International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-5, January 2020

Mechanical and Wear Properties of Al6063 Metal Matrix Composite Reinforced with Al_2O_3 Particles

Abdul Nazeer, Mir Safiulla

Abstract: ***Composite material has replaced conventional material drastically in recent years, due to its strength to weight ratio, easy forming, cost-effectiveness, good aesthetic appearance. Metal matrix composite has successfully replaced in a structural application in the field of automobile, construction, aerospace, marine, medical etc. of which aluminum matrix has widely accepted high strength to weight ratio, ease of fabrication, corrosion resistance, and high resistance to wear, etc. In this study an attempt was made to investigate the effect of alumina Al_2O_3 when reinforced with aluminum 6063 matrix, liquid metallurgy route (Stir Casting Technique) adopted for the preparation of composite, the reinforcement varied from 0 to 8wt% in steps of 2wt%. Mechanical, wear, fractography and X Ray diffraction studies conducted on prepared composite systems and testing done as per ASTM and ISO standard. After the test results revealed uniform distribution of reinforcement in matrix alloy, from mechanical test it was observed that as contain reinforcement is increased the mechanical properties like hardness, toughness, tensile strength have improved similar observation were made in wear test increase in containing reinforcement resulted better wear resistance, fractured tensile specimen was studied under Scanning electron microscope SEM which resulted in the mode of fracture for all composite systems and results shows the transition mode of fracture with increase in reinforcement, X-Ray Diffraction (XRD) studies were conducted to identify the presence of reinforcement on prepared specimen and results were successfully compared with JCPDS Cards.***

Keywords: Aluminum 6063 matrix composite, Alumina, Stir Casting, SEM, XRD and Mechanical Tests, Wear studies.

I. INTRODUCTION

Due to rapid change in manufacturing processes in industry the importance of material created a huge attention which made researchers to focus on development of composite material which focuses on high strength to weight ratio, low density, high strength, low coefficient of thermal expansion, low corrosion resistance high wear rate low friction coefficient, many these properties are achieved only by proper variation of reinforcement in matrix alloy and proper selection of matrix.

Manuscript published on January 30, 2020.
* Correspondence Author
Abdul Nazeer*, Research Scholar, Mechanical Engineering, Ghousia college of Engineering, Visvesvaraya Technological University, Balgavi, Karnataka, India.
Mir Safiulla, Professor & Principal, Islamiah Institute of technology, Bangalore, Visvesvaraya Technological University, Balgavi, Karnataka, India.

Based on the application composite are broadly classified as polymer matrix composite, metal matrix composite, ceramic matrix composite, reinforcing phase are classified as continuous, discontinuous, whisker, particulate, powder. Metal matrix composite gaining more importance in structural application in automobile, aerospace sector due to its superior properties like light weight, good resistance to corrosion and wear resistance. Aluminum matrix composite have attracted many researcher because ease of manufacturing good resistance to corrosion etc. Researcher tried many combination of reinforcement with different grades of aluminium majority have focused on aluminum 6061 with silicon carbide [3,6,12,14]. Some researcher worked with aluminum graphite composite [10]. Particulate reinforced metal matrix composite has widely accepted in last few decades, the present trends of potential applications is to improve the temperature effect, tribological properties and mechanical properties. Researchers identified number of reinforcement for Aluminium based metal matrix composite like TiB_2, SiC, TiO_2, Al_2O_3,TiC, Gr to improve the properties of composite [4,6,7]. Manufacturing process of composite material also plays a vital in properties of composite Ashwatha et al[17] worked on various conventional routes to study the overall performance of composite and resulted "that, using the powder metallurgy process, mechanical properties of the MMC's of aluminum alloy 2xxx were comparable and the factors like wettability, homogeneous dispersion of reinforcements in matrix, density, sintering conditions, particle size, volume percentage of particle can be played carefully to enhance the properties at low cost of manufacturing avoiding secondary operations". With increase in content of reinforcement of alumina the mechanical property like hardness, tensile strength have increased and elongation has decreased[1], Sic has been widely accepted as reinforcement because of it good bonding with aluminum which results a composite with better mechanical properties, it has observed that as the content of reinforcement is increased the distribution is uniform in matrix and ultimate tensile strength increased by 15.8-27% and breaking load in increased by 2-15% [15]. Hybrid composite have also made a greater impact to replace the conventional materials. Reinforcement like SiC/Gr a hybrid reinforcement in aluminum matrix have improved significantly the tensile strength and reinforcement are evenly distributed as resulted [1].

Reinforcing more than one reinforcement has focused much attention as hybrid composite like (SiC + Al2O3) mixture and weight percentage of 0.5, 1.5 and 2.5 wt.-% of CeO2 keeping total wt% of reinforcement less than 30 wt.-%. It was found that with reinforcing cerium oxide by 2.5% the microhardness increased by 17% whereas with only two reinforcement alumina and silicon carbide resulted 13.2%
increase in hardness compared with matrix alloy, the microstructure shows significant reinforcement with addition of cerium oxide[16]. Researcher also worked with AA7075 with Titanium Boride (TiB2) with stir casting technique to study the mechanical properties and wear behavior which resulted improvement with in mechanical properties and wear resistance also improved. Also found that with reinforcing the flyash with 5% and 10% by weight in Al6063 hardness, tensile and wear properties have improved [2].

II. EXPERIMENTAL DETAILS

2.1 Materials

2.1.1 Matrix material

Aluminum 6063 is used as metal matrix, Alumina as reinforcement in lab grade powder form.

Table 1: Composition of Al6063

Elements	Si	Fe	Cu	Mn	Mg	Al
%(max)	0.2-0.6	0.35	0.1	0.8	0.1	Balance

2.1.2 Reinforcing material

Table 2: Mechanical properties of Matrix and reinforcement

Material/ Properties	Density gm/cc	Hardness	Strength MPa	Elastic Modulus
Matrix -Al6063	2.7	73	130	68.9
Reinforcement Al_2O_3	3.69	1440	2600(C)	375

Table 3: Composition of composite systems

Samples		Alumina (%)
1	100	00
2	98	02
3	96	04
4	94	06
5	92	08

2.2 Preparation of Composites

Aluminum 6063 ingots are first clean to remove dirt and other chemical agents then the ingots are preheated to remove moisture, similarly the reinforcement are also preheated to remove moisture and other gases. The ingots are placed in crucible and heated till the melting of aluminum takes place then gradual mixing of reinforcement is done in molten matrix with consistently stirring stirrer. The stirring time was 10min. The molten composites maintained at a constant temperature of 700°C. Each set of composite were prepared with mixing of reinforcement from 2%, 4% 6% and 8% in sequence, cast specimen were machined to require dimensions. Fig 1a-1b shows the pouring of molten composite Al6063- Al_2O_3 in molds and prepared samples. Here the mould used for casting is made of cast iron and the tool used machining the specimen is High speed steel (HSS).

Fig 1 Pouring of molten material into mold

2.3 Fractography analysis

Fractography analysis was carried out on fractured tensile specimens to find the mode of fracture occurred for different weight percentage of reinforcement using a Scanning Electron Microscope (SEM). In SEM, the bombardment of electrons that are reflected are formed as an image. The analysis was conducted on Hitachi SU 3500 make

III. TESTING OF COMPOSITE

Fig 2 Samples prepared for various tests

The following tests were conducted to determine the mechanical and wear properties of the aluminum alloy and its composites systems.

3.1 Tensile Test

In order to identify the ability of material to withstand under static load tensile test was performed on Al6063 alloy and its composite systems on 40 ton capacity FIE (Fluid Instruments and Engines) machine and test were performed according to ASTM B557M standard

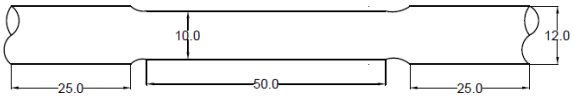

Fig 3: Tensile test specimen

3.2 Charpy Impact Test

The specimen prepared as per IS: 1757 standard. The specimen is cut into 10 mm × 10 mm cross section area and a length of 55 mm and a notch of 2 mm from top in the center of the specimen and test was conducted to identify the impact strength of material for Al6063 alloy and its composite systemsThe specimen of size 55×10×10 mm^3 is clamped in a support at the bottom of the machine.

The notch is situated in bottom facing apposite to hammer of the arm.

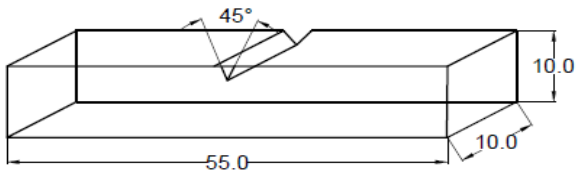

Fig 4: Charpy impact test specimen

3.3 Hardness Test

Hardness is a property to resist indentation, Vickers micro hardness tests were performed on matrix and
its composite systems the micro hardness tests was conducted on the polished samples. The micro hardness tests performed on Shimadzu Micro hardness tester.

3.4 X-Ray Diffraction

Al6063-Al_2O_3 composites systems for all weight percentage of (0, 2, 4, 6, 8) were tested to identify the presence of reinforcement and diffraction pattern were recorded to confirm the presence of Al_2O_3 in the composite. The sample is in powder form so that it can be easily placed in sample holder of dimension 24.6mm x1.0 mm. the test was conducted.

IV. RESULT AND DISCUSSION

4.1 Hardness Test

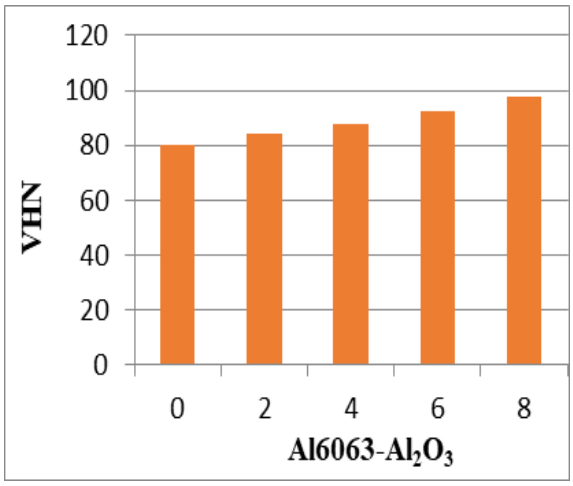

Fig 5: Variation of microhardness with increased content of Al2O3 for cast matrix alloy and its composite systems

It is observed from the graph that the hardness values of composite goes on increases with increase in hard reinforcement for all composite with different reinforcement which indicate that hardness of the base alloy can be increased with increase in reinforcement. This is the primary reason for the gradual increase in hardness when compared to base aluminum alloy samples.as reported by many researchers [10,14,15] It is observed that increased content of reinforcement in the matrix alloy results in enhanced hardness of the composite for all the systems studied. Addition of 8wt% Al_2O_3 enhanced the hardness of systems by 21.7%.

4.2 Tensile test

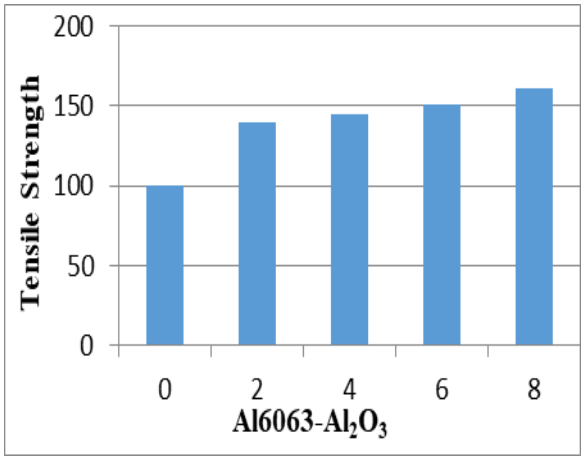

Fig 6: Variation of Tensile Strength with increased content of Al2O3 for cast matrix alloy and its composite systems

The test is conducted matrix and its composite systems to identify the tensile behavior. From the above graphs we can observe there is almost linearly varying in the tensile strength from 0 to 8wt% for the reinforcement which shows successful fabrication. However all the composite studied do exhibit a higher ultimate tensile strength when compared with matrix alloy.

Table 4: variation of maximum load, tensile strength and percentage elongation for all composite systems

Sample	Maximum Load(kN)	Tensile Strength (MPa)	% Elongation
1	10.22	100	12.05
2	17.54	139.41	9.9
3	17.8	145.01	8.4
4	19.1	150.46	7.06
5	19.78	161.44	4.66

4.3 Stress Strain Curve

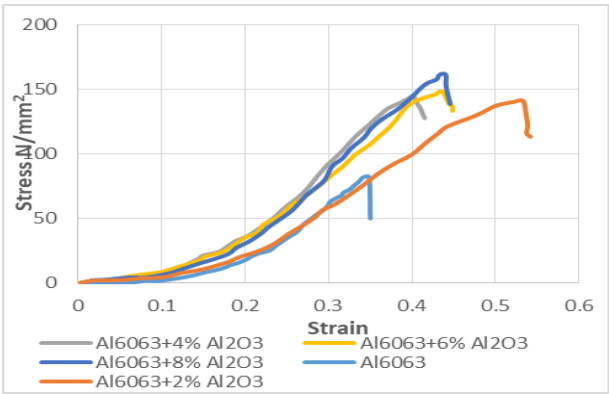

Fig 7: Variation of stress strain curve with increased content of Al_2O_3 for cast matrix alloy and its composite systems

Above figure represents the stress–strain graphs which were combined for all composite systems generated from computer attached to Universal Testing Machine.

The behavior of different composite are discussed in stress–strain diagram which follows similar trend as alloy, but with addition of reinforcement there is significantly increase in strength and ductility as compared to base alloy, also the maximum yield and tensile strength is for 8wt% of reinforcement. The ultimate tensile strength (UTS) is 161.4MPa and maximum yield strength is 135.8MPa, which can be attributed to the presence and relatively good dispersion of reinforcement mixture. From the stress strain curve it is clear the ultimate tensile strength is obtained for 8wt% of reinforcement followed by 6%, 4%, 2% and 0%, similar trend is observed with other researcher [12].

4.4 Compressive Strength

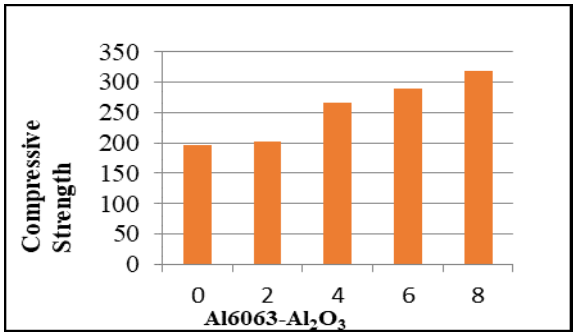

Fig 8: Variation of Compressive Strength with increased content of Al_2O_3 for cast matrix alloy and its composite systems

4.5 Charpy Impact Test

It has been observed from the graph that as due increase in percentage of reinforcement the ductility of the material is decreased and brittleness is increased so due impact the energy absorbed by composite is decreased with increase in percentage of reinforcement.

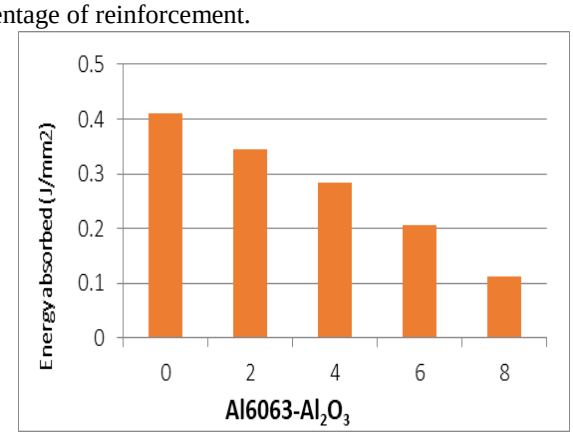

Fig 9: Variation of Impact Strength with increased content of Al_2O_3 for cast matrix alloy and its composite systems

Table:5 Variation of Yield stress, hardness and energy absorbed for all composite systems

Sample Identification	Yield Strength (MPa)	Hardness (VHN)	Energy Absorbed
Al6063	45.28	80	0.41
Al6063 + 2% Al_2O_3	59.8	84.334	0.345
Al6063 + 4% Al_2O_3	68.5	87.904	0.284
Al6063 + 6% Al_2O_3	74.5	92.466	0.205
Al6063 + 8% Al_2O_3	101.7	97.397	0.113

4.6 Fractography studies

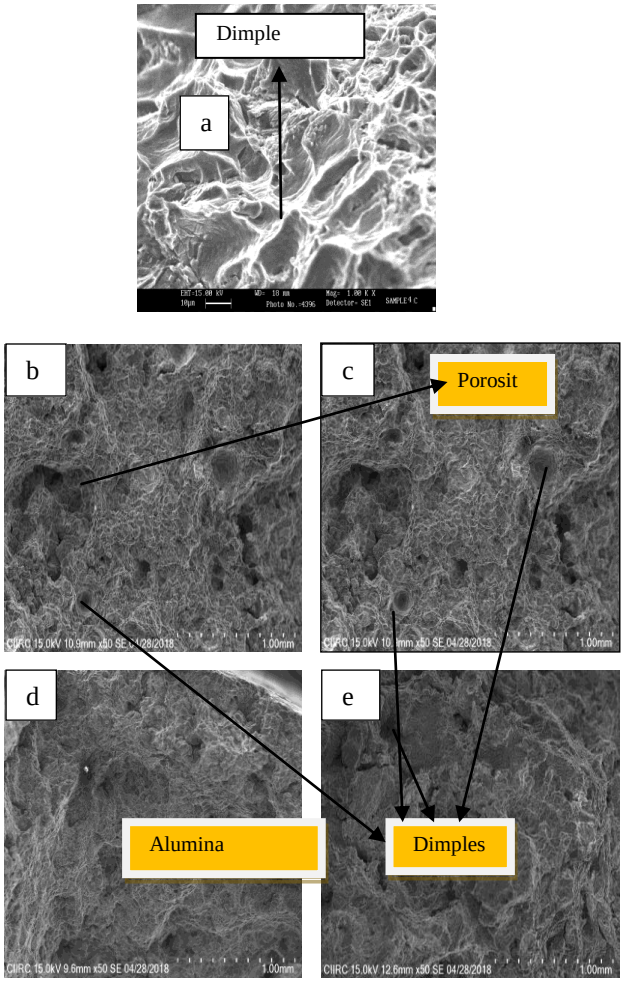

Fig 10: shows SEM of tensile fractured surface of cast Al6063 matrix alloy and its composite systems (a)Al6063 matrix alloy (b) Al6063-2wt% Al2O3 (c) Al6063-4wt% Al2O3 (d) Al6063-6wt% Al2O3 (e) Al6063-8wt% Al2O3

It is evident that the base matrix alloy has got larger dimples when compared with different composite system studied for given content of reinforcement. Al6063 matrix alloy showing very large dimples indicate ductile fracture as shown in Fig 7(a)whereas in case of Al6063 -8wt% composite, particles of reinforcement medium sized dimples are visible as evident from Fig 7(b.e). Further it is also observed fractograph of Al6063-8wt% indicate particles of Al_2O_3 with dimples of fracture and agglomeration.

4.7 X-Ray diffraction analysis

XRD graphs and results given below clearly indicates the presence of reinforcement in the matrix alloy with varying percentage, XRD results shows variation in amount of reinforcement embedded in matrix alloy this is because XRD samples in powder form in minute quantity from particular region are taken

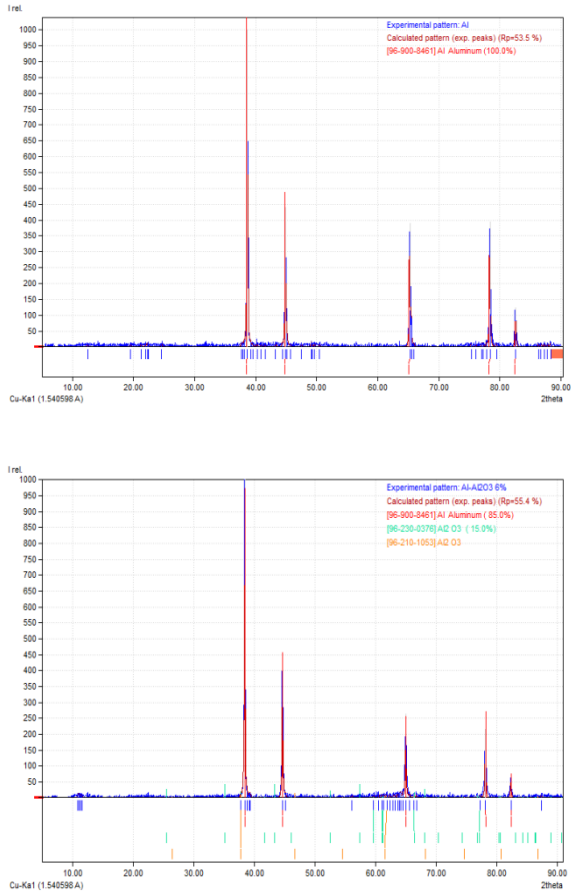

Fig 11 XRD Pattern for Al6063 matrix alloy and its composites (a) Al6063 matrix alloy (b) Al6063 +Al_2O_3

Above figure confirms uniform distribution of reinforcement in matrix alloy Al6063 and also shows the presence of reinforcement in matrix alloy wt% of Al_2O_3. In XRD pattern (Figure 8a-8b), total obtained peaks in the span ranging from 5 to 90 but the common peaks at 2. Of 38.44°, 44.7°, 65.32° and 77.2° belongs to Pure Al and the peaks at 2, of 34.030, 43.74°, 50.80°, 62.46° and 82.48° belongs to Al_2O_3. With the help of Match software the XRD graphs are well matched with JCPDS card JCPDS file #04-0787.

4.8 Wear Studies:

4.8.1 Effect of reinforcement

Figure 12 shows the effect of reinforcement on wear rate of composite systems. It is clear that as contain of reinforcement is increased the wear rate of composite is reduced. As the hard reinforcement is reinforced in soft alloy which increased the hardness of material due to which the wear resistance is improved and seizure resistance of materials. Also possibility of inhomogeneous transfer layer formation which consist of other debris, as observed from the microstructure the good bond between reinforcement and matrix alloy is also reason for improvement in wear resistance.

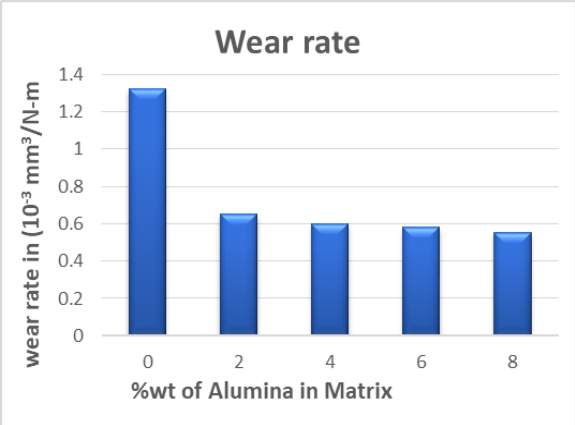

Fig 12: variation of wear rate with increased content of Al_2O_3 for cast matrix alloy and its composite systems

4.8.2 Effect of load

Here the study is carried to identify the effect of load on wear rate for matrix alloy and its composite systems, here the load is varied from 10N to 60N with a constant velocity of 0.632m/sec for a duration of 30min for each specimen. Figure 13 indicates that the wear rate is constantly increasing for both matrix alloy and its composite systems up to a load of 40N then with increase in further load the wear rate is increased steeply.

Table 6: variation of wear rate for all composite systems at different loads

Sl. No	Alloy/ Composite Designation	Wear Rate in Microns(µm) **Alumina**					
	Load (N)	**10**	**20**	**30**	**40**	**50**	**60**
1	Al 6063	0.54	0.88	1.1	1.06	1.22	1.38
2	Al 6063 + 2%Al_2O_3	0.6	0.71	0.74	0.79	0.94	1.09
3	Al 6063 + 4%Al_2O_3	0.63	0.67	0.69	0.73	0.85	0.96
4	Al 6063 + 6%Al_2O_3	0.61	0.63	0.65	0.68	0.81	0.94
5	Al 6063 + 8%Al_2O_3	0.6	0.62	0.63	0.66	0.73	0.81

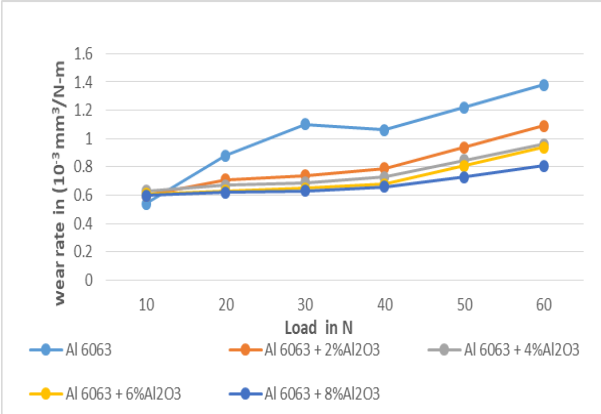

Fig 13: variation of wear rate with increased in load for cast matrix alloy and its composite systems

The wear rate is increased with increase in load due to the fact that tendency for large plastic deformation which promotes the extent of wear debris formation leading to higher wear rates.

V. CONCLUSION

- Successful synthesis and characterization of Al 6063 aluminium oxide composites obtained,
- With increase content of Al_2O_3 tensile strength of composites increased significantly and observed the maximum tensile strength is obtained for 8% Al_2O_3
- Energy absorbed during impact test on composites decreased with increase in content of Al_2O_3 in matrix alloy under identical test condition.
- Microhardness of composites increased significantly with increase content of Al_2O_3,
- It has been noted that the compressive strength of composite increased with increasing content of reinforcement and is higher than base aluminum alloy,
- SEM Studies clearly shows the modes of fractured occurred
- XRD Analysis confirms the presences of Al_2O_3in Al6063 composite with varying percentage
- Wear rate is reduced with increase in content of reinforcement also the wear rate increase with increase in load and after 40N wear rate increased significantly.

REFERENCES

1. Bartakke Nikhil N.,Chivelkar Amey A., Devrukhkar Vaibhav L., Jamsutkar Sahil R.,Rajnitu Rakshaskar, "Mechanical Property Analysis Of Aluminum Alumina Composite By Varing The Percentage Of Alumina", International Journal of Mechanical And Production Engineering, (2016) Vol- 4, Issue-6.
2. P.V. Senthiil., Aakash, Shirrushti., 'Characterization of Aluminum Fly Ash Composites Using Stir Casting Technique'. International Journal Of Research Science & Management,1(6) (2014)
3. P.B.Pawar., Abhay, A. Utpat., 'Development of Aluminum Based Silicon Carbide Particulate Metal Matrix Composite for Spur Gear' Procedia Materials Science 6 1150 – 1156 (2014)
4. Madeva, Nagaral., Bharath., V.V. Auradi., 'Effect of Al2O3 Particles on Mechanical and Wear Properties of 6061al Alloy Metal Matrix Composites' J Material Sci Eng, Vol-2 Issue 1 (2013)
5. O.I.Sekunowo., S.O. Adeosun., G. I. Lawal., S. A. Balogun., "Mechanical Characterization of Aluminium Bronze-Iron Granules Composite", International Journal Of Scientific & Technology Research, Vol-2, Issue 4 (2013)
6. Manoj, Kumar, Yadav, Bijender, Saini., Ashu, Yadav., 'Experimental Analysis of Mechanical Properties of Al6063 and SIC Composite' International Journal of Mechanical and Industrial Technology Vol 3, Issue 1, pp: 221-227 (2015)
7. Johny,James.S, Venkatesan.K., Kuppan,P., Ramanujam,R., Hybrid Aluminum Metal Matrix Composite Reinforced With SiC and TiB2 Procedia Engineering 97 (2014) 1018 – 1026 (2014).
8. V. Bharath, Mahadev, Nagaral., V. Auradi., 'Synthesis and Characterization of 6061Al/Al2O3 Particulate Metal Matrix Composites' (ICCOMIM - 2012), 11-13 (2012).
9. K.R.Padmavathi., Dr. R.Ramakrishna., 'Tribological behaviour of Aluminium Hybrid Metal Matrix Composite' Procedia Engineering 97 660 – 667 (2014).
10. B. Sai, Jagadish., 'Synthesis and characterization of aluminium2024 and graphene metal matrix composites by powder metallurgy', International Journal of Mechanical Engineering (SSRG-IJME), vol-2 Issue 7 (2015).
11. Z.F Zhang., L.C Zhang., Y.W Mai., "Wear of ceramic particle-reinforced metal matrix composite", Journal of material science, Vol-30 pp 1961-1966 (1994).
12. Mohanakumar., K.C Rajashekar, H., "Development and Mechanical Properties of SiC reinforced cast and Extruded Al based metal matrix Composite", Procedia Materials Science 5 934 –938 (2014).
13. Satya,Kumar, Dewangan., Dr. Arun, Arora., "Mechanical Properties of Aluminum 6063 Alloy based Graphite Particles Reinforced Metal Matrix Composite", IJSRD - International Journal for Scientific Research & Development| Vol-3, Issue 05, (2015).
14. M. K. Aravindan, K. Balamurugan, G. Murali, "Effect of reinforcement of AL-6063 with SiC on mechanical behavior and microstructure of metal matrix composites", Applied Science Innovations Pvt. Ltd., India Carbon – Sci. Tech. 6/2 (2014) 388 – 394.
15. Vipin Kumar Sharma_, Vinod Kumar, "Development of rare-earth oxides based hybrid AMCs reinforced with SiC/Al2O3: mechanical & metallurgical characterization", journal m a t e rial research technology (2019) 8(2).
16. M. Ramesh, Jafrey Daniel, D M. Ravichandran, "Investigation on Mechanical Properties and Wear Behaviour of Titanium Diboride Reinforced Composites", FME Transactions (2019) 47, 873-879.
17. P. Ashwatha, M. Anthony Xavior, "Processing methods and property evaluation of Al2O3 and SiC reinforced metal matrix composites based on aluminium 2xxx alloys", Journal Material. Research, (2016) Vol. 31, No. 9,

AUTHORS PROFILE

Abdul Nazeer Research Scholar at Ghousia college of engineering**,** Visvesvaraya technological university. He graduated B.E (Mechanical Engineering) in 2008 and M-Tech (Machine Design) in 2011 Visvesraya Technological university Belgavi, He has 09 years of teaching experience and published 07 journals paper and 01 conference paper**.** His research interest metal matrix composite

Dr. Mir Safiulla specialized in areas of Composite Materials, Metal Forming. Manufacturing Processes & Technology, Automotive Engineering, Management and Maintenance Engineering. B.E. (Mechanical), Mysore University, Mysuru. M.E. (Metal Casting Science & Eng), Bangalore University, Bengaluru. Ph.D. (Composite Materials), Visvesvarya Technological University, Belagavi. He has 35 Years of Teaching, Research and Administration with 89 publication in national and international journals and 45 publication in conferences and Conferences Conducted: 44.