat alloy at 6wt % Graphite, metal powder-filled alloy composite. The similar behaviour observed in ZA-27 Gr filled alloy composite that the wt. % Graphite particles increases the decrement in flexural strength the motive is The increased amount of the brittle graphite particles together with the increased tendency of crack initiation and propagation at the graphite/metal interface are responsible for these effects.[10]

3.5 EFFECT OF IMPACT STRENGTH ON Gr. METAL POWDER-FILLED ZA-27 ALLOY COMPOSITES.

The effect on impact strength graphite particle filled ZA-27 alloy composite. The filler content Increases, the impact strength are decreases. Highest impact strength is found in 0 wt. % graphite particle filled ZA-27 alloy composite (i.e. 22.76 J) and the minimum impact strength is found 6 wt. % graphite particle filled ZA-27 alloy composite (i.e. 14 J).

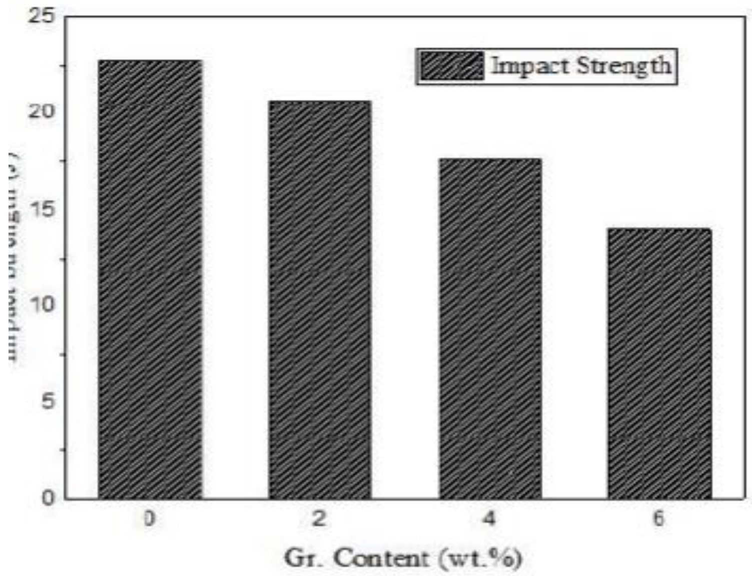


Figure 3.4 Variation of Impact strength with Graphite filled content.

The impact strength decreases with filler content because hardness reduce With increase in filler content. it is shown in fig.3.4The graph indicates that impact strength decreases with filler content from 22.75 J at 0wt.-% of Graphite metal powder to 20.68 J at 2 wt.-% Graphite powder in the unfiled matrix. On extra addition of Graphite powder filler, the impact strength is 17.64 at 4 wt.-% Graphite Metallic powder to 14 J at wt. % Graphite Metal Powder. The impact strength of the Gr-filled composites decrease gradually with increase in filler contents [50].

4. CONCLUSIONS

In this research paper fabricate different type of composite by stir casting method i.e. Al-alloy (ZA-27) Hybrid composite with reinforced Gr, Sic and Marble Dust .The experimentally proved that the Hybrid reinforced physical and mechanical properties of the composite when compared with the monolithic material. This research work describes the density, void contents, Hardness, compressive Strength, Impact strength.

• Stir casting Method has been used for fabricate Al – alloy hybrid composite .The stir casting technique is most economical and conventional method of casting component.

• The wt.% of Gr reinforced increase in the composite leads to increase the experimental density of the composite and void content also increase with increase the wt.% of reinforced in fabricated Hybrid Composite.

• The wt. % of Gr filler content increase in the Hybrid Composite leads to decrease the hardness of the composite. The neat alloy highest hardness is found in 0 wt. % graphite particle filled ZA-27 alloy composite (i.e. 42 HV)

• The wt. % of Gr filler content increase in the Hybrid Composite leads to increase the compressive strength of the composite. The Compressive Strength of the composite increase up to 22.16% (i.e. 496 MPa) at ZA-27-Gr6 %.

•The impact on flexural strength of Graphite particle filled ZA-27 alloy composite, the Increase in filler content the flexural strengths gradually decreases as observed in Fig.3.3 the Highest flexural strength is 0 wt. % Graphite ZA-27 alloy composite 552 MPa. The wt. % of Gr filler content increase in the Hybrid Composite leads to decrease the impact strength of the composite. The Highest impact strength is found in 0 wt. % graphite particle filled ZA-27 alloy composite (i.e. 22.76 J).

REFRENCES

[1] Erol Feyzullahog˘lu, Nehir S akiroglu,"the wear of aluminium-based journal bearing Materials under lubrication", Materials and Design 31 (2010) 2532–2539.

[2] Zhengang Liu, GuoyinZu, HongjieLuo, Yihan Liu and Guangchun Yao, "Influence of Mg Addition on Graphite Particle Distribution in the Al Alloy Matrix Composites" J. Mater. Sci. Technol., 2010, 26(3), PP, 244-250.

[3] Karthick E, Joel Mathai, Michael Tony J, Senthil Kumar, Marikkannana, "Processing, Microstructure and Mechanical Properties of Al2O3 and Sic Reinforced Magnesium Metal Matrix Hybrid Composites" Materials Today: Proceedings 4 (2017), PP 6750– 6756.

[4] Fei CHEN, Tong-min WANG, Zong-ning CHEN, Feng MAO, Qiang HAN, Zhi-qiang CAO, "Microstructure, mechanical properties and wear behaviour of Zn−Al−Cu−TiB2 in situ composites " Trans. Nonferrous Met. Soc. China 25(2015), PP 103−111.

[5] A. Baradeswaran, A. Elaya Perumal., 2013, "Influence of B4C on the Tirbological and mechanical properties of Al 7075–B4C composites", international journal of Composites: Part B 54 (2013), PP 146–152.

[6] A.A. Agbeleye , D.E. Esezobor , S.A. Balogun , J.O. Agunsoye , J. Solis , A. Neville, "Tribological properties of aluminium-clay composites for brake disc rotor applications" Journal of King Saud University – Science xxx (2017) xxx–xxx.

[7] P. B. Pawar and A. A. Utpat, "Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite for Spur Gear," Procedia Mater. Sci., vol. 6, no. Icmpc, pp. 1150–1156, 2014.

[8] F. Akhlaghi and A. Zare-Bidaki, "Influence of Graphite content on the dry sliding and oil impregnated sliding wear behavior of Al 2024-Graphite composites produced by in situ powder metallurgy method," *Wear*, vol. 266, no. 1–2, pp. 37–45, 2009.

[9] V. Brahmam, T. V. Swamy, and A. Khurshid, "Characterization of Za27-Fly Ash Graphite Particulate Reinforced Hybrid Composites," vol. 2, no. 2, pp. 1–8.

[10] Ranganath G, Sharma SC, Krishna M, Muruli MS (2002) J Mater Eng Perform 11:408–413

[11] Ramesh, A., Prakash,J.N.,Gowda,A.S.S.S.,Appaiah,S.,Comparision of the Mechanical properties of Al6061/Albite and Al6061/Graphite metal matrix Composite. *Journal of Minerals and Material Characterization and Engineering*, 8,93-106, 2009