iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** XII **Month of publication:** December 2020

DOI: https://doi.org/10.22214/ijraset.2020.32507

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue XII Dec 2020- Available at www.ijraset.com

Development and Analysis of Metal Matrix Composite of Aluminium LM-25 Alloy using Silicon Nitride and Flyash Reinforcements

Er. Varinder Pal Singh[1], Er. Gora Ram Sharma[2]
[1, 2]Bhai Maha Singh College of Engineering, Sri Muktsar Sahib

Abstract: Aluminium based composites has wide range of applications due to its excellent property combinations like improved mechanical properties, better wear and high corrosion resistance, ease to process and probably reduced production cost etc. The two or more phases combined together to form a composite one is base metal alloy and other is reinforcement ceramic. The most commonly used reinforcements are carbides, oxides and nitrides. A lot of research has taken place including carbide and oxide as reinforcement particles for aluminum matrix composites (AMCs). Researchers also incorporated flyash by-product of thermal power plant as reinforcement to prepare AMC's. Present work is focused on study of properties of composite developed with aluminium alloy (LM25) as matrix with reinforcement of silicon nitride and flyash. Samples are prepared by varying the %age of silicon nitride from 5% to20% increment of 5% and keeping the flyash content fixed at 5%. Stir casting method is utilized to prepare the samples. Tensile test, wear test, hardness test are done to analyze the mechanical properties of composite whereas SEM and optical microscopy is performed for characterization of AMC's. The results so obtained are correlated and compare with pure aluminium alloy. Results showed that hardness and wear resistance is more in the AMC having 20%wt of silicon nitride and 5% flyash. On the other hand tensile strength is more in sample having 15%wt of silicon nitride and 5% flyash. SEM and optical microscopy showed the homogeneous mixture of reinforcements in the aluminium alloy.
Keywords: Composites, flyash, silicon nitride, stir casting

I. INTRODUCTION

A metal matrix composite (MMC) is composite material consisting of at least two parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or compound. A MMC is also called hybrid composite if it consist of three materials. New materials are being developed with the advancement in technology and advanced applications. Most promising materials in the present scenario are Composites and recent interest in newer developments has led to Metal matrix composites (MMCs) which possess significantly improved properties compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements The aim in designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics [1]**.** The addition of high strength, high modulus refractory particles to a ductile metal matrix produce a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement. Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Many of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (physical property of steel are similar to those of pure iron) . Favourable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance **[2].**

The use of low cost reinforcements, cost effective processing techniques and standardization of processing parameters could facilitate in wide application of metal matrix composites. There has been an increasing interest in composites containing low density and low cost reinforcements. Due to the increasing cost of energy, metal alloys and conventional ceramic reinforcements used in fabricating metal matrix composites (MMCs), great interest has been shown in the use of inexpensive reinforcements such as natural minerals and fly ash in particulate aluminum MMCs. Fly ash, being a waste by-product of coal combustion in thermal power plants, is available in large quantities and is appreciably less expensive than other ceramic particles used currently in particulate MMCs, such as Al_2O_3, SiC, TiC andB_4C. A recent economic analysis showed that beneficiated fly ash cost 11–22 cents/kg as compared to \$2.78/kg of aluminum and approximately \$3.3–6.6/kg for SiC **[3]**.

As such, fly ash-reinforced aluminum MMCs reinforced are likely to find applications in the transportation industry where the conventional particulate MMC shave not been cost effective. Incorporating fly ash into aluminum alloys to make MMCs is advantageous in that it will not only reduce the environmental impacts of the current fly ash disposal methods, but will reduce energy consumption and air emissions resulting from aluminum production [4].

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue XII Dec 2020- Available at www.ijraset.com

II. EXPERIMENTATION

Silicon nitride and flyash is used as reinforcements in MMC for the present investigation. Si_3N_4 is added in varied proportion and flyash content is kept fixed in MMC. Flyash used in the present research work is collected from Bathinda thermal power plant. It is the byproduct of coal combustion used in power plant. So present work also emphasized on reuse of waste flyash. Flyash is also a major source of silica along with other constituent like Al_2O_3, Fe_2O_3 and CaO. The particle size of the ash used was in the range from (75-105µm). The chemical composition of flyash is shown in table 2.1.

Table 2.1: Chemical compositions of coal fly ash particles

Constituents	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	MgO	CaO
Amount, %	61.43	26.60	2.65	1.65	1.65	1.40

Flyash content is kept fixed at 5% while silicon nitride Si_3N_4 is varied with the increment of 5% in successive samples.
The matrix material for the preparation of composites was LM25, whereas Coal Flyash and Silicon nitride were used as the reinforcement materials. Initially, LM25 with the density of 2760 kg/m^3 alloy was fed into the graphite crucible and heated to 750 ºC till the entire alloy melted in the crucible. The reinforcement particles were preheated to 800^0C for 1 hour before incorporating into the melt. After the molten metal was fully melted degassing tablet was added to reduce the porosity. Simultaneously, 1 wt. % magnesium was added to the molten metal to enhance the wetability between ash particles and the alloy melt**.** It was noticed that without the addition of magnesium, the particles of fly ash were rejected. The stirrer made up of stainless steel was lowered into the melt slowly to stir the molten metal at the speed of 600 rpm. The speed of the stirrer can be controlled my means of regulator provided on the stir casting setup. The preheated ash particles were added into the molten metal at a constant rate during the stirring time. The stirring was continued for another 5 minutes even after the completion of particle feeding. The mixture was poured into the mould. Using this method5, 10, 15 and 20% by weight ash particle and silicon nitride reinforced composites were produced.

Table 2.2: Composition of MMC's

Sr.no	Sample no.	Composition
1	Sample A	LM 25
2	Sample B	LM 25 + 5 wt. % Si_3N_4+ 5wt.% fly ash
3	Sample C	LM 25 + 10 wt.% Si_3N_4+5wt.% fly ash
4	Sample D	LM 25 + 15 wt.% Si_3N_4+5wt.% fly ash
5	Sample E	LM 25 + 20 wt.% Si_3N_4+5wt.% fly ash

III. RESULTS

A. Optical Microscopy

Optical microscope was used to determine the microstructure of composites. The microstructures of composites are shown in figures 3.1 to 3.5. The magnification of optical microscope was kept at 250x. The black spots can be seen in the microstructures showing the presence of flyash content and remaining portion show the Si_3N_4 reinforced aluminium alloy. Different figures of optical microstructure are as follows:

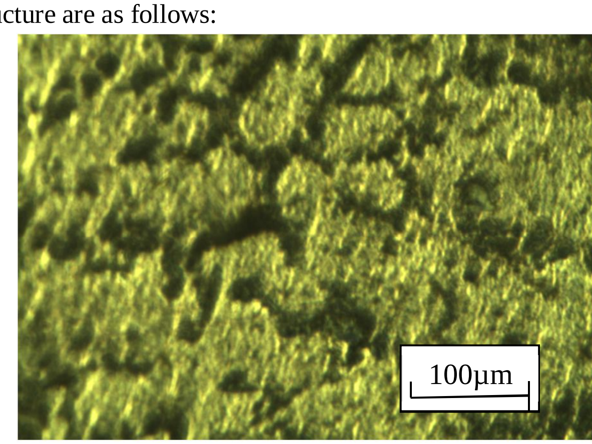


Figure 3.1: pure Al Alloy S1

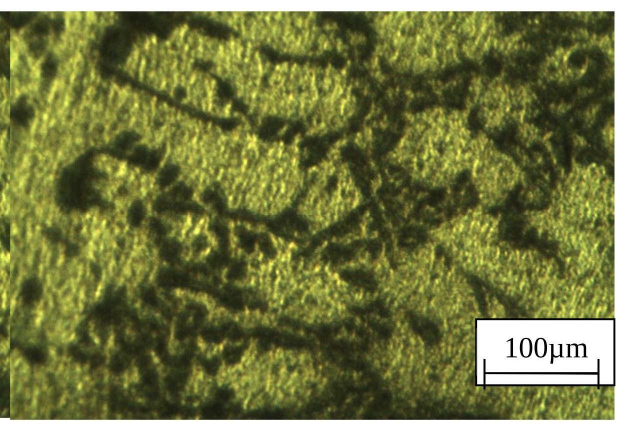


Figure 3.2 microstructure of MMC S2

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue XII Dec 2020- Available at www.ijraset.com

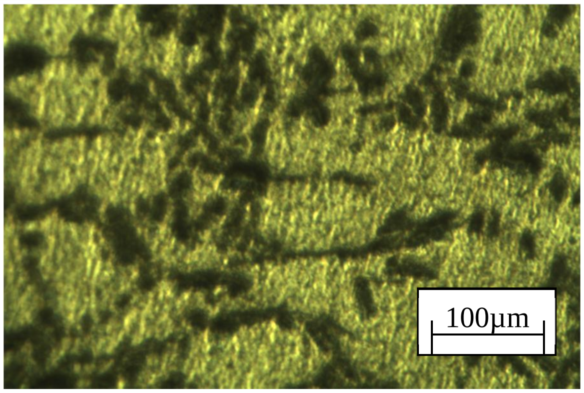


Figure 3.3 microstructure of MMC S3

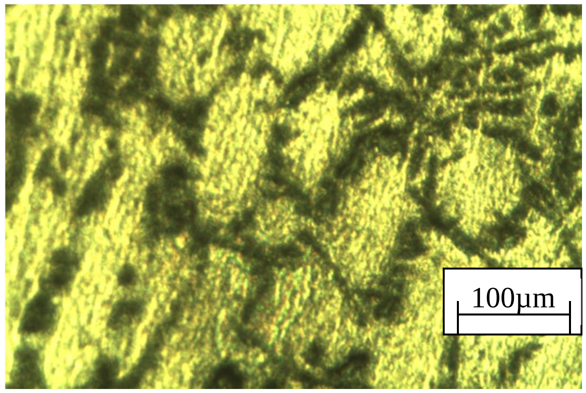


Figure 3.4 microstructure of MMC S4

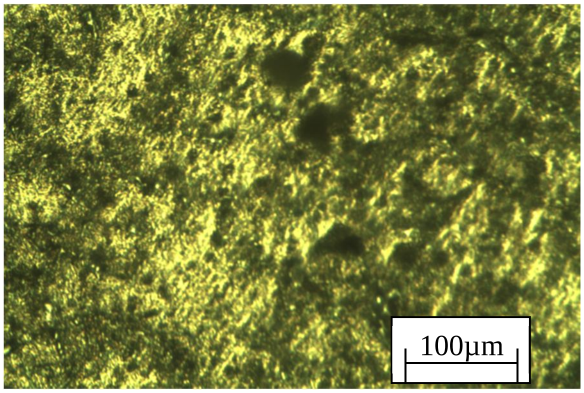


Figure 3.5 microstructure of MMC S5

B. Microhardness

The Micro Hardness of Aluminium LM-25 obtained is 68.2 VHN. For the Al, Si3N4 &coal fly ash MMCs the Micro Hardness for samples S2, S3, S4, S5 are 72.9, 76.3, 79.4 and 83.2 VHN respectively. This hardness test is performed to know the hardness that has been imparted by the reinforcement particles to the composite. The hardness of the Al alloy is found to be the lowest (68.2 VHN) and this is due to the softer matrix surface which is unable to resist the deformation caused by the indenter. The inner surface of the FGM shows higher hardness (103 VHN) than the unreinforced alloy as this is due to the concentration of a few Si_3N_4 particles. The middle surface of the FGM has a higher concentration of reinforcement than the inner surface and, hence, higher hardness (83.2 VHN) is achieved at this surface. The homogeneous composite S5 exhibits better hardness than the aforesaid three surfaces, as this is due to the uniform distribution of reinforcement particles in the surface. These particles resist crack formation due to good bonding and, therefore, higher hardness is obtained. Hard Si3N4 particle segregation is more at this region. These hard, protruded particles diminish the matrix contact area with the indenter and, therefore, exhibit less indentation, which results in higher hardness. From the hardness results, it is understood that the hard Si3N4 particles strengthens the matrix and reduce the deformation to a greater extent, and the same mechanism is observed [**5**].

Table3.1 Micro Hardness Test Results

Sample No	Composition	Mean Micro hardness (VHN)
S1	LM 25	68.2
S2	LM 25 + CFA 5wt%age+Si_3N_4 5%wt	72.9
S3	LM 25 + CFA 5wt%age+Si_3N_4 10%wt	76.3
S4	LM 25 + CFA 5wt%age+Si_3N_4 15%wt	79.4
S5	LM 25 + CFA 5wt%age+Si_3N_4 20%wt	83.2

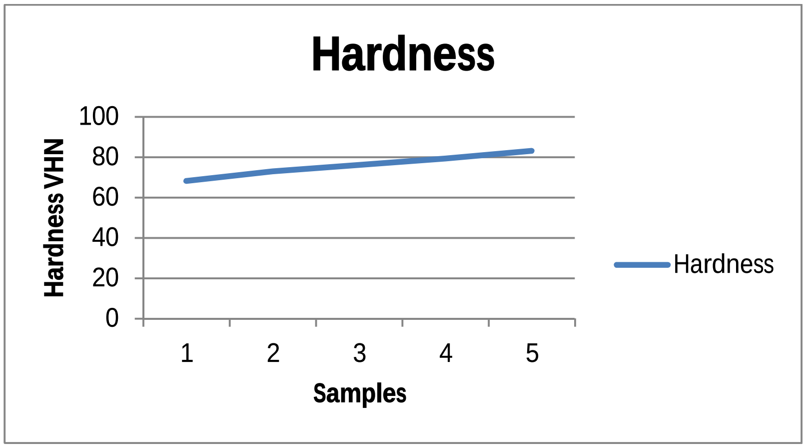


Figure 4.8: Hardness variation

The incorporation of ash particles in Aluminum matrix causes reasonable increase in hardness. The strengthening of the composite may be attributed to dispersion strengthening. It was observed that hardness in case of the coal fly ash reinforced MMCs is more than composites prepared using only Si_3N_4. Thus, ash as filler in Al casting reduces cost and increase hardness which are needed in various industries like automotive etc.

C. *Wear Behavior*

Wear behavior of different composite was studied with different parameter like rpm, running time, disc radius and applied loads. The results are given in the table 4.2. For the entire composites the rpm was taken as 600 rpm, disc radius was 50mm, total running time is 20min and applied loads taken were 10, 30 and 50N.

Table 3.2 Wear test at different loads

<table>
<tr><th>S No.</th><th>Sample</th><th>Initial wt (g)</th><th>Final wt (g)</th><th>Weight Loss(g)</th><th>Length (m)</th><th>Density (g/cc)</th><th>Force (N)</th><th>Wear Rate (x 10^{-13}) (m^3/Nm)</th><th>Avg. Wear Rate</th></tr>
<tr><td>1</td><td>S1 A</td><td>5.5882</td><td>5.5284</td><td>0.0598</td><td>1884</td><td>2.7579</td><td>10</td><td>11.5092</td><td rowspan="3">10.15457</td></tr>
<tr><td>2</td><td>S1 B</td><td>5.1344</td><td>4.9821</td><td>0.1523</td><td>1884</td><td>2.7579</td><td>30</td><td>9.7704</td></tr>
<tr><td>3</td><td>S1 C</td><td>5.269</td><td>5.0304</td><td>0.2386</td><td>1884</td><td>2.7579</td><td>50</td><td>9.1841</td></tr>
<tr><td>4</td><td>S2 A</td><td>4.6432</td><td>4.5887</td><td>0.0545</td><td>1884</td><td>2.5392</td><td>10</td><td>11.3924</td><td rowspan="3">9.210067</td></tr>
<tr><td>5</td><td>S2 B</td><td>5.5074</td><td>5.3862</td><td>0.1212</td><td>1884</td><td>2.5392</td><td>30</td><td>8.445</td></tr>
<tr><td>6</td><td>S2 C</td><td>5.4392</td><td>5.2528</td><td>0.1864</td><td>1884</td><td>2.5392</td><td>50</td><td>7.7928</td></tr>
<tr><td>7</td><td>S3 A</td><td>5.08</td><td>5.0485</td><td>0.0315</td><td>1884</td><td>2.2919</td><td>10</td><td>10.4007</td><td rowspan="3">8.783667</td></tr>
<tr><td>8</td><td>S3 B</td><td>5.5753</td><td>5.4965</td><td>0.0788</td><td>1884</td><td>2.2919</td><td>30</td><td>8.5114</td></tr>
<tr><td>9</td><td>S3 C</td><td>5.5077</td><td>5.3802</td><td>0.1275</td><td>1884</td><td>2.2919</td><td>50</td><td>7.4389</td></tr>
<tr><td>10</td><td>S4 A</td><td>5.2289</td><td>5.2103</td><td>0.0186</td><td>1884</td><td>1.911</td><td>10</td><td>7.2951</td><td rowspan="3">6.4279</td></tr>
<tr><td>11</td><td>S4 B</td><td>5.2435</td><td>5.2024</td><td>0.0411</td><td>1884</td><td>1.911</td><td>30</td><td>6.0831</td></tr>
<tr><td>12</td><td>S4 C</td><td>5.2662</td><td>5.1987</td><td>0.0675</td><td>1884</td><td>1.911</td><td>50</td><td>5.9055</td></tr>
<tr><td>13</td><td>S5 A</td><td>5.5776</td><td>5.5264</td><td>0.0512</td><td>1884</td><td>2.6129</td><td>10</td><td>5.166</td><td rowspan="3">4.2402</td></tr>
<tr><td>14</td><td>S5 B</td><td>5.6238</td><td>5.4981</td><td>0.1257</td><td>1884</td><td>2.6129</td><td>30</td><td>3.8051</td></tr>
<tr><td>15</td><td>S5 C</td><td>5.5876</td><td>5.4045</td><td>0.1831</td><td>1884</td><td>2.6129</td><td>50</td><td>3.7495</td></tr>
</table>

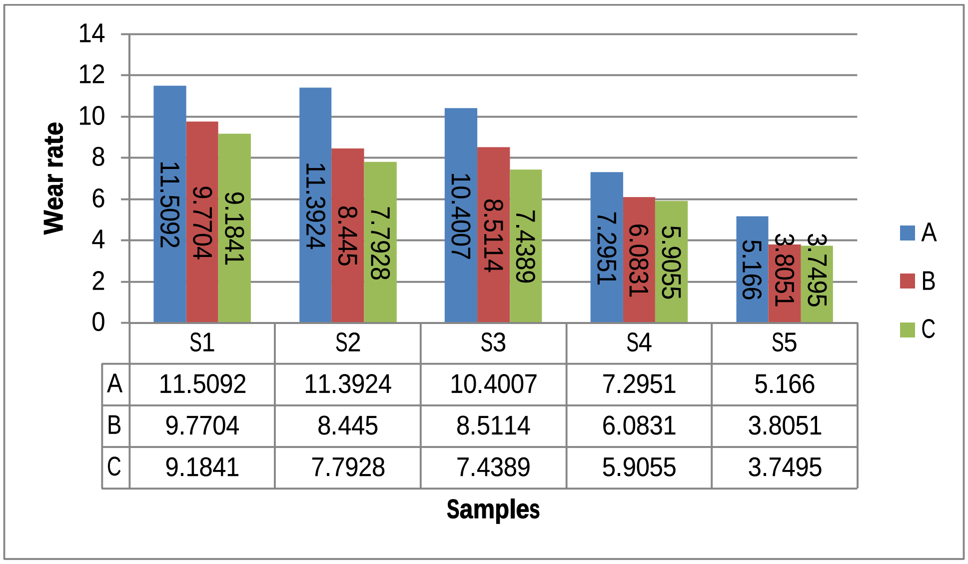


Figure 4.7: wear rate variation with reinforcements

The figure show the wear curves and bar charts of MMCs specimen with 5% Si_3N_4, 10% Si_3N_4, 15% Si_3N_4 and 20% Si_3N_4 along with 5% flyash at normal load of 10N, 30N, 50N. All the MMCs showed a linear wear regime. After a certain sliding distance, the wear has increased linearly with load indicating steady state wear regime. From the graph Fig.4.7 it is evident that the wear resistance of MMCs is much greater than the al alloy LM-25 .Wear decrease with addition of fly ash and silicon nitride content significantly. This is because of the presence of hard fly ash particle which will increase the over all hardness.

D. Tensile Test

The following table shows the observed readings of ultimate tensile strength of Al composites reinforced with 5%, 10%, 15% and 20% Si_3N_4 and 5% fixed flyash samples. The maximum ultimate strength comes out to be 301 MPa in sample S4 and minimum ultimate strength is in sample S1.

Table 3.3 Tensile test Results

Sample No	Composition	UTS (MPa)
S1	LM 25	260
S2	LM 25 + CFA 5wt%age+Si_3N_4 5%wt	275
S3	LM 25 + CFA 5wt%age+Si_3N_4 10%wt	288
S4	LM 25 + CFA 5wt%age+Si_3N_4 15%wt	301
S5	LM 25 + CFA 5wt%age+Si_3N_4 20%wt	265

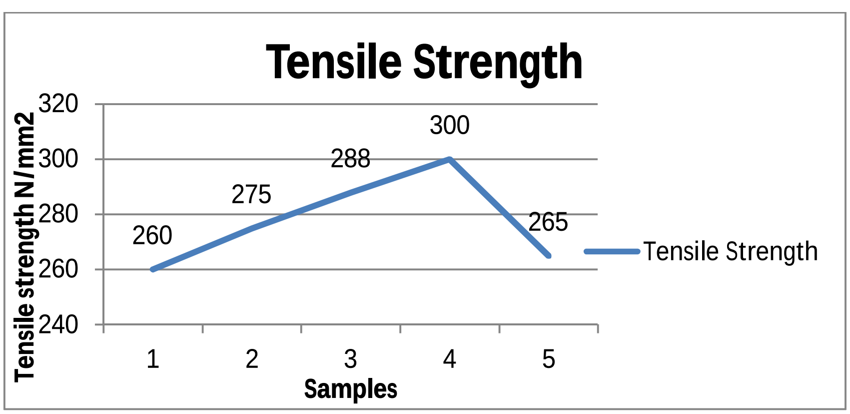


Figure 4.6: Tensile strength variation

IV. CONCLUSIONS

Different experimental techniques were used to fabricate and characterize physical and mechanical properties of stir cast aluminium alloy LM25 reinforced with fixed proportion of coal flyash and variable wt %age of silicon nitride. The results were investigated by using different test techniques like micro hardness, tensile test, optical microscopy, scanning electron microscopy (SEM), energy dispersive x-ray spectroscopy (EDX).the following conclusions were drawn from the study:

A. The composite of AL alloy LM25 reinforced with coal flyash and silicon nitride are successfully fabricated through stir casting process.

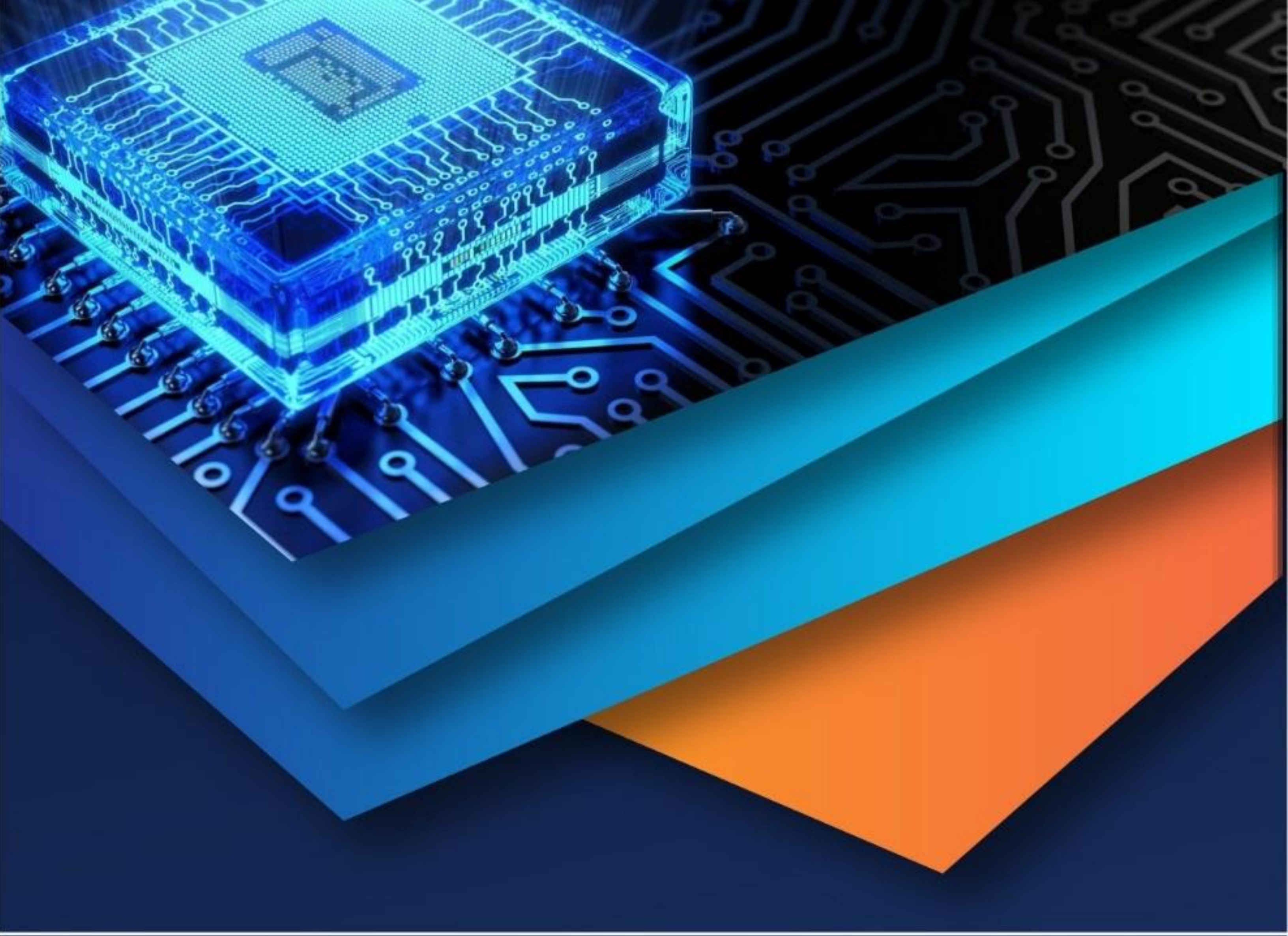
B. Microstructure and EDX results show the presence of C, Si and many other constituents in the composite. The investigations show homogeneous distribution of reinforced particles within the composite.

C. The results revealed that the composites have better qualities in comparison with base alloy. The resulted tensile strength, microhardness and wear resistance is more than base alloy.

D. The tensile strength and microhardness increases with increase in wt %age of silicon nitride and coal flyash.

REFERENCES

[1] Ahmad Zeeshan, Khan Sabah, Hasan Shabahat (2020) “Microstructural characterization and evaluation of mechanical properties of silicon nitride reinforced LM 25 composite” Journal of material research and technology (JMR&T), vol.9 (4):9129–9135.
[2] A.K Ranjeet, T. Amit (2020) “Silicon Nitride as a Reinforcement for Aluminium Metal Matrix Composites to Enhance Microstructural, Mechanical and Tribological Behavior” International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Vol.9 Issue-3.
[3] Khan Sabah, Ahmad Zeeshan (2018) “Comparative analysis for coefficient of friction of LM 25 alloy and LM 25 granite composite at different sliding speeds and applied pressure”.Int J Mech Prod Eng Res Dev (IJMPERD) 2018;8(Jun (3)).
[4] Y. Pazhouhanfar, B. Eghbali (2018) “ Microstructural characterization and mechanical properties of TiB2 reinforced Al6061 casting process”, Mater. Sci. Eng., A 710; 172–180.matrix composites produced using stir
[5] K. Govindan, J.G. Raghuvaran, V. Pandian (2017) “Weldability study of LM25/ZrO2 composites by using friction welding”, Matéria (Rio de Janeiro) 22 (3).
[6] Sharma Pardeep, Sharma Satpal, Khanduja Dinesh (2015) “A studyon microstructure of aluminium matrix composites”. J Asian Ceram Soc 2015;3(Sep (3)):240–4.
[7] Ministry of Coal, Ministry of Power, Ministry of Environment & Forest, Ministry of Science & Technology (2013), “Fly Ash Utilisation”, 2nd Annual International Summit, New Delhi, pp. 2.
[8] Apasi A., Madakson P.B., Yawas D.S., Aigbodion V.S. (2012), “Wear Behaviour of Al-Si-Fe Alloy/Coconut Shell Ash Particulate Composites”, Tribology in Industry Vol. 34, No 1, pp. 36-43.
[9] Prasad D. Siva and Krishna A. Rama (2012), “Tribological Properties of A356.2/RHA Composites”, J. Mater. Sci. Technol, 28(4), pp.367-372.
[10] Prasad Saripalli H K R, RaoAbburiMohana , Prasad PydiHari, Murthy B.S.N, Prasad D. Siva (2012),“Scanning Electron Microscope Studies on Dry Sliding Wear Behavior Of Metal Matrix Composites With Aluminum And Rice Husk Ash”, Int. J. Int sci. Inn. Tech. Sec. B, Vol. 1, Issue 2, pp. 1-5.
[11] Rino J. Jenix, Chandramohan D. and Jebin V. Daniel (2012), “Research Review on Corrosion Behaviour of Metal Matrix Composites”, International Journal of Current Research Vol. 4, Issue, 09, pp. 179-186.
[12] Singh Kamaljit (2012), “Mechanical Behaviour of Aluminium Based Metal Matrix Composites Reinforced with Aluminium Oxide”, Thesis Thapar university pg 28-33.
[13] Uju W.A. and Oguocha I.N.A. (2012), “A Study Of Thermal Expansion Of Al–Mg Alloy Composites Containing Fly Ash”, Materials and Design, 33, pp. 503-509.
[14] Hansen N., GodfreyA., WuG.H., LiuQ.(2011), “Materials & Design”, Volume 32, Issue 7, pp. 3810-3817
[15] Kumar Anil H.C., Hebbar H.S., Ravishankar K.S. (2011), “Mechanical Properties of Fly Ash Reinforced Aluminium Alloy (Al6061) Composites”, International Journal of Mechanical and Materials Engineering (IJMME), Vol.6, No.1, pp. 41-45.
[16] Pal Harinder, Nripjit, TyagiAnand K, SidhuSarabjeet (2011), “Metal Casting- A General Review”,Advances in App.lied Science Research, 2 (5): pp. 360-371.
[17] Prasad D. Siva and Krishna A. Rama (2011), “Production and Mechanical Properties of A356.2 /RHA Composites”, International Journal of Advanced Science and Technology Vol. 33.
[18] SalihSiham E., Al-Saffar Sahib M. andDarkhanSolafMajeed (2011), “Effect of Fly and Dust Ash Additions on Hardness and Wear Resistance of Composite Metal Matrix (Al-Si-Mg)”, Eng. & Tech. Journal, Vol.29, No.16.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY